A Message From The President of the Radio Club of America

When I began to write my comments for inclusion in the Radio Club of America's 100th Anniversary Yearbook, I pondered those made by my friend, mentor and predecessor Fred Link upon the 75th anniversary of our Club (and may I note that Fred Link referred to us as the "World's First Communications *Society*" in his preface). Fred recapped the previous 25 years and commented on the good health of the Radio Club.

He also reflected on a period when the Club "was beset with problems." The problems he noted primarily were financial, as the Club's "finances were almost non-existent," and he was pleased to tell the readers that the Club's "staunch supporters" provided the resources to make the Club solvent.

Well, I am very pleased to say that, even during these trying financial circumstances, the Club not only is solvent but it also is growing in size -- and it maintains its stature in the communications community. Twenty-five years ago, Fred commented on the recently formed Grants-In-Aid program and that it had grown to $74,600. I now am happy to say that program's funding now is many times larger and growing, due to the generosity of our members, and myriad associations and corporations.

To say that things have changed in the past 25 years is an understatement. The Diamond Jubilee Yearbook was dedicated to *"The Spirit of Good Fellowship and the Free Interchange of Ideas Among All Radio Enthusiasts."* Our recently adopted tagline says "*Honoring the Past, Committed to the Future*."

Some individuals numbered among our membership have devoted themselves to the task of preserving the history of the Club, its members and RF communications by documenting our history. Others assist by maintaining collections of documents and historic artifacts to teach present and future individuals about the rich history of radio communications. We continue to do our best to document the history of radio communications, including Land Mobile Radio (including Public Safety), Broadcast, Cellular, Amateur Radio and any other use of radio frequency (RF) propagation. It is amusing to note that the term "wireless" that was deemed old-fashioned and out of date many years ago has resurfaced as the most modern and up-to-date way to define the transfer of information via RF. It also is funny to realize that many people who rely on their cellular telephones on a continuing basis fail to realize that their complex, multi-function handheld devices basically are two-way radios!

An ancient Chinese proverb says *“Preserve the Old, but Know the New.”* Our modern tagline also reflects this sentiment, and we are indeed “committed to the future.” In addition to our scholarships, there has been the successful launch of our new “Youth Education Committee,” whose goal is to familiarize students in K-12 with radio communications and to encourage them to pursue more advanced studies in technology. Once again, this initiative has been funded through the generosity of our members. Also of note, a continuing-education program in Information Technology (IT) for communications personnel was created by our members to fill a void and to enable the better understanding of the transition and integration of digital processes into radio communications. With the encouragement of the Association of Public Safety Communications Officers (APCO), this program is being refined for training sessions at their various meetings.

None of our members could have contemplated careers in communications without the combined efforts of our predecessors. One hundred years is more than the average lifetime of an individual, yet the Radio Club has survived and will continue to thrive for the next 100 years. I have witnessed the transition from vacuum tubes to semiconductors to large-scale integration. During my years in the Radio Club of America, I have been honored to meet some of the forefathers who began in wireless using spark gaps and coherers, thus creating the foundation of our current industry.

Who would have thought that the primary distribution of the Platinum Yearbook would not be with a bound publication as in the past, but rather via the bits and bytes contained on a ubiquitous DVD?

My hope is that future members will feel the same excitement when they join the Radio Club of America and meet the heroes of our industry as I did, and that they continue to preserve our rich history and encourage continued participation by the youth of today and tomorrow.

73,

Stan Reubenstein, WA6RNU

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An Opinion

By Martin Cooper (F)

The Radio Club of America, founded in 1909, is the world's oldest radio communications club (society) and promotes cooperation among those interested in the advancement and scientific study of radio communications. It also offers a great opportunity for networking with industry peers.

We, the members of the Radio Club of America, are an eclectic group. We are engineers and scientists, marketers and businesspeople, lawyers and regulators, professionals and amateurs, lobbyists and educators military people and administrators - and not infrequently, combinations of these. We share an interest in radio, its history, its evolution and its technology. We support the objectives of our Club, the scholarships, the collegial meetings, and the preservation of the history of radio.

That is what we are today! We may not have started that way but then, none of us was around a hundred years ago when our club took root. We don't really know what the exact intentions of our founders were, and that is really not important. What's important is that we believe that our combined efforts are achieving the Club's objectives, and that we keep the Club healthy and growing with the expanding radio community.

Our membership is what it is! Because of the diversity of our membership, there are bound to be differences: differences in our vision for the future, differences in emphasis in our objectives. Such differences have to be resolved by collegial discussion and compromise. But we are a democratic organization, and there are principles that cannot be compromised. Until we change our by-laws, the Radio Club of America is open to ALL who share our interest in radio – to ALL. If there are members who are unhappy with this reality, they are free to express their views. They can join the group of selfless and hard-working volunteers who keep the RCA machinery running. They can join the committee members and committee heads, directors and officers who help to perpetuate our Club and its functions. There are processes in place, democratic and disciplined, that provide for modifying the way we do things, for changing what we are to something that is different and, hopefully, better. And these processes MUST, because of the democratic basis of our Club, be transparent, open and pristine. The RCA is not a secret society nor is it a political entity managed by insiders.

We don't have to agree with each other, but it is important that we deal with each other respectfully, with appreciation for the efforts of our team and tolerance for our imperfections. Only with this kind of continuing mutual and sincere respect, will our Club continue to flourish, to grow and to succeed.

Events during the two years preceding our centennial celebration have challenged the unifying principles that have perpetuated the Radio Club for the past 100 years. In direct contradiction of these principles, our Club rejected from our membership roles members who did not meet the standards of behavior laid down by other members. It is not the purpose of this opinion article to criticize or to judge but rather to appeal to future leaders of the Club to view and understand these events in the objective light that only time can shed. It is my hope that our future leaders will err on the side of tolerance, open-mindedness and respect for individual members and for the will of the membership as a whole. It is my fervent wish that the governance of the Club be conducted with full visibility, with trust and with mutual respect.

The technical world is changing, as is the very nature of what we call "radio." If the Radio Club of America is to survive, it will have to accommodate these changes, to shape itself to it the modern world without compromising its principles. The Club has managed to do this for 100 years. That history, that heritage, that momentum will provide us with the wisdom and strength to move on to the next 100 years.

APCO International

Association of Public-Safety Communications Officials-International, Inc.

July 24, 2009

Stanley Reubenstein
Radio Club of America
P. O. Box 621074
Littleton, CO 80162

Dear Mr. Reubenstein,

On behalf of the Board of Officers of the Association of Public-Safety Communications Officials (APCO) International, I would like to congratulate the Radio Club of America (RCA) on its centennial celebration, and thank you for your partnership over the years to advance radio communications. RCA is a model organization and your contributions to our industry have had and will continue to have a great impact on public safety.

We are extremely proud of our successful collaboration with such a revered organization and look forward to 100 more years of advancement to our industry through our partnership.

Sincerely,

Chris Fischer
President
APCO International

ANTIQUE WIRELESS ASSOCIATION, INC.®
PO BOX 478
APALACHIN, NEW YORK 13732

Founded 1952.Chartered
As a non-profit corporation
by the State of New York

Antique Radio Club of America®

To:

Radio Club of America

The Antique Wireless Association Inc. and A.W.A. Electronic Communication Museum (AWA) would like to congratulate the Radio Club of America (RCA) on its 100th year anniversary.

Both of our organizations have similar beginnings. Both were started by a small group of enthusiast looking to form a club of like interested persons. The Junior Wireless Club soon to be the Radio Club of America gathered to share the latest development in Wireless communications. The Antique Wireless Association was formed to preserve the history on Wireless and Electronic Communications. AWA has tracked the development of the founding fathers that developed electronic communications, many of whom were RCA's founding fathers. Such as W.E. D. Stokes, Prof. R.A. Fessenden, Harry Houck, Paul Godley, E.H. Armstrong to name a few.

The Curators of the AWA Museum have all been or are members of the Radio Club of America. We have all been interested in the development of communications to its present day. Several of our Club members have been long standing members of RCA as well.

The Radio Club of America is the oldest club of its kind in the world and its members have made many of the major developments in communications. For this accomplishment you should all be very proud.
Again congratulations from AWA Members on your 100th year and many more to come.

Bruce D. Roloson

Curator A.W.A. Museum

Troy Wideman, W6HV
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909-798-2212

Stanley Reubenstein, WA6RNU
President,
Radio Club of America
PO Box 621074
Littleton, CO 80162

22 July 2009

Dear Mr. Reubenstein,

On behalf of the Old Old Timers Club (OOTC), I wish to extend to the Radio Club of America our sincere congratulations on the achievement of your 100th anniversary.

The efforts of your membership over the last century have provided significant contributions and achievements in the advancement of the wireless technologies that we all now enjoy. Without the efforts of your pioneering membership, these state of the art technologies would surely not exist.

Again, please accept our sincere congratulations. The OOTC hopes that you will see another successful century of growth and advancement.

Sincerely,

Troy Wideman, W6HV
President OOTC

100th Anniversary Platinum Jubilee Yearbook
Radio Club of America

PREFACE

The year 2009 is the one-hundredth anniversary of The Radio Club of America, which is now, always has been, the oldest Radio Club in continued existence. The Club was founded on 2nd January 1909, by a small group of young boys, with a common interest in wireless communications, at a special meeting held at the Hotel Ansonia in New York City, initially known as ***The Junior Wireless Club.***

By 1911 the interests in amateur radio were beginning to grow by leaps and bounds, and the initial membership in the Club had doubled. It was therefore decided on 22nd April, 1911, to hold subsequent meetings at the home of Frank King, who resided in New York City, and at a special meeting on 21st October, 1911, to change the name from The Junior Wireless Club to ***The Radio Club of America***, the name that exists today.

The first regular Meeting of the Club, under its new name, at Frank King's house, was held on 4th November 1911. At a regular meeting on 20th January, 1912, the Club emblem, which we use today, designed by Frank King, was unanimously accepted. The Club soon outgrew its quarters at Frank King's house, and so the following regular (monthly) meetings were held at Columbia University, New York City.

In 1915 the Club installed a transmitting and receiving station in the Hotel Ansonia, where Admiral Fletcher had made his head quarters. This station operated by Club members handled the Admiral's traffic with the fleet in the Hudson River. Several messages were handled, and President Wilson himself sent a message from the ***Mayflower*** commenting on the good work. The Navy League presented the Club with a banner in recognition of its service.

The official publication ***The Proceedings of The Radio Club of America*** dates back to May 1913, but prior to this year club records tell us that six papers were presented (perhaps published?) by Club members.

We begin in the Preface of this Yearbook, by looking at the Golden (50 year) and Diamond (75 year) Jubilee Yearbooks, particularly the Golden Jubilee Yearbook, since many of the charter members and early honorary members were still members of the club, and letters written by some of them were published in the Yearbook for that year 1959. Both the Golden Jubilee Yearbook (50th year published in 1959) and the Diamond Jubilee Yearbook (75th year published in 1984) began by a reproduction of the history of the Club as it appeared in the earlier Yearbooks. We do so here but differently. Using today's technologies, computers and scanners, all previous publications of The Radio Club of America have been scanned, by Ron Jakubowski, K2RJ, Board Member, and are to be found, along with our Platinum Jubilee Yearbook, on this DVD Diskette.

So let me begin. The 50th Anniversary Yearbook of the Radio Club of America features in the last Section entitled **Who's Who in The Radio Club of America** letters written by five Honorary Members (HMs), who were there at the beginning of practical wireless communications: Dr. Alfred N. Goldsmith, HM, 1915; John V.L. Hogan, HM, 1915; Dr. J. Zennick, HM, 1916; David Sarnoff, HM, 1926; and Henry J. Round, HM, 1952. Dr. Zennick did not write his letter in the year of the Yearbook, because he died in April 1959, the year the year the Yearbook was published. All together (2009) the Radio Club of America has had 28 honorary members, Robert H. Marriott, John Stone Stone, Alfred N. Goldsmith, and John V.L. Hogan were the first, becoming honorary members (HMs) in 1915.

The Radio Club of America was founded, by an organizational meeting in New York City on 2nd January 1909. The Society of Wireless Telegraph Engineers (SWTE) was founded in Boston on 25th February 1907, and so it was the first group in United States, if not the world, to get together to develop radio communications. The organization meeting of The Wireless Institute (TWI) was held on 10th March 1909. But of these three organizations the Radio Club of America is the only one that has continued its established basis, now for the past 100 years. The TWI and the SWTE consolidated to form the Institute of Radio Engineers (IRE), on 13th May 1912, and so these two wireless institutes passed out of the picture. The first President of the IRE was Robert H. Marriott, HM, 1915.

At that time the dominant organization of electrical engineers was the American Institute of Electrical Engineers (AIEE). In the first half of the 20th Century, radio communications experienced great expansion, and there was clearly a need for an authoritative journal disseminating new results among practitioners and researchers. The Proceedings of the IRE was established in 1913. Alfred N. Goldstein, HM, 1915, edited the PIRE for 41 years. Dr. Zennick, HM, 1916, was the first Fellow of the IRE. Clearly at the beginning anyone who was anything in radio was a member of The RCA.

John Hogan, HM, in his letter referenced above, said the Radio Club of America was derived from radio amateurs and the wireless institutes from “so-called” professionals, but he could not see any difference in their common objective, which was to improve the state of the art by interchange of technical information. Both groups held meetings regularly, usually at Columbia University, and he could see no great difference in the caliber of papers presented by one or other of the two organizations. Major Howard Edwin Armstrong, a giant in our Club, who died in 1954 (suicide), presented his first paper to The Club in May 1913. Professor Reginald Aubrey Fessenden was a Charter Member of The Radio Club of America, and while I can find no evidence that he actively participated in Club meetings, his technologies clearly had a strong influence on the early members the Club (Charter Members) --- reference the letter written on 10th March, 1910, signed by 5-members of The Junior Wireless Club, to Hon. Chauncey M. Depew, US Senate, in reply to his dated 17th March, 1910, in connection with a proposed bill to Regulate Radio Communications, a Bill that would have practically prohibited amateur radio experimentation (the proposed Depew bill is discussed later in this Yearbook).

John Hogan said that when The RCA was formed he was away from New York City, at school, otherwise he might have been a founding member, since when living in New York City, up to about 1906, he had an amateur radio station in operation.

The AIEE was founded in 1884, in Boston. Until the 1940s the IRE was a relatively small engineering organization, but the growing importance of electrical communications and the emergence of the discipline of electronics resulted in negotiations about merging the IRE and AIEE, in c1957, which resulted in the establishment of the Institute of Electrical and Electronic Engineers in 1963 --- the IEEE (apparently) claims that 2009 is the 125 anniversary of that organization.

In April 1914 The Radio Club of Hartford, CT accepted Hiram Maxim’s idea to develop a new organization, banding together amateur wireless operators in United States, to improve the reputation of radio amateurs with the general public, initially by developing the concept of radio relay to provide wide areas communications during natural disasters (floods in 1915). Hence the name for the new organization: The American Radio Relay League. In February 1915 the ARRL became an independent organization, and began publishing QST in December of that year. But the ARRL was not the only organization concerned with banding together radio amateurs, developing the concept of radio relay. The Radio League of America (RLA), organized in New York, in October 1915, by Hugo Gernsback was also plying for nationwide membership and public attention. On 6th February 1917 the ARRL achieved transcontinental radio relay, passing a message from coast to coast by way of amateur radio relay. In lauding this achievement Hiram Maxim seems to have forgotten that RLA achieved this a year earlier on 22nd February 1916. Both relays were said to be in remembrance of George Washington’s Birthday. WW I interrupted what was quickly becoming a competition between these two organizations, since radio amateur stations were closed down during the war. After the war the RLA was mentioned briefly, but quietly faded away. Although radio amateur stations could not go-on-the-air during the war, QST was published regularly. Of these two organizations only the ARRL exists today.

While the current interests of members of the ARRL are widely different than putting stations on-the-air for radio relay, radio amateurs are pursuing linking (not relay) for instantaneous coast-to-coast and currently for world wide communications, using today’s methodologies and technologies --- internet.

The Radio Club of America claims to be ***The World's Oldest Radio Club***, current members say Society, but founding members insisted it was a Club, dedicated to: ***"The Spirit of Good Fellowship and the Free Interchange of Ideas Among All Radio Enthusiasts".*** In early years anyone who was anything in radio was a member of the Club. Now, with so many national and international organizations, the IEEE, the IEE, with their scores of Societies, the RCA never will be such a key organization. The theme of our Proceedings is ***remembering the past devoted to the future.*** In the year 2009 we will publish a Yearbook remembering (to some extent) the last 25- years of technology change, and where we are going.

Throughout the history of wireless amateur radio has made significant contributions to the art and science of communications. Amateur radio represents a unique environment that is not duplicated in the labs or research parks of either industry or the government --- perhaps to some extent in our Universities since many universities have an Amateur Radio Club. And for the record (postings on the WEB) many of these amateur radio clubs are remembering their early history. Existing at the intersection of the social, economic, cultural, and scientific spheres (recall that many "amateurs" are professional radio amateurs), amateur radio leverages this position to **invent and innovate (**emphasis perhaps on the word innovate) from a unique prospective. Marconi claimed to be a radio amateur, and he was, he was certainly an avid wireless experimenter, but principally he was a business-man (concerned with sending messages for money). Fessenden, the pioneer that devised the methodologies and technologies that are like those used today, held two call signs, VP9F and 1XA.

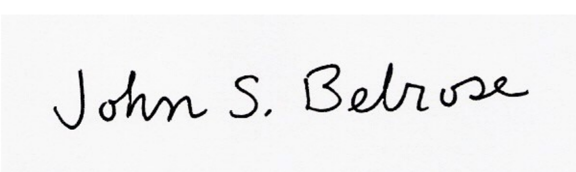
The RCA was founded by a group of young wireless experimenters. Professor Fessenden, Consulting Engineer, was the only professional charter member. For our 100th Anniversary we need to tell the story about what amateurs have done, and are doing, during the past 25 years (a follow on from the Laport et.al., IEEE Communications Society 1981 paper). Following papers will overview, but only briefly, touching on a few areas of research, what the academic and commercial world is doing.

Twenty-five to thirty years ago radio systems were analogue. Analogue radio is here to stay. But analogue systems are getting more sophisticated. Recently available commercial short wave (SW) receivers, for the SW listener, employ synchronous detection so that one can listen to the LSB, USB or both side bands of an AM signal (to cope with selective fading). Nearly all SW broadcast stations are AM, but an increasing number are now digital, which employ DRM (Digital Radio Mondiale). And, in modern amateur radio receivers, the quality of signal reception is enhanced, by selective digital filtering, and by selectable digital noise reduction algorithms. Increasingly wireless systems are changing to digital; and new radio transmitters/receivers are controlled by software (software defined radio --- a new acronym SDR). While firmware upgrades are currently available (by Yaesu for example, for the FT-950 and FT2000 transceivers, with 30-or more front panel controls) to improve the digital signal performance of the receivers, SDR will eventually super-cede these digital/analogue transceivers. The transmitted audio/ digital (voice and messaging) signal itself can be digital --- D-Star radios used by radio amateurs. And D-Star can be routed transparently --- radio-to-radio, via repeaters using the gateway backbone network.

So called "smart cellular phones" are becoming more and more complicated, and smaller in physical size. Global Systems for Mobile Communications (GSM) are currently more and more interconnected, and the cell size is decreasing: from tens of kilometers, the original cellular phone system; to a few kilometers, WiFi and WiFi broadband local area networks; to meters, Femtocells for local indoor environments. Femtocell radios are linked to wider cell coverage areas by WiFi systems. While GMS is currently the most widely used phone, there are competing technologies, e.g. UMTS (Universal Mobile Telecommunications Systems). GMS and UMTS phones use different frequency bands, in different countries. Interoperability and global roaming, and security, particularly when the phone is connected to a personal computer, are issues yet to be resolved satisfactorily.

Wireless networks are also changing, e.g. mesh networks --- and wireless systems are being developed to better function in their operational environments --- cognitive radio brain-empowered wireless communications.

In my view software defined radio and cognitive radio brain-empowered wireless communications is the way to the future. There will be papers over viewing some of these new technologies.



John S. (Jack) Belrose, PhD Cantab, VE2CV, VY9CRC
Member, Radio Club of America Board of Directors
Platinum Jubilee Yearbook Editor

Postscript

The 21st Century has prompted a number of organizations to remember their past, and to foretell their future. This year 2009 the Radio Club of America is celebrating its 100th Anniversary.

In the interests and background of author Belrose, Cambridge University is remembering its 800th Anniversary in 2009, since its origin dates to 1209. The Cavendish Laboratory was opened in 1874, initially located on the Free School Lane site, in the middle of Cambridge, and it was still there when author Belrose was a member of John Ashworth (Jack) Ratcliffe's Radio Group (1954-1957). But it has now moved and considerably expanded its facilities and scope of research.

Radio Astronomy in Cambridge grew from Ratcliffe's determination to re-create in the Cavendish Laboratory the ionospheric physics research that had been dissolved during WW2. Among other members of The Telecommunications Research Establishment, he brought Martin Ryle from his team carrying out radar research during the war, and encouraged him to branch out into ionospheric physics by working on the recently discovered radio emissions from the sun. While the early research by Ryle, and his Group, was concerned with the sun, it soon appeared that the techniques they were developing, could be used to locate other celestial radio sources, already discovered by Grote Reber, J.S. Hey, and J. Bolten. In 1957 Mulliard Ltd., with the support of the Science Research Council, provided the resources to develop the Mulliard Radio Astronomy Observatory, which celebrated its 50th Anniversary in 2007 **[A]**.

The foundation for international space science dates to 1932, the date of The IPY (the Second International Polar Year), 1932-1933, which was a major effort for many nations. The IGY (International Geophysical Year), 1957-1958, was a much larger, a major undertaking.

The Sixties was a decade of exponential growth in the field of space research, prompted by COSPAR (Committee on Space Research) which was created in October 1958. COSPAR celebrated if 50th Anniversary in 2008 **[B]**. One of the main accomplishments in this time period was The Alouette/ISIS program. The first satellite was launched on 29th September 1962, into a 1000 km circular orbit, at 80^0 inclination. This was a remarkable Canadian/USA achievement (Canada built the satellite and the USA launched it). The satellite carried a top-side sounder, see reference **[C]**, a VLF receiver listening to the natural EM environment in the 100 Hz to 10 kHz band, and several energetic particle detectors.

As previously noted, the IEEE (Institute of Electrical and Electronic Engineers) claims to be celebrating in 2009 its 125th anniversary. This organization was created by the combining, in 1957, of the AIEE (American Institute of Electrical Engineers), which was founded in 1884, and the IRE (Institute of Radio Engineers), which was founded in 1912. The anniversary date of organizations clearly depends on the point of view of its members. In accord with what we said earlier, in 1957 the AIEE and the IRE ceased to exist, and the IEEE was formed, and so in 2007 the IEEE should have celebrated its 50th Anniversary.

Continuing, the pre-runner of the IEEE Antennas and propagation Society (author Belrose is a Life Senior Member of the AP-S), known as the IRE Group on Antennas and Propagation was founded in 1949 --- and so this Society should be celebrating its 60th anniversary in 2009.

The International Year of Astronomy (IYA 2009) is celebrating its 400th Anniversary in 2009 --- dating back to the year 1609, when Galileo Galier first turned his telescope to the night sky, and made astounding discoveries that changed humankind's understanding of our position in the universe, including mountains and craters on the Moon, a plethora of stars invisible to the naked eye and moons around Jupiter **[D, E].** The NASA Project Phoenix successfully landed a rocket on Jupiter in 2008 **[F].**

The career of the author spanned the 50+ years we have been reviewing **[G],** and the history of the Radio Club of America pre-dates this time period by another 50 Years.

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F. On-Line: http://www.planetary.org/news/2008/0525_Phoenix_Arrives_on_Mars_with_Flawless.html

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Honoring the past, committed to the future

Pioneering spirit of the Radio Club of America

Pioneers are traditionally associated with a specific time in history. The dictionary states that a pioneer is "one who is first or among the earliest in any field of inquiry, enterprise, or progress." They are leaders and pathfinders.

Because of the wireless industry's continuous technological growth, breadth and relevance, its pioneer spirit spans a century. This year the Radio Club of America is celebrating its 100th year anniversary. The Radio Club of America (the Club) is the oldest radio communications organization, founded to promote cooperation among those interested in the advancement and scientific study of radio communications. The Club currently has more than a thousand modern trailblazing members set to lead communications into the next century.

The Club was formed in New York City in 1909 by a few amateur radio entrepreneurs under the name "Junior Wireless Club of America, Ltd." The charter members were W. E. D. Stokes, Sr., Miss E. L. Todd, Prof. R. A. Fessenden, W. E. D. Stokes, Jr., Mr. Seymour, George Eltz, W. Faitoute Munn, Frank King and Frederick Seymour. Monthly meetings were held and the name was soon changed to the Radio Club of America in 1911 to include enthusiasts nationwide. Papers were prepared and read to members since very little information was available. Amateur radio operators had a scant description of Marconi's experiments with which to try and build their own receivers and transmitters (there were no radio manufacturers or finished designs for reference). These first members were truly technological innovators, sharing their failures and successes by word-of-mouth.[1]

(Pictured above: W.E.D. Stokes, Jr., far right.)

W.E.D. Stokes, Jr., at the wise age of 14 was the first president of the Club from 1909-1911. He led a Club delegation to Washington in 1910 to oppose the passage of the Depew bill for the regulation of radio communications. He was the youngest activist that had ever appeared before a Senate committee. He apparently turned down an invitation for dinner with the president to return to his workroom on the 16th-floor of the Ansonia Hotel to work on his "wireless telegraphy and wireless telephone instruments." When asked about his son's future profession, W.E.D. Stokes, Sr., replied, "That hasn't been decided upon yet. The youngster is simply enjoying himself just now. His electrical things make the time go by fast, and he is clever enough and energetic enough to want constantly to improve on what instruments he has."[2]

The greatest value one can receive from the being a member of the Radio Club of America today is the knowledge that you are investing in the future of our children and grandchildren, America, and the industry to which we have dedicated our lives. Beyond that, it is the opportunity to serve and the joy of meeting and working with some of the finest leaders in the public and private sectors who are dedicated to using telecommunications technology for the betterment of man and innovations as a tool to success. As members of the RCA, we have an opportunity to play our part in protecting the history of our industry while honoring the present and promoting the future. Each of us has a chance, in some small way, to impact the evolution of our industry, without regard to any personal or corporate gains and for the sole purpose of promoting strong educational programs for future generations and leaders in the entire Telecommunications Industry. Craig M. Jorgensen, director and Fellow.

Throughout its first 100 years, the Club has included or been associated with:

- Dr. Allen B. DuMont (perfected the first commercially practical cathode-ray tube and developed the modern oscilloscope)
- William Lear (known for his patents in electronics and the Lear Jet)
- Paul Godley (while in Wales in 1921 representing the American Radio Relay League (ARRL), he reported success of the first transatlantic tests for amateur wireless stations)
- Dr. Louis Hazeltine (inventor of the Neutrodyne circuit), John V. L. Hogan (held the 1912 patent of a single-dial tuning system for radio receivers and built the first high-fidelity radio station)
- Raymond Heising (has over 100 U.S. patents including the Class C amplifier and diode-triode detector amplifier circuit patents)
- Joseph E. Keller (a lawyer and Fellow of the Institute of Radio Engineers (now Institute of Electrical and Electronics Engineers (IEEE); offered much-needed legal counsel to the International Association of Fire Chiefs (IAFC).
- David Sarnoff (responsible for bringing radio, and later television, into the household; became president of Radio Corporation of America and later formed NBC and was credited with transmitting news from the Carpathia regarding the sinking of the *U.S.S. Titanic*).
- Frank Gunther (original developer of short wave radio equipment; worked closely with military, police and fire depts.)
- Jack Poppele (built the original 250-watt transmitter for New York's WOR; in 1953 President Eisenhower appointed him director of the Voice of America.)

(Pictured, left, Major Edwin H. Armstrong's FM transmitter, provided courtesy of the Antique Wireless Association).

It's no secret that the Club's membership reads like a who's who of dedicated visionaries who have continued to advance wireless technologies, two-way and amateur radio, radio and television broadcasting, paging, and wireless voice, data and messaging. The list of Honorary Members of The Club, published in our Golden Jubilee Yearbook certainly reads like a Who's Who in respect to the emerging radio technologies: Dr. Alfred N. Goldsmith, John V.L. Hogan, Robert H. Marriott, Prof. Michael I. Pupin, Henry J. Round, Brigd. Gen. David Sarnoff, John Stone Stone, and Prof. Johnathan Zenneck. Hogan, Marriott and Stone Stone were among the founders of the Institute of Radio Engineers (IRE), in 1912. Marriott was the first president of the IRE. Goldstein edited the Proceedings of the IRE, at the beginning, and for 41 years. Some historians consider Edwin H. Armstrong's superheterodyne receiver (c1912) to be the most significant of early radio technologies. The heterodyne methodology was devised (basically) in the mind of Prof. Reginald Aubrey Fessenden, a decade earlier (his Aug. 12, 1902 patent), but it could not be used practically until vacuum tubes became available. John V.L. Hogan's classic Proc. IRE 1913 paper (reference also his Club Proceeding's paper, Nov. 1914) clearly demonstrated the significance of this technology, a technology that remains the standard of radio today.

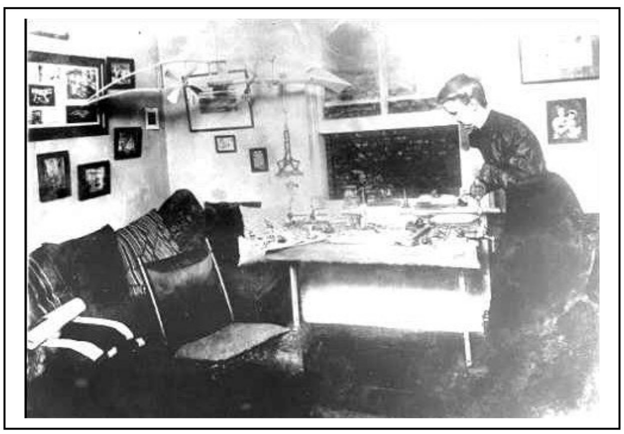
RCR Wireless, a long-standing industry publication, has ranked many past and current Club members in its "Wireless Hall of Fame," including Major Edwin H. Armstrong (father of frequency modulation-FM-technology), Martin Cooper (father of the first portable cellular phone), Fred M. Link (founder of Link

Radio Corp. and father of two-way radio), Mal Gurian (CEO of OKI Telecom responsible for OKI receiving the first FCC type certification for a cellular telephone like the one which was used to make the first commercial phone call to Alexander Graham Bell's great nephew who was in Germany at the time Oct. 13, 1983), James Dwyer (founder of CTIA–The Wireless Association and challenged the FCC in the 70's to allow competition), Robert Galvin (president of the family's business, Motorola, for 34 years), Jai Bhagat (built nationwide paging industry with John Palmer), Dale Hatfield (former chief of FCC's Office of Engineering and Technology), Jay Kitchen (led industry trade PCIA- The Wireless Infrastructure Association, for 10 years, after it merged with the National Association of Business and Educational Radio.), Morgan O'Brien (founded Nextel in 1987, competitor to cellular) and Arlene Harris (45-year wireless veteran; founder of the Jitterbug and creator of the highly regarded SOS emergency phone; wife of Martin Cooper, father of the first mobile cellular phone).

The Radio Club of America is important as a crucial source of industry history, that bridges the beginning, to today's wireless radio and broadcast technology. I cannot imagine anyone who is involved in wireless, radio or broadcast as either a hobby, or a professional not wanting to be involved with RCA. Carroll Hollingsworth, director and Fellow.

Women and the Club

At the formation of the Junior Wireless Club of America, Ltd., in 1909, Miss Lillian E. Todd (L.E. Todd) was honorary president due to her interest in both flying and wireless (also true of the other charter members).



(Pictured left, Lillian E. Todd in her design studio at home. Photo from Library of Congress.)

It wasn't until 1973 when the Club welcomed its next female member at the invitation of Fred Link. Vivian Carr has had an accomplished engineering career with Bell Telephone Labs; she's been chairman of the IEEE NY section, is past president of the IEEE Engineering Management Society and Treasurer; and she is a member of the IEEE Communications Society.

Wireless publishing professional Mercy Contreras served as the Club's first female president in 2003-2004. She began her 35-year communications career with *Communications Magazine* and the *International Wireless Communications Expo* (IWCE). She moved on to roles as group publisher of industry publications *Mobile Radio Technology*, *MRT International*, *Cellular Business* and *Wireless World*. She is currently sales director for *AGL magazine* and Executive Director of the Communications Marketing Association (CMA). She's been a member of the Association of Public-Safety Communications Officials (APCO) and served on its Commercial Advisory Committee.

Other accomplished women are members of the Radio Club. For example, Elizabeth Sachs is a member and Fellow of the Club. She has specialized in communications law as an attorney in the Office of Government Relations at Motorola, Inc., in Washington, D.C. She is the General Counsel for the American Mobile Telecommunications Association (AMTA) since its inception. Liz Maxfield is also a member and Fellow with the Club. Liz was senior vice president for industry affairs, vice president and executive deputy director for CTIA. She's represented various communication clients in cellular, local exchange, broadcast and microwave before the FCC. She's also served as deputy director for the FCC's Office of Public Affairs.

Debra Baker has been a writer and editor in the wireless industry since 1981. She's a member and Fellow of the Club and she's been a board member and chaired the Publications Committee for many years. She received the "Special Services Award" from the Club in 2004. June Poppele has been involved in the Club for over 30 years, with 20 of those years as chair of the Good & Welfare committee. She is a Life and Honorary member and Fellow of the Club. Connie Conte started working for Jack Poppele and the Club 30 years ago and has worked tirelessly as the banquet coordinator. Connie is a member and Fellow of the Club.

(Carole Perry (fifth from left) with young adults during a reunion in Boulder, Colo. These children had presented at Carole's Youth Forum at the Dayton HamVention over the past 17 years. Photo provided by Carole.)

Carole Perry has been a member of the Club since 1991 and she is also a Fellow. After a 16-year career as executive vice president for RapidCircuit Inc., an electronics manufacturing company, Carole joined the staff of Intermediate School 72 in Staten Island, NY, where she created the curriculum for "Introduction to Amateur Radio." She retired in 2004 and now currently serves as a columnist for *WorldRadio magazine*. Carole is the recipient of the "Dayton Ham of the Year" award, the ARRL "Instructor of the Year" award, the Veteran Wireless Operator's Association "Marconi Memorial" award, the Quarter Century Wireless Association "President's Award," and the Club's "Barry Goldwater Award." At this year's Radio Club banquet, Carole is the recipient of the RCA President's Award in 2009.

This information is just to whet your appetite to learn more. For a complete history of the Club visit our Web site at www.radioclubofamerica.org.

The camaraderie and networking with interesting and talented people is what I value most about being a member of RCA. I would recommend that anyone looking for a great opportunity to participate with a variety of technical, interesting people should join RCA. For those interested in preserving our rich wireless communications heritage; or those who want to join our efforts in introducing technology classes into schools across the country; we welcome you. Carole Perry, director, Fellow and co-chair of the Radio Club's Education Committee.

Fast forward 100 years. The Club's members are still trailblazing a path through the wireless industry. They've progressed to satellite-based Global Positioning Systems, wireless voice and data devices that for many have replaced landline telephone and the sharing of information through mobile Internet and "smart" networks. The 4G wireless network standard for mobile video and high-speed wireless data services looks to achieve download transmission speeds of 300 Mbps, with Long Term Evolution (LTE) technology ahead in the race as the next-generation wireless network standard.

What's available for today's Club members?

The Club's unique impact goes beyond its impressive membership list. There are various reasons why wireless professionals - men and women – join the Radio Club of America. It's a great way to network with like-minded professionals and continue to share concerns, rally around causes and celebrate successes.

Members meet for breakfast at major industry trade shows like the IWCE and APCO annual conferences. The Club also has a booth at major events to encourage new membership and donations to the scholarship fund, the purchase of Club-sponsored merchandise, service on committees and attendance at the annual banquet. Members also receive the *Aerogram* quarterly for Club news and activities and *The Proceedings* twice per year which offers a more historical and scholarly approach. A *Directory* is published for members every other year. Members also receive a monthly e-newsletter for late-breaking information and news. Finally, the Web site, www.radioclubofamerica.org is a good resource for learning more about the Club and its members and posting news releases, events and sharing industry information.

It is always a value to be able to communicate with other members who have had many of the same experiences as you and how they were able to handle the problems. It is where the older meet the new members and have an opportunity to share their experiences. Also, it is where the young members meet the older members and are given the time to share their views. It took me several years to make up my mind and a lot of discussions with Fred Link before I finally sought membership in the Club. Now after 26 years and looking at my membership, signed by Fred that has been hanging on my office wall all of these years, I have to ask myself why I waited so long. These valued membership associations will continue the rest of your life and hopefully be passed along to your children when you decided to step down. Ray Collins, Fellow.

(Fred Link pictured far right, was not only known as the "father of mobile radio," but he was known for encouraging active industry men and women into joining the Radio Club.)

What does membership mean?

Members receive a strong backbone of support with an almost infinite access to a variety of technical expertise and resources.

There are various levels of membership. Regular members receive all the benefits of the Club. Based on tenure in the Club and professional accomplishments, members can advance to "Senior" membership. Certain members whose contribution to the Club has been outstanding may also be awarded "Fellow" status if deemed appropriate by the Board of Directors. Those distinguished members who have given their time, talent and energy life-long to the Club in substantial ways may be deemed "Life" members. Members can also be elected to serve on the Board of Directors.

The Club has seven officers, 14 directors and an executive committee that includes the officers. The executive committee meets four times per year via conference call in addition to the board meetings. Board meetings are held twice a year (a mid-year meeting the first weekend of June and a meeting in November during the awards banquet weekend. Directors serve two-year terms.

There are also various committees that seek to advance the Club:

- **Awards & Fellows Committee.** Working with the Executive Committee, the chair works to determine noteworthy annual award winners and members to be elevated to "Fellow" status. *Contact: Vivian A. Carr, chair, executive vice president and Fellow, v.a.carr@ieee.org*
- **Banquet & Meetings Committee.** Duties include organizing the Club's annual awards dinner including locating keynote speakers. *Contact: Mal Gurian, chair, president emeritus, Life Member, and Fellow mgurian@malgurianassoc.com*
- **Centennial Celebration Committee**. Responsible for planning the 100th –year Anniversary Banquet and Awards Ceremony. *Contact: Debra Baker, chair, director and Fellow, dbaker@telecomweb.com*
- **Constitution & By-Laws Committee**. Serves as legal counsel for the Club. *Contact: Robert H. Schwaninger, Jr., co-chair, vice president/counsel and Fellow,*

rschwaninger@sa-lawyers.net. Robert B. Famiglio, co-chair, vice president/co-counsel and Fellow, rbfamiglio@AOL.com

(Thank goodness "education" in wireless has changed a bit! W.E.D. Stokes' book collection pictured at left. Photo courtesy of the Antique Wireless Association.)

- **Education Committee.** This Committee consists of two groups. One focuses on students in grades 12 and below who have demonstrated technical excellence and creativity in wireless communications and are eligible for the newly created "RCA Young Achiever's Award." It also works on introducing and supporting amateur radio/technology programs in high schools and junior high schools across the country. *Contact Carole Perry WB2MGP, co-chair, Director and Fellow: WB2MGP@ix.netcom.com.* The second group wants to further outreach through providing programs, seminars and short lectures through continuing education at Club and industry events. *Contact: Richard P. Biby, P.E., co-chair, director and Fellow, rbiby@ag-magl.com.*
- **Finance Committee**. Responsible for all financial aspects of the Club. *Contact: position open.*
- **Good & Welfare Committee.** Gives comfort and support to those who are ill or those families who may have lost a loved one. *Contact: June P. Poppele, chair, Life and Honorary Member and Fellow.*
- **Historical Committee, Museums & Archives** Committee. Responsible for the research, tracking and upkeep of all historical aspects of the Club and industries. *Contact: Kenneth A. Hoagland, chair and Fellow, kenhoagland@hughes.net.*
- **Long Range Planning Committee.** Responsible for preparing for future activities and operations of the Club. *Contact: Philip Casciano, chair, president emeritus and Fellow, Philc@pmcreps.com.*
- **Marketing Committee**. Responsible for creating and implementing strategies to attract new members, sponsors, speakers and volunteers and to help increase donations. *Contact: Sandra L. Black, chair, director, and Fellow, slblack@tn.twcbc.com.*
- **Membership Committee**. Responsible for leading the quest to encourage qualified new membership.*Contact: Craig Jorgensen, chair, director and Fellow*, *jorgensen@quantum-telecommunications.com.*
- **Nominations & Elections Committee.** Responsible for overseeing the Club's election process. *Contact: Anthony Sabino, Jr., chair, president emeritus and Fellow, tsabino@regionalcom.com.*
- **Publications Committee.** Oversees all member publications. *Contact: Debra Baker Wayne, chair, director and Fellow, dwayne@accessintel.com.*
- **Scholarship Fund Committee.** Oversees requests for consideration from colleges, makes recommendations to Board and receives scholarship funds for grants. *Contact: John E. Dettra, Jr., chair, director and Fellow, jdet1@verizon.net*.
- **Sections/Industry Conferences Committee.** Facilitates the formation of the Club Sections (or chapters), forms affiliations with kindred non-profit organizations, hosts events and meetings of members and guests of RCA at radio industry conferences, and promotes the Club with exhibit booths at radio industry events. Future goals include having a liaison network including numerous radio industry

organizations and having an experts/speakers bureau. *Contact Richard J. Reichler, chair, Life Member and Fellow, rjrwireles@aol.com.*

- **Regional Conferences Committee.** Manages the annual Texas Event including providing technical sessions (the Digital IP for Radio Professionals training course) at Texas APCO annual conference and the IWCE/APCO Conference breakfasts. Also includes the Technician of the Year Award and the Club's being an exhibitor and sponsor of the Texas event. *Contact: Carroll L. Hollingsworth, chair, director and Fellow, dhlago@aol.com.*
- **Web site Committee.** Committed to collecting and posting information to honor the past and promote the future. *Contact: Bruce McIntyre, chair, Vice President and Fellow, bruce@towerinnovationsinc.com.*

Because of the Club's commitment to the future of the industry and continued training and education of its participants, several areas need to be highlighted:

Scholarships

Somewhat unique to non-profit organizations in these difficult economic times, the Club continues to offer a healthy scholarship and education program to ensure that talents and skills are available for future technological advancements. In 2008, for example, the Club awarded scholarships totaling $18,000 to 15 deserving students – young people who without this assistance wouldn't have been able to complete college. The addition of new scholarships is also growing each year, enabling the Club to increase its investment.

As stated in the Radio Club's constitution, the Radio Club shall provide a 'scholarship fund for needy and worthy students for the study of radio communications'. However, over the years the Radio Club's membership and officers have become diverse in the related fields. The Club is a Section 501(c)(3) corporation by which donations to the Scholarship Fund are tax deductible.

Over the years several of our Club members and/or their families have established a named fund in honor of their commitment to the development of studies of students pursuing college degrees in the related fields of radio communications. Some of the named funds besides the General Scholarship Fund are the Goldwater, Gunther, Link, Poppele, Brownson and other funds. The Scholarship Fund is completely separate from the general operating fund and only the interest/dividends from these funds are used for grants to the various colleges to be applied to the tuition of upper class students studying in the related communications fields. Generally, the grants are $1,000.

The Scholarship Funds are invested in highly rated securities and bonds so our grants have been fairly stable over the last several years. In order to get about $1,000 return for the year, a fund should be established at $20,000. When the grants are made the college/student are told that the grant was made by the named fund. Many of the colleges that receive grants are located near members of the Club so that the Club member can attend scholarship functions and meet the student that received the grant. When the grants are made, it is requested that the student acknowledge the grant, what the grants means to them, and then the Club makes them a student member of the Radio Club for two years free. As a 501(c)(3) organization, the granting of scholarships is the main part of the Club's service and outreach program. The Chairman of the Scholarship Committee makes an effort to relay the letters received from the students to those that have a named fund. These letters are most heart warming and communicate that these grants have made a difference and helped students graduate with a degree. The Club is proud of the students to whom it has made grants and are now outstanding leaders in wireless fields of interest. Questions? Contact: John Dettra, Chairman, Radio Club Scholarship Committee, 703-790-1427.

I value membership in the Radio Club as a connection to the present, future and past of the radio industry. Membership in the Club is an opportunity to network with industry movers and shakers. Another reason that I value membership in the Club is that my father had a lifetime involvement with the radio industry. I grew up with transmitters, receivers, nets and call signs. Some of my first words were pronouncing the call sign for the station where my dad worked, KFYR and his amateur call sign W0CJC. He was an inspiration in my education and career path. Although my dad was not a member of the Radio Club, my membership connects me to an industry that he valued during his life. Manny Gutsche, Fellow.

Education

In November 2008, the Radio Club created the Education Committee which serves both the talented young amateur (youth in grades 1 through 12) as well as the technically savvy radio professional. The Committee also wants to increase awareness of amateur radio at events like the Dayton Hamvention.

(It's never too early to teach children about radio! Pictured left, kids are being given a radio demonstration at the Villages Amateur Radio Club. Photo provided by Carole Perry).

Youth outreach

The first goal is to encourage promising young achievers in secondary and primary schools across the country, beginning in Staten Island, New York. One of our goals is to locate students in this demographic who have demonstrated creativity and technical excellence in wireless communications. A special "RCA Young Achiever's Award" certificate has been created to present to these youngsters along with a stipend check to encourage them in their technical pursuits. To date, we have given out 11 Young Achiever Awards; nine to Dayton Youth Forum speakers, one to a high school senior in Staten Island, New York, and one to an accomplished special needs senior in Long Island, New York.

The Richard G. Somers Youth Educational Fund was recently "established to encourage and support educational, technical, ham radio and related activities of young people through high school," according to Carole Perry, co-chair of the RCA Education Committee. Richard Somers brought the fund to $100,000 in recognition of RCA's 100th anniversary and the fund's sole purpose is to assist young people in expanding their studies and interest in wireless communications. A contribution of $8,200 from the remaining treasury of the former National Mobile Radio Association, known for its activities to lobby the FCC and Congress in support of community repeater and SMR operators' interests, also went to increasing the Somers Youth Educational Fund. Many Club members were either members or contributors to that association so it seemed fitting.

In July 2009, the Education Committee began an equipment donation program for schools and now accepts used radio equipment. The committee has a system in place that is able to receive donated radio equipment, and is set up to inspect and repair the equipment. The donations are then forwarded to a pre-determined school or to a group that works with young children. For more information, contact Carole Perry at WB2MGP@ix.netcom.com.

Another goal of this Committee is to seek out schools that have wireless technology programs that may be in need of funding. One of our missions is to encourage the establishment of ham radio/technology classes in as many schools as possible.

It's wonderful to belong to an organization that is predicated on honoring the past achievements of our industry's pioneers and the present day successes of our colleagues. In addition, and most importantly, RCA is profoundly influencing the future by working with young children interested in radio and providing scholarships to deserving college students. Phil Casciano, president emeritus and Fellow.

Continuing education for professionals

The second group of the Education Committee strives to offer current wireless professionals a way to learn about new technology and advance professionally through providing education programs, seminars and short lectures as continuing education at Club events.

Tom Janca, CETsr with the Electronics Technicians Association (ETA) and Richard P. Biby, P.E., committee co-chair, director and Fellow of the Club, has developed an Internet Protocol (IP) basics one-day course, designed to provide the fundamentals needed to work effectively within the changing world of communications networks. As radio systems are technically, functionally and organizationally becoming more of an extension of an integrated network, with backhaul and voice- and data-carrying capabilities, radio networks are being integrated under IT departments and no longer can be viewed as stand-alone networks. Because radio networks are fairly complex, the course was developed to help radio technicians and technical staff understand the fundamentals of IP networks, rather than help IT groups understand radio networks.

The first course was held at the Texas APCO annual conference in April 2009. The committee plans to make three presentations in 2010. Working with the Radio Club, the ETA is developing a companion technical certification to the training. The Digital Two-Way Radio Network Technician credential will be ready for release by the end of 2009. ETA will provide Continuing Education Credit's for the new training.

Although this course and others could become a profit maker in the future, it's being pursued currently to promote awareness of the Club and assist wireless industry professionals. This is a timely, relevant and needed course by many people in the industry; however, as a single day long course, it can only help establish the fundamentals of many important technologies. Currently, this course covers the basics of IP networks and is geared for radio communications professionals; this is not a radio-over-IP course. For more information, contact Richard P. Biby, P.E., co-chair, director and Fellow.

The Annual Banquet and other Club events

Over the years, the Annual Banquet has been held in New York City. The 2009 banquet to commemorate the 100th anniversary will be held at the Georgetown University Hotel and Conference Center in Washington, D.C., a first in the Club's history. There will be the opening cocktail reception Friday evening, the technical symposium, exhibit room, silent auction and amateur radio special event station on Saturday leading up to the banquet.

(Steve Forbes, pictured far right, receives a Special Recognition Award from Mal Gurian and the Club for his Outstanding Achievement and Leadership in Global Communications.)

Past guest speakers and other guests-of-honor have been Senator Barry Goldwater (member and Sarnoff Citation recipient); media and business magnate Steve Forbes; "60 Minutes" commentator Andy Rooney (honorary member); broadcast giant and amateur radio licensee Walter Cronkite (honorary member and Armstrong Medal recipient); newscaster Brian Williams (the Sarnoff Citation); Princess Maria Elettra Elena Anna Marconi, daughter of Guglielmo Marconi; Morgan O'Brien (Fellow) and Steve Largent, president and CEO of CTIA.

I value meeting and working with interesting people from the entire spectrum of the radio community, learning about stimulating aspects of radio science and history, and supporting RCA's worthwhile charitable, educational, and scientific missions. I recommend that people join RCA for those same reasons. Rich Reichler, Life Member and Fellow.

The awards to be given out at this year's banquet are:

- ☆ Fred M. Link Award – Terry G. Daniels, Fellow
- ☆ Ralph Batcher Memorial Award – Bart Whitehouse, Senior member and Fellow
- ☆ Jack Poppele Broadcast Award – George Woodard
- ☆ Alfred H. Grebe Award – Larry Conlee
- ☆ Barry Goldwater Award – Ralph A. Haller, Fellow
- ☆ Special Service Award – Richard P. Biby, P.E., director and Fellow
- ☆ Special Service Award – Carroll L. Hollingsworth, director and Fellow
- ☆ President's Award – Carole J. Perry, director and Fellow
- ☆ NPSTC's Richard DeMello Award – Donald E. Root, Jr., member

All Radio Club of America Awards

To commemorate the Centennial anniversary of the Club, here is a list of all the available awards and their significance in history:

- ★ The Armstrong Medal, est. 1935 – bestowed on a member who has made an important contribution to the Radio Art and Science.
- ★ The Sarnoff Citation, est. 1973 – to a person or Club member for significant contributions to the advancement of electronic communications.
- ★ The President's Award, est. 1974 – president selects person for unselfish dedication to support of the Club.
- ★ The Edgar F. Johnson Pioneer Citation, est. 1975 – annually to long-time members who have contributed substantially to the success and development of the Club or the art of Radio.
- ★ The Special Services Award, est. 1975 – persons who have contributed substantially to the support and advancement of the Club.
- ★ The Ralph Batcher Memorial Award, est. 1976 – member who has assisted substantially in preserving the history of radio and electronic communications.
- ★ The Allen B. DuMont Citation, est. 1979 – awarded to a person who has made important contributions in the field of electronics to the science of television.
- ★ The Henri Busignies Memorial Award, est. 1981, who has contributed substantially to the advancement of electronics for the benefit of mankind. Busignies invented the UHF direction finders used in WWII to track down enemy submarines with very short sample time of transmission.
- ★ The Lee DeForest Award, est. 1983 – person for significant contributions to the advancement of radio communications.
- ★ The Fred M. Link Award, est. 1986 – persons who have contributed substantially to the advancement and development of land mobile radio and communications.
- ★ The RCA Centenarian Award, est. 1989, to any living member attaining the age of 100 years.
- ★ The Jack Poppele Broadcast Award, est. 1989, person who has made important and long-term contributions to the improvement of radio broadcasting.

- ★ The Barry Goldwater Amateur Radio Award, est. 1994 – recognition of long record of service to the public through the use of amateur radio.
- ★ The Alfred H. Grebe Award, est. 1994 – recognition of achievement of excellence in engineering and manufacturing of radio equipment.
- ★ The Frank A. Gunther Award, est. 1996 – major contributions to the advancement of military electronic communications systems.
- ★ The Jerry B. Minter Award, est. 1996 – significant contributions to the electronics art through innovation in instrumentation, avionics and electronics.
- ★ The Special Recognition Award, est. 2000 – in appreciation to individuals for their dedicated service to the Club.
- ★ The NPSTC's Richard DeMello Award, est. 2006 – individual in public safety communications who has demonstrated the highest levels of personal and professional conduct and performance in the local, state and national arena.

Amateur/ham radio supports the Radio Club of America

When the Radio Club of America was founded in 1909, most everyone involved in radio was an amateur as commercial radio communication was also in its infancy. At one time all of the Club's members were amateur radio operators, and now while not as many of our members are radio hobbyists, a large portion of members are either active operators or still maintain their licenses.

"Many of us began our communications careers via an interest in amateur radio, and one of our current goals is to expose as many individuals as possible in the next generation, to communications and technology via amateur radio," said Stan Reubenstein, president and Fellow.

Many of the Club's ham members also founded radio companies or become active in the communications industry. A few notables who were Club members (some were mentioned above): Art Collins, W0CXX (Collins Radio), Walter Cronkite, KB2GSD, Senator Barry Goldwater, K7UGA, Fred Link, W2ALU, Bill Halligan, W9AC (Hallicrafters), Jim Larsen, K7GE (Larsen Antennas) and Bill Eitel, W6UF (Eitel-McCullough, co-founded with Jack McCullough). "I am pleased to say that as a member of the Club I was able to meet all of these individuals and many more, said Reubenstein.

More recently two of the Club's members who are also hams are Carole Perry, WB2MGP, and Ken Miller, K6IR – both awarded the "Ham of the Year" award at the Dayton Hamvention.

<u>The 100th Anniversary Commemorative QSO Party</u>

The 100th Anniversary QSO Party was a two-day affair held Jan 2-3, 2009 to help celebrate the centennial birthday of the Radio Club of America. A "QSO" is a conversation or contact via amateur radio. The original "Q" codes were created in 1909 by the British Government as a standard three-letter message that stood for either a statement or question. They were developed for use with commercial radiotelegraph communication and later adopted by amateur radio. Q codes continued to be employed after the introduction of voice transmissions.

January 2 was the actual date the Club was formed so it added historical significance to the QSO Party. More than 160 conversations were logged by W2RCA alone along with dozens more by member stations.

Ham radio operators Eric Stoll, Gil Houck and Mike Katzdorn staffed W2RCA Friday, Jan. 2 and Bob Raide staffed it Saturday, Jan. 3 as W2RCA. Almost two dozen member stations checked in for both days, but not all the logs are in yet.

The Club call, W2RCA, caused quite a stir on Saturday when most people were home from work. There were times on the 20-meter band where more than several stations were calling in at the same time.

More than two dozen stations, both members and non-members, followed W2RCA to all three bands. Some of the member stations to achieve this "Triple Crown" feat were K0RL, N9UPG and N2NA, just to name a few. Some of the members who worked W2RCA included Stan Reubenstein (WA6RNU), W6NSV, N9UPG, N2NA, K2GJJ, N0JG, K0RL, W9PSE, AA1A, K0TTY, W5VXI, VE2CV, K4NBC, W8FSF, KB3LSX, W3BXO, W6EM and W2RS.

Why I value the Radio Club: I value the friendships I've made along the way. The mentoring and education that I have received for those who share their life with me and their experiences in the Club. I really enjoy the camaraderie of the intellectuals getting together without the competitor egos and agendas getting in the way. I love the education the most. To become a part of History, present and the future thoughts and dreams of everyone who participates in the Club. To see and be first hand while the world changes from one path to another in all aspects of communications, passing the torch from one generation to another for the preservation of our future. Knowing you are part of the world that very little get to see but effects everyone who touches our dreams by their small participation by utilizing our ideas in their everyday lives. Sandra Black, director and Fellow.

This white paper was written for the person who may be considering membership in the Radio Club of America but who may not be familiar with the organization. This information is in no way all-inclusive but hopefully will whet the appetite of someone interested in learning more about the Club, the benefits of membership and the importance of its history and commitment to furthering education and technical advancement in the wireless communications history.

Attributes in putting together this overview of the Radio Club of America:
1 1923 article by The Editor of the publication Radio Broadcast, Volume II, November 1922 to April 1923, Double Day, Page & Company, 1923, entitled ***"The First Amateur Radio Club in America"*** see http://www.archive.org/stream/radiobroadcast02gardrich#page/n3/mode/2up
2 May 1, 1910 article by The New York Times Sunday edition, Magazine Section, Page SM5, entitled ***"Wireless Wonder Aged 14 Amazes Senate Committee."***
3. The Radio Club of America Web site and various Club members who provided information.
4. Special thank you is extended to the Antique Wireless Association for use of their early industry photos.

Reprinted from *Radio Broadcast*, Volume II

The First Amateur Radio Club in America

A Club That Dates from 1909 and Has Among Its Members Men Who Have Helped to Make Radio Broadcasting Possible

PIONEERING in any field is in itself as valid a claim to fame as producing something of lasting good. Sticking to an ideal over a period of years, through the dark days when the very ideal itself seems to be threatened with extinction—that, too, deserves recognition.

With this in mind, we shall review the Radio Club of America's claim to lasting fame in the annals of radio. First of all, the Club dates back thirteen years—thirteen long years of the formative period of radio. This organization has stood for and has bitterly fought for amateur radio, even during those days when sinister wireless bills in the hands of unscrupulous and misinformed legislators were being discussed with the avowed intention of smothering amateur activities. This organization brought about an interchange and exposition of constructive ideas long before the founding of the present radio journals which serve that purpose so well. It has at every turn encouraged progressive steps and can, with pardonable pride, point to many names on its roster which have come to have real meaning in the first ranks of radio. That, in brief, is the background of the Radio Club of America.

> The story of the Radio Club of America and its members who were among the pioneers and are to-day leading the advances in radio, has never before been published. We greatly appreciate the valuable assistance given us by officers and members of the club in preparing this account of what we believe to be the first amateur radio club in America. It is doubtful that any other group of young men, banded together for the purpose of lending each other assistance in radio as well as the betterment of the art itself, can point to a record in any way comparable to the enviable record of the Radio Club of America.—THE EDITOR.

It was in 1909, when amateur radio was just beginning to be taken up by a few pioneer experimenters that the Radio Club of America came into existence. Under the name of the Junior Wireless Club of America, it was founded through the efforts of W. E. D. Stokes, Jr., Frank King, George J. Eltz, Jr. and others as the first association of amateur experimenters in the land. At first, the headquarters of the organization was in the Hotel Ansonia, in the residential heart of New York City, but soon the monthly meetings were held at Mr. King's house, 326 West 107th Street, at about the same time that the name was changed to the Radio Club of America. The reason for the change of name was that it was desired to have the organization national in its scope, with various branches in different parts of the country.

Perhaps the word "club," in this case, is unfortunate. A club is a place for good fellowship, true; and that describes the Radio Club of America, which has already stimulated good fellowship in radio and more specifically among its members. In that sense, the word stands.

But in the case of this group of young men, there has been something more than a club atmosphere. With the serious intentions of its members, the thoroughness of the papers and discussions marking its meetings, and the scientific value of its experiments and tests, the word "club" is almost a misnomer. This organization might well call itself a scientific society, although it does retain that spirit of fellowship which goes with the usual meaning of club.

The papers prepared and read by members during those first few meetings of the young Radio Club of America were quite crude, and a family gasolene chariot was often called into service to carry long-wave receivers or "coffin" type transformers from the Long Island or Jersey residence of the speaker for the evening, in order to illustrate his "paper" by actual demonstration. Among the early papers were: "A Square Law Variable Condenser," by George J. Eltz, Jr., which by the way, disclosed this type of condenser for the first time; and it is interesting to note that a long while afterward a condenser of this character was placed on the market by several companies and is used in several well-known wavemeters.

Another paper, "A Telephonic Relay Amplifier," was prepared and read by that ardent amateur, Dr. Walter G. Hudson, who has since died. Doctor Hudson also prepared a paper on the oxide filament for vacuum tubes, and this idea of his has since become an important factor in the construction of efficient vacuum tubes. It was tubes with oxide-coated filaments which our Army and Navy used to so great an extent during the war. They are widely known under the designations "J" and "E", the former being used for detecting and amplifying, and the latter in low-power radio telephone and continuous-wave telegraphy. At present, they are also employed in what are termed "power" amplifiers.

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GEORGE BURGHARD
President of the Radio Club of America

Still another of the early papers was "The Wavemeter, Its Operation and Uses," by Louis G. Pacent. This paper marked the first attempt to disclose to radio amateurs the mysteries of the wavemeter and the measuring of radio waves. Before then, the wavemeter was used only commercially.

Again, there were papers entitled: "Ground Antennae," by Walter S. Lemmon; "Radio Telephony," by Frank King; "A Radio Equipped Automobile," by Paul F. Godley; and "Audio Receiver System," by Edwin H. Armstrong.

The membership of the Club grew and grew and has kept on growing. Its serious character attracted the attention of early radio workers, so that aside from papers prepared by its own members, it was soon honored with addresses by such well-known radio men as R. H. Marriott, Dr. A. N. Goldsmith, J. V. L. Hogan, F. Lowenstein, Dr. J. Zenneck, F. Conrad, W. C. White, and others. Subsequently, all of these men became members.

In order that one may have a better appreciation of what the pioneering work of the Radio Club of America meant, it is well to sketch a true setting by way of contrast with the conditions of to-day. Turn back to 1909, and you find a very few young men, here and there, fascinated by the newspaper accounts of wireless attempting to receive and send radio messages. Wireless, it was then called, although the founders of the club had the vision to choose the word "radio" for their club name. Little or no real information on the subject was available. With a scant description of Marconi's experiments as a basis, the amateur of that day started to construct his set. There were no journals to guide him. He constructed his set through ingenuity of his own, and as often as not the finished product would not work. Occasional articles on the commercial stations appeared in newspapers and magazines, and each new idea, gleaned from various sources, was added piecemeal to the experimenter's stock of knowledge.

It should be borne in mind that there were no radio manufacturers to turn to for complete sets and units. All the apparatus had to be constructed by the amateur. The success of each experiment was passed along by word of mouth to other amateurs and eagerly picked up. The coherer was then used as a detector; some of the more ambitious amateurs procured the Marconi magnetic detector. Later came the microphone, crystal and electrolytic types. All tuning was accomplished by means of sliders on coils of wire wound on the handiest block of wood obtainable, often a broomstick or a bread roller. The use of variometers and variable condensers was then unknown to amateurs.

For transmitting, we find a conglomeration of small spark coils, usually home-made. These coils were operated with a mechanical interrupter and battery current, but later the electrolytic interrupter and lighting current came into use. A distance of 100 miles with an amateur transmitter was considered a remarkable achievement. To-day, with a continuous-wave transmitter at one end, and a regenerative receiver at the other, an amateur spans one thousand miles with ease and thinks little or nothing of it!

One amateur, desiring to erect the best possible aerial, came across an article describing the Cape Cod aerial as used by the Marconi Company for transatlantic work. It was in the shape of a huge square funnel, the upper ends or rim of the funnel being insulated. A carefully built miniature copy of the aerial only four feet on one side and six feet high was built, with little realization of the change in the electrical constants between the Cape Cod aerial and the miniature copy. Needless to say, the miniature copy did not work very well, and it was only by chance that the amateur discovered that a stretch of telegraph wire worked far better.

The Radio Club of America, a gathering of progressive amateurs for the purpose of exchanging ideas and experiences and avoiding the repetition of mistakes, was a necessity. The meetings, at which important papers were read, served, as nothing else could, to stimulate improvement in amateur radio.

Experiments were made with different types of aerials. It must be understood that the technical knowledge of the amateur in those days was very limited. He merely had the idea presented to him and would go ahead and experiment on any possible improvement that came to his mind. Some experiments were made with kites flown by a wire in place of the customary string. Those who tried this were sometimes surprised when, the kite having reached a height of several hundred feet, they received a good shock. This furnished considerable amusement. One member proudly announced that he would not get shocked from the wire because he had on O'Sullivan's, and walked about the tin roof with his toes in the air. The manipulator of the kite-string rather doubted the insulating qualities of rubber heels against static charges, and at a favorable moment brought the kite wire very close to the boastful young man's ear. Said boastful young man received a distinct shock despite his O'Sullivan's, which then, as now, were intended for something more practical than insulating their wearer against static electricity. But the kite aerial gave excellent results.

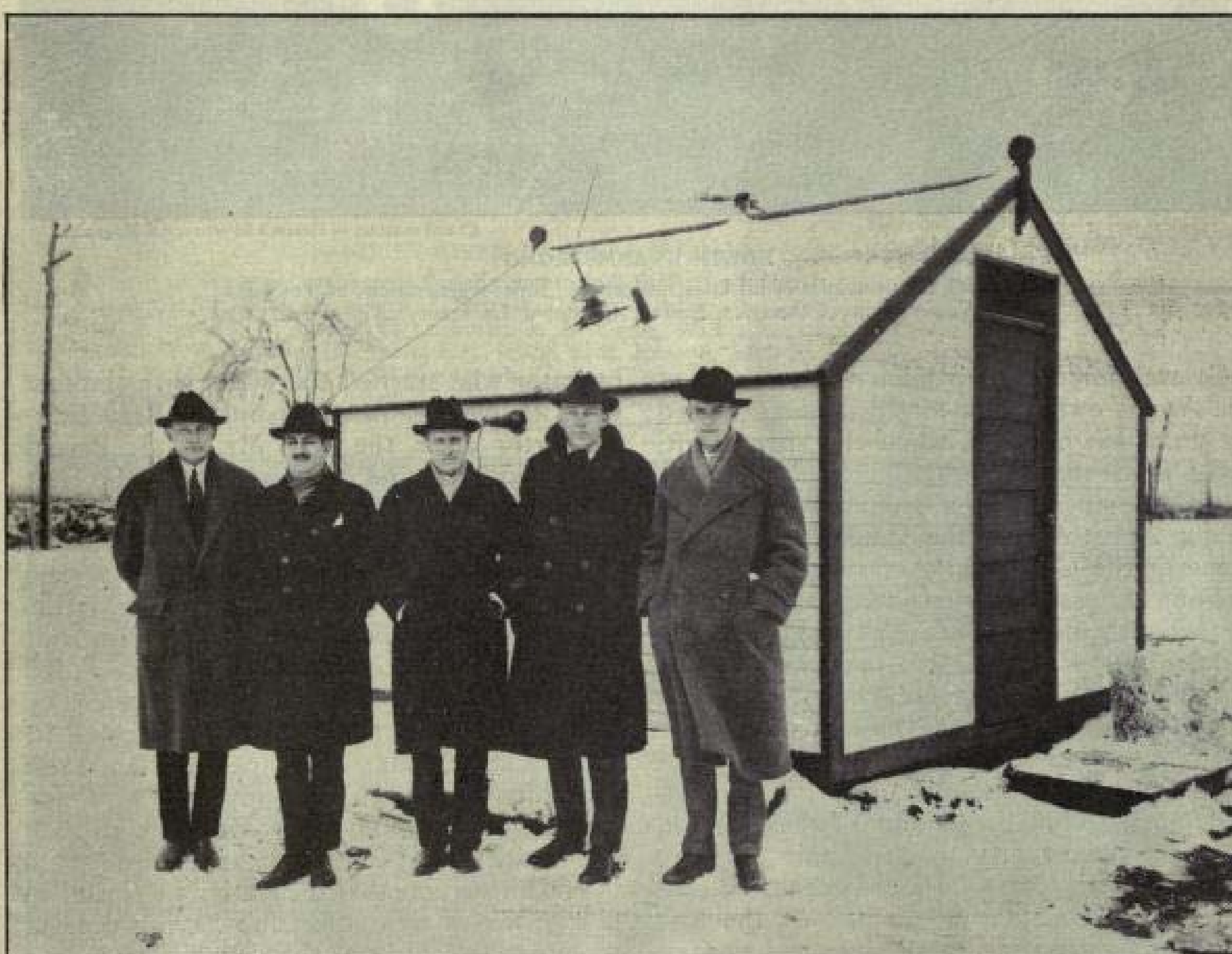
Things were once far from cheerful for experimenters. In 1910, the legislators at Washington, urged by certain radio factions, turned their axes towards amateur radio. For a while everything seemed quite gloomy; amateurs in general felt that the death knell of their hobby had been sounded. There was to be no more listening-in or "talking" via radio. There were many protests and discussions, but no concerted action was brought to bear against the proposed measure until the Radio Club of America by promptly applied efforts, prevented the passage of the Depew Bill. If it had been passed, it would have terminated the art, as far as amateur radio is concerned.

Two years' respite followed, and then came the Alexander Wireless Bill, in 1912. This dangerous piece of proposed legislation was killed in committee by the quick work of the Club. Not long after the Armistice the bill was definitely buried by concerted action and immediate pressure brought to bear by the Radio Club of America through several members who had served with distinction in the Army and the Navy, and others who had helped in civilian capacities. T. Johnson, Jr., Lieut. Harry Sadenwater, U. S. N., Ensign Frank King, U. S. N., Ensign George Eltz, U. S. N., John Grinan, Ensign George Burghard, U. S. N., L. G. Pacent, Ensign T. J. Styles U. S. N., Capt. E. V. Amy, U. S. A. and others convinced the legislators that amateur radio was a constructive and necessary study.

But we are ahead of our story. In 1913, two of the members, Frank King and George J. Eltz, Jr., installed one of the first radio telephone *broadcasting* stations in the United States, at 326 West 107th Street, New York. The apparatus was all home made, and naturally crude. Successful transmission was obtained, however, and phonograph records were played for the benefit of several battleships swinging at anchor a short distance away in the Hudson River. An arc, burning in hydrogen, with an improvised syphon cooling arrangement, was used. The hydrogen was supplied by vaporizing alcohol, and several amusing incidents occurred when the mixture in the arc chamber became explosive and the operators were forced to beat a hasty retreat.

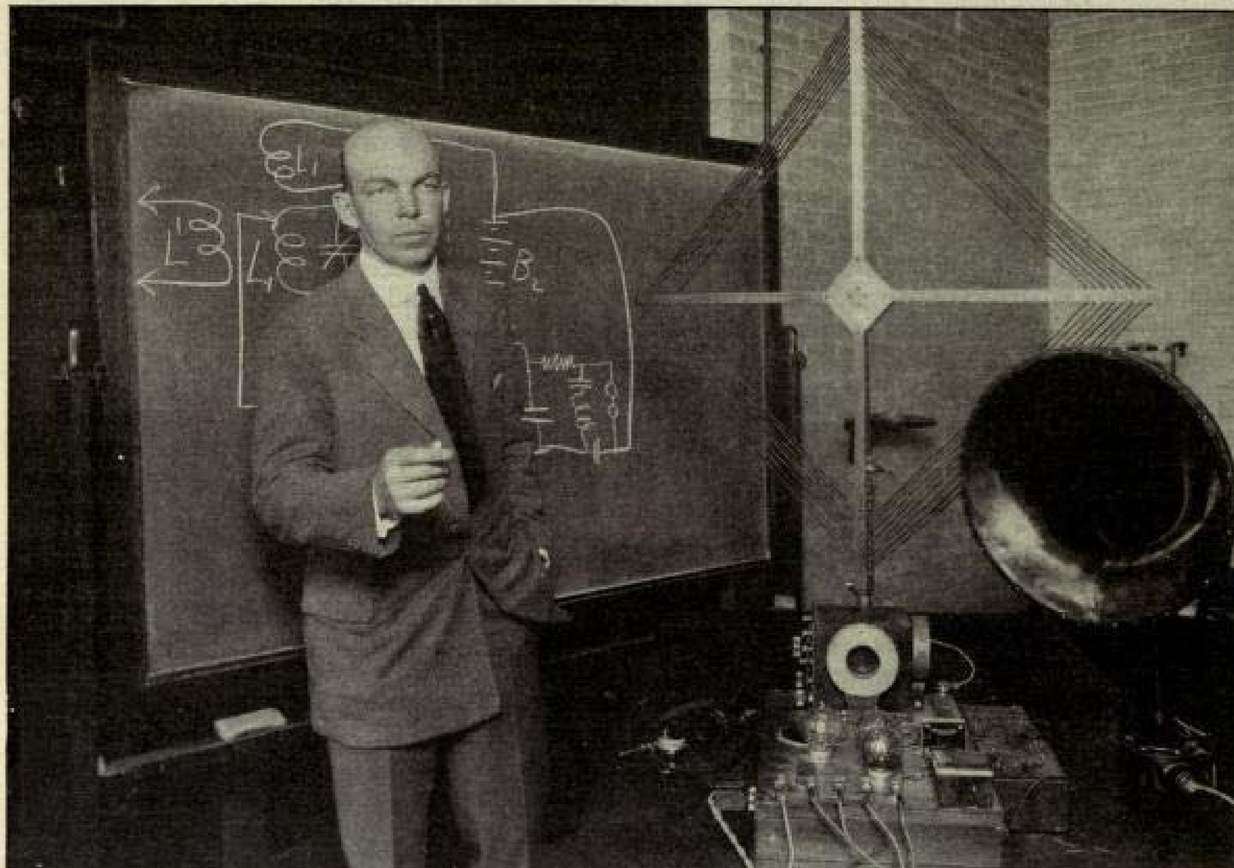
It was during July, 1915, that the Club installed a model radio station in the Hotel Ansonia, the headquarters of Admiral Fletcher and his staff, enabling the visiting admiral and his men to keep in communication with the vessels of the fleet, anchored in the Hudson River. The station was operated by members of the Club for a period of ten days and handled over one thousand messages during that period. Because of this commendable work an interesting radiogram from President Wilson, who had reviewed the fleet on the last day from the deck of the *Mayflower*, was received by the Club. Furthermore, a large banner was awarded the Club by the Navy League as a token of its patriotic activities.

When, in 1917, we found it necessary to become a warring people virtually overnight, the Radio Club of America was fortunately a going concern with a corps of highly trained members. The first business then being the winning of the war, the Club proceeded to devote its energies toward that end. Many of its members, through their training and experience, soon found important work to perform with the uniformed and civilian forces. Space does not permit of a full account of the Club's war record but we cannot refrain from mentioning the notable work done by Major Edwin H. Armstrong in the Signal Corps of the A. E. F. Also the flight of Lieut. Harry Sadenwater as radio officer in the NC1, during the attempted transatlantic flight at the close of the war. The



THE FIRST AMATEUR TRANSATLANTIC STATION

It was built in less than two weeks and operated by (left to right) E. V. Amy, John Grinan—the first amateur to send directly across the U. S.—George Burghard, E. H. Armstrong, inventor of regeneration and supper-regeneration, and Minton Cronkhite



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EDWIN H. ARMSTRONG

Explaining the principles of his latest invention, "super-regeneration" at a meeting of the Radio Club of America, held in Columbia University, New York City

NC1 was forced to abandon the attempt at the Azores owing to a forced landing caused by uncertain bearings, while the sister craft, NC4, made the entire flight.

In November, 1919, a banquet was given to Major Armstrong at the Hotel Ansonia, the scene of the Club's early efforts. All of the prominent local radio engineers were present to join with the members in paying homage to Armstrong. His work is so well known that nothing more need be said of it here. Sufficient to state that he made radio broadcasting of the vacuum-tube variety possible.

One eventful evening one of the Club members, Mr. John F. Grinan of New York, saw an opportunity to transmit a relay message to the Coast. He did so and received a reply from California. This was the first amateur transcontinental message and was not pre-arranged. About a week later, Mr. Grinan performed the remarkable feat of transmitting to California direct.

Another member of note is Jack Binns, the operator who startled the world with the first C. Q. D. message from the sinking *Republic*.

Shortly after the war Mr. L G. Pacent suggested the first transatlantic radio test with amateur transmitters and receivers. At that time the suggestion may have seemed fantastic—but it was carried out only two years later. When this first message was sent in the winter of 1921, from station 1BCG located at Greenwich, Conn., operating on 200 meters and 900 watts input, the messages were received by Paul F. Godley, a member of the Club, in Ardrossan, Scotland. The messages were also heard in Hamburg, Germany, and Catalina Islands, Cal. Thus 1BCG covered more than one fourth of the earth's circumference. It is interesting to note that the station was installed in two weeks' time, the Club having decided to enter the contest at the eleventh hour.

Although a period of thirteen years has elapsed since the formation of the Club, practically all its original members are still active, a fact which in itself is a tribute to the fascination of radio. Thus we trace its history from a mere handful of interested experimenters, lacking in knowledge but filled with enthusiasm, to a well-organized body of three hundred members.

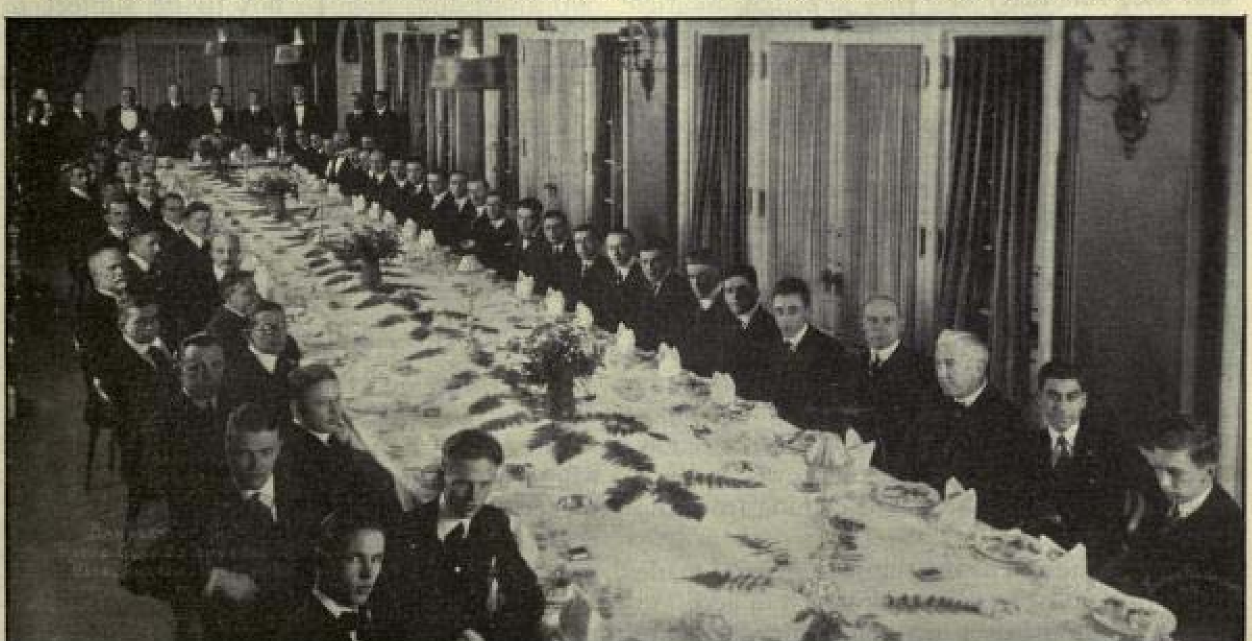
The present officers include: President, George E. Burghard; Vice-President, E. V. Amy; Recording Secretary, L. C. F. Horle; Treasurer, John Di Blasi; Corresponding Secretary, R. H. McMann, 380 Riverside Drive, N. Y. C.; Board of Directors, E. H. Armstrong, P. F. Godley, L. G. Pacent, J. F. Grinan, Minton Cronkhite, W. S. Lemmon, A. A. Herbert, Frank King, J. O. Smith and Nelson Dunham.

A branch has been started in Chicago, where many of the pioneers of that city and the vicinity are enrolled as members. The Affiliation Committee is working on plans to open other branches in Schenectady (N. Y.), Cambridge (Mass.) and Pittsburgh (Pa.) while plans are well under way to establish other branches throughout the country.

Since their high school and college days, most of the members have made radio their life work. The boys who used to climb to the topmost branches of trees or scale roofs, to the horror of their parents and landlords; the boys who delighted in erecting antennas in forbidden places and who broke many a window with slings used to carry wires from apartment houses on opposite sides of the street; who built their transmitters and receivers in wood-sheds or barn lofts with tools taken from their dads' chests; who sat up into the wee hours of the morning much to the discomfort of solicitous parents, in order to add a few more miles to a distance record or pick up stations they had not "worked" before; whose deep-throated spark transmitters or musical rotary gaps kept whole neighborhoods awake; the boys who dimmed the lights of their community every time they pressed their keys; who fought the power companies tooth and nail; who succeeded in putting radio on the map and in thousands of homes—these boys, grown up, are now doing the same thing in business, in a less spectacular manner, no doubt, but as full of life and enthusiasm as before. They have left their original rôles to the beginner of to-day and have taken up the more important work in the radio field: they are pioneers, inventors, manufacturers, lawyers, lecturers, engineers, sales managers, editors and authors—and they are still boys.

BANQUET GIVEN IN HONOR OF MAJOR E. H. ARMSTRONG

Many of those present are famous in radio, and include W. F. Diehl, Harry Styles, John Styles, Thomas Styles, Jack Shaughnessy, H. Scutt, H. Houck, A. Herbert, Dr. C. C. Godfrey, C. E. Braden, C. R. Runyon, C. Calm, E. V. Amy, Paul F. Godley, A. Aceves, C. Cushman, A. H. Grebe, Walter Lemmon, Minton Cronkhite, A. Miesner, F. Humers, Prof. Hazeltine, W. Davis, E. J. Simon, L. R. Krumm, Prof. M. I. Pupin, E. H. Armstrong, T. Johnson, Jr., J. V. L. Hogan, Dr. A. N. Goldsmith, George Clark, J. A. White, L. G. Pacent, D. Sarnoff, W. Dubilier, C. Marshal, C. Hunt, C. Estey, C. Kaliant, E. Meyers, B. H. Noden, S. A. Barone, J. Di Blasi, H. Silversdorff, C. Burche, A. P. Morgan, C. Thomas, L. Spangenburg, E. Glavin, Joe Stanley, George Crouse, and others

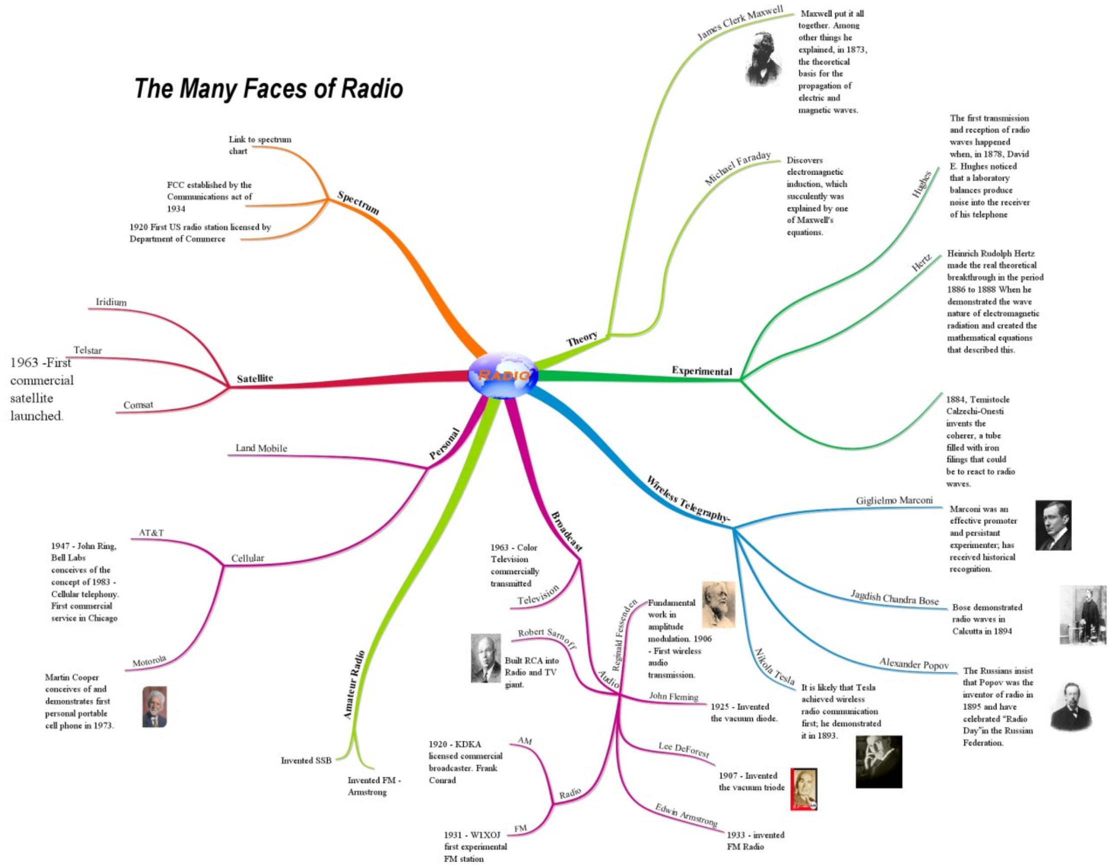


The Many Faces of Radio

By Martin Cooper (F)

The term "*radio"* was first used around 1906, only a few years before the Radio Club of America was established, although the science and technology supporting radio dates back to at least 1873. The word *"radio"* embraces any form of electromagnetic communication. The history of radio is especially rich in colorful contributors and conflicting claims. For example, depending upon national or historical biases, any one of at least four persons was the inventor of radio. The stories about the conception of the scientific principles behind radio and the evolution of the many industries it has spawned are dispersed into hundreds of books, articles, and other documents. The archives of the RCA contain many of these stories and the Jubilee Proceedings include much of this material.

The *"Many Faces of Radio"* is a project intended to create a living history of radio that provides simple access to this rich history. The basis of this project is a "mindmap," a pictorial representation that acts as a source of information with portals into the Internet as well as notes, video and audio clips. A picture of the beginnings of this mindmap looks like this:



The initial screen of the *"Many Faces of Radio"* mindmap is, in itself, an incomplete overview that offers an introduction to the complexities of a history of radio that has evolved during the past 140 years. It also is, in a sense, a description of our membership and a guide for the recruiting efforts of those who strive to grow and refresh our membership. But even more, the *"Many Faces of Radio"* offers the opportunity to access, with the click of a mouse key, the vast body of historical data resident on the Internet, in RCA archives and in the minds of RCA members. It is intended that the "Many Faces of Radio" becomes a living, constantly evolving archive that seeks to enhance one of the fundamental aims of the Radio Club of America, the preservation of the history of our passion.

We invite the Radio Club membership to contribute to *"Many Faces of Radio"* so as to maintain it as a living document. The *"Many Faces of Radio"* mindmap and instructions for such contribution appear at www.dynallc.com and, we expect, from the Radio Club of America Web site.

P.S. To read the small print on the mindmap in this document, you will have to zoom in using the Microsoft Word Zoom button. When opened as a Web Page, the zoom button on that page will magnify the picture.

The Mythical Spectrum Shortage

by Martin Cooper (F)

People are mobile! They are naturally, inherently mobile. You see that every time you drive the streets of your city or walk its malls. It seems that few people are where they want to be and they all seem to be on there way to somewhere else. And yet we in the telecommunications business have a history of constraining this need for mobility. We started by chaining people to there homes and desks with copper wire, then we introduced wireless and trapped them in their cars, and now that cellular telephony is a reality, we offer mobility for their computers but give them a choice between very expensive and slow cellular service or the constraint of a WiFi "hot spot" that lengthens the chains but hardly eliminates them. Personal telecommunications requires ever increasing bandwidth delivered to individuals at ever decreasing cost. There is no technological or economic reason that keeps us from doing just that. But the telecommunications industry is far from fulfilling this need; and at the top of the list of excuses for our painfully slow progress is the radio frequency spectrum.

The primary reason for our inability to move rapidly in availing ourselves of the potential of low-cost personal broadband wireless is our inability to manage the radio frequency spectrum. Instead of encouraging new technology that drives the cost of services down, we create the appearance of scarcity that discourages innovative spectrum use. Instead of driving more effective use of the spectrum we incentivise spectrum hoarding. Instead of allowing market forces drive our industry forward, we meddle with the market for spectrum and keep these market forces from operating.

A different technology based view of the spectrum might accelerate our progress and that is the subject of this paper.

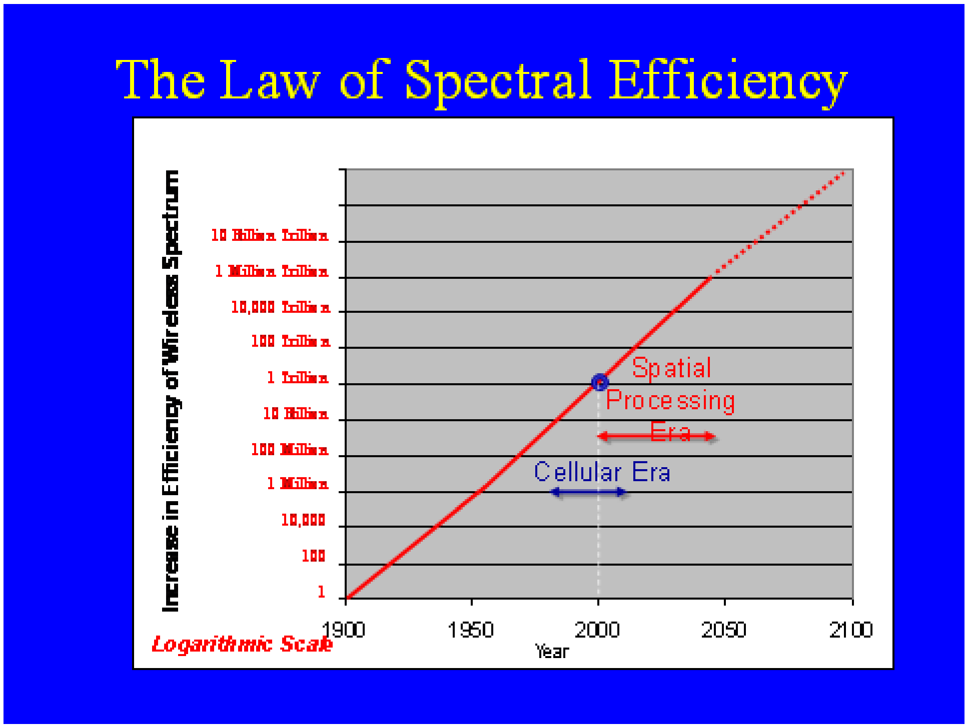
Let's start at the beginning. Is there really an increasing need for personal spectrum, how have we met this need in the past, and how the need for spectrum will be fulfilled in the future? There is no doubt that our society will ultimately secure the freedom, the productivity, and the many other benefits that come from using radio frequency spectrum. It will take a lot of technical and regulatory creativity, a lot of financial and intellectual investment before that happens. . But there is a direct correlation between our prosperity and our ability to communicate. We can, and should move faster.

The radio frequency spectrum has some unique properties. It has become common to refer to the radio frequency spectrum as a form of property and yet spectrum has no substance, no dimensions, and no real physical properties. In fact, for all practical purposes the spectrum does not really exist until we either use it - or misuse it. The one aspect of the spectrum that is the real source of all of the technological, legal, and regulatory machinations that have been going on for over a hundred years is that *use of the spectrum for any practical purpose requires some form of exclusivity*. Spectrum is analogous to space, rather than property. That is to say, two objects or two people cannot occupy the same space at the same time. Similarly in order to extract a unique signal, or message, out of the cacophony of electromagnetic energy that surrounds us, some of it natural but mostly man-made, that signal or message has to occupy a portion of the spectrum with enough exclusivity to allow us to extract it to separate it from all of the other messages and noise that permeate the spectrum. CDMA, ultra wideband, and some other technologies purport to occupy one segment of spectrum with multiple signals, but there is no free lunch. All of the technologies that we use to access the spectrum, whether they are time division, frequency division, code division, or spatial division, carve up the radio spectrum in such a way that any one piece of it is usable for a specific communication only to the exclusion of all other communications.

There are degrees of exclusivity. An extreme example of exclusivity occurs in the television broadcast bands where, in an overzealous attempt to defend the right of the public to watch the 50th rerun of “Law and Order”, a single television broadcast channel not only has exclusive use of a specific range of frequencies, (of spectrum) but also of a number of other frequency ranges that could offer added channel capacity but are prohibited from doing so because, at some time in the distant past there was the possibility that someone operating in these other spaces could create signals that would interfere with the primary channel. The result of this overzealousness is that, in some cases, a single 6 MHz television channel had, until recently, regulatory exclusivity of as much as 30 or 40 MHz. We call the restrictions, the guard bands, that keep us from using all of these channels “taboos”, and if that term brings to mind magic and sorcery it's not surprising because there is very little connection with the taboos today’s reality.

Most users of the spectrum do not have the luxury that was been enjoyed by the television broadcasting industry during the past 60 years or so. Unlike real estate property, you can't build a fence around a segment of radio spectrum. Your neighbors, whether they are geographic neighbors or frequency neighbors or code neighbors, *always* intrude on your property (we call that interference); it's only a question of how much. And that very simply is the essence of why we have needed some form of government regulation since Marconi discovered some years ago that his competitors could put him out of business by just transmitting on the same frequency as he was.

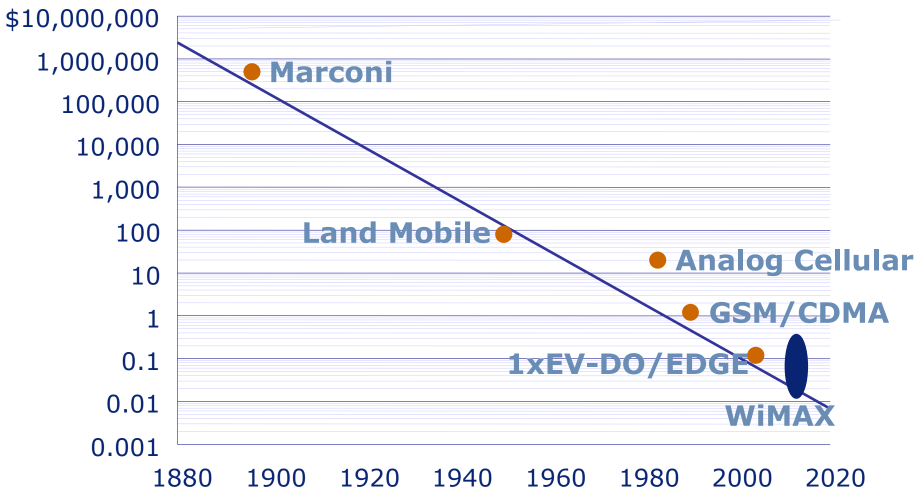
These remarks are focused upon the technology of spectrum use but a mention of the legal and regulatory aspects of spectrum may be appropriate. If, by some magical means, we could suddenly create a huge abundance of radio spectrum, the need for all of the creative proposals for new ways of regulating the spectrum would become unnecessary. If there was enough available radio spectrum so that anyone who needed to occupy a portion of the spectrum in a given place for a given amount of time could do so, we could dispense with that part of the regulatory process that has slowed us down so much and get on with the technology of bringing the benefits of the radios effect from to the people. And yet since the beginning of radio, since Marconi made his first transatlantic transmission of hundred and 10 years ago, technology has been doing just that. By at least one measure, technologists have essentially doubled the amount of information that can be passed through all of the usable radio spectrum every 2 1/2 years, every 30 months for the past 110 years (see Chart 1).



In technical terms the measure of throughput of personal communications, of spectral efficiency, is bits per second per hertz per sector. There is a simpler way of viewing the capacity of spectrum to accommodate communications. Think about a measure of throughput as the number of bits per second that can be put in the form of messages from one point to another over all of the useful radio spectrum, using the best technique available at any given time, over the entire world. By this measure, the capacity of the radio spectrum has doubled every 30 months for over 110 years. That's a very profound conclusion. The spectrum has, for the past 110 years, grown faster than our ability to use it. The useful technical capacity of the spectrum, its ability to carry information has increased by a trillion times in 110 years.

Furthermore we engineers already know enough about the technologies of the future to safely predict that the world is going to be able to continue this rate of expansion of the capacity of the spectrum for at least another 50 or 60 years.

Let me point out three interesting observations about this expansion of capacity. First, the growth has not been continuous, but rather sporadic. The real leaps forward were made when people were either starved for spectrum by regulatory abuse or when the government mandated improvements in spectral efficiency. Second, almost all of the increase in capacity of the spectrum was by virtue of geographic sharing. Finally, there is a direct correlation between the cost of delivering communications and the efficiency of the process. The cost of delivering a message has dropped in half about every 42 months for over a century (chart II).



Wireless System Cost per "Delivery"
Chart 2

Source: ArrayComm analysis

We have never used very much of even the part of the radio spectrum that we understood how to use and we are certainly not using very much of it today. So let me make a statement which may be considered outrageous but which is readily provable.

There is no scarcity of spectrum today - there never has been a shortage of radio frequency spectrum, and there never need be.

Most of the radio spectrum today is unused, vacant. Here are some of the ways in which we keep spectrum from being available to benefit the public:

- Guard bands are assigned to protect assignees of spectrum that were appropriate in the past that do not reflect improvements in technology.

- Spectrum is assigned to entities who underuse the spectrum, or who don't use it at all

- Spectrum is assigned over broad geographic areas to entities that use it in limited portions of these areas

- Spectrum is assigned to entities that use the spectrum for only a small proportion of time

- Spectrum assignees continue to use obsolete technology

And yet, despite this apparent squandering of an important natural resource, we always seem to find room in the spectrum for new services and technologies. We are, very simply, creating spectrum faster than it is being consumed.

Before I get on to explaining this conclusion, allow me to diverge for a moment to discuss the issue of demand for radio spectrum.

Just how much bandwidth is needed to connect an individual electronically to the services that an individual may need. The need of people for personal bandwidth is a moving target. For many years we satisfied that need with radio pagers that require just a few bits to operate. We graduated to analog voice with a bandwidth of about 4 kb per second and then to digital voice, as used in cellular today at 10 kb per second. And yet when we listen to CDs and our iPods, we demand fidelity that takes 100 kb per second and higher to fulfill. There is lots of room for improvement in voice communication alone. But video communications is much more demanding. For over 60 years we have been watching television pictures comprising a few hundred thousand pixels. After well over 20 years of industry and regulatory effort, we can now watch HD TV with, effectively, about 1.5 million pixels. But hidden in each of your eyeballs are 20,000,000 rods and 7 million cones that, when connected to your brain, provide you with sufficient resolution to distinguish the headlights of a car as two separate objects 39 miles away. Our grandchildren are simply not going to be satisfied with a million pixels - even simple digital cameras now offer 10 million pixels. And while the industry is delivering 10 million pixels to each individual now, the demand will arise for three-dimensional pictures that will create even further demand for spectrum (Chart 3 below).

Personal Wireless Bandwidth
How Much is Enough?

Voice	Telephone quality – 64 kb/sec(10 kb/sec compressed)
	Cell phone – 10 kb/sec
	MP3 quality – 128 kb/sec
	CD quality – 256 kb/sec
Browsing (text and Pictures	One Megabit per sec peak – >50 kb/sec average
Video (with compression)	
	TV – 1 mb/sec
	HDTV – 5mb/sec
	Movie theater – 20 mb/sec
	Human eye – 250 mb/sec (each eye)

Chart 3

Let us return now to the issue of how we are going to create this new spectrum. How can we squeeze more information, more bits per second, through a given bandwidth?

There are just a few technological methods for doing this:

- Extend the range of radio frequencies over which we can conduct useful communication

- Use more efficient techniques that squeeze more bits per second through a given bandwidth
- Use methods that constrain communications to the minimum area required (geographic sharing such as cellular telephony)

Extend the frequency range: The upper frequency limit of practical radio transmission is determined by two key factors. The more important is the ability to transduce energy through antennas that shrink by half each time we double the frequency. Effectively, the higher the frequency, the less range we can achieve with a given amount of power. Secondly, the frequencies above 3 GHz or tend to be more affected by rain, foliage, and other natural and man-made obstructions. Personal communications systems now extend up to 2.5 GHz. It is unlikely that there will be significant further improvement.

More efficient techniques: In the 1940s, Claude Shannon developed a theorem that established an upper limit on the amount of data that could be transmitted over a channel of a given bandwidth and with a given signal to noise ratio. There's a lot of technological wizardry that can allow us to approach Shannon's channel capacity, especially if the noise on the channel is not random, but we've pretty much exhausted this approach to improving channel capacity. The new technologies, WCDMA for example, allow us to operate at higher data rates but do not improve overall channel capacity very much.

Geographic sharing: Most of the improvement in spectral efficiency since Marconi has resulted from different forms of geographic reuse; in the future almost all the improvement will come from this source.

How we are going to pull off this extraordinary multiplication of the amount of spectrum?

By 2020, we will effectively have the capability of multiplying the efficiency of spectrum use for personal communications by about 32 times. Any block of spectrum in the usable range will thus be able to accommodate 32 times more throughput than can be achieved with today's technologies. How are we going to achieve this huge multiplication of spectral capacity? Most of the improvement is going to come from deployment of a technology that we call multi-antenna signal processing, or MAS. MAS involves the use of multiple antennas at either or both ends of all wireless communications path. The term MAS includes a plethora of technological tricks that we engineers have created to maintain the mystic qualities of our profession including "smart antennas", MIMO, spatial multiplexing, space-time coding, adaptive arrays, and so forth. This is not new technology; it is widely deployed with proven performance. There are almost 300,000 base stations in China, Japan, and elsewhere serving nearly 100 million people using advanced MAS technology. There are millions of WiFi access points deployed using MAS. And the requirement for MAS technology is now embedded in the standards for WiMAX and LTE, and for HSDPA handsets that will be part of the third generation cellular offerings.

While there are many forms of MAS, let me take a few moments to describe the principles involved in most effective form of MAS.

Cellular systems achieve their spectral efficiency familiarly through reuse and hand off. A city is divided into a number of coverage areas, which we call cells, each of which is served by a central station that transmits and receives radio frequency signals. In transmitting, these signals are broadcast throughout the area of the cell. Almost all of this transmitted energy is wasted; the only useful part is the tiny bit of energy that actually impinges upon the antenna in your cell phone. Not only is this energy wasted but it forms the interference that prevents others in this cell and surrounding cells from using a particular frequency channel. Similarly when the base station attempts to receive a signal from your handset, it only wants to listen to you but it is exposed to transmissions from every other user in the cell who might occupy the same radio channel.

How wonderful it would be if we could focus the attention of the base station on a single user and give it the ability to ignore other users on the same channel in a given cell. Equally wonderful that would be the ability to transmit directly to a user with minimal interference to others. MAS gives us the power to do just that. An MAS equipped they station initially listens for a mobile signal are requesting its attention. It hears a different version of that signal with each of anywhere from two to a dozen antennas. Now we get to the "processing" part. All of these signals are delivered to a very powerful processor that combines them in such a way that the desired signal is maximized in the undesired signals are minimized.

Here's a simple analogy: Let us assume a base station with only two antennas. If we receive a signal from a handset to each of these antennas and feed the output of the antennas to a processor, the processor can add these signals together and provide an outlet that is twice as large as random information coming from other sources. But if the signal is from an undesired source, the processor can do just the opposite; it can subtract one signal from the other and essentially cancel the signal out. In this simple case, a base station receiver can extract a signal from its surroundings even in the presence of other signals on the same radio channel even if these other signals are stronger than the desired signal. Similarly, once the transmitter knows the characteristics of the handset whose signal it is receiving, it can send information back to this handset and avoid wasting energy by sending the information throughout the cell.

If this sounds arcane, think about how you unconsciously use the fact that you have two ears. If you were to close your eyes and I walked around your room while continuing to talk, you could point at me with incredible precision. That ability is useful to you in several important ways. In a noisy room you can listen to someone talking even though the surrounding noise is louder than the voice of the person you're listening to.

My example and analogy are necessarily oversimplified. There are many creative ways of combining the outputs of antenna arrays to improve wireless communication systems. Functionally, MAS does some combination of the following:

- Increase range and coverage
- Reduce interference
- Increase capacity
- Increased data rates
- Make channels more robust - fewer dropped calls
- Improve spectral efficiency

All of these improvements translate to one very important result. MAS can improve the economics of wireless communications by at least an order of magnitude. Every one of the improvements listed above can be achieved in existing cellular systems by adding cell sites, increasing power of base stations, or by simply acquiring more spectrum. But the most important challenge in bringing the benefits of broadband communications to mobile people is the cost of the service. Wireless carriers have been struggling for years to discover new applications that will increase their average revenue per user. When they are able to make the cost of service low enough, the applications will appear. Unfortunately for the carriers, the ARPU will not go up significantly since people have only a limited amount of their income that they can apply to such applications.

Here is a final suggestion about the regulatory process for radio frequency spectrum. If, in fact, the value of the spectrum, properly used, will continue to grow at a rate anything close to what I suggested earlier, then selling the spectrum at a fixed price makes no sense at all. Whatever process is used to assign spectrum whether for commercial purposes or for government use, there should be a mechanism that recognizes that proper use of the spectrum will continually increase its value. To properly reflect this, spectrum assignees should do one or more of several things:

- Start measuring the efficiency of spectrum use in each of the services that license spectrum from the government
- Be prepared to demonstrate that they are using the spectrum effectively or to return the spectrum to a public pool.
- Pay an increasing royalty to the government for the privilege of using this public resource

Conclusion

Broadband wireless delivered at affordable cost can improve our productivity, entertain us, educate us, and improve our safety and health. But it can only achieve these benefits if it can be delivered affordably and if the spectrum is used efficiently enough to provide this affordability. Spatial technology, MAS, is here today and offers us a solution to the spectrum problem that does not require radical changes in the way we allocate spectrum.

The radio frequency spectrum belongs to the public. It is licensed to entities under the condition that they use it in the public interest. Those entities should be required to avail themselves of the most spectrum efficient technologies.

About the Author

Martin Cooper (F) is chairman and co-founder of ArrayComm Inc. A pioneer in the wireless communications industry, Cooper conceived the first portable cellular phone in 1973 and is cited in the Guinness Book of World Records for making the first cellular telephone call. He led the 10-year process of bringing the product to market. He has been referred to as the father of portable cellular telephony. He is widely recognized as an innovator in spectrum management.

During 29 years with Motorola, Cooper was responsible for many of the business and technological concepts behind today's paging, mobile radio and cellular businesses, built and managed both its paging and cellular businesses, and served as a division manager and as Corporate Director of Research and Development. He led, during his 29 years at Motorola, the creation of a number of major businesses including high-capacity paging, trunked mobile radio, cellular radio telephone, quartz crystals and oscillators, liquid crystal displays, and piezo-electric components, Motorola A.M. Stereo technology, and various mobile and portable two way radio product lines. Products introduced by Cooper have had cumulative sales volume of more than $80 billion.

Upon leaving Motorola, Cooper co-founded Cellular Business Systems, Inc. and led it to dominate the cellular billing industry. Cooper has been granted eleven patents in the communications field and has been widely published on various aspects of communications technology and on management of research and development.

Cooper co-founded ArrayComm in 1992. It has grown from a seed-funded startup in San Jose, Calif., into the world leader in smart antenna technology with over 400 patents issued or pending. ArrayComm also created the i-BURST mobile broadband wireless Internet access system that uses its antenna technology to deliver a revolutionary Wireless broadband Internet experience. IBurst service is provided by operators such as Personal Broadband Australia and WBS in South Africa.

Cooper was involved in industry and government efforts to allocate new radio frequency spectrum for the land mobile radio services in the U.S. and has testified before the FCC and the Senate. He serves on the U.S. Department of Commerce Spectrum Advisory Committee that advises the President of the United States on spectrum policy. He has been widely published on various aspects of communications technology and on management of research and development.

Cooper received the American Computer Museum's George R. Stibitz Computer and Communications Pioneer Award in 2002, he was an inaugural member of *RCR*'s Wireless Hall of Fame, *Red Herring* magazine named him one of the Top 10 Entrepreneurs of 2000, and Wireless Systems Design provided him with the 2002 Industry Leader award. He was a winner of the Wharton School of the University of Pennsylvania Business Transformation Technology Change Leader Award. He is a recipient of the IEEE Centennial Medal and is a Fellow of the IEEE. He is a recipient of the Radio Club of America's Fred Link Award and is a fellow of that organization. He holds a B.S. and an M.S. in Electrical Engineering from Illinois Institute of Technology on whose board of Trustees he serves.

He was a Distinguished Lecturer for the International Engineering Consortium and served on its advisory board. He has participated in the founding of several other companies and has served on the boards of several public and private companies.

He has bachelors and masters degrees from the Illinois Institute of Technology, was awarded an honorary doctorate by that institution, and serves on its board of trustees.

He served in the U.S. Navy during the Korean conflict as an officer on destroyers and submarines.

He has two children and four grandchildren.

Cooper was born in Chicago on Dec. 26, 1928.

The Amateur Radio Service and the International Telecommunication Union

By Kenneth Pulfer, VE3PU

Introduction

As we will see below, the International Telecommunications Union (ITU), an agency of the United Nations, provides a forum for the development, and subsequent amendment in international conferences, of a multinational treaty governing the regulation of the radio spectrum between 10 kHz and 1000 GHz.

One of the ITU objectives is to "facilitate equitable access to, and rational use of, the natural resources of the radio-frequency spectrum and the geostationary-satellite orbit".[1]

To carry out this work, users of radio frequencies have been somewhat arbitrarily classified into "services" or groups of users that communicate with each other, and have a common interest in minimizing interference from each other and from other groups of users. The "aeronautical mobile service", the "aeronautical radionavigation service", and the "fixed satellite service" are examples. The "amateur service" and the "amateur satellite service" are also protected by the international regulations. In fact, amateur radio has been recognized by the ITU as a legitimate radio service since 1927, and is represented within the organization by the International Amateur Radio Union (IARU), a society representing national amateur radio associations around the world.[2]

An important aspect of the international radio regulations is the allocation of the radio frequency spectrum to the various competing services. In other words, many services have access (sometimes exclusively) to particular frequency "bands" or blocks of spectrum for their own use. It may come as a surprise to many that the amateur services have access to about 10 percent of the allocated spectrum.

History of the ITU [3,4]

[1]Mission of the ITU: http://www.itu.int/net/about/mission.aspx

[2] DeSoto, C. B. (1981). Two hundred meters and down, the story of amateur radio: Radio amateur's library, publication no. 13. West Hartford, Conn: American Radio Relay League.

[3] History of the ITU: http://www.itu.int/net/about/history.aspx

[4] Kevin William Lloyd McQuiggin (2001), Amateur Radio and Innovation in Telecommunications Technology: Masters thesis, Simon Fraser University

In 1844, Samuel Morse sent his first public message over a telegraph line between Washington and Baltimore. It was not long before similar systems were in operation around the world.

During the following 20 years, telegraph lines did not cross national borders and because each country used a different system, messages had to be transcribed and re-transmitted over the telegraph networks of neighboring countries. It soon became obvious that some form of standardization was desirable.

In 1865, the first International Telegraph Convention was signed in Paris by 20 countries, and the International Telegraph Union (ITU) was established to facilitate subsequent amendments to this initial treaty. International conferences, sponsored by the ITU, were subsequently held periodically to discuss technological developments and amend the treaty as necessary.

Following the invention of the telephone in 1876, the International Telegraph Union began, in 1885, to draw up international regulations governing telephony as well as telegraphy. Some 20 years later with the invention in 1896 of wireless telegraphy, the first type of radiocommunication, it was decided to convene a preliminary radio conference in 1903 to study the question of international regulations for radiotelegraph communications. Long distance propagation increased the possibility of international interference, making such regulation even more important.

With the subsequent development of radiotelephony and radio broadcasting, the role of the ITU expanded, and it was decided to change the name to The International Telecommunication Union. The new name came into effect on 1 January 1934.

After World War II, in 1947, the ITU became a specialized agency of the newly created United Nations. Currently over 180 countries belong to the ITU.

Although full ITU membership is open only to sovereign states, by the beginning of 21st century some 360 scientific and industrial companies, public and private operators, and regional/international organizations including the IARU took part in ITU's ongoing work. These so called ITU Sector members cannot vote on agenda items during a conference, but must achieve their objectives by informally influencing positions taken by country delegations.

History of the IARU [2]

In the early 1900s, as radiotelegraphy came into use for maritime safety and subsequent commercial communications, frequencies above about 1.5 MHz were difficult to generate and thought to be of little use. They were therefore left to experimenters or “radio amateurs”.

In the early 1920’s, radio amateur Hiram Percy Maxim, then President of the American Radio Relay League, recogized that the higher frequencies were capable of long range communication with low power and simple antennas and that these frequencies would soon be reallocated from amateur use to broadcasting, commercial communications and military applications. He therefore saw the need for an international organization to protect the interests of radio amateurs.

In 1924 Maxim met in Paris with an international group of amateurs from France, Great Britain, Belgium, Switzerland, Italy, Spain, Luxembourg, Canada and the USA and made preliminary plans for an organization to be known as the International Amateur Radio Union.

In 1925, the amateur radio representatives of 23 countries met again in Paris to create the IARU and to adopt a constitution. While most of the countries represented were from Europe, there were also delegates from North and South America, and from Japan.

It was soon realized that international lobbying was essential to the continued existence of Amateur Radio, in what was becoming a far more competitive and aggressive environment. The first ITU meeting in which the IARU participated (as a subcategory of private experimental stations) was the International Radiotelegraph Conference held in Washington, DC in October-November 1927 that resulted in the Washington Convention of 1927. The IARU representatives likely functioned through the US delegation with some assistance from a small handful of other friendly administrations; there was no credentialing of an "IARU delegation" as such.

The first time the IARU was admitted to the work of the ITU in its own name was at the Madrid conference in 1932. The first preparatory meeting at which we find a record of IARU participation was held in Portugal in 1934. The IARU was admitted by specific action of the Madrid conference (one of five international associations so admitted).

During the subsequent 75 years, the IARU has gradually become more effective, with its influence at the ITU increasing markedly in the past twenty years. The primary emphasis of the IARU is now the promotion and protection of the Amateur and Amateur Satellite Services. IARU representatives regularly participate in the International and Regional telecommunication conferences, as well as in the on-going Study and Working Groups which are part of the ITU structure.

Amateur radio participation in ITU studies and at World radio Conferences

National delegations participating in the work of the ITU often contain one or more licensed radio amateurs. These amateurs of course must speak on behalf of their country rather than amateur radio, although within the delegation, and in preparation for meetings, they can try to ensure that the country position is favourable to amateur interests.

On the other hand, when the IARU attends meetings at the ITU, it speaks on behalf of, and represents the interests of, all of the world's radio amateur population. In order to do this the IARU has set up a structure to ensure that its policies are developed "from the ground up".

In a great majority of countries there are national radio societies, groups of amateurs banded together for mutual support and cooperation. Currently, in each country a single such national organization has been chosen to represent its members in IARU.

The IARU has divided its Member-Societies into three geographical regions. A conference is held in one of the three regions every year. Each Member Society has the responsibility to attend the triennial conferences of its own regional organization and help to shape IARU policies. Positions on matters which might affect Amateur Radio are ironed out well in advance, first by Member Societies, then internationally at meetings of the three IARU Regions.

Because the IARU cannot vote at the World Radio Conferences, nor at meetings of regional telecommunication organizations, how therefore can it be effective?

What the IARU does at the ITU

Over the past eighty four years the IARU, staffed entirely by volunteers, has promoted, preserved and protected the Amateur Service. Of the over 2500 delegates who have attended recent WRCs, an IARU delegation of 4 to 6 people seems insignificant. How can such a small delegation succeed in achieving significant changes to the Radio Regulations, minimize intrusion of other services into amateur spectrum allocations, and, in fact, obtain new worldwide spectrum allocations in the face of strong government and commercial competition?

- Participation in non conference work
    - Much of the work of the ITU has to do with preparation of Reports, Recommendations, and Handbooks which provide guidance to administrations but are usually not mandatory like most of the International Radio Regulations. The IARU strives to keep a number of such items related

to the amateur service in the day to day work plans of the ITU Working Parties.

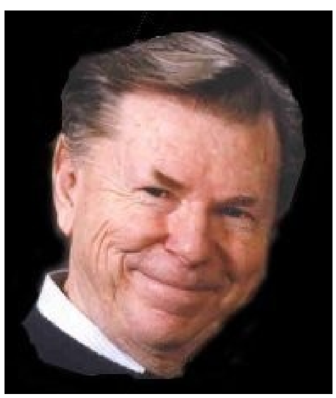
  - The IARU also participates, in cooperation with the ITU, in the preparation and delivery of educational material and instructional courses for administrators in developing countries, to help them to appreciate the value of the amateur service in providing a pool of trained operators, ready to provide radiocommunication services in times of natural disasters.
  - And thirdly, the IARU enhances its visibility by attending as an observer, when feasible, meetings concerned with the day to day management and administration of the ITU.
  - The above activities serve two purposes, they provide guidance to regulators on the administration of the amateur service, and they serve to ensure that the amateur service is active and visible in the work of the ITU.

- Participation in the selection of items to be placed on the Agenda of a World Radio Conference
  - Decisions taken at a WRC are strictly limited to items on the conference agenda. An important part of the work of each conference is the selection and approval of agenda items for the following conference.
  - The IARU continually strives to have items placed on the agenda supporting the objectives of the amateur services, such as new or expanded frequency allocations, and to discourage the selection of items which might pose a threat to the amateur service.
- Participation in the Conference preparatory process
  - IARU delegations, often consisting of a single individual, attend all Study Group and Working Group meetings concerned with preparation for Conference agenda items which may impact the amateur services. These delegations participate fully in the preparatory discussions, submitting technical and regulatory documents, and defending their positions at a level equal to that of the government and commercial delegates.

- IARU representatives are selected for their strong technical backgrounds in the subjects being discussed, and can usually come up with documented and convincing arguments supporting their case.
- IARU representatives must establish a reputation for willingness to work and to accept responsibility for active participation in the chairing of meetings, preparation of output documents and carrying more than their share of the routine work involved in the preparatory process.
- As a result, IARU delegates are respected as equals and when they take the floor in discussions, other delegates take note of the points they make.

Recent examples of the success of this kind of concerted action by the IARU took place at the World Radio Conference in 2003, when an international broadcast allocation at 7.1 to 7.2 MHz was replaced by a worldwide amateur allocation, and again in 2007, when a new worldwide band from 135.6 to 137.8 kHz was allocated to amateur radio.

About the Author



James Kenneth Pulfer has held an Amateur Radio license since 1949, VE3PU. He has a Master of Science in Electrical Engineering, 1955, and an Honorary Doctor of Science. Electrical Engineering, University of Manitoba 1984. He worked for the National Research Council of Canada (NRCC), initially as a Research Officer in fields including counter-counter measures, rocket telemetry, computer graphics and man-machine communications. Then, as Director of the Division of Electrical Engineering at NRC (a staff of about 250, conducting research in antenna engineering, computer technology, power engineering etc.). And, finally as Vice President he was responsible for the operation of all of NCR's Laboratories and facilities including 16 laboratories across the country, and astronomical observatories in Algonquin Park, Penticton, Victoria and Hawaii.

Pulfer also is responsible for the NRC part of the Canadian space program including Canadarm and the astronaut program. Since 1997 he has been he has been an Advisor to IARU in the development and delivery of a revised and updated course on the Administration of Amateur radio for third world countries, and he taught courses in USA and in Dakar Senegal. He has been a member of Canada's delegation to WARC 2000, 2003, and 2007.

Amateur Radio Contributions to the Art and Science of Communications - Revisited

By John S. Belrose, VE2CV, VY9CRC and Kevin McQuiggin, VE7ZD

Preface

The first radio amateurs of the Twentieth Century, immediately following Fessenden and Marconi, were absorbed with the vision of communicating through space. That vision led them to serious experimentation and invention. It was these early experimenters who founded radio technology. In 1981 Edmund Laport, 1CBO, Edward Tilton, W1HDQ, and Richard Rowe, K2BK, wrote a paper with the same title and theme that we have chosen for our paper, and so we consider our paper to be an up-date [1].

Amateur radio represents a unique research and development environment. Both the telecommunications industry and the public service communications sectors owe a significant debt to amateur radio, which has served as a source of many of their ideas and operating techniques. A Radio Club of America (RCA) radio pioneer who made many inventions that greatly improved the art of long range radio communications was Harold Beverage, 2BML. Author Belrose has corresponded with Bev Beverage. Harold was only 15 years old in 1908 when he designed and built his first spark gap transmitter. In April 1912, he copied messages for two days from the Titanic rescue ship Carpathia as it was taking 705 survivors to New York. This was a catalyst that inspired many young men to see interesting wireless careers. Hiram Percy Maxim, 1ZM (later W1AW) founder of The American Radio Relay League, was actively on the air in 1915 from his home in Hartford, CT. Frederick E. Terman, 6AE/6FT, began operating his station in 1914, in Palo Alto, CA. Later he published “Radio Engineering” and “Radio Engineers’ Handbook” in 1932 and 1943, a bible for many. Belrose has a copy of the 1943 edition of Terman’s book on his book-shelves. Irving Vermilya, 1VN, was one of the first radio amateurs in United States, he probably was not, but he said he was [2]. Certainly he was the first licensed radio amateur. Irving joined The RCA in 1911. We could continue, since there are many famous radio amateurs, reference the on-line list: **http://users.tellurian.net/gjurrens/famous _hams.html/.**

Forward

John Belrose has been a radio amateur for 62-years, licensed in 1947 as VE7QH (currently VE2CV), while attending The University of British Columbia, Vancouver, BC. He was a member of the UBC Amateur Radio Club, station call sign VE7ACS (now VE7UBC). The UBC 1950 Yearbook, ***The Totem,*** published a photograph of him, see **Figure 1**, together with three other members of the Club, in front of a 100 watt transmitter he built.

Figure 1 Hams kept promise to contact anyone, anywhere, anytime.

As a highlight to our paper read the published caption: ***"Hams kept promise to contact anyone, anywhere, anytime",*** of course none of us said that --- it is certainly a challenge impossible to achieve, even today.

The Beginning

By 1906 or so, only a few radio amateurs had appeared, here and there throughout United States and Canada, and England. In the early days most radio amateurs operated with skill and efficiency, but some did not. In this unregulated era, those "that did not" were a nuisance to commercial and military stations, and as well to fellow amateurs (spark transmitters were broad band devices and receiver selectivities were poor). On 27th February, 1909, the US Navy published an article in ***Outlook*,** commenting on interference blocking their attempts to contact "The Great White Fleet" as it returned from an around the world voyage. The US Government decided it had to do something. The Depew Wireless Bill, in draft, a copy of which was sent to the President of the Junior Wireless Club (JWC), which later became the Radio Club of America, on March 17th, 1910, prompted an immediate response; reference the letter dated 19th March signed by five members of the club [4]. This Draft Bill could have practically prohibited amateur radio experimentation. The JWC pointed out that interference problems were largely due the primitive equipment in use, even by the US Navy, and, some of the commercial interference was intentional. The letter noted that Marconi, in an attempt to prevent traffic he was sending from Clifden, Ireland, to Glace Bay, NS, being copied by others, viz. Fessenden's station at Brant Rock, MA, requested that his station at South Wellfleet, Cape Cod, send a constant interference of dash-dash-dash continuously. But Fessenden's station at Brant Rock selectivity tuned out the interference and copied the messages from Clifden, which Marconi himself, at Glace Bay, could not copy, and delivered all messages to Lord Northcutt, at the Hotel Regis. This letter lead to a meeting, reported in *The Globe* on 28th April 1910, with The Committee of Commerce in the Senate, Washington, DC; and the result was killing the bill.

But regulation was needed. The Alexander Bill made its first appearance on 11th December 1911. Hugo Gernsback, a “Champion of the Radio Amateur”, certainly played an important role in amending the Bill. Hugo in anticipation of wireless bills, had on 9th January 1909, founded the Wireless Association of America (WAOA). The purpose of the WAOA was to guard against unfair legislation as far as the radio amateur was concerned. The Radio Act of 1912, the Alexander Bill in final draft, was certainly not “unfair” for the radio amateur, as we now know, in fact far from it. It prohibited the radio amateur from using frequencies having wavelength greater than 200 meters, which was thought to be a desert. But this wide spectrum of frequencies, as we now know, includes most of the radio spectrum currently in use! The radio amateur had at last come into his/her own. President Taft signed the Alexanderson Bill into law on 13th August 1912. The Bill paved the way to standardizing and licensing amateur radio station operation. According to Hugo, the usefulness of the WAOA had come to an end, and thus matters rested. Hugo became a member of The RCA, joining in 1919.

Although most amateur enthusiasts were men, see for example Hiram Maxima’s 1915 station in **Figure 2a**, a few women in the US in that time period were rapidly awakening to the fact that radio operating was a worthwhile accomplishment.

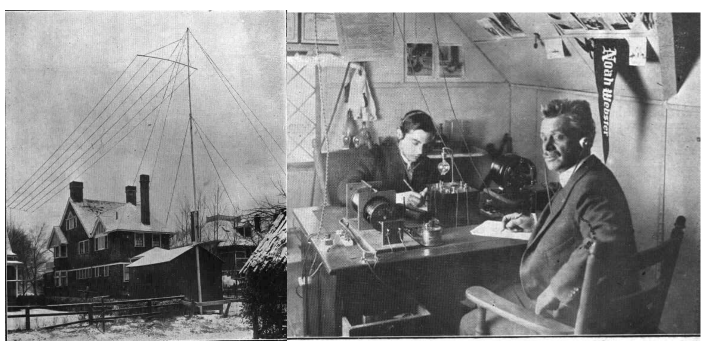


Figure 2a Hiram Percy Maxim, 1ZM’s station, (later W1AW), 1915 (after John Dilks, K2TQN, WEB Site Posting).

Figure 2b shows Kathleen Perkin, 6SO, San Rafael, CA, operating a station she put together herself in 1916 [3]. Kathleen was probably the first YL (Young Lady radio amateur).

Figure 2b Kathleen Perkin, 6SO, probably the first

YL (Young Lady amateur radio operator)

operating her amateur radio station, in 1916.

By 1920, continuous wave transmissions had been well established. In 1921, the ARRL instituted a (second) transatlantic test (the first one a year earlier was too short and no signals were heard in Europe), by sending Paul F. Godley, 2ZE, to Scotland to listen for American amateur stations [5]. It was mostly a test of 200m (1.5 MHz) transmissions on continuous waves. Paul set sail for England in November 1921, and it is here where the story of 1BCG begins. Paul was a member of The RCA. On 18th November 1921 six members of The RCA at an informal meeting decided to be a part of the transatlantic test, to build a transmitting station that would be heard in England, which remarkably they did. "Remarkably" because there was not much time to fabricate the station, since the listening schedule was planned for the nights of 9th – 11th December, 1921. Various locations were discussed. It was decided to build the station at Greenwich, CT, at the location of E.P. Cronkite's station 1BCG. The six members of the team were E.H. Armstrong, E.V. Amy, John F. Grinan, Walker Inman, Milton Cronkite, and G.E. Burghard.

Edwin Armstrong certainly played an important role, not only in design of the transmitter, which for the first time employed a master oscillator –power amplifier; but the receiving system used by Paul Godley employed a superhetrodyne receiver, intermediate frequency 100 kHz, with adjustable regeneration for maximum selectivity/sensitivity. Both methodologies were inventions of Armstrong.

The transmitter was not cabinet enclosed, but used table-top construction, see **Figure 3**. This figure also shows the 2000 volt DC generator. It was lucky no one was electrocuted, while constructing and tuning the transmitter, and in the excitement of sending.

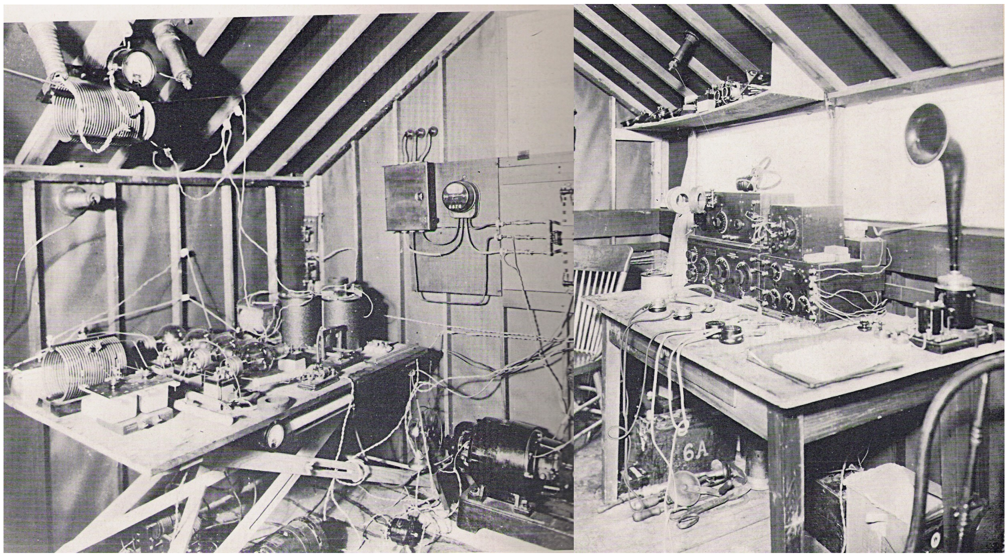


Figure 3 Picture on the left, the 1BCG transmitter, employing four type “P” Radiotron UV204 vacuum tubes, the oscillator tube on the right, the three tube amplifier on the left. A 2000 volt DC motor generator provided the HV power supply. The receiver, on the right, on the opposite side of the shack, employed the Paragon RA 10, a superhetrodyne regenerative receiver, and a BFO circuit for CW reception.

Earlier transmitting stations coupled a high power oscillator directly to the antenna system, and since the antenna was a part of the tuned circuit, as it swayed in the wind the frequency changed.

The transmitting station employed was a T-type antenna, cage construction, see **Figure 4**, fed against an elevated counterpoise.

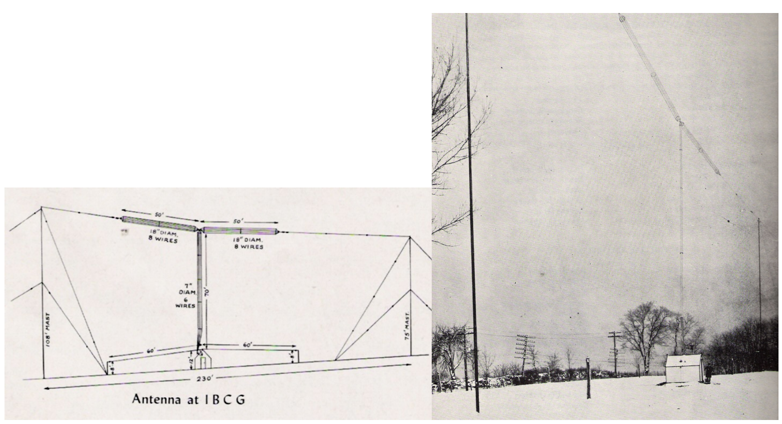


Figure 4 Antenna system for amateur radio station 1BCG, on the left

a sketch, and on the right a photograph.

While not cited in reference [5], this concept was certainly a design of Beverage, 2BML, who was also a member of the Club. And, the receiving antenna at Androssan, Scotland, was a wave antenna, also an invention of Beverage.

While some 30 stations took part in the contest, since all members at the transmitting station, and Paul Godley at the receiving station were all members of the Club, clearly 1BCG was a principle station. When Godley reported hearing a total of 27 stations (6 were spark stations), a feeling of liberation appeared among hams. Edward Rogers, sr, 3BP, located at Newmarket, near Toronto, ON, was one of the spark stations heard by Godley.

While, as noted, many stations were heard, station 1BCG is accredited with having sent a 12-word message, which was copied without error at Androssan. This important demonstration set off speculation concerning broad horizons, for world-wide radio, amateur or otherwise. Through 1923 and 1924 distance records were greatly and rapidly lengthened.

The achievement of the first 2-way radio amateur transatlantic communications (on 100M wavelength) was an achievement that was particularly heralded at the time (and remembered today). Leon Deloy, 6AB, in Nice, France, on 27th November 1923 worked Fred Schnell, 1MA, West Hartford, CT, and later the same night the “group” became three, John Reinhartz, 1XAM, South Manchester, CT, worked 6AB. All three radio amateurs used home built transmitters and receivers essentially based on designs by John Reinhartz. The story of this achievement was headlined and published in the January 1924 issue of QST. Further on John Reinhartz see Propagations section.

The (so called) first “ultimate DX” (communications with a distant station), was a 2-way contact between the UK and New Zealand, which took place on 19th October, 1924, when Cecil Goyder, operating the Mill Hill School station, 2ZS, North London, UK, heard a reply to his “test” transmission on a wavelength of 100m (3 MHz), from Frank Bell, Z4AA, in Palmerston South, NZ. The QSO (contact) lasted 90 minutes, and a QSL (contact confirmation) card was received [6].

With that our brief account of early history is concluded.

Introduction

In what follows we have organized our paper in 3-parts: antennas, propagation, and communication system technology. Today Cellular Radio and the Internet have had had a very great impact on radio communications, and on amateur radio. In the 1970s and 1980s hundreds and thousands of amateur radio VHF/UHF repeaters appeared. Hilltop and mountain top repeater sites provided wide local area coverage. Some were linked with the telephone system (autopatch). Later repeaters were linked, using touch-tone control, which provided inter city communications, then under computer control, linking become more and more extended, providing province/state wide communications. Today research is concerned with making radio systems operate more and more like the Internet, and Internet Radio linking is becoming popular, reference [7].

Kevin McQuiggin, VE7ZD, provides an overview of the history of amateur radio in the context of the process of innovation in his 2001 thesis [8]. It is clear from his research that amateur radio has been the source of a large number of innovations and important contributions to the state of the radio art, and most interestingly, that such creativity is more difficult (or at least constrained) in the commercial R&D environment. Pat Hawker, G3VA, has written a popular column published monthly in the Radio Society of Great Britain's Radio Communications magazine (RadCom), 1958-2008, entitled Technical Topics (TT), see reference [9]. Pat, considering that he was going to stop writing his columns, began in 2007 to write overview columns, which are well worth reading.

In thinking about what he wrote, and the impact of what he wrote on amateur radio, Pat noted that unlike the major and continuous changes in equipment and communications techniques, the basis of antenna design remains ageless. Some antenna system developed up to 100 years ago are as valid today as they were when they first emerged from such pioneers as Fessenden, 1AS/VP9F, Franklin, Beverage, 2BML, Uda-Yagi, George W. Brown, of RCA, Kraus, W8JK, and many others. This comment is certainly true, since the 1983 IEE book entitled **"Antenna Design Handbook"**, see reference [10], while design tools have changed significantly, the book is still being sold. Clearly a few engineers are beginning to realize that they do not have the benefits of earlier work, but only a few, since many papers written nowadays merely reinvent the wheel, or as a result of their misunderstanding of fundamental limitations, a great deal of time is wasted in rebuttals, telling the some authors that the antenna they described simply will not work, as claimed. More on this topic will follow.

Note: Author Belrose is well familiar with the W8JK dipole antenna array. In fact he has extended the "feed-out-phase" methodology to an antenna system comprising a full wave horizontal quad loop [**http://www.davekalahar.com/Misc_Files/ARRL%200802%2080%20Meter%20Loop.pdf**], which is a good antenna system for working DX (distant stations), since the radiation pattern has an overhead null, which reduces interference from strong not too distance stations. The pattern maximum is toward the horizon. The radiation pattern for conventionally fed dipole and horizontal loop antennas, mounted at practical heights, for the 160M and 80M bands is a maximum overhead.

While 50-years ago, amateur radio was still rooted in valve technology, with a few experimental uses of germanium bipolar transistors just emerging. RF power transistors, integrated circuits, surface mount technology, and etc., were years away. Now all that has changed. And, beginning in the mid-70s, the introduction of the computer into amateur radio operation was a pivotal moment for the radio amateur. Digital began to replace analogue, old skills are becoming redundant, and the computer is beginning to determine the future of the hobby, simultaneously enabling new modes, techniques, and social applications of amateur radio. Software is becoming the new field for research, whereas in the past development and tinkering served to increase communications capabilities. The future is Software Defined Radio (SDR), which while touched on here is described in more detail in later papers.

Okay, so where do we go from here, in writing this paper? The rate of change is overwhelming. We can only touch on a few topics here.

Antenna Systems for the Radio Amateur

In the time period of this overview, 1984-2009, the development of computer modeling to simulate the performance of antennas, particularly (see below) the Numerical Electromagnetic Code (NEC), based on Method of Moments, made a considerable impact on antenna design, by both professionals and radio amateurs. The performance of antennas in their operating environments can now be predicted, reference the comprehensive overviews published in 1983 and 1989 [11, 12]. This field of research and development quickly became one of considerable interest. ACES (Applied Computational Electromagnetics Society) which began in 1985 as a 4-day workshop, that was followed by several newsletters, in 5-years grew into an international co-operation society, which continues today [**http://aces.ee.olemiss.edu**].

While during the recent years that computational electromagnetic programs were developed, simulating the performance of antennas in their operational environments, a number of very different programs were developed, some could numerically model the body of the operator (a person holding a hand-held cellular phone), the one that many professionals and most professional radio amateurs use is NEC. **MININEC**, which was the first in the series of program development, assumes a perfectly conducting ground beneath the antenna. But the far field can be real ground. The radiation pattern simulating propagation in the far field is calculated by assuming Fresnel reflection. The accuracy of prediction using MININEC is in fact quite good, particularly if the antenna is not too close to the ground; and for MF Broadcast antenna design, since MF antennas employ many buried radial wires that simulate a good conducting ground beneath the antenna system. Note: MININEC is by name a misnomer, since the analysis programs for NEC and MININEC are quite different.

NEC-2, which is in the public domain, can be used to predict antenna performance over real ground, providing the antenna system does not touch the ground. Author Belrose has extensively developed techniques that simulate a ground connection, using resonant radial wires at a height of two or three wire diameters above the ground, since this results in a strong interaction with the ground, without actual "ground connection" [13].

In fact the concept of elevated resonant radial wires has resulted in a whole new class of antennas: phased arrays for MF broadcasting, vertical monopoles with drooping radial wires, and other ground plane (GP) type of antennas, e.g. the half diamond loop. "Half" because as originally conceived by Belrose, this antenna could be full wave resonant, since when the antenna system was ground mounted, employing a buried radial wire ground systems, the other half of the antenna system was the virtual image of the half-loop in the ground plane. The half-diamond with elevated resonant radial wires is a very good antenna system, and can be directional, by employing 2-radials, one at each of the lower ends of the vertical loop, pointing in the desired direction of fire [14].

The Part 3 paper, in this series of papers, introduces the concept of a monopole antenna with parasitic elements [15].

NEC-4 permits connection to the ground, but not wires lying on the ground, buried radial wire ground systems, or a ground stake. But this program is not in the public domain, one has to be licensed to use NEC-4. NEC-4 double precision is the program most frequently used by Belrose. Particularly, initially, to model MF antenna systems, since a main purpose of the early work was to validate the NEC-4 program, and a large amount of measured data is available (proof of performance measurements), to compare measurement with prediction, see references [16, 17].

MININEC/and NEC-2 are the programs used by most radio amateurs: this is because a user friendly version of these programs has been written by Roy Lewallen, W7EL [reference Roy's on-line home-page **http://www.eznec.com**]. In 1993 an Internet list (NEC-List) was started, which provides a forum for discussion on computational electromagnet problems [**http://www.robomod.net/mailman/listinfo/nec-list**]. Radio amateurs can receive advice from professionals, and professionals can learn about problems that are of concern to the radio amateur community.

Recall our comment made earlier, Bev Beverage was on the right tract, a T-type antenna with elevated radials --- lifting the radials off lossy ground.

A brief overview on the performance of wire antennas in their operating environments, initially addressed by Belrose et. al. in reference [12], has more recently been published, addressing antenna systems of interest to radio amateurs[18].

Wave Antennas, The Beverage Antenna: As noted above the Beverage antenna was used in 1921 to receive the first transatlantic signals. This antenna is in fact the best antenna to receive long distance low band (80M and below) radio signals. Belrose, Litva, Moss and Stevens [19] have overviewed the subject of Beverage aerials for receive --- a single Beverage wire for point-to-point communications; and a Beverage rosette array for direction finding. And as well, these authors addressed the concept of using several closely spaced Beverage antennas in an array configuration, for transmitting, since a single Beverage wire has a very low radiation efficiency.

The paper referenced has particularly a nostalgic recall for author Belrose, since when writing it he had frequent interesting correspondence with Bev Beverage, who in that time period was still alive and well, and he had retained a good recall of his early work.

Electrically Small Antenna Systems: Electrically small antennas are currently of wide interest, for the radio amateur, since while dipole and full sized loops perform very well indeed, most radio amateurs have a minimum sized back yard, or no land at all; and there is a wide interest in HF mobile communications, antenna mounted on vehicle. And, for commercial applications, antennas for cellular radio are used for hand held portables. Topics of particular interest are antennas for applications that require electrically small antennas for multi-band and wideband systems; and for the radio amateur antennas for the new bands being explored, 137 kHz and 500 kHz.

Author Belrose's early work, and follow on research many years later, was concerned with electrically small antenna systems, antennas for VLF/LF communications; and for the radio amateur interest, center inductively loaded whip antennas for vehicular HF mobile communications.

Center-Loaded whips: Bob Hansen has recently published a book that addresses the subject of electrically small antennas [20], a book that is certainly well worth reading; and since he extensively numerically modeled center-loaded whip antennas in 1975, he devotes quite a bit of space discussing such inductively loaded antennas. In this book he refers to "pioneering work" by Bulgerin and Walters, a 1954 paper. But author Belrose published a paper in 1953, considering the antenna as an opened out transmission line [21]. While this analysis technique is now superseded by modern numerical analysis methods, the early analysis is surprising correct. The trends are right, and results agree rather well with the more rigorous analysis of Hansen, who analyzed this inductively loaded antenna by numerical moment-method techniques. But both these early analysis techniques could not take into account the effect of the vehicle on which the antenna was mounted – the vehicle as part of the antenna system had to await the development of NEC. And so in 1995 Belrose revisited HF whips on vehicles, reference [22]. In a follow on paper Belrose and Parker addressed the issue of remote tuning the antenna system, reference [23].

Electrically Small Loop Antennas for the HF Band: In 1993 author Belrose wrote a paper on electrically small loop antennas for HF communications, particularly based on a study (numerical analysis and experimental) of the transmitting loop antennas systems developed and marketed by Christian Kaferlein, DK5CZ (now a SK); a single turn loop tuned by a capacitor at the top, and a subsidiary input loop, to provide an input impedance equal to 50 ohms (see **Figure 5** on the left). This figure also shows (on the right) two AMA compact loops, in the background, and a vehicular mounted HF mobile antenna [reference 23].

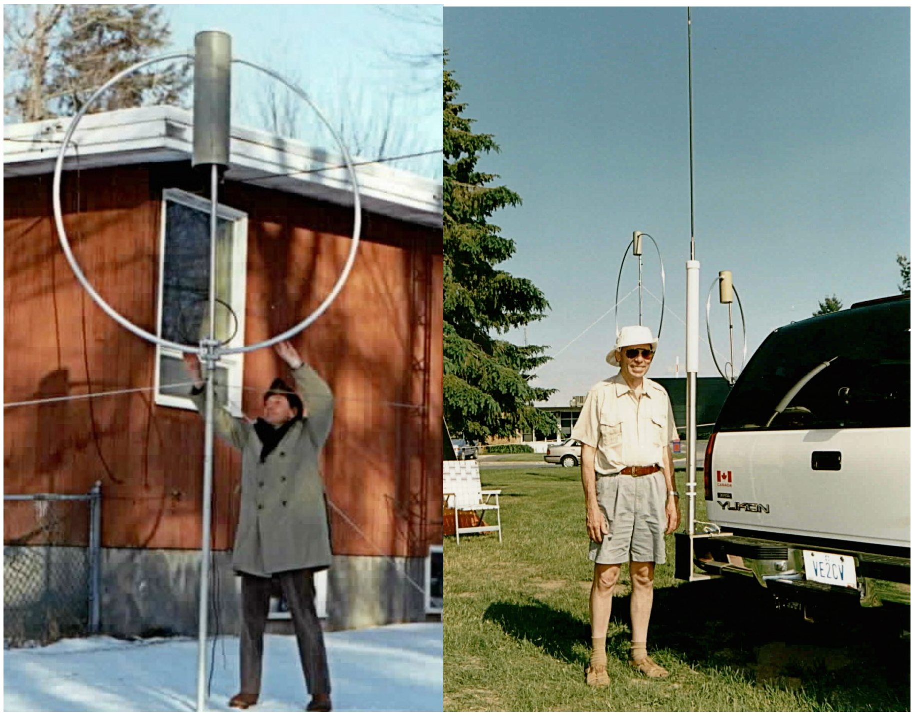


Figure 5 Author Belrose experimenting with an AMA 1.7 m diameter loop, on the left, and, on the right, two compact loop antennas and a vehicular mounted HF whip antenna, a tunable all bands antenna (TABA), in use during a simulated emergency communications exercise.

Over the frequency range 1.7 MHz to 30 MHz loops with diameters 0.8 to 3.4 m have been used (perimeter/wavelengths (P/.) range from 0.03 to 0.25 wavelength). Belrose used NEC-2, and initially a simplified wire model (a five sided polygon) to simulate a single turn air core loop --- follow on papers modeled the loop as a 20-sided polygon. He thought, at that time, that he had analyzed with sufficient accuracy the expected performance of electrically small loop antennas. But an attention grabbing paper entitled **"Magnetic Loop or Small Folded Dipole?"** published in 1997, by Mike Underhill, G3LHR, started a controversial debate that continued and continued, and still goes on today in the mind of Prof. Underhill. Underhill and Harper later published their views in two IEE Electronics Letters in 2002 and 2003, papers that Bob Hansen considers in his book [20] to be an "egregious example of claiming antennas that violate the fundamental principles of small antennas".

In the mind of Belrose the debate is finished, reference [24, 25]; but, while Underhill still holds his views, he has given up publishing papers in magazines (professional or amateur) --- since one can post whatever one likes on the Web.

In spite of the low radiation efficiencies for such small loop antennas (about 1% for P/a = 0.03, and 22% for P/t = 0.18) compact loops are very useful for communications from restricted sites, and for transportable applications. Since a particular loop can be tuned over a 6/1 frequency range, without the need for an additional antenna system tuning unit, it is an ideal antenna for emergency communications.

Austin and Murry [26] have particularly explored the use of compact loops for vehicular communication. Their measurements show that the loop is ideal for near vertical incidence skywave (NVIS) applications, since the loop has at least up to a 15 dB advantage over a short whip antenna (which exhibits a null overhead). The NVIS radiated power requirement for this application is very modest, and so the loop's radiation efficiency is not an issue.

Hula Hoop, DDRR, Halo Loop and Inverted-F Antennas: These types of antennas have been around for more than 30-years, and have been written about and tried by many authors, professional and amateur. Some authors (including so called inventors) did not understand the radiation characteristics of the antennas. Belrose [27] wrote a paper in 1975, in an attempt to explain that these types of antennas were basically transmission line radiators. But no one, certainly not today's antenna designers, have ever referenced his paper. Users of the various versions of these type of antennas have been caught up by the names given by the so-called inventors, names which are much more impressive than performance [20].

The basic version of this type of antenna is an Inverted-L Antenna (ILA) above a horizontal GP. Since the input impedance of the ILA is very low, it was fed by a vertical stub part way along the horizontal element, from the grounded end, hence the name Inverted-F Antenna (IFA). While the current on this stub partially cancels the radiating current on the grounded "monopole" element, the dominant current is the current on the monopole.

If the horizontal linear top element is bent into the shape of a loop, the name given for this version was Directional Discontinuity Ring Radiator (DDRR). It was however pointed out that this was not a suitable name (directional discontinuity?), but the name DDRR stuck (Directly Driven Ring (or Resonant) Radiator). But it is not the ring that radiates, and most antennas are directly driven.

Continuing with this loop version: if you look at our textbooks describing electrically short antennas above a ground plane (GP) you will see that the "virtual image" of the antenna below the GP is shown by a dashed line. Currents on the vertical elements of the antenna and on its virtual image in the ground plane are in phase, currents on the horizontal elements and its virtual image are out-of-phase, and so radiation due to the current on the horizontal elements (real and virtual) essentially cancel.

An ideal real "image" can be created by replacing the virtual image by real wires, and hence the antenna system can be lifted off the ground plane. One such antenna type is the Halo Loop. The Halo Loop can also be the result of bending a folded dipole into a halo shape, which results in identically the same radiation characteristics, only the location of feed differs.

The IFA has been widely used as an antenna for hand-held radios (cellular radios). More recently, if the horizontal linear element is replaced by a plate, the antenna becomes by name a Planar Inverted-F Antenna (PIFA). Many papers have been written about IFA and PIFA antennas, but little or nothing is said about currents on the so-called “ground plane”, which for the hand-held radio is a vertical (not a horizontal) rectangular plate, or the chassis of the radio. In the case of the IFA, it is mounted above the top edge of this rectangular plate. Certainly currents flow on the edges of this plate. Probably more radiation comes from currents on the plate then from the IFA element itself above the top edge of the plate --- and around the plate is the users hand, with the IFA element close to the head (and eye) of the user. It is surprising how well this antenna system seems to work, but in most cases the local repeater is indeed “local”.

There is no reason that the IFA cannot be configured in the manner described above, where we spoke about replacing the “virtual image” (horizontal GP concept) by real conductors, and so, by using a balun (balanced to unbalanced transformer) to feed this transmission line radiator, one can isolate the antenna from the chassis of the radio.

For the radio amateur, Belrose has emphasized the importance of using an end-fed half wave antenna element, which minimizes current flowing on the chassis of the hand-held radio. But users of cell phones do not want to see the antenna, and so indeed the antenna has to be small.

Integrated antenna systems, for hand-held radios, GPS navigator devices, and for computers (WLANs) is currently a field of research.

Electrically Small Antennas for Multi-Frequency/Broad-Band VHF/UHF Frequencies: A great many papers, an astonishing numbers of papers, have been published in recent years on interesting to look at antennas, antennas with fancy names: so called Fractal Antennas; von Koch monopoles, Sierpinski monopoles, Hilbert monopoles, Minkowski monopoles and loops, and the Peano curve antennas. These approaches to antenna configurations are said to produce desirable broadband, multi-frequencies responses. They are certainly multi-frequency, multi-resonant, but they are not broadband antennas. The only technology that author Belrose is familiar with that produces a broadband frequency response is based on multiple fed arrangement, see **Figure 7** [28]; and log periodic dipole arrays.

The Sierpinski monopole (see **Figure 6** top antenna) is a very interesting antenna to look at, an antenna that has been written and re-written about. But a bent wire antenna (**Figure 6** bottom antenna), based on the known fact that in the case of a triangular plate antenna, most of the current flows on the outside edges of the triangle, and so a triangular wire antenna with respect to being multi-resonant performs just as well.

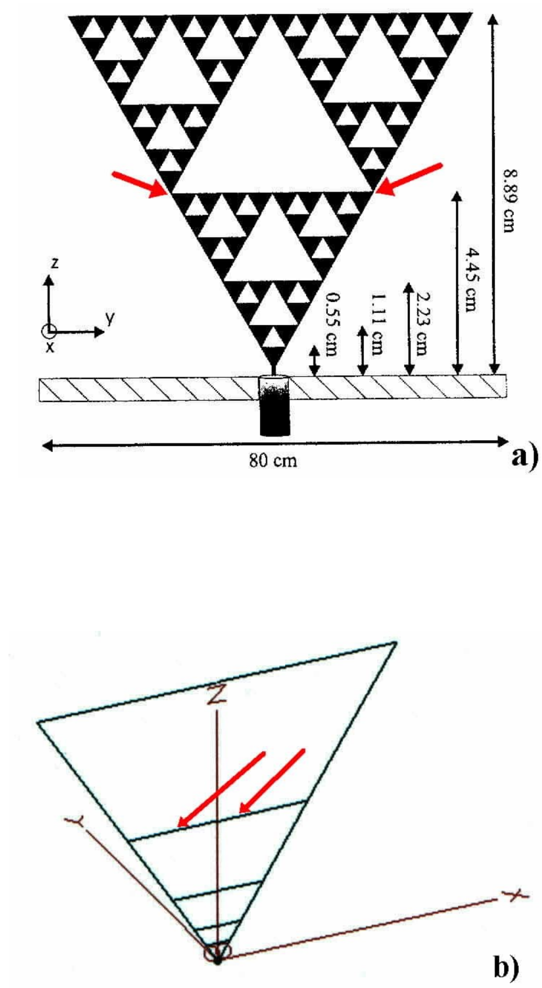


Figure 6 Serpinski monopole antenna, upper figure, and an equivalent wire model lower figure.

Note the arrows indicate the 2nd resonance.

Clearly the triangular wire antenna is multi resonant (**Figure 8** top); whereas the input impedance of the multiple-fed wire antenna in **Figure 7** is broad band, see **Figure 8** bottom graph (but over a smaller range of frequencies). Author Belrose [29] has considered in detail the azimuthal radiation patterns, **Figure 9**. A lot of authors consider feed point impedance, standing wave ratio (SWR) only.

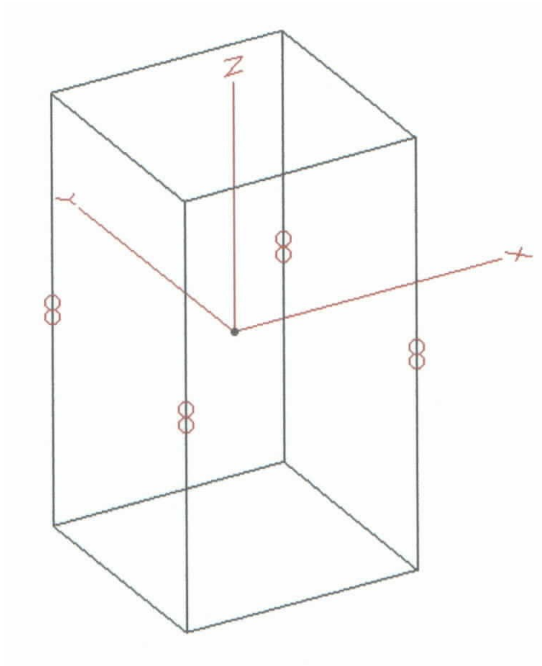


Figure 7 Multiple fed dipole antenna, wire model.

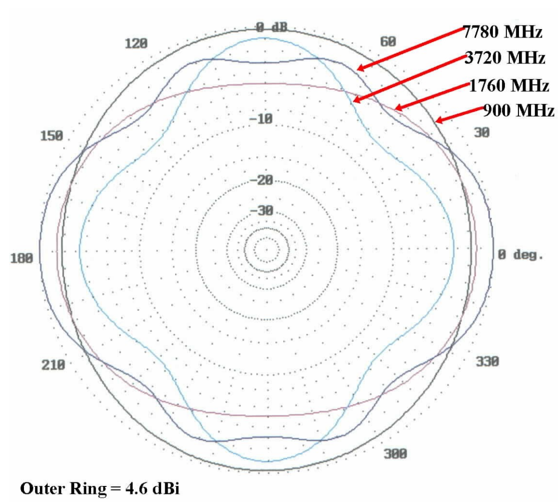


Figure 8 VSWR versus frequency for wire model of the Serpinski monopole, upper plot; and for the multiple fed dipole, lower plot.

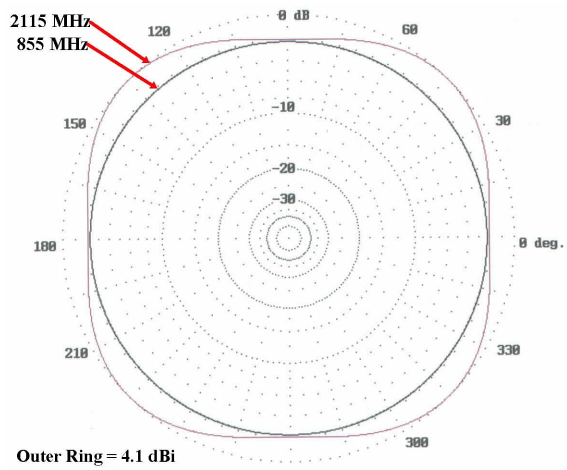


Figure 9 Azimuthal radiation patterns, for the Serpinski monopole, upper figure, and a multiple fed dipole, lower figure.

Figure 6's antenna systems are really a multi-frequency antenna system, not a broadband antenna.

Electro-magnetic Antennas: The use of a magnetic loop antenna combined with a vertical monopole, described as an electro-magnetic electrically small antenna (E-M-ESA) system, has been proposed as a technique to miniaturize antenna systems, providing improved radiation efficiencies and bandwidth. Author Belrose [30] did not believe what was claimed: wide-band and increased gain. This antenna system is in fact not superior to that for a vertical dipole alone, and it is certainly not broadband. But an interesting unexpected discovery, is that if the 2-elements (loop and dipole) are fed in phase quadrature, a directional cardiodal shaped pattern is produced, providing 3 dB gain compared with feeding one element alone, and a F/B ratio of 23 dB. The antenna system would however be tricky to feed, for quadrature feed, and, one must ensure that there is no current flow on the outside surface of the feeder coaxial cables.

The Crossed Field Antenna: The so-called crossed field antenna (CFA) system was conceived by Hately and Kabbary in the late 1980s --- and these authors, and many follow on experimenters, broadcast antenna engineers or radio amateurs, continued to try and make the antenna work for a decade or more (see below). The CFA was said to be based on a new principle: that E- and H-fields could be separately generated, and that if the currents feeding the two elements generating these E- and H-fields were in phase quadrature, and in the right power ratio, the E/H field ratio in the near field region could be made identical to the E/H ratio in the far field region --- thus providing an ideal match (antenna to propagation medium) to generate a strong outgoing EM wave --- minimizing the problems often associated with strong near fields!! Their CFA was said to be very broadband, and very efficient, so that an electrically very small antenna system could produce radiation efficiencies equivalent to a quarter wave monopole.

The H-field was said to be produced by a disk above a ground plane --- see **Figure 10** lower figures, showing a photograph of Belrose's experimental model, and the wire grid model for numerical analysis --- the E-field by a cylinder above the disc.

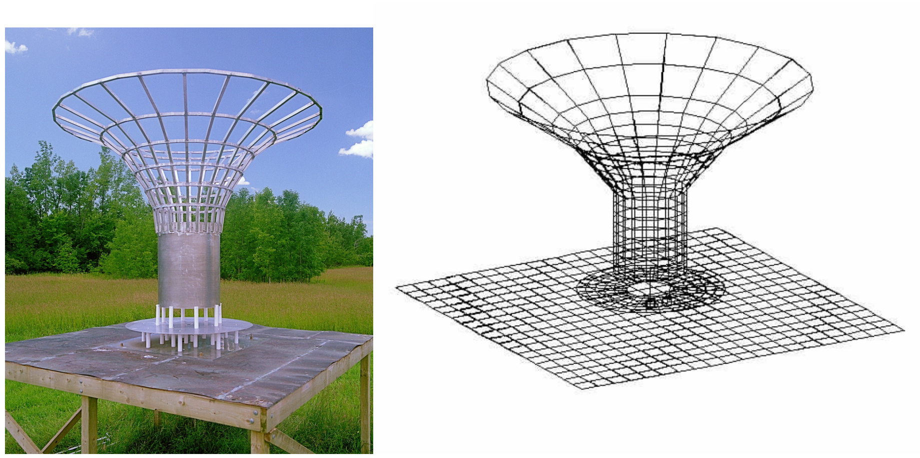


Figure 10 The MF CFA in operational use at Tanta, Egypt (left); and a scale model fabricated for experimental measurements (right) along with the wire grid model created for numerical analysis.

But the devisers of the CFA have not realized (considered) that it is not possible to devise an electromagnetic antenna that radiates only component of the EM field, and they have not considered that their antenna system is in effect two closely coupled antenna elements --- mutual coupling was never ever mentioned. Numerical analysis (by NEC) reveals that the cylinder is a better radiator, and an important practical feature of the numerical modeling study is that the resistive component of the disc, with quadrature feed is negative, which is consistent with what one expects --- two closely coupled antenna element, be they of unconventional shape (a cylinder and a disc) or both electrically short vertical dipoles. This complicates tuning the antenna. NEC assumes that the power surging back is totally reflected, but practically this cannot be achieved (by conjugate match) without additional power loss. Since Hately and Kabbary, and none of the many follow on experimenters, ever mentioned a problem associated with quadrature feed, we have to conclude that in fact they never fed the elements of their antenna system in phase quadrature --- they only thought they did.

The CFA generated such a wide interest, by MF Broadcasters in several countries (USA, UK, Germany, Italy, Brazil, Australia, China), and by radio amateurs around the world, and in Canada as well, that controversial debates continued for years [20, 31]. There are problems: the radiation efficiency is poor, a large amount of power has to re-reflected back by the antenna system tuning unit, and the bandwidth is low. And, not addressed by amateurs or professionals, currents flowing on the outer surface of feeder coaxial cables must be minimized so that these currents are not a part of the radiating system. The two antenna elements were fed by coaxial cables with using a balun. For Kabbary's CFA on the roof of a building, see Figure 10 top photograph, note that the building is encased by a well grounded wire grid structure. Currents on the grounded wire grid structure beneath the antenna are not considered (by Kabbary) to be a part of the radiating system, but these currents contribute significantly to the radiated fields. In retrospect it is astonishing, the amount of time energy and money that has been spent, and as well by author Belrose de-bunking the CFA (concept and performance claims). The CFA is being used nowhere (as far as we know) excepting in Egypt.

Propagation

Early History: Reginald Aubrey Fessenden, a radio scientist, engineer, "professional" radio amateur, is accredited to be the first to systematically study antennas and propagation in c1905, even earlier (1902). In 1905 he patented an antenna system identically like the base-loaded umbrella top loaded antennas used today. In 1906 he published a figure showing the night-to-night relative amplitude of his 80 kHz transatlantic signal strengths received at Machrihanish, Scotland, from his sender at Brant Rock, MA, during the month of January. Certainly he correctly interpreted that the received signal was due to reflection from a conducting layer(s) in the upper atmosphere --- the Kennelly/Heaviside ionospheric layers --- Kennelly was a friend of Fessenden. John Reinhartz (JL, 1XT, 1XAN, 1QP, K6BJJ) is acclaimed to be the first HF radio amateur (Fessenden did not hold a radio amateur license during the time period of his early work on frequencies less than 200 kHz) to conduct numerous studies of antennas and propagation during the early 1920s (reference the April 1925 issue of QST). He devoted much of his efforts to "solving" (copy from words written about his published articles) the problem of skip in short wave communications. "Solving" because that subject has been written and written about during the past 75+ years --- and later, papers by Reinhartz himself, since when joining The Radio Corporation of America in the early thirties, he conducted further research on radio propagation and short waves. His 1921 Reinhartz tuner (receiver) had (at that time) an unheard of tuning range, from 200M to 28M. In 1923 John Reinhartz was operating on 108M, reference earlier cite, in 1925 he set a new record for HF DX, by communicating, from his station in South Manchester, CT, with 6TB in Santa Monica, CA, on 20M at noon. Of course there is much much more we could write, recalling the contributions radio amateurs have made to our understanding of ionospheric propagation, but that is beyond the scope of this article.

Since radio amateurs are currently experimenting on LF and MF frequencies, 137 kHz and 500 kHz, let us recall that Belrose has overviewed his research studies on MF, LF, and VLF propagation [32]. One purpose of his early research was concerned with providing reliable communications during times of radio- black-out conditions, associated with geomagnetic storms, that disrupt HF communications in high latitude (high geomagnetic latitude) regions. Canada is a high geomagnetic latitude nation; the geomagnetic pole is located within Canada's boundary. And, Belrose overviewed the subject of high latitude HF propagation [33].

Radio amateurs are currently studying propagation and communications in two new bands, outside conventional bands, at 137 kHz and 500 kHz. Certainly very reliable, long ground wave LF links, are now possible using today's signal processing techniques. Of historical interest, 500 kHz is the frequency used by Marconi's for his first transatlantic communication experiments, in December 1901 [34]. Papers on amateur radio exploratory communications tests on these two new (for the radio amateur) bands are included in this yearbook..

Radio amateurs have contributed significantly to the field of propagation research over the years, systematically monitoring HF and VHF beacon transmitters, and while some results of these experiments have been reported, in national radio amateur magazines, the reporting has been rather ad-hoc and random. The studies of Radio amateurs in the UK, coordinated by The Radio Society of Great Britain (RSGB), are reported in a more organized way. RadCom publishes monthly HF propagation predictions, and every now and again overview papers on propagation are published (for example "Interpreting Digital Ionograms --- Using modern digital ionosonde ionograms for understanding real-time propagation conditions", by Gwyn Williams, G4FKH, RadCom, May 2009, pp. 43-46).

Specifically we should reference the **RSGB Propagation Studies Committee**. The PSC stems from a suggestion made in 1957 by Dr. Smith-Rose, then Director of the Radio Research Station, Slough, and later President of the RSGB, that a committee should be formed to correlate radio amateur observations, with auroral, ionosphere, meteorological (and other) conditions. The PSC is very active today, since communications between members is easy using the Internet --- **http://www.keele.ac.uk/depts./por/psc.htm** .

Each member of the Committee is a specialist in at least one aspect of radio propagation, and there are always several projects in hand, currently on sporadic-E, and tropospheric propagation at 50 MHz. LF communications experiments is a monthly column in RadCom.

Frequency Selective fading is a problem with HF propagation, for digital communications, and particularly for SW broadcast using conventional SW AM-receivers. Some modern receivers for the SW listener employ synchronous detection, and selectable LSB, USB, or both sidebands [Belrose has an *Eton e1* receiver]. Many SW broadcasts currently employ DRM (Digital Radio Mondiale) which broadcasters have (apparently) decided provides better reception under conditions of frequency selective fading --- whether it does or not (author's comment) is a study in itself --- whatever DRM broadcasts are presently here. DRM requires a special receiver, or a SDR (Software Defined Radio) receiver with appropriate software. The DRM broadcast consists of about 50 carriers spaced about 50 Hz apart, so that the available 10 kHz channel is filled with carriers. Hence the DRM broadcast signal provides a means to observe frequency selective fading, employing available software (Dream Software), a sound card, and a computer. John Stanley, K4ERO, has recently made a brief study of selective fading in real time with Dream Software [35]. Note: a Google search on the words "Dream, DRM, software, download" should enable one to find the latest version. You can also find more information at **sourceforge.net/projects/drm**.

Radio Communications Technology

Radio amateurs were present at the dawn of the Space Age, creating the first amateur satellite in 1961, and radio amateurs have been active on this "final frontier" ever since, the technical details of which is a story in itself, beyond the scope of our paper.

And, as noted above, beginning in the mid-70s, the introduction of the computer into the hobby was a pivotal moment for the radio amateur. Digital began to replace analogue, and the computer is beginning to determine the future, simultaneously enabling new modes, techniques, and social applications of amateur radio. Software is becoming the new region in which in the past development and tinkering served to increase communications capabilities. The future is software-defined-radio (SDR), which while mentioned here is described in more detail in follow-on papers.

Amateur Satellites: Following the Soviet Union's launch of the first ever space satellite, Sputnik-1, on 4th October, 1957, there has been a great deal of interest in amateur radio satellites. Sputnik 1's beep-beep-beep signals, operating on frequencies allocated for amateurs, were heard by radio amateurs and radio research laboratories all over the world. The first American satellite fabricated by radio amateurs was launched on 12th December 1961, OSCAR-1 (Orbiting Satellite Carrying Amateur Radio). Project OSCAR, built by a California Group of radio amateurs, fabricated and launched four satellites. The AMSAT (Radio Amateur Satellite Corporation) was founded in 1969. All OSCARs have been financed through donations of time, hardware and cash from radio amateurs in many nations. The OSCAR-5 satellite was built by Australian students. To date 45 satellites, high-tech OSCARS have been built, and launched, launched by free rides to space as ballast on US, Russian, European, and Japanese government rockets, that happened to be carrying commercial or government satellites to orbit. However, with available space overbooked these days, paid tickets usually are now required. Russian hams have built and operated 20 satellites, called Radiosputniks, or RS satellites.

A vast range of equipment is available for use by radio amateurs to communicate via amateur satellites. Clearly research is involved, in fabricating the amateur radio platforms, and, in the development of ground stations, in addition to being educational tools, and having been used in research programs by universities around the world [36]. These satellites are available to use by anyone who holds an amateur radio license issued by the Governments of the nations, and are an untapped resource for teaching communication engineering and technology at the university level.

One of the many hurdles in pursuing satellite communications, be it commercial, military, or private in nature, is that of licensing. Regulations are different in different countries, aided by guidelines set by the International Telecommunications Union (ITU). Laws regarding the allocation of bandwidth present considerable financial and political difficulty to parties without a great deal of resources. But these difficulties can be circumvented by the use of the amateur radio satellite service, since radio amateurs have a spectrum assigned for their use. And, the equipment used in amateur satellite programs is vastly cheaper than used in commercial environments, since redundancy and extreme reliability are not required.

An example of this is Canada's MOST Space Telescope [37], which has a number of ground stations using amateur radio equipment and technology, to command and control this earth-orbiting telescope. This basic space science experiment is a joint venture of Canadian Universities and the Canadian Space Agency. Other research programs such as this one could be tailored to accommodate an institution's interests, and budget.

HF Digital Communications: PSK31 is the most widely used HF digital communications mode on the HF amateur bands today. PSK31 was developed by British radio amateur Peter Martinez, G3PLX, in 1997 [38], as an enhancement of the basic work that had been done by Pawel Jaloca, a Polish hobbyst. PSK31 is named after the technical characteristic of its modulation. "PSK" stands for "phase-shift-keying", a method of modulating or impressing digital information upon a carrier wave, while "31" stands for the baud rate, or signaling rate of the transmission. Where RTTY (radio teletype) uses two specific frequencies to communicate the binary data, PSK31 does the same thing by shifting the phase of a single audio frequency tone, 0 in the data stream generates a phase shift of 180º, but 1 does not, in sync with the 31.25 bit-per-second data stream. Not only does PSK31 transmission occupy a very small amount of spectrum, about 50 Hz wide, which is actually narrower than the average CW signal, but this modulation technique is said to be much superior to other forms of sending digital data under conditions of frequency selective fading. At the receiving end, the PSK31 software uses digital signal processing to detect the phase changes, even for very weak signals, in fact PSK31 exceeds the weak signal performance of CW [7]. Without error correction the text may not be error free, but it is usually good enough to understand.

PSK31 achieves its superior performance by including the human brain in the communications process. From a communications standpoint PSK31 is interesting because it is a hybrid technology: it combines digital and analogue techniques. Digital signal processing and the home computer provide unprecedented signal decoding capability and spectral efficiency. The lack of error detection and correction in the mode, however, places the operator back in the loop where he/she provides interpretive and interpolation functions. What is especially interesting is that PSK31 places the human into the communicative process by design. The power of the mind to provide unquantifiable benefits and bring extraordinary insight to the analytical process is very impressive and cannot (at least yet) be duplicated by our digital assistants (words ala the new field of "Visual Analytics").

Unlike packet radio, PSK31 data is transmitted a single character at a time. Automatic error detection and correction are sacrificed in favour of acceptable real time, interactive performance. The human operator fills in this gap, and provides detection and correction himself!

> Tha avqrxage humzn isz pwrfect%ly capab)e of perf%(O)rming this inte&polaive
>
> f@3unct+on with a h.gh degreeee pf ackur:cy

JT44: New Digital Mode for Weak Signals: Radio amateurs, in today's computer age, are increasingly using modes of communications that have been known 50-years ago, but with today's signal processing protocols can be used for communications with spectacular success. These modes for VHF/UHF communications include meteor and ionospheric scatter, and earth-moon-earth (EME) communications, where the moon is the reflector of the radio signal. Joe Taylor, K1JT, has, for the radio amateur, pioneered weak signal detection protocols, based on the mathematics of information theory (by C.E. Shannon, 1948). Current versions of the protocol devised by K1JT, include error correction features that make them very robust, even for signals far to weak to be heard by other means. **Figure 11** shows the screen display for reception of an EME communications experiment, conducted by Joe Taylor [39].

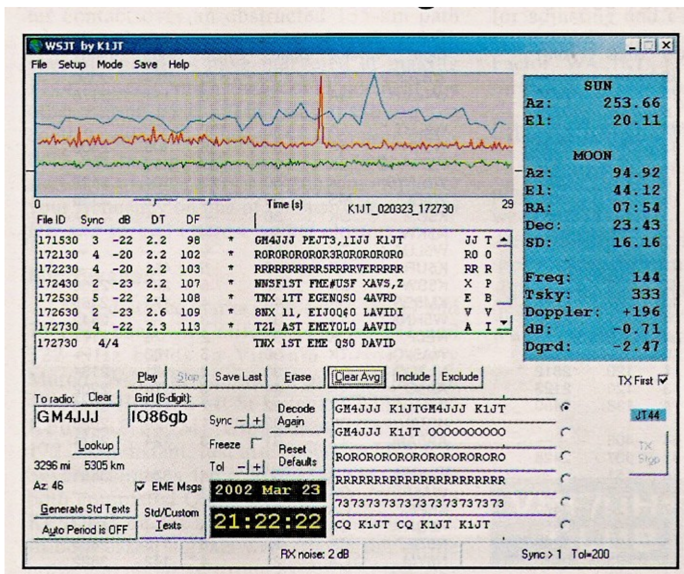


Figure 11 Main screen of WSJT in JT44 mode displays K1JT's

EME contact with GM4JJJ. The large box shows WSJT's

attempts to decode GM4JJJ' signal in successive 30-second periods.

The commercial version on which JT44 is derived (JT65), involves 135 intervals of 0.19 seconds long, in which 69 of the intervals, the single tone 1270.5 Hz is transmitted, for synchronization. In the remaining 66 intervals, tones of various frequencies are transmitted corresponding to 0 through 9, and letters A through Z.

The most recent published papers by Joe, describe applications for EME, and meteor scatter [39, 40]. The

JT65 protocol is described in reference [41], designed to optimize EME communications. Reference [39] describes Joe's first-ever EME contact on 23 March, 2002, between K1JT in Princeton, and GM4JJJ, in the UK, on 144 MHz. Numerous terrestrial contacts have been made on various frequencies from 50 MHz to 10 GHz.

Digital Voice: Initially station-to-station communications was via FM voice, or by digital data modes (packet radio systems provide error free digital communications). But digital voice (DV) systems are making inroads into VHF/UHF amateur repeater systems. Initially users of DV by radio amateurs employed a commercial signaling system, APCO-25, which has been used by police, fire, EMS, for more than 10-years. Radio amateur systems employing such DV systems needed no new development, only modification for radio amateur use. There was clearly, in the minds of some radio amateurs, a need to develop an all-amateur digital voice system (mode). A current system, just now coming into use, developed by The Japanese Amateur Radio League (JARL), is called D-Star. D-Star was designed from ground up to be linked to the Internet.

D-Star digital voice signals carry a 1200 bit/sec data signal, that can be used for text. To use this data signal, one has to connect to a computer, it cannot be connected to the radio directly. Radio amateurs setting up D-Star repeater systems are currently busy writing programs to take advantage of this data signal for sending text and small files.

There is no doubt that analogue-only radio systems will eventually be phased out, replaced by D-Star, or a next generation new horizon system. While cellular radio systems have the edge, almost unlimited resources because cellular is a commercial world-wide system, used by million-and-millions of users, radio amateurs are doing what they are doing, and radio amateurs will be there when commercial systems fail (see Radio Amateurs Emergency Communications, discussed briefly in a following Section).

HSMM: In 2002 the ARRL Technology Task Force (TTF) established a High Speed Multi Media (HSMM) Working Group, with John Champa, K8OCL its chairman. The first paper on HSMM was published in QEX in 2004 [42]. The studies to date have employed WiFi equipment to form the basis for high speed data transport at 2.4 GHz. Why 2.4 GHz: Bi-Directional Amplifiers (BDA) can be purchased from Fab Corporation [www.fab-corp.com] specifically designed for amateur HSMM radio experimenters. We mentioned earlier that radio relay was a part of the early history of radio --- HSMM can be used for radio relay for the 21st Century. Clearly there are many applications for HSMM technology, the reference paper mentions some of them (for example high speed link extensions for emergency communications). Certainly amateur radio operators will always find new uses for state-of-the-art technology.

Internet Radio Linking: Most VHF/UHF repeaters are stand-alone devices, providing extended coverage areas, but a significant number are now linked, to other repeaters. Internet linking has in recent years expanded exponentially, making possible world-wide communication through a local repeater. There are (at least) four Internet linking systems, the details of which are beyond the scope of this paper. Two of them are IRLP (Internet Radio Linking Project) [see **www.irlp.net**]; and EchoLink [see the **www.echolink.org**].

IRLP invented by David Cameron, VE7LTD, is a project that links amateur radio stations around the world using Voice over IP (VoIP) **[43]**. Each gateway consists of a dedicated computer running custom software, that is connected to both the radio and the Internet. Since the end user communicates using a radio as opposed to using a computer directly, IRLP has adopted the moto ***"Keeping the Radio in Amateur Radio".*** Linux is the operating system, since the designer, VE7LTD, found it allows the best in reliability, programmability, efficiency and functionality. As of April 2007, there were over 1,280 nodes across 7-continents.

EchoLink, like IRLP (the difference between IRLP and Echolink is beyond the scope of this paper), also allows licensed Amateur Radio stations to communicate with one another over the Internet, using the voice-over-IP (VoIP) technology. The program allows worldwide connections to be made between stations, or from computer to station, greatly enhancing Amateur Radio's communications capabilities **[44]**. Echolink, designed by Johnathan Taylor, K1RFD, runs under Microsoft Windows Vista. Radio amateurs using the Echo-Link software can operate in one of two modes: 1) Single User Mode. If they have an Internet-connected computer, they can use the computer's microphone and speakers to connect to (or through – see below) other Echo-Link-enabled computers over the Internet and talk to the amateur at the other end; or 2) Syrop Mode. This entails connecting their own VHF or UHF transceiver to their Internet-connected PC with a specially-designed hardware interface. Doing this enables another another radio amateur with their own transceiver, who is within radio range of this station, to communicate with (or through) any other EchoLink-equipped station anywhere in the world. This is the unique feature of EchoLink.

Radio amateurs without EchoLink software can take advantage of the EchoLink network if they are within the range of a sysop EchoLink station. It is also possible to link a syop mode EchoLink station to a local repeater, further enhancing the communications possibilities. There are (at the time of writing) more than 200,000 validated users worldwide — in 162 of the world's 193 nations — with about 4,000 online at any given time.

To date, on the radio side, the transceivers employ FM. But that is now changing. Ray Jacob, W2RJJ, see QST August 2008, has recently described how a Six Meter Millennium Net, based in New Jersey has been integrated using the EchoLink protocol into their SSB 50 MHz net, which has now become an all corners of the USA net. **Figure 12** shows Ray Jacob's station. Speaking into the PC microphone allows the operator to speak to both the local area radio net and to those calling in from wherever via EchoLink.

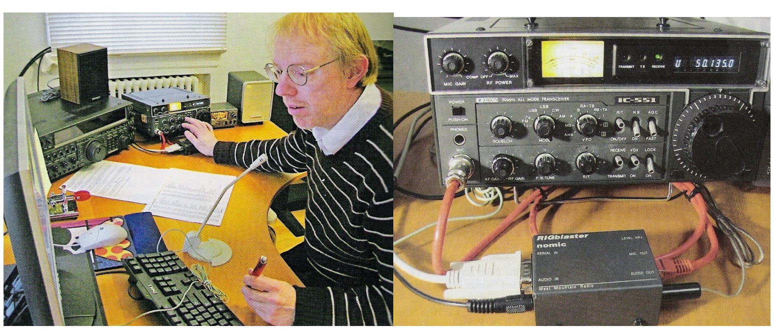


Figure 12 Ray Jacob, W2RJJ, (left) operating his SSB 50 MHz amateur radio station provided with Internet-operability. The sound card interface to his transceiver (right). The VoIP (Voice over Internet protocol), and EchoLink operation, allows him to speak both to amateurs locally, radio link(s), as well as to amateur radio operators where-ever

(copied from QST, August 2008).

Internet linking of NVIS 80M SSB nets has so far not been used. Canada and USA have many 80M nets, some operating continuously every day (during daytime) because of the use of such nets for emergency communications. Certainly Internet linking of such nets could enhance their capability during times of natural disaster.

What a Difference in 100 Years: In conclusion, **Figure 13** shows, for visual illustrative purposes, photographs of the "radio shack" at the ARRL Headquarters, in 1925, station 1MK (photograph is a copy of a QSL card); and today's Hiram Percy Maxim Memorial Station, W1AW (three operating positions are shown) --- which can be compared with Maxim's 1915 home station, 1ZM in **Figure 1**; and the 1BCG station in 1921, see **Figure 3**. Compare, what a difference!!

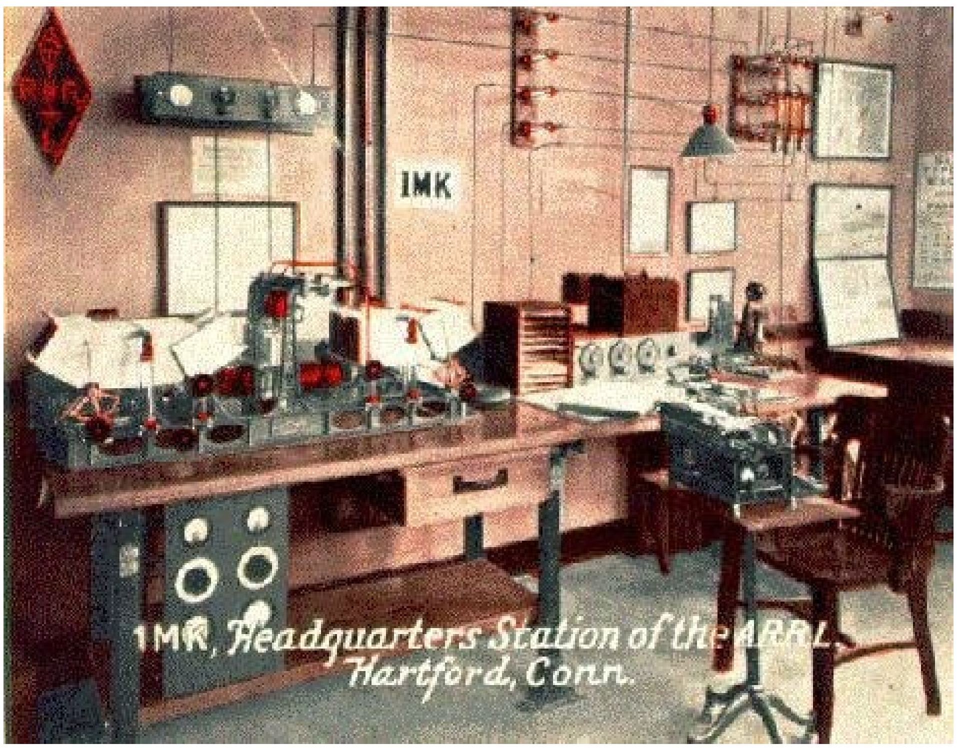


Figure 13 Top, a photograph (from a QSL card) of the 1925 ARRL station, 1MK; and (below) the modern amateur radio communications station (Studio Three, ARRL Hiram Percy Maxim Memorial Station W1AW, ARRL Headquarters, Hartford, CT). Note: there are 3-operating positions, the one with the key-board, providing computer interface, is configured for PSK31 capability.

The photographs show the progress from primitive spark-gap transmitters/receivers, to early vacuum tube equipment, to solid state equipment --- not SDR transmitters/receivers, but incorporated selectable functions controlled by a microprocessor(s). We have not shown an outside photograph of the antenna systems used today, at the ARRL Headquarters, multi towers, with multi-element yagi-antennas of all sizes, and wire dipoles for various bands, which do not show (photographically) so well as the flat-top of wires for the 1ZM station in 1915, or the cage T-antenna for the 1BCG station in **Figure 4**.

In the future equipment will shrink in size and complexity, and wireless communications will move to higher and higher frequencies. There are those that say that ***"HF is dead",*** replaced by iPhones, RIM-Blackberrys, Idous, or whatever --- "***but in our view HF may be dead, but it won't lie down***". HF provides the opportunity to speak directly person-to-person, group-to-group, city-to-city, province-to-province, state-to-state, and country-to-country --- not with the same quality, reliability, or available bandwidth --- but the communications channels are there --- and radio amateurs will continue to try and retain them for their use for whatever purpose.

Amateur radio emergency communications

Note: ***"In time of emergency, amateur radio steps forward and applies its specialized knowledge to the task of replacing and restoring and supplementing the normal communications system. That is our traditional responsibility --- a tradition we have ourselves built and a responsibility we have ourselves sought. War is the gravest emergency of all, and it is now our duty to discharge that traditional responsibility to the war emergency with discipline and patriotic duty ---", by order of the***

FCC Commission, T.J. Slovie, Secretary, 8 December 1941.

This is copied from the preamble heading the Notice to all Amateur Licensees notifying them that they are hereby ordered to suspend all “normal” radio amateur operations in continental United States, its territories and possessions. This notice was published in the January 1942 issue of QST: reproduced by the ARRL on the Sixty-Fifth Anniversary of that issue in January 2007.

But ceasing “normal” operations did not prevent the FCC from returning particular stations to the air, whose operations was judged to be essential to national defense. The notice continues: stating that by special authority the ARRL headquarters station W1AW would remain indefinitely on-the-air, conveying government announcements to amateurs and watching over the amateur bands. It is interesting to re-read that Notice, and to re-read that issue of QST.

In times of crisis and natural disasters, amateur radio is often used as a means of emergency communications when wire-line, cell phone, and other conventional means of communications fail. Unlike commercial systems amateur radio is not dependant on single elements of the terrestrial systems that can fail. It is dispersed throughout a community and can operate without mains power, employing battery power, solar-power, gasoline driven motor generators. Amateur radio operators can use hundreds of frequencies and can quickly establish networks tying agencies together to enhance interoperability --- interoperability is a major problem with conventional systems.

Amateur radio represents direct, unmediated communication that bypasses and has no dependencies upon millions (billions) of dollars of commercial infrastructure in getting the message from the send to the receiver. Hence when disasters occur and these commercial systems go down, amateur radio can still "get through". HF has particular power in this regard. Of course there are tradeoffs (lower bandwidth, more reliance on the HUMAN operator and their knowledge, skills and abilities) but we should not forget the basics.

In Canada and United States amateur radio emergency communications is organized by the ARES (Amateur Radio Emergency Service), which is sponsored by the Radio Amateurs Canada (RAC) and by the ARRL. A few examples of natural/man made disasters follow, in which radio amateurs provided or tried to provide emergency communications:

One of the worst natural disasters in author Belrose’s experience was the Canadian ice storm in 1998. Freezing rain started to fall on Monday 5th January 1998. The storm coated everything. Ice build-up brought down power lines and poles, causing massive power outages. It was virtually impossible to purchase power generators. At the height of the storm, 57 communities in Quebec and Eastern Ontario were without power. About 600,000 people had to leave their homes, 130 power line towers were destroyed, and more than 30,000 utility poles fell. Over 4-million people in Ontario, Quebec and New Brunswick lost power. About 100,000 people went into shelters. Twenty-eight people died from hypothermia, 945 people were injured. Three weeks after the beginning of the storm there were still 700,000 people without power. With the phones down innovation was the rule. Amateur radio operators were asked to help and they did when they were not fighting there own problems, towers down, wire antennas down, and no power. In Quebec during the storm we lost 12 repeaters 4 of which were fixed by HAMS during the storm. Helicopters brought fuel. Hiking teams pulled recharged batteries. Over 700 hams were operating at one time or another and in the largest part of the storm period, 250 hams were on at one time!

More recent examples include the 2001 attacks on the World Trade Center in Manhattan, the 2003 North American Blackout, and Hurricane Katrina in September 2005, when amateur radio was used to coordinate disaster relief effort activities when other systems failed. The largest natural disaster in the US, Hurricane Katrina, triggered the response of more than one thousand ham operators from all over the US, converging on the Gulf Coast in an effort to provide emergency communications. For 37 days more than 200 Amateur Radio operators from 35 states and Canada deployed to the field by the American Red Cross in Montgomery, AL, delivered a vital public service.

Many disaster situations transcend national boundaries. Emcomm radio amateurs (Emergency Communications radio Amateurs) are often involved in international scenarios. The International Amateur Radio Union Region 2 (which includes Canada and the US), abbreviated EMCOR, is an international coordinating and planning organization, familiar with the emergency communications structure in the nations [7].

Disasters frequently occur in remote or less populated areas (comparing with those mentioned above), yet still radio amateurs co-ordinate some relief efforts. On December 26, 2004, an earthquake and resulting tsunami across the Indian Ocean wiped out all communications with the Andaman Islands, except for an amateur radio DX-expedition station that provided a means to co-ordinate relief efforts. And more recently, Amateur Radio operators in the Peoples Republic of China provided emergency communications after the 2008 Sichuan earthquake.

Many of the worst natural disasters occur in areas where commercial infrastructure is NOT well developed, therefore simple and reliable technologies such as amateur radio are much more appropriate for disaster mitigation deployment. They don't need infrastructure, and if the radios or antennas break some guy with a soldering iron and a multimeter can fix them. You can't get much simpler than CW (transmitter ON, transmitter OFF!).

Radio Astronomy

Grote Reber, W9GFQ, was the founder of radio astronomy. He was born in Chicago on 22nd December 1911, but he lived and worked, and built his first radio telescope in Wheaton, IL. He wrote many papers, some in quite diverse fields, he was an engineer, an astronomer, a meteorologist, a botanist and an archaeologist . A number of overviews in memoriam papers (Reber died on 20th December, 2002, in Tasmania, Australia) have been written, but the paper we like best, for general reading on the theme of our paper, is the one by John D. Kraus [45]. John begins his paper: ***"Grote Reber first became known to me through his Wheaton neighbour, E.H. "Bill" Conklin. Bill was a radio amateur, W9FM, so was Grote, W9GFZ, and so was I, W8JK."***

When Grote learned about Karl Jansky's discovery of radio waves from the Galaxy (i.e., the Milky Way) in 1932, Grote decided that this was the field of research he wanted to study. He applied for a job at the Bell Labs, where Jansky worked, but this was a time period of recovery from the great depression, and Bell was not hiring. So Grote decided to study radio astronomy on his own. He constructed his first telescope in 1937, a parabolic "mirror" (see **Figure 14**), 9.6 metres in diameter, focusing radio waves at a point 6.1m above the dish.

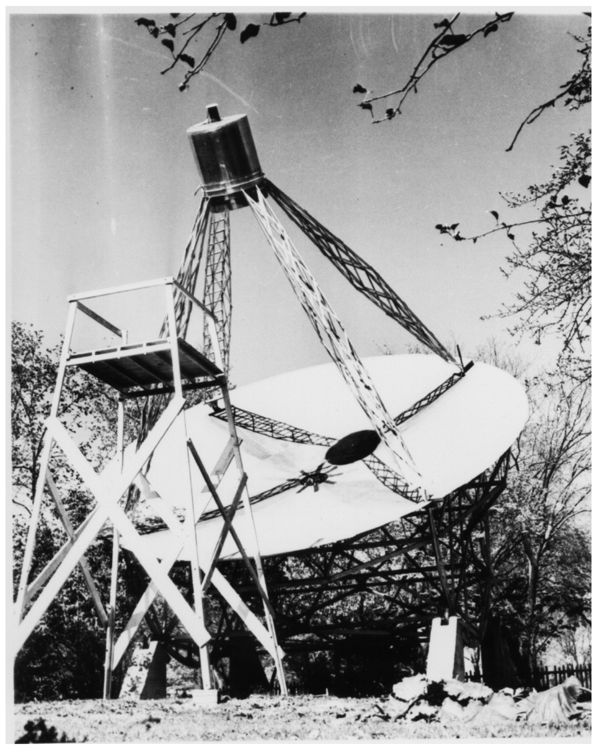


Figure 14 Grote Reber's telescope constructed in 1937, in his back yard in Wheaton, IL (a suburb or Chicago), which he constructed at his own expense.

In that time period, no one was studying radio astronomy, but it was thought, by those considering radiation from the galaxy, that Cosmic Static probably came from thermal radiation, and so the noise level should be higher at high frequencies. In fact Grote's early studies showed that Cosmic Static was higher at low frequencies. Grote's first receiver was designed for 3300 MHz, but he failed to detect signals from space. His second receiver was at 900 MHz, no luck. His third receiver was at 160 MHz, and at this frequency he was successful in detecting radio emission from the Milky Way. But at this frequency Grote's parabolic antenna had too broad a beam width (12°). Later when he went successfully to a wavelength of 62 cm (484 MHz), he could successfully begin to map the sky. Grote spent long hours every night scanning the skies with his telescope. He had to work at night because of automobile spark engine interference (**Figure 15**).

Figure 15 Grote Reber spent long hours every night scanning the skies with his telescope. He worked at night because there was too much interference during the day due to automobile spark engines.

His first map took a long time in the making, in part because WW II took Grote to other duties. Radio Astronomers at first did not understand what he trying to tell them, but when he published his first map in 1949, see **Figure 16**, they started to take notice.

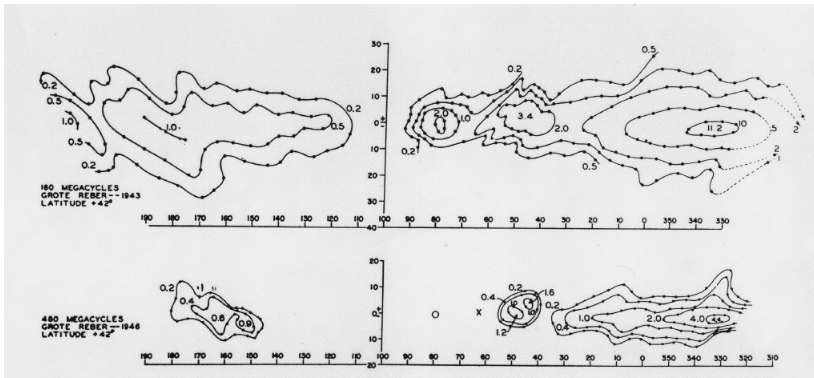


Figure 16 Grote Reber surveyed the radio radiation from the sky and presented the data as contour maps showing the brightest areas in the Milky Way. The brightest part is toward the center of the Milky Way galaxy in the south. Other bright radio sources, such as Cygnus and Cassiopeia, were recognized for the first time (published in 1949).

The diagram was plotted in galactic coordinates, which they could understand, in which the galactic equator runs horizontally. Most of the radiation is in or near the galactic equator. The vertical axis are galactic latitude in degrees, the horizontal axis are galactic longitude in degrees, in which the direction toward the center of the galaxy has a longitude = 0^o. Other bright radio sources, such as Cygnus and Cassiopeia, were recognized for the first time.

It was not until the 1950s that a Russian physicist, V.L. Ginzburg, worked out the theory of synchrontron radiation, which results from electrons (and other charged particles) moving at speeds close to the speed of light in magnetic fields.

Grote Reber donated his telescope to the National Radio Astronomy Observatory, at Green Bank, WV, in the early 1960s, where it stands painted red, white and blue for the US bicentennial, on a turntable where it can be pointed in any direction (Grote's telescope in Wheaton could only be rotated in elevation). The Mullard Radio Astronomy Astrophysics Observatory (MRAO), Cambridge England has a plaque on the wall and some of his ashes to remember the work of Grote Reber. The MRAO Observatory was 50-years old in 2007. It was Grote's encounter with John Kraus during the war years, which convinced Kraus to establish the Ohio State University Radio Observatory, in Columbus, OH.

The University of Cambridge, UK, is celebrating 800 years in 2009. The Cavendish Laboratory is celebrating 135 years in 2009, the MRAO Observatory 52 years. The field of Astrophysics is a major field of research, leading to an understanding of the formation of stars and planets. Grote Reber was a living legend in his time.

Conclusions

In this review, however briefly, we have touched on some of the highlights in the past 25 years of amateur radio, with a brief reference to the beginning of wireless communications. We have attempted to show that this record testifies the worth of the amateur approach in every phase of the radio communications art. The diverse culture and educational background of the radio amateur serves to imbue the R&D environment within the hobby with motivation, pattern of thought, and investigative insight, which is usually not captured within institutional R&D environments. The relevance of this non-traditional R&D is self evident, in the diversity and type of innovation that has come out of the hobby over the past century. The authors anticipate that this source of creativity, new ideas, new technologies, and the innovative application of existing technologies, all of which have been adopted and commercialized, or put to work in the public sector to improve the quality of life will continue, throughout the second century of wireless development.

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About the Authors

John S. (Jack) Belrose was first licensed in British Columbia in 1947 with the call sign VE7QH. At a later date he held the call sign VE3BLW. He has held his present call sign VE2CV since 1957. He is the licensed holder for the Communications Research Centre Canada's amateur radio station VY9CRC.

His amateur radio interests and work related interests were (still are) very similar, research in the field of antennas and propagation (A&P), and research concerned with the history of wireless (particularly Reginald Aubrey Fessenden, the principle pioneer of radio as we know it today). When he retired in 1998 he was Director of the Radio Sciences Branch, CRCC. Presently in honour of a 50+ year career in radioscience, he has the status of an Emeritus Researcher at CRCC . He has three university degrees, BASc and MASc degrees (1950 and 1951) in Electrical Engineering, University of British Columbia; and a PhD Cantab, in Radio Physics, Cambridge University, England in 1958. Jack is a Life Senior Member of the IEEE Antennas and Propagation Society, a Member of the ARRL (he is an ARRL Technical Advisor since 1981), a Life Member of the QCWA, a Member of the AWA, a member of RAC (Radio Amateurs Canada), and a Fellow Member of The Radio Club of America (presently a Member of the Board of Directors).

Kevin McQuiggin has over thirty years experience with information technology projects, and over ten years of experience as a senior manager in both the public and private sectors. He holds a B.Sc. in Computing Science and a Masters' degree in Communication from Simon Fraser University and is recognized as an innovator and advocate of relevant application of new technologies in both corporate and community settings. A popular speaker on innovation and leading edge technologies, he is a newly-appointed Adjunct Professor at Simon Fraser University's new Cybercrime Research Centre in Surrey, British Columbia. He is also a qualified commercial pilot and flying instructor, and has over thirty years teaching experience.

Amateur Exploration of 500 kHz

By Frederick H. "Fritz" Raab, Ph.D., W1FR

Abstract

The 600-meter band was used for nearly a century for maritime distress and calling, but is now mostly idle due to the transition to the Global Maritime Distress Signaling System (GMDSS). This classic part of the radio spectrum offers radio amateurs unique opportunities for technical investigations as well as emergency communications. Radio amateurs from nine countries have begun the exploration of this classic part of the radio spectrum.

1. INTRODUCTION

The first International Wireless Telegraph Convention, held in Berlin on November 3, 1906, designated 500 kHz as the maritime international distress frequency. This same convention also designated "SOS" to replace "CQD" as the distress signal.

The "600-meter band" (495 - 510 kHz) for nearly 100 years served as the primary calling and distress frequency for maritime communication. In the 1980s, a transition began to the Global Maritime Distress Signaling System (GMDSS), which uses UHF communication via satellite. In the 1990s, most countries ceased using and monitoring CW communications. Today, the 600-meter band is idle with the exception of occasional transmissions by heritage maritime stations and amateurs operating under experimental licenses and special permits.

The frequencies below 1.8 MHz have been little explored by radio amateurs since our banishment to "200 meters and down" in 1912. The 600-meter band is located (Figure 1) near the geometric mean of the 2200-m (137 kHz) and 160-m (1.8 MHz) amateur bands. It is of interest to radio amateurs for a number of reasons:

- Reliable regional emergency communications via ground wave,
- Investigation of different propagation and noise environment, and
- Experimental work with antennas, modulation, and signal processing.

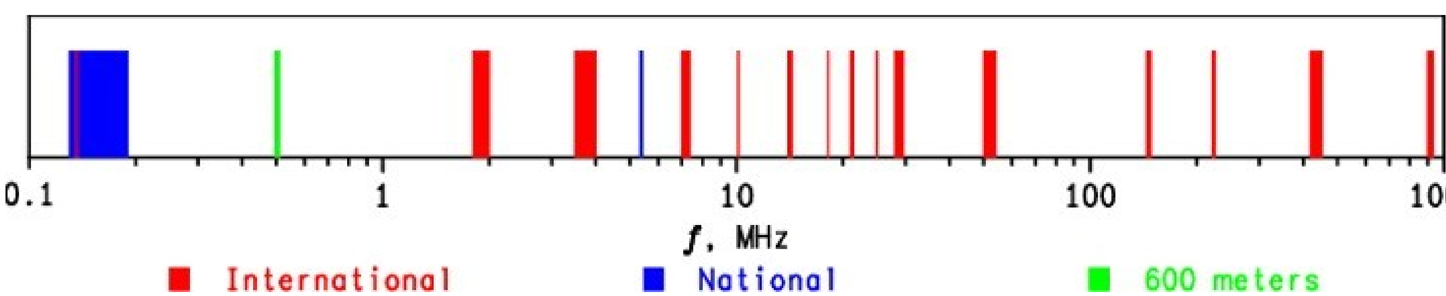

Figure 1. Amateur-radio spectrum from 100 kHz to 1 GHz.

2. AMATEUR EXPLORATION OF 600 METERS

The frequencies currently used by amateurs exploring 600 meters are shown in Figure 2.

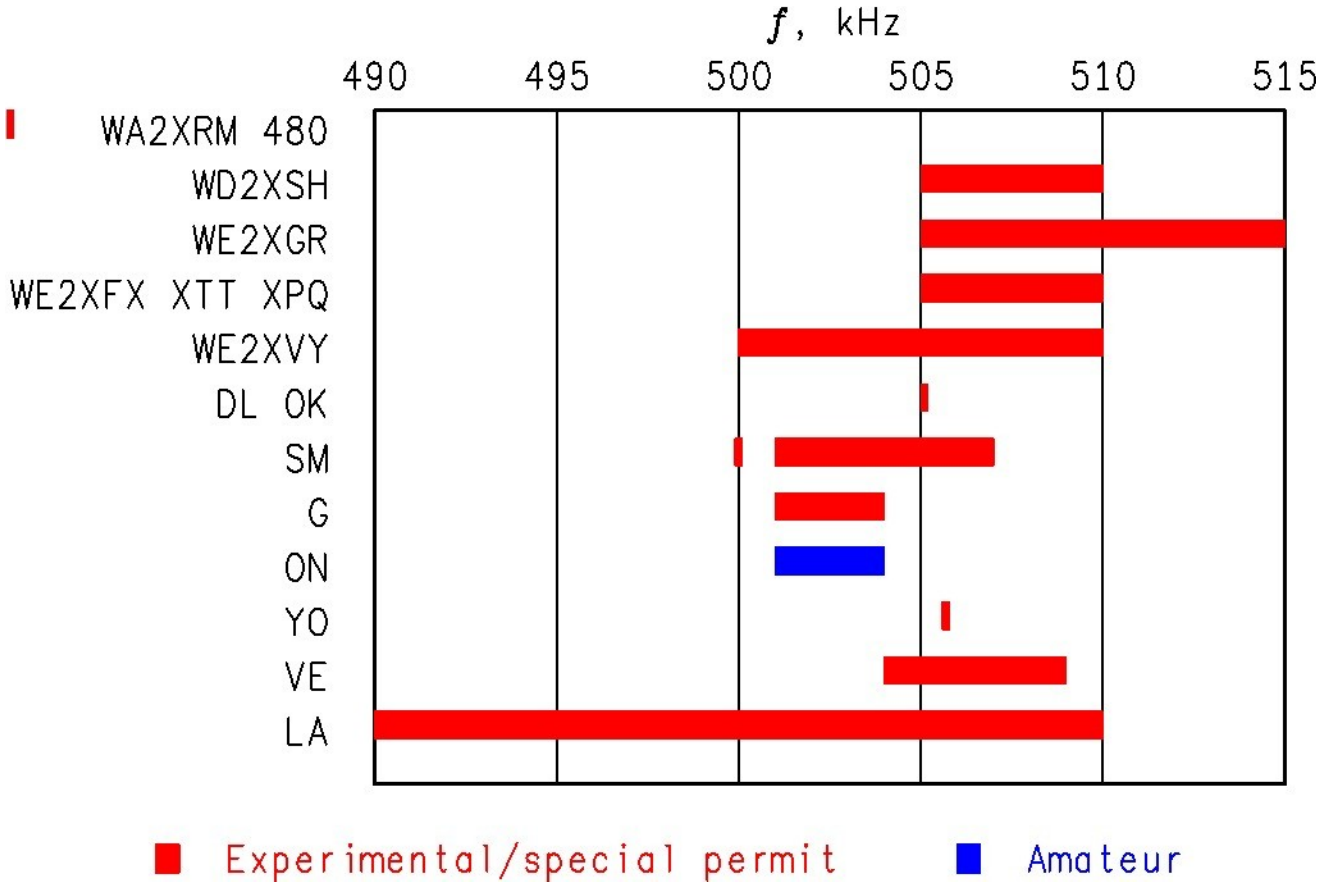

Figure 2. Worldwide amateur activity on 600 meters (March 2009).

Amateur exploration of the 600-meter band began with the Six-Hundred-Meter Research Group (600MRG) organized by Ken Gordon W7EKB in 2001. The 600MRG included 35 members at various locations across the USA. In December 2001, the 600MRG was granted experimental license WC2XSR and authorized to use 440, 470, 480, 495, and 166.5 kHz. Several members began experimental transmissions almost immediately. However, within a week or two, the authorizations for 440 - 495 kHz were withdrawn because of fears of interference to the new high-accuracy differential-GPS system being developed by the U.S. Coast Guard. One member of this group, Paul Sigornelli W0RW, obtained his own experimental license WA2XRM in 2004 and continues to operate on 480 kHz.

In 1999, the author was involved in an LF radio-navigation project and observed that the once-busy band from 435 to 510 kHz was now essentially "dead". At that time, the ARRL was busy trying to obtain a US amateur band near 137 kHz. The author's involvement in the 500-kHz experiment began in February 2004. Following a chance e-mail exchange with W0RW, the author contacted several members of the 600MRG to ascertain what had happened. A quick check of the frequency allocations suggested 495 to 510 kHz as a possible amateur band. The author then contacted the U.S. Coast Guard about possible objections and the ARRL about how to proceed.

The ARRL filed an application for an experimental license in April, 2005. After a meeting between the ARRL and the FCC in June 2006, the WD2XSH license was granted on September 13, 2006. It permitted 21 amateurs (Figure 3) to operate from 505 to 510 kHz with an effective radiated power (ERP) of 20 W. The author began transmitting later that day, as did one other station (/11). By the weekend, station /10 was on the air and signal reports were being received. This license has been renewed through August 2010 and currently permits CW, slow-speed CW (QRSS), PSK-31, FSK-31, and MSK-31 modes of operation. A pending modification request will add about 20 more stations and allow operation from 495 to 510 kHz. At the time of writing, five other USA experimental licenses have been issued and several more are pending.

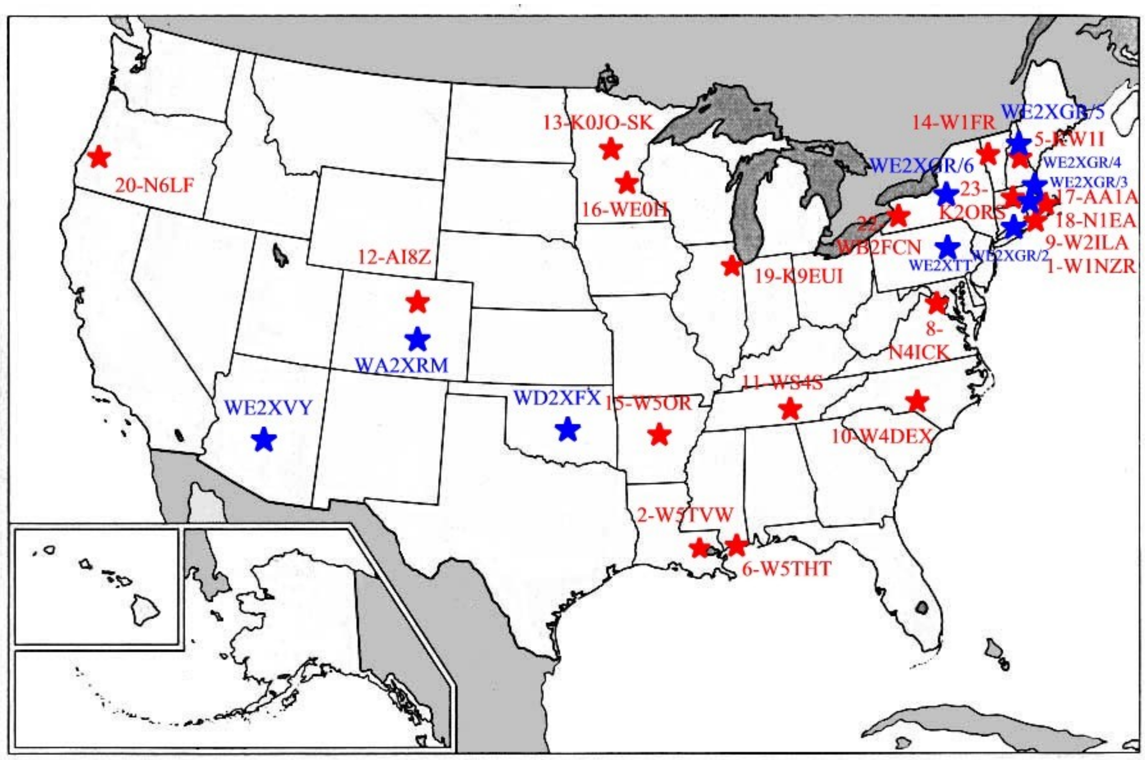

Figure 3. Locations of US experimental stations.

Brent ("Gus") Gustafson SM6BHZ received permission in December 2006 from the Swedish Posts and Telecommunications to operate between 505.0 and 505.2 kHz with an ERP of 20 W. His band has since been expanded to 501 to 507 kHz. Another Swedish station, SK6RUD, began operation of a beacon on 500 kHz from Oxaback in August 2008.

Meanwhile, Walter Staubach DJ2LF obtained permission in late 2005 to operate DI2AG on 440 kHz from Dormitz near Nuernberg, Germany   He was joined in 2006 by Geri Holger DK8KW operating under experimental license DI2BO from Peine near Hannover. In December 2006, these stations switched to operation at 505.0 to 505.2 kHz to match the authorizations of WD2XSH and SM6BHZ. They have since been joined by four other German experimental stations.

Beginning in March 1, 2006, UK amateurs were allowed to operate from 501 to 504 kHz under a special permit ("Notice of variation"). They were initially permitted to radiate only 0.1 W ERP, but that has since been increased to 1 W and in February 2009 to 10 W.

Beginning in early 2008, the Belgian amateurs with "full" licenses were permitted to operate from 501 to 504 kHz with up to 5 W ERP. This is the first actual amateur allocation for 600 meters. Other European countries with 500-kHz stations include the Czech Republic and Romania. Starting in 2009, Canadian amateurs will be able to apply for a special permit to operate from 504 to 509 kHz with an ERP of 20 W. Norwegian amateurs should also gain access to 500 kHz during 2009.

3. EXPERIMENTERS AND EQUIPMENT

Most of the US amateurs participating in the 500-kHz experimental work have advanced or extra-class amateur licenses. Most are experienced electronics professionals, and many have maritime-radio backgrounds.

In the finest tradition of amateur radio, experimenters are using a wide variety of approaches to produce their signals. Photos of some of the equipment in use can be found in an earlier paper by the author [1].

The receiver is typically a commercial amateur-radio receiver or transceiver. Most commercial receivers can receive signals below the AM-broadcast band, but the sensitivity is often poor. In many cases, this is the result of an attenuator that is switched-in to prevent overload by AM-broadcast stations. The most common receiving antenna is an active whip (e.g. AMRAD design) consisting of a short vertical element (1 meter) with a preamplifier. Other receiving antennas include rotatable loops, long wires, and the K9AY crossed loop.

The power amplifiers in commercially available amateur equipment in general are not capable of operating at 500 kHz, or at least do not operate very well. Consequently, experimenters have needed to build their own power amplifiers or adapt surplus equipment. Some experimenters are using state-of-the art class-D or -E high-efficiency, solid-state amplifiers. Others have adapted commercial vacuum-tube amateur equipment. Still others have adapted maritime reserve (back-up) transmitters or transmitters for non-directional beacons (NDBs). The signal source can be an amateur transceiver, but is more often a dedicated signal synthesizer. The latter is especially useful for QRSS transmissions in which maintaining frequency to a fraction of 1 Hz is essential.

A wide variety of transmitting antennas are in use in these experiments. The most common is a top-loaded vertical antenna. Typically the height is 10 to 20 m, but some experimenters have been able to put up 30-m antennas. Less common are large loops (10 m x 10 m or more) and simple vertical antennas.

Antenna tuners for the short vertical antennas must employ large loading coils. The required inductance can be as large as 700 μH. The diameters range from 20 to 30 cm, and the lengths 30 to 60 cm. Some installations use variometers for fine adjustment. Both ferrite-loaded transformers and LC networks are used to match the real part of the antenna impedance.

4. PROPAGATION AND NOISE

Both ground-wave and sky-wave propagation (Figure 4) are of interest at 500 kHz. The ground wave travels along the surface of the earth and provides regional communication that is not subject to the whims of the ionosphere. The sky wave provides longer-range communication. The basic factors affecting these signal paths are:

- Antenna gain (hence radiated power),
- Propagation loss, and
- Noise level.

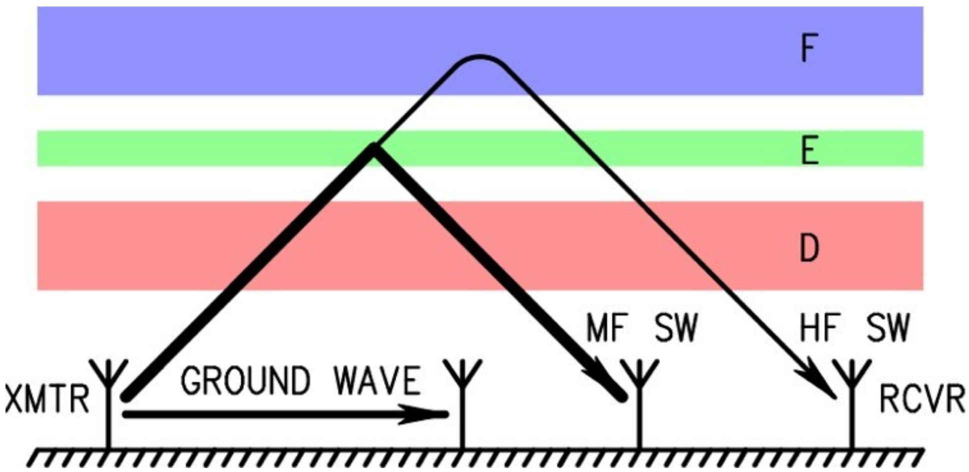

Figure 4. Propagation paths.

Antenna Gain

Virtually all antennas used by radio amateurs at medium frequencies will be electrically short. Consequently, the gain of the antennas increases as frequency increases.

A typical example of an amateur antenna is a 15-m (50-ft) vertical (monopole) with sixteen 30-m radials. The low-angle/ground-wave gain predicted by NEC for this antenna over good ground (conductivity of 0.01 S/m) is shown in Figure 5. While different short antennas have different gains, all have the same variation in gain with frequency (6 dB per octave or 20 dB per decade) while they are electrically short. As the frequency increases past the quarter-wavelength frequency (5 MHz in this example), the gain continues to increase, but at a slower rate.

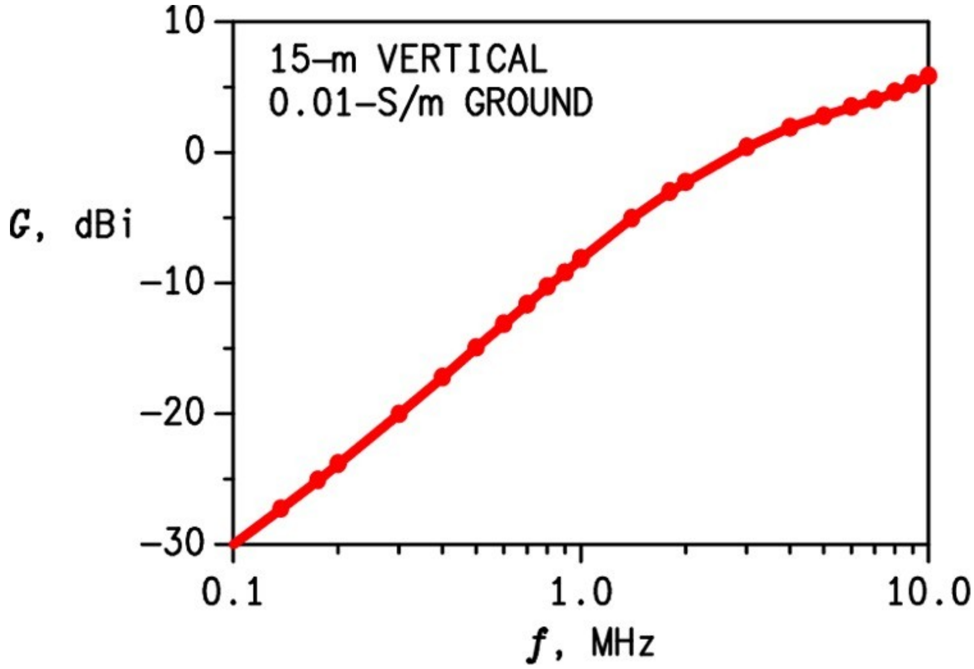

Figure 5. Low-angle/ground-wave gain of 15-m vertical antenna.

Atmospheric Noise

Atmospheric noise is dominant at medium frequencies in the evenings in the spring, summer, and fall. Man-made noise [2] is often dominant in winter evenings and days in the spring, summer, and fall. Atmospheric noise is impulsive, which means that much of the noise power is concentrated in bursts. In contrast, man-made noise is often composed of 60-Hz harmonics.

The median atmospheric-noise levels vary with location, time of day, season, and frequency. Median noise-level data are provided in [3] in terms of an "atmospheric-noise factor" F_{am} at 1 MHz. The atmospheric noise factor is a convoluted mechanism that treats the noise as if it were originating in the front end of a receiver. The atmospheric-noise factor Fam for a given location, time, and season is then adjusted for the desired percentile level and frequency, after which it is converted to rms field strength.

The atmospheric-noise factors for the central USA are given in Table 1. The noise level can vary by 30 or 35 dB over a day. The highest noise levels occur at night (especially 20:00 - 04:00 local time), while the lowest occur in the late morning (08:00 - 12:00). Noise levels are highest in the summer and lowest in the winter.

SEASON	F_{am}, dB at 1 MHz
Winter	35 - 70
Spring	50 - 85
Summer	60 - 90
Fall	45 - 80

Table 1. Atmospheric-noise factors for central USA.

Examples of the variation of atmospheric-noise levels with frequency are shown in Figure 6. The left graph shows the median noise levels (exceeded 50 percent of the time) for 70-dB (maximum winter, typical spring and fall) and 90-dB (summer) noise factors. The right graph shows the noise levels for summer noise that are exceeded 10-, 50-, and 90-percent of the time. These represent exceptionally quiet conditions, the median level, and very noisy conditions (e.g., thunderstorms nearby).

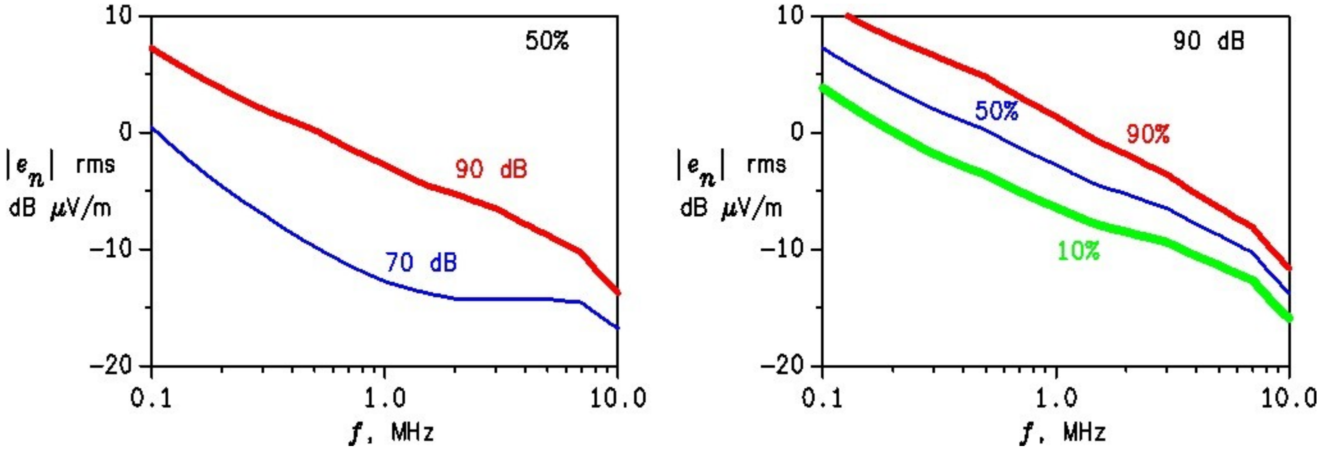

Figure 6. Variation of atmospheric-noise levels with frequency

Ground-Wave Propagation

The "ground" or "surface" wave is excited by the interaction of the electromagnetic waves produced by the antenna with the conducting surface of the earth. The ground wave transitions through three separate regions as it propagates away from the antenna:

- Free-space region,
- Flat-earth region, and
- Spherical-earth or shadowing region.

In the free-space region, the field strength is proportional to the inverse of distance. In the flat-earth region, the field strength is proportional to the inverse square of distance. This is the region in which most useful ground-wave communication occurs. In the spherical-earth region, the field strength decays exponentially.

The behavior of the ground wave in the flat-earth region was originally derived by Sommerfeld and extended by Norton [4]. The "Sommerfeld reduction factor" (SRF) is applied to the amplitude of a free-space signal to obtain the amplitude of a ground-wave signal. The most popular form of the SRF is a simple formula devised by Terman [5]. A tractable form of the SRF that includes spherical-earth shadowing is given by Boithias [6].

Examples of how the amplitude of the ground wave varies with frequency, distance, and ground conductivity are shown in Figure 7. The left side shows the variation of signal strength with distance for a 1-W, 500-kHz transmitter and an antenna with a gain of 0 dBi at the horizon. Typical conductivities for good soil, poor soil, and sea water are 0.01 S/m, 0.001, and 4 S/m, respectively. Higher conductivity results in lower propagation loss. Shadowing begins at about 400 km and puts a quick end to useful ground-wave communication.

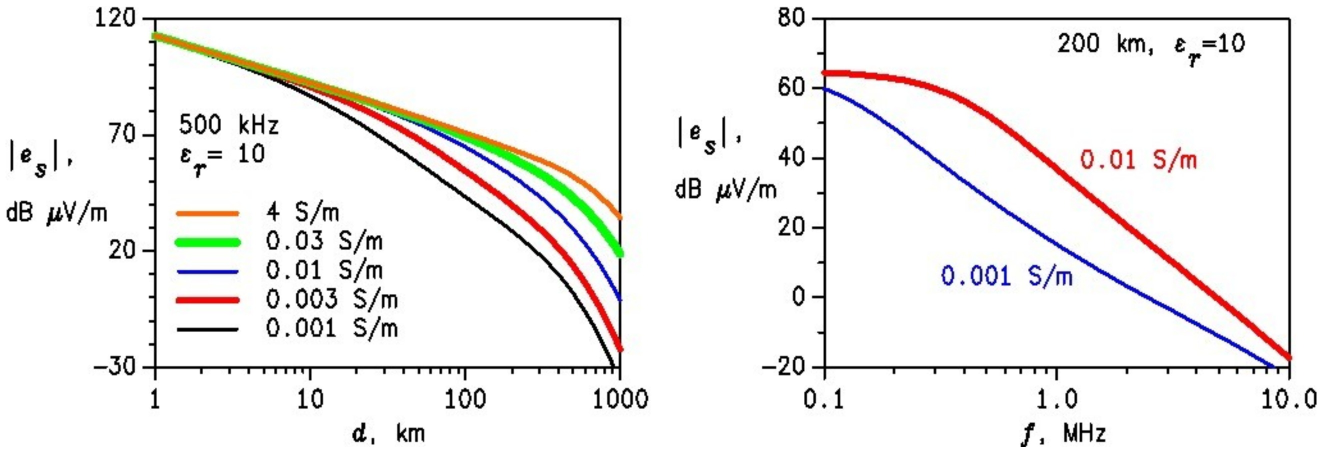

Figure 7. Amplitude of the ground-wave signal.

The right side of Figure 7 shows the variation of the signal amplitude with frequency at a distance of 200 km. For good soil, the signal level starts to decrease at 300 kHz, while for poor soil the decrease starts at about 100 kHz. It is apparent that ground-wave propagation favors the use of lower frequencies.

Best Working Frequency for Ground-Wave Communication

As discussed previously, the behavior of the antenna gain and the atmospheric-noise level favor the use of a higher frequency, while the ground-wave propagation loss favors the use of a lower frequency. The combined effects are shown in Figure 8. These graphs are based upon

- 0.01-S/m ground,
- 1-W RF input to antenna,
- 0-dBi antenna gain,
- 1-Hz receiver bandwidth,
- 70-dB atmospheric-noise factor, and
- Median noise level.

It is apparent that the signal-to-noise ratio (SNR) for regional communication (100 - 300 km) is maximum between 400 and 600 kHz. This makes 500 kHz an ideal frequency for regional uninterruptable emergency communication by ground wave.

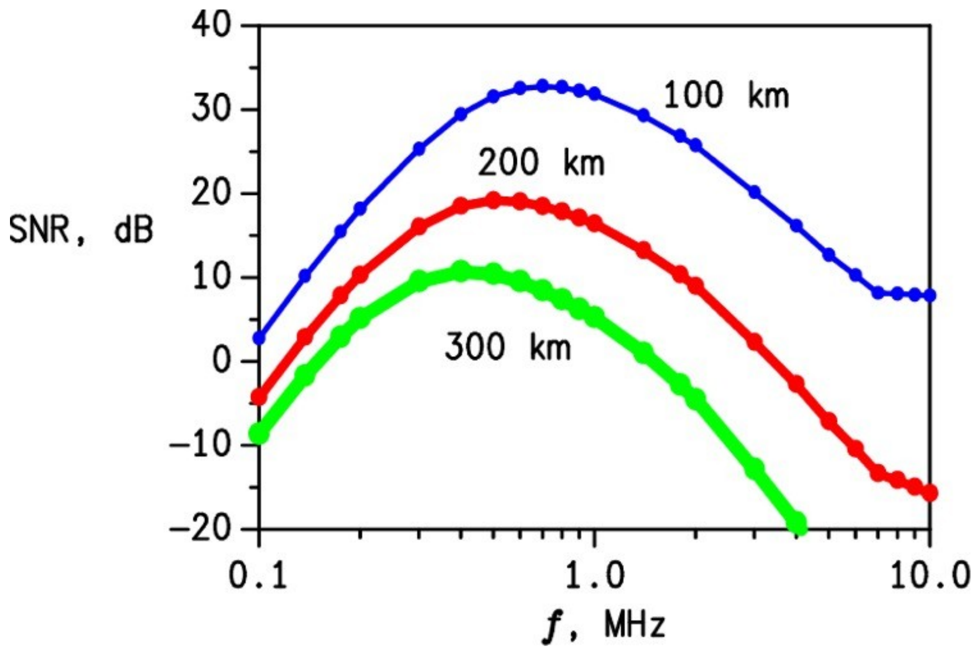

Figure 8. Ground-wave signal-to-noise ratio.

Sky-Wave Propagation

The sky wave allows long-range communication via refraction in the ionosphere. As shown in Figure 4, the ionosphere is divided into three layers. The D layer extends from 50 to 90 km. It is created by ionization of the atmospheric by ultraviolet light from the sun and is therefore present only during the daytime. When present, it significantly attenuates signals at MF. The E layer extends from 90 to 140 km, with peak ionization and the effective height usually occurring near 100 km. The E layer is primarily responsible for the sky-wave signals at MF. The F layers extend from 200 to 600 km. During the day there are two distinct F layers (F1 at 200 - 300 km and F2 at 400 - 600 km), but at night the two layers merge. The F layer is primarily responsible for HF sky-wave signals. At MF at night, the amplitudes of the ground wave and sky wave are generally about equal at a distance of 150 km.

A detailed discussion of the ionosphere at MF is given by Davies in Chapter 11 of [7]. The critical frequency varies from about 1 MHz at low latitudes to 4.5 MHz at a geomagnetic latitude of 60°. Chirp sounders regularly probe the ionosphere at HF, but the number of soundings at MF is relatively small.

Since sky-wave propagation at 500 kHz is primarily due to the E layer, the readily available prediction programs for HF are not applicable. Three methods are available for predicting the MF sky-wave field strength:

- FCC (Region 2),
- ITU, and
- Wang.

A nice summary of these methods is provided by DeMinco [8]. All are empirical techniques and based primarily upon observation of signals in the AM-broadcast band (535 - 1700 kHz).

ITU (CCIR) recommendation 435-7 [9] is a heuristic method of calculating the median field strength at night and well after sunset. It includes factors for power, sea gain, polarization, geomagnetic latitude, slant propagation distance, ionospheric losses (absorption, focusing, terminal, hops), season, and time of day. While it is straightforward, it is quite tedious and best done by a computer program.

Wang [10] reviews FCC and CCIR methods and provides an improvement upon the FCC method that remains much simpler than the ITU method. In his method, the median field strength in dB relative to 1 μV/m is given by

$$F = F_C + 10 \log P + G + 9.54 \quad , \qquad (1)$$

where G is the gain relative to an ideal small vertical antenna (4.77 dBi) and P is in kW. The factor F_C is given by

$$F_C = (95 - 20 \log d) \; - \; (\pi + 4.95 \tan \Phi)\,(d/1000)^{0.5} \quad , \qquad (2)$$

where Φ is the mean geomagnetic latitude of the transmit and receive sites (north is positive) and d is in km. The value of f is limited to a minimum of 250 km and the Φ is limited to the range of -60° to +60°. The three methods can differ from each other by 10 dB and from measurements by 18 dB [10].

The predicted median field strength is shown for three geomagnetic latitudes in Figure 9. These signal levels are based upon an output of 1 W to an antenna with a gain of 0 dBi. All decrease rapidly with distance above 250 km. Signals are stronger at lower geomagnetic latitudes (e.g., 30°) and weaker at high latitudes. This is probably assiciated with variations in the E layer. The graph on the left assumes an isotropic (omnidirectional) antenna, while the graph on the right includes variation of the gain with the cosine of the elevation angle as in a short vertical antenna.

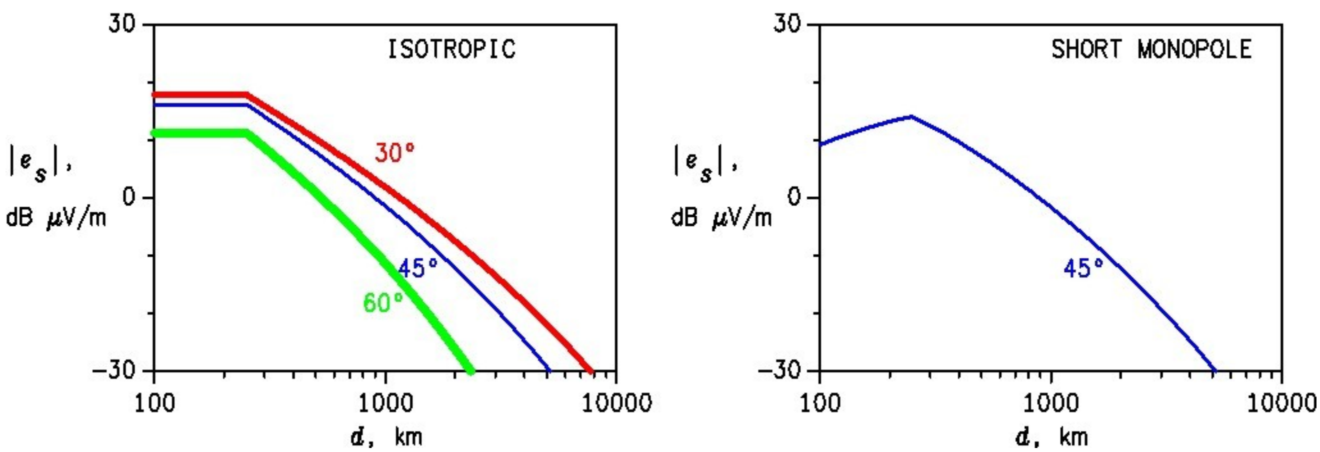

Figure 9. Median MF sky-wave signal strength.

Attenuation of the MF sky wave by the D layer disappears at night. This plus some changes in the E layer cause a difference of 30 to 45 dB between the amplitudes of the signals from noon to midnight [8],[11]. Seasonal changes are on the order of 10 to 20 dB [12].

The variation of the median field strength with frequency is relatively small (e.g., 1 to 3 dB across the AM-broadcast band) at night [10]. It is, however, more pronounced right after sunset.

The upper-decile level (exceeded only 10 percent of the time) is about 8 dB above the median level. The 99th percentile level is 12 dB above the median.

The level of the MF sky wave is reduced during periods of higher solar activity [13]. This effect is most pronounced in North America, and more pronounced during day time. The variation from sunspot minimum to maximum is about 7 to 17 dB, and is most significant right after sunset. The signal strength is typically maximum in the year after the sunspot minimum.

5. AMATEUR RESULTS TO DATE

The ARRL 500-kHz experiment maintains formal logs of operation (MS Excel) and has a web-based system for filing reception reports. Reports are prepared quarterly and posted on the experiment web site [14]. The statistics from the WD2XSH operations include (as of Feb. 28, 2009):

- 33,476 total hours of operation,
- 335 QSOs,
- 8,318 reception reports filed, and
- Zero interference complaints.

Given the relatively small number of transmitting stations, QSOs are not always possible. Thus in contrast to amateur operations at HF, beacon transmissions make up a significant portion of the operating time at 500 kHz. The beacon transmissions expand the experiment beyond the limited number of authorized transmitting stations by allowing any amateur to file a reception report.

The WD2XSH QSOs criss-cross the continental USA (Figure 10). Reception reports for station 6 (Long Beach, MS) are shown in Figure 11, and the "DX" reception reports and contacts are shown in Figure 12. For a typical winter evening, the distances for overland QSOs or receptions are as follows:

- 500 mi (700 km) is routine,
- 1000 mi (1400 km) is not unusual,
- 1500 mi (2100 km) sometimes happens, and
- 2000+ mi (2800 km) happens, but is rare.

Reception of European stations on the US east coast and vice versa is not unusual on a winter evening.

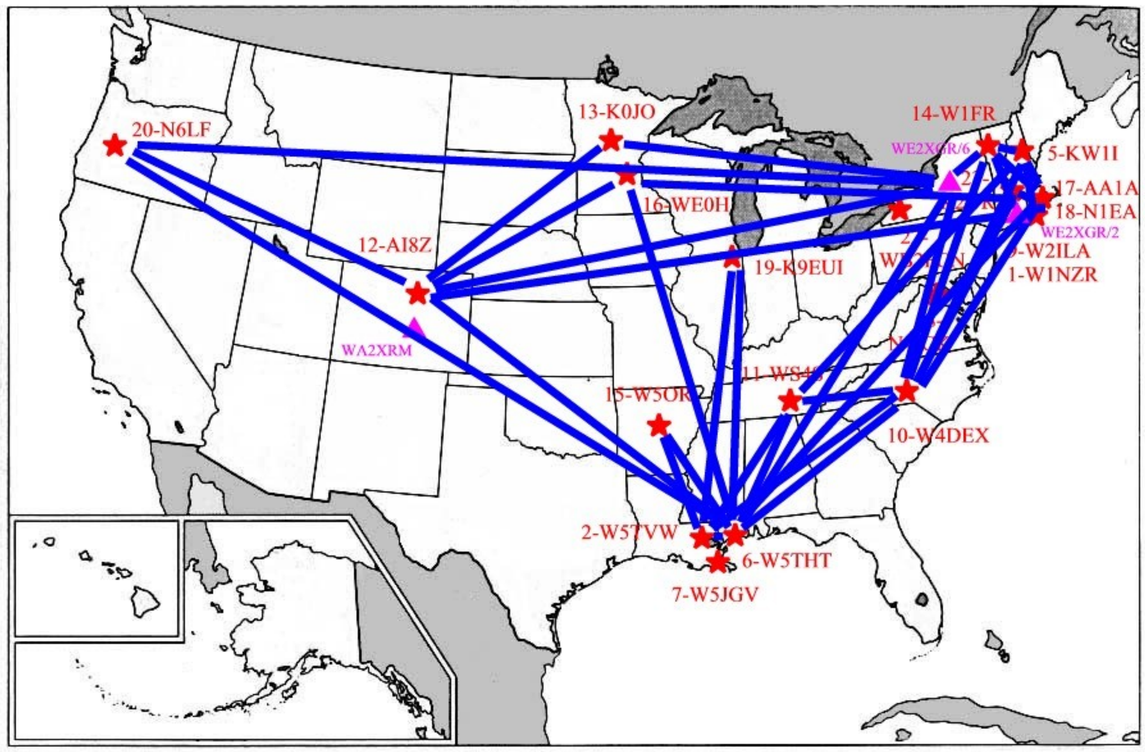

Figure 10. WD2XSH QSOs.

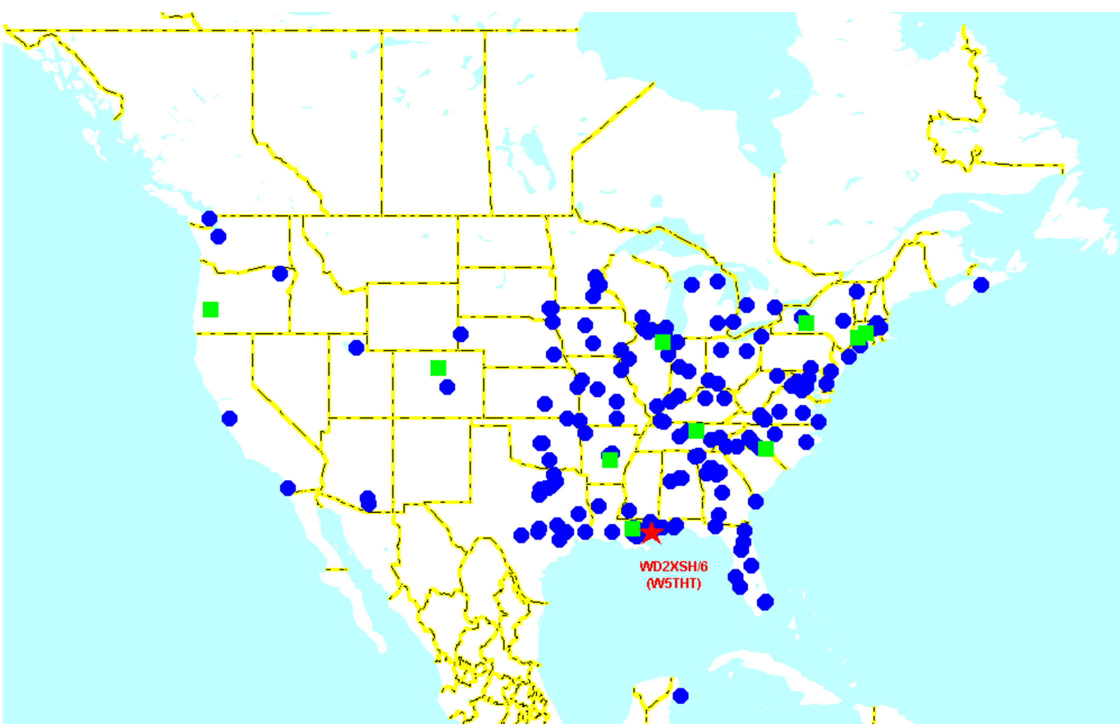

Figure 11. Reception reports for WD2XSH/6 (Mississippi) *(Courtesy WØRPK)*.

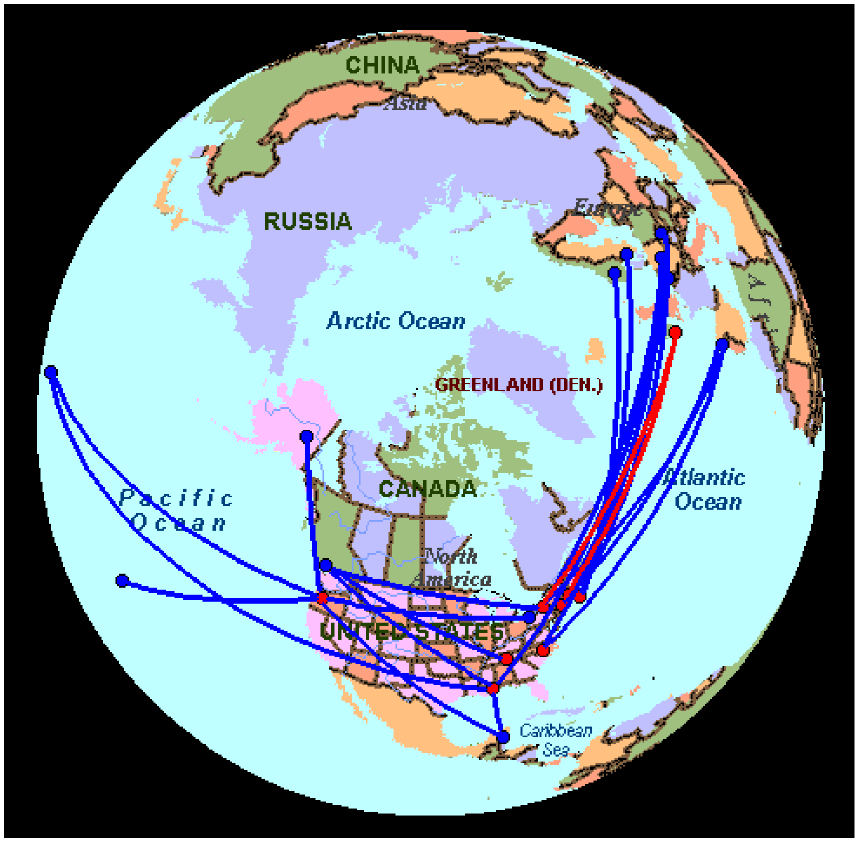

Figure 12. DX QSOs and reception reports *(Courtesy WØRPK)*.

The record distances are:

- CW QSO over land - 2,301 mi (WD2XSH/20 OR - WE2XGR/2 CT),
- CW QSO over ocean - 3,144 mi (WE2XGR/6 NY - EI2CF Northern Ireland),
- Simultaneous CW reception - 3,583 mi (WD2XSH/17 MA - SM6BHZ),
- CW reception - 4,736 mi (WD2XSH/20 OR - V73NS Kwajelein), and
- QRSS reception - 6,679 mi (WD2XSH/6 MS - V73NS Kwajelein).

Jay Rusgrove, WE2XGR/6 and Finbar O'Connor EI2CF also made a QSO in which WE2XGR/6 was using SSB.

Ground-Wave Experiments

Several tests of ground-wave communication have been conducted by WD2XSH and WE2XGR stations. These tests were conducted at midday during the summer so that the D layer eliminates the sky wave, and this is verified by a received signal that is free from fading. In general, the tests show that ground-wave communication at 500 kHz can be achieved

- Over 100 mi with little problem,
- Over 200 mi in most cases, and
- Sometimes to 300 mi.

These tests used CW, QRSS, and PSK-31. Some of the paths tested are shown in Figure 13.

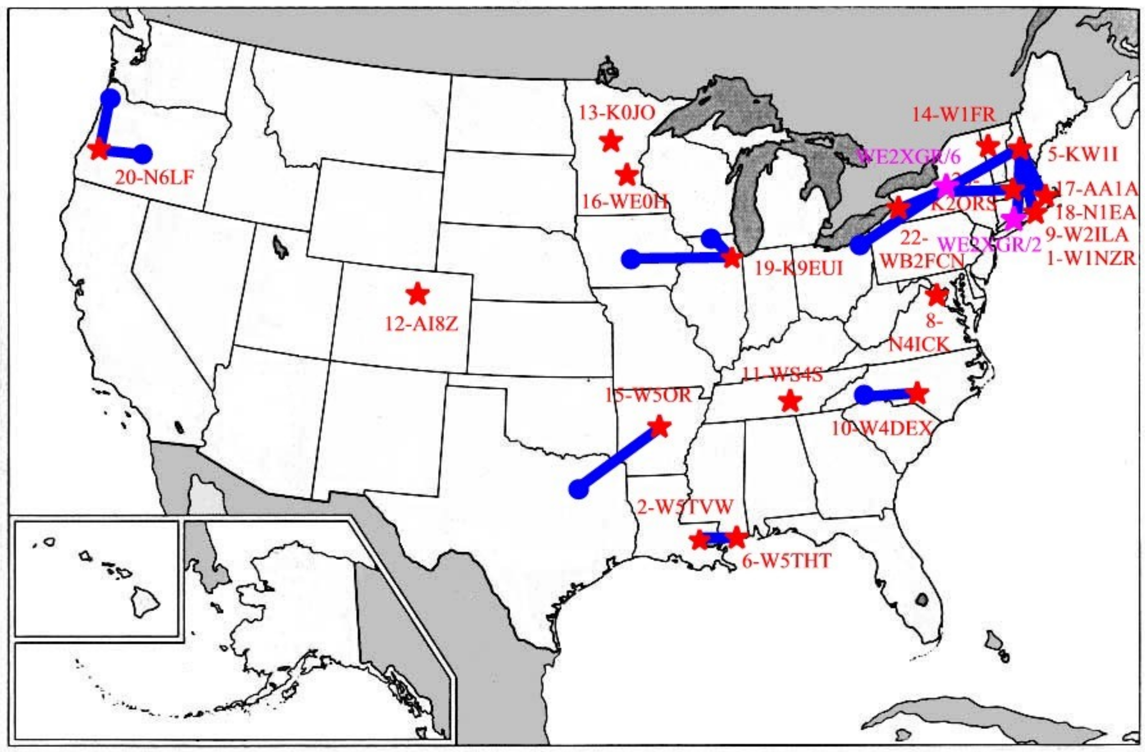

Figure 13. Demonstrated daytime ground-wave links.

Daytime Sky-Wave Communication.

A surprising discovery was the occasional long-range contact or reception during the day (Figure 14). These paths are longer than could reasonably be supported by ground wave. Most of the paths involve a station in New England, and all such links have occurred in December or January. This suggests that the D layer is sometimes unusually weak at northern latitudes during the winter.

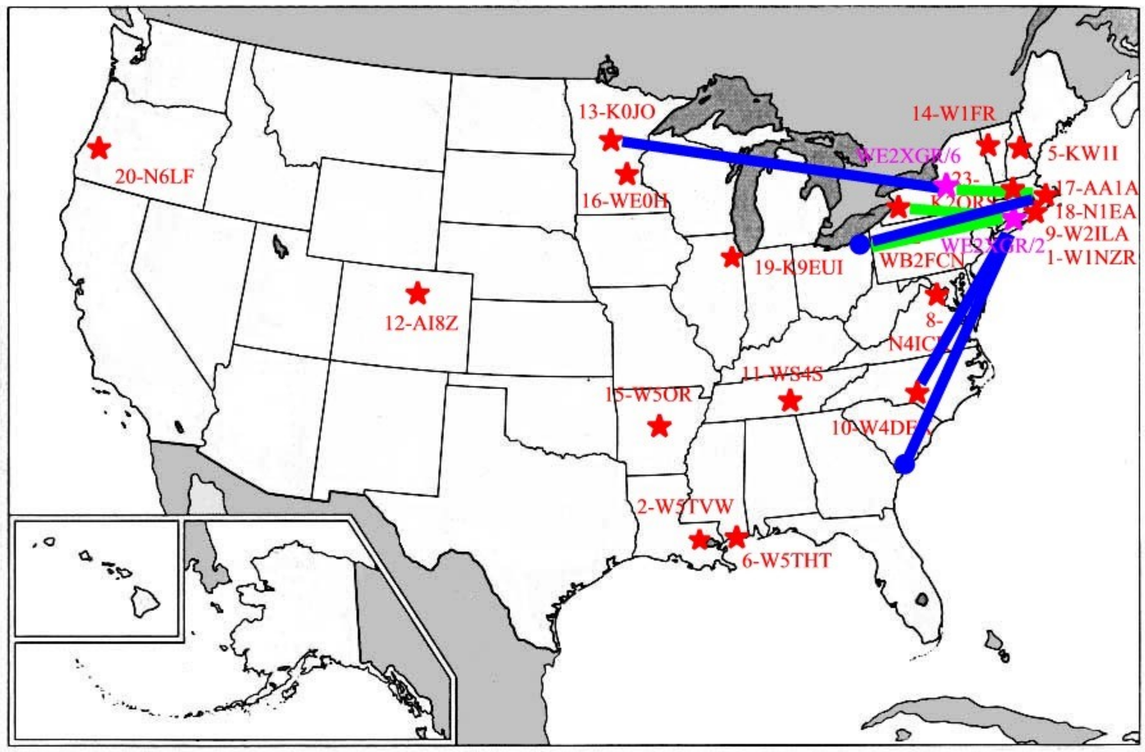

Figure 14. Daytime sky-wave communication.

Digital Modes

The spectrum available for a new amateur band near 500 kHz is limited. Operations in this band will therefore most likely be limited to CW, QRSS, and narrow-band digital modulation.

One example of a suitable digital modulation is PSK-31. PSK-31 provides data transmission at a 31 b/s rate, which (due to variable-length coding) is sufficient for real-time keyboard communication. The data pulses in PSK-31 are shaped like half sine waves to constrain the required bandwidth; only 62 Hz are required for a 31-b/s data rate. Thus a 5-kHz band can in principle simultaneously support 80 different stations using PSK-31. PSK-31 appears to work well for both ground-wave and sky-wave links at 500 kHz.

An important advantage of PSK-31 is that it provides the minimum bit-error rate for a given signal-to-noise ratio. QPSK-31 can provide twice the speed in the same bandwidth, or the same speed in half the bandwidth.

One possible disadvantage of phase-shift keying is that during day-night transitions, rapidly changing mixes of ground and sky waves may make the phase unstable. As of the time of writing, no observations have been made of how PSK performs during the day/night transitions. FSK does not require phase stability and can therefore be used during the transitions, although it requires higher power (about 6 dB) for the same data rate.

A disadvantage of PSK-31 is that the time-varying envelope requires a linear RF-power amplifier. MSK [15] is a form of QPSK with half-sine-wave data shaping (like PSK-31). However, shifting the data bits on the quadrature carrier by half a bit results in a constant-amplitude carrier and eliminates the need for a linear amplifier. To date, the amateur community has made little use of MSK, although it is widely used in VLF and LF communications.

The WE2XGR group has tested a wide variety of digital modulations on 500 kHz [16]. The modes include PSK-31, QPSK-31, PSKFEC-31, PSK063F, PSK-10, PSKAM10, WOLF, RTTY45, MSK-31, MSFK16, MSFK8, OLIVIA4-250, DOMINO-EX4, WSTJ-JT2, and WSPR. The comparisons reported to date are somewhat qualitative in nature and dependent upon specific software packages as well as the underlying modulation process. Some of these include PSK with envelope shaping, while others are multi-frequency FSK. The latter seem to have performed well.

6. AREAS FOR TECHNICAL EXPLORATION

The 600-meter band has been in use for over a century. One might therefore assume that everything about this frequency range is already known. This is hardly the case, as the advances in technology during the past fifty years have been minimal. As an example, regenerative "reserve" (back-up) receivers were still being manufactured in the 1970s. Areas for future amateur technical investigations are discussed below.

Antennas, Propagation, Modulation/coding, and Signal processing.

The design of electrically short monopole antennas is discussed in a number of text books. However, virtually all such discussions assume that the antenna can be installed in a clear space with a large ground system. In most amateur applications, the space available for a ground system is quite limited and construction of a large radial field may be too expensive. In addition, many amateur antennas must be placed near trees or buildings. Trees near a short vertical antenna are thought to reduce inefficiency, which is consistent with the application of an intense electric field to a poor conductor. Loops generate an intense magnetic field but only a small electric field, and there is some evidence that they are more efficient when placed near trees. Nearby trees as well as the ground may also cause changes in antenna impedance with weather and season. For example, the reactance of the author's 15-m vertical antenna (nominally about -2000 Ω) varies over a range of 100 Ω. Higher reactance occurs under dry and cold conditions, while lower reactance occurs under wet and warm conditions.

Propagation at 500 kHz is different from propagation at either 136 kHz or 160 meters and therefore warrants further investigation. WD2XSH operators have observed good conditions in one part of the country while bad conditions are present in another. We have also observed good conditions on 600 meters while conditions on 160 meters are poor. Sky wave at 500 kHz appears to be subject to deep, slow fading. For example, QRSS30 (slow-speed CW with 30-s dots for weak-signal reception) often is not useable because the fading effectively removes parts of the Morse characters. The phase stability of the sky-wave and ground-wave appear to be adequate for PSK transmission, but the behavior at sunset and sunrise need to be investigated further. Also, more extensive tests of ground-wave communication are needed to establish its utility for emergency communication.

A variety of software packages are available for digital communication, but none are optimum for 500 kHz. While FSK is easy to detect, it does not provide the minimum bit-error rate (BER) for a given SNR. PSK provides the best possible BER for a given SNR. However, PSK-31 and other techniques employ half-sine-wave envelope shaping to constrain the spectrum and to allow easy data-bit synchronization. This reduces the average transmit power to half of the peak PEP transmit power, and necessitates the use of a linear (and often inefficient) power amplifier. Minimum-shift keying overcomes these problems by modulating in-phase and in-quadrature carriers by data bits with half-sine-wave shaping and half-bit offsets. Unfortunately, it is not well supported at present by existing software packages.

LF and MF atmospheric noise is impulsive. One consequence is that a large number of consecutive data bits may be wiped out by a single burst of static. In-between bursts, the SNR is relatively good. This suggests the incorporation of a burst-error correcting code into a software package tailored to LF and MF operation. The impulsive nature of the noise also suggests the use of nonlinear processing such as clipping, editing, or an optimum nonlinearity to improve the SNR.

Man-made noise is often composed of 60-Hz harmonics. It also generally has electromagnetic characteristics (ratio of electric to magnetic field, direction of arrival) different from that of a propagating signal. This suggests the use of a noise cancelling system. Some of the products intended for amateur use have been used with some success. Experiments by the author with a more sophisticated system demonstrated 10 to 30 dB of noise cancellation at VLF [17].

7. EMERGENCY COMMUNICATIONS

Events such as Katrina can disrupt normal communication infrastructure over a whole region. Amateurs have proven their ability to provide emergency communications when all else fails.

A 600-meter band will provide amateurs with a unique capability for uninterruptable communication via ground wave. Since the ground-wave signal is not dependent upon the ionosphere, communications based upon ground waves are not interruptable by solar events (sunspots, solar storms, coronal mass ejection) nor by a high-altitude nuclear detonation that disturb the ionosphere. For example. a burst of solar activity in November 2003 produced significant aurora and disrupted HF ionospheric communication for several days. While other methods (such as VHF tropospheric scatter) can span similar distances, they cannot easily provide the "party-line" communication that is desirable for emergency communication.

Nodes in a 600-meter ground-wave emergency network could be either fixed or portable. Fixed stations could be set up at club sites or by individual amateurs. Portable stations would be housed in a van and driven into the affected area, where a 50-ft umbrella-loaded vertical antenna would be deployed. The communication vans would use VHF and UHF for short-range communication within the affected area, and 500-kHz digital links for communication with each other and with nodes outside of the affected area.

8. POSSIBILITIES FOR AN AMATEUR BAND

Article 13 of the ITU Radio Regulations restricted the use of 495 to 505 kHz to maritime distress and calling via CW. This restriction was removed at WRC-07 in November 2007. The upper guard band from 505 to 510 kHz was similarly protected until 1999. Consequently, these bands remain relatively empty and offer the best potential for a world-wide amateur band near 500 kHz. Frequencies slightly below and above this band may become available as many of the nondirectional aircraft beacons (NDBs) are phased-out over the next ten years.

The creation of an amateur band at 500 kHz will also preserve this frequency range for "heritage" operations. An example is the maritime coastal station KPH/KSM in Bolinas, CA. The Maritime Radio Historical Society [18] operates this station with vintage equipment and in a historically accurate fashion in order to preserve the traditions of maritime radio. KSM and KPH are joined on special occasions by several other coastal stations and ships that still have operational 500-kHz equipment.

The 2007 World Radio Conference (WRC-07) adopted a resolution (1.23) to consider at WRC-11 the allocation of about 15 kHz in the band from 415 to 525 kHz to the amateur service on a secondary basis. We are hoping this will come to pass.

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NOTES

Portions of this paper have appeared in a previous paper by the author [1].

ACRONYMS

GMRR = Green Mountain Radio Research
IEEE = Institute of Electrical and Electronics Engineers
ISU = Iowa State University
HKN = Eta Kappa Nu
ΣΞ = Sigma Xi
AOC = Association of Old Crows (electronic warfare)
AFCEA = Armed Forces Communications and Electronics Association
RCA = Radio Club of America
ARRL = American Radio Relay League

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Frederick H. Raab is Chief Engineer and Owner of GMRR, a consulting firm which he founded in 1980. He received B.S., M.S., and Ph.D. degrees in electrical engineering from Iowa State University in 1968, 1970, and 1972. He received the I.S.U. Professional Achievement Citation in Engineering in 1995 and was named an IEEE fellow in 2006. The textbook *Solid State Radio Engineering*, coauthored by Dr. Raab, is widely used by both academics and practicing engineers. Other professional achievements include publication of over 100 technical papers and award of twelve patents. Professional leadership includes serving as technical program chairman for RF Expo East '90 and founding technical committee MTT-17 that expands the IEEE MTT Society to include HF/VHF/UHF engineers. He is a member of IEEE, HKN, Sigma Xi, AOC, AFCEA, RCA, and ARRL. "Fritz" is extra-class amateur-radio operator W1FR, licensed since 1961, and is coordinator of the ARRL 500-kHz experiment.

Peer-to-Peer Wireless Technology: Past, Present and Future

By B. Otis, A. M. Stevens, N. Pletcher and J. Rabaey

I. Introduction

The rate of progress enjoyed by wireless technology over the past few decades is truly remarkable. Built upon the foundations of the classic radio architectures invented in the mid 20th century, and leveraging exponential reductions in transistor dimensions, portable wireless devices have now achieved ubiquity. This paper explores the past, present, and future of peer-to-peer wireless devices. We will draw comparisons between Ham radio and Wireless Sensor Networks, describe a specific example of a miniaturized radio that was inspired by the mostly-forgotten super-regenerative receiver architecture, and discuss the opportunities and challenges that await designers in the future.

II. Ham radio: the original peer-to-peer network?

Amateur (HAM) radio can be considered as one of the original peer-to-peer networks. Starting with the early spark gap and heterodyne transmitters and early crystal & vacuum tube RF receivers, Ham operators have been prominent experimenters in wireless radio technology. The ability to communicate over long distance without landline wire & cable would prove to be the best of all worlds for the Amateur radio hobbyist.

Marconi's pioneering work in the practical generation and receiving of long-range radio signals sparked much interest in utilizing wireless communications systems for shipping, military and commercial use. It wasn't long before hobbyists became interested in applications of this technology. Independent ham operators became so prolific that regulations and qualifications became necessary to regulate and control the airwaves, bringing about spectrum licensing. In the early 1900's, small groups of Hams using short range spark coils formed a radio club to promote the idea that messages could be relayed over long distances by establishing a multi-hop network. Eventually this network would become the American Radio Relay League- ARRL.

During the First World War, amateur radio operators played a major role in military communications using the skills and knowledge of radio communications gained through ham radio. Many of these radio operators would return from the War to pursue radio as an avocation. From the early discoveries in electromagnetic induction, the Telegraph, and radio wave propagation by Heinrich Hertz followed by advancements by Marconi, Fleming, Fessenden, DeForest, and Armstrong (to name a few), wireless radio communications would soon become a reality.

Wireless beginnings - A.M. Stevens

Having been born in the 1920's into a military family and being the son of a radioman, my Navy brat childhood gave me ample opportunity to see and hear the sounds of radio activity from Naval Radio Shacks at several shore locations. The most interesting to me were at Honolulu, TH, Fire Island, NY, Sandy Hook, NJ, Darien, Canal Zone (CZ) Panama and several California locations where Dad was deployed.

Viewing the radio shacks on the submarines, battle ships and destroyers that Dad took me aboard for visits as a kid was a thrill and provided me with an early interest in communications. My first real experience with wireless radio was in Darien, CZ while experimenting with a coil of wire and 6 volt car battery. I attempted to send code using one of my dad's keys into a long wire under our house. The response received for this effort, not having a receiver and ear phones, was my dad swiftly informing me that I was interfering with the reception at the Naval Radio Shack receivers and to shut down my operation.

Darien Naval Radio station was in an isolated location about halfway through the Panama Canal. The station was constructed in 1913 and produced a 100kW CW signal to antenna connected to three 600 foot self-supporting triangular towers. It was the first of the Navy's chain of radio stations installed around the world. After the Darien location we were subsequently stationed at the Balboa Naval Radio Station, and the Toro Point Radio Station (both in the CZ) before returning to the States before WWII started.

Following in my Dad's footsteps, the Navy provided me with practical training in radio and radar operations. The latter proved to be where the majority of my time would be spent until completing my enlistment and starting my formal education at the University of Kansas majoring in Electrical Engineering. My amateur radio experience was limited to becoming a Novice which provided me many hours of interesting communications with Hams that would take the time to respond to my CQ call.

Editor's Note: Fessenden's technologies, continuous waves, electrolytic detector, his heterodyne methodology for wireless telegraphy; and, modulated continuous waves, wireless telephony, although achieved in November/December 1906 using a HF Alternator, operating at frequencies 40-100 kHz, were (more or less) impractical until vacuum tubes were invented. No one excepting Alexanderson duplicated what Fessenden did in 1906 --- a HF Alternator operating at such frequencies --- and such low frequencies were not practical for most radio communicators, certainly not for radio amateurs (antenna size for acceptable radiation efficiencies).

Most stations consisted of Spark gap transmitters with an Audion receiver and crystal detector connected to an aerial wire. The switching between transmit and receive modes was done manually. Coils were hand wound for use in transformers, oscillators, and antenna coils by early Hams. In the early 1920's, the Spark Gap days were beginning to yield to new architectures, providing AM, FM and eventually SSB, no code, repeaters, amateur satellites, digital, and finally ubiquitous connectivity.

III. Introduction to ad-hoc wireless sensor networks

One of the driving forces behind radio advancements has been advances in device technology. The rapid miniaturization of silicon transistors has led to the following significant capabilities:

1. **Size:** the ability to integrate millions of active devices on a few square millimeters of silicon allows a tremendous amount of computation with an extremely small footprint.
2. **Power:** a reduction in the required power supply voltage (now 1.1V, and as low as 300mV for highly optimized digital logic [1]) allows a large reduction in power dissipation.
3. **Speed:** modern inexpensive integrated circuit (IC) processes are capable of operating at frequencies well in excess of 100GHz [2]. Thus, entire transceivers are now routinely integrated into extremely small ICs.

These three advancements have led to a previously inconceivable vision: an *ad-hoc* wireless sensor network (WSN) of tiny, wirelessly interconnected nodes that collectively perform distributed sensing or actuation. A node is a self-contained module which contains an energy source, computing resources, memory, one or more sensors or actuators, and a wireless link. See Figure 1.

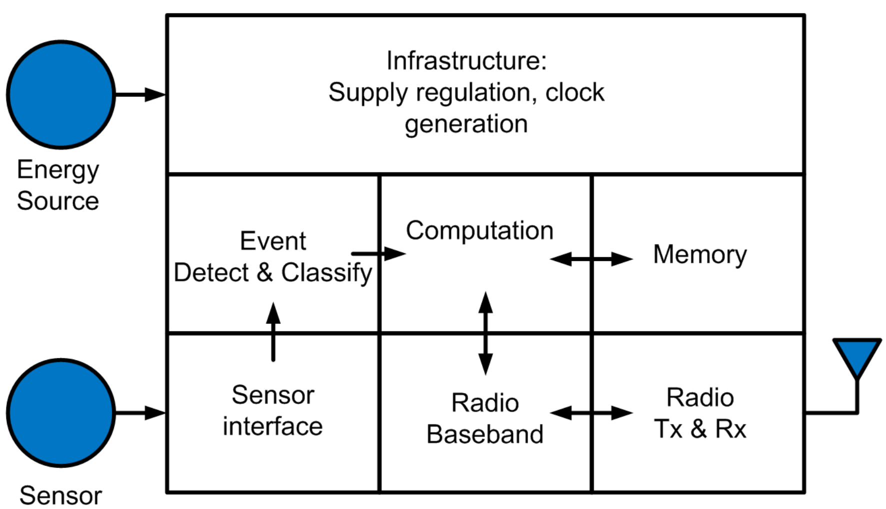


Figure 1. Block diagram of a basic sensor node architecture. The node is completely self-contained and modular, allowing a variety of sensor and energy source configurations.

The nodes are spatially distributed over the area to be monitored: an industrial plant, a home, an aircraft, etc. Each node monitors its local environment with one or more sensors, such as temperature, pressure, or acceleration. The node then relays information back through the network to any querying node or base-station.

The *ad-hoc* nature of the network is an important characteristic of this vision. The dynamic network environment constantly changes due to individual nodes entering or leaving the network (temporarily running out of power) or varying channel conditions such as interference or fading. For this reason, WSNs must self-configure and employ distributed routing protocols to ensure that data may be successfully relayed throughout the network.

Sensor networks can take a variety of forms depending on the application. For example, a network might be deployed in an outdoor environment to provide fine-grained data about temperature or humidity over a large area. In this case, nodes may need to communicate over a range of tens of meters or more. However, an application like smart surfaces, where nodes are distributed with higher density over a smaller area, might require shorter range communication but more data throughput.

In summary, WSN are employed in applications where they must be small and unobtrusive, deployed in large numbers, and last for a long time with little or no maintenance. These factors drive three main characteristics common to all sensor networks:

- Low cost – The hardware costs must be low enough for large numbers of nodes to be deployed economically.
- Small size – In most monitoring applications, sensing nodes should be unobtrusive and blend into the environment.
- Low power – Due to the large number of nodes comprising the network, it is not feasible to provide wired power or replace batteries on a regular basis. Nodes must be fully self-sufficient for multiple years, demanding extremely low levels of power dissipation in all electronics. The average power dissipation of the entire node must be significantly less than 1mW.

As in early Ham radio networks, WSNs also utilize multi-hop networks to communicate data efficiently to remote locations. Since the received power transmitted from an omnidirectional antenna diminishes with the square of the communication range, it can be shown that dividing the communication link into multiple smaller hops can reduce the transmitted power cost to a linear function, saving a significant amount of energy. As with Ham networks, cooperation and opportunism amongst sensor network nodes is critical for realizing an efficient network. Figure 2 compares a vintage Ham radio setup to a wireless sensor node used for tracking and social network experimentation of small songbirds.

Figure 2. Left: vintage Ham radio transmitter/receiver setup. Right: a wireless sensing node comprising a 900MHz transceiver, low power microcontroller, and non-volatile memory.

IV. Radio circuit design: past, present, and future

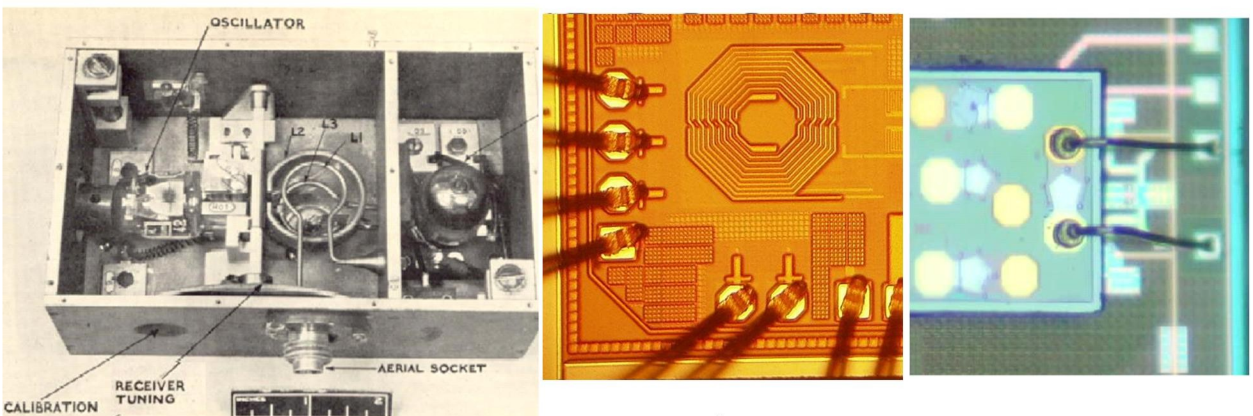
Reducing the size, cost, and power dissipation of wireless communication devices remains one of the great challenges for ubiquitous wireless sensing. Emerging applications in industry, science, and healthcare require small form-factor and infrequent battery replacement. Future deployments may even necessitate a completely thin-film transceiver powered through solar, thermoelectric, or wireless energy sources. Even with continuing technology scaling, the wireless communications link remains the most challenging aspect of many wireless sensor deployments. However, just as advances in solid-state devices dramatically changed the application space of radios in the 1950s, new devices are today promising another revolution in wireless technologies. Recent advances in micro-electromechanical systems (MEMS) components can help tackle both the size and power consumption limitations of the current generation of wireless transceivers. MEMS devices can provide highly selective filtering, saving power by relaxing the requirements on the active circuitry. They can also be used to generate a stable frequency reference, potentially replacing the ubiquitous-but-bulky quartz crystal resonator in some applications.

The radio requirements for WSN are unique. In terms of performance, the radio links are usually short (on the order of 20m or less) and data rates are application dependent. For a typical environmental monitoring application, the data rate requirements are on the order of kilobits per second. However, if the wireless link is designed to be capable of higher data rates, the system can save power by communicating with a lower duty cycle, while still achieving the same aggregate data throughput. Tradeoffs abound, and many doctoral theses have been written on various aspects of efficient WSN protocols, networking, hardware, security, locationing, and information processing.

The system-level requirements described above (low cost, small size and low power), are the driving factors that influence the design of a sensor node's radio. The most important constraint is clearly power. Reducing power consumption translates to direct savings in cost and size. With modern microelectronic technologies, the integrated circuit itself is tiny, while the battery or power generation hardware dominates the implementation volume. Often, the largest portion of system power consumption is devoted to the radio. For this reason, a radio design that offers a power reduction may have the largest impact on node power, size and cost.

If possible, all radio functionality should be integrated on a single chip to eliminate the need for large off-chip passive components. The choice of carrier frequency will also impact node size and cost, with higher carrier frequency being more desirable due to smaller passive sizes.

As a first step, we spent a great deal of time revisiting the advancements that radio transceivers have enjoyed in the past 80 years. Figure 3 shows an evolution of wireless devices.



a. b. c.

Figure 3. Evolution of RF design showing a.) Bulky vacuum-tube design using high quality passives, b.) Current RF design using on-chip passives, and c.) Our vision of future RF design using fast commodity transistors and high-quality passive devices

Radio designers of the 1920's had no chance of realizing a miniaturized, portable transceiver. Each vacuum tube alone was a few cm^3 and required several Watts to heat the cathode. Additionally, the tubes require a high supply voltage >100V, further complicating system integration. The devices were slow and expensive. In our opinion, two important factors allowed the creation of reliable radio links from these inferior devices: designer ingenuity and very good passive components. Indeed, early radio sets utilized high quality inductors, low-loss transformers, and hand-tuned airgap capacitors that allowed the realization of RF receivers using only two active devices.

Things have changed dramatically. Figure 3b shows an example of a modern radio frequency integrated circuit (RFIC) implementation. The active devices are extremely fast (f_T>100GHz), but the integrated passive components are very poor. Designers today regularly implement lossy (Q~10) on-chip inductors that consume a huge amount of chip area. In a 45nm CMOS process, a 300μm x 300μm inductor consumes the same amount of area as about one million logic transistors! The fact that chip architects are willing to trade that much digital functionality for one lossy inductor is a clear indication of the importance of tuning elements. Inductor Q directly affects oscillator phase noise and LNA noise-figure, for example.

Figure 3c shows our vision for future RF design, which we have been developing since our early demonstrations of high performance CMOS/MEMS co-designed oscillators [3]. Designers will continue to enjoy process technology scaling, but will also leverage emerging MEMS devices to allow a large reduction in power and size. This photograph shows a 2GHz bulk-acoustic wave resonator (Q~1000) assembled on a CMOS oscillator we co-designed with the resonator.

It is interesting to revisit classic vacuum tube circuit topologies and study them in the context of modern devices and standards. Since designers were constrained to a low tube count, early circuits were necessarily sparse but often quite complex in operation. A great example of this is the once-popular super-regenerative receiver invented by Armstrong in the 1920's [4]. This unique architecture achieves extremely high gain by periodically cycling an RF oscillator on/off. Since the receive antenna is coupled to the oscillator, even very low amplitude RF input signals will measurably reduce the start-up time of the oscillator. The oscillator start-up transient is then demodulated, which recovers the original baseband data.

Since both high gain and downconversion are achieved without a low noise amplifier, mixer, and local oscillator, the power dissipation of the receiver can be very low. A block diagram and chip photograph of our IC implementation of a super-regenerative receiver is shown in Figure 4.

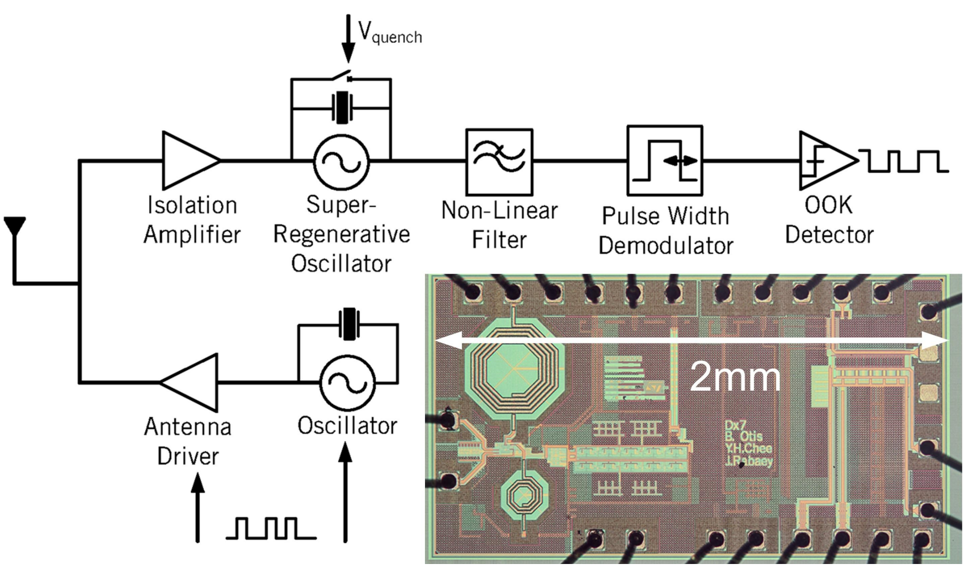


Figure 4. Integrated circuit implementation of a super-regenerative transceiver.

The radio chip is 1mm x 2mm, uses MEMS devices for frequency selectivity, and dissipates less than 1mW when receiving data at 10kbps [5].

V. Looking toward the future

The next few decades promise further exciting advances in wireless technology. Some of the innovation will be device-driven, where radio architects will leverage new device technology to realize ever smaller, faster, and cheaper systems. Just as the transition from vacuum tubes to solid-state devices enabled new radio architectures and better performance, emerging passive and active devices will spur further architectural innovation.

Possibly even more profound will be application-driven advances. One interesting example of this is the interplay that is currently underway between neuroscience research and integrated circuit research. The availability of small, low power electronics that were developed for Wireless Sensor Networking is helping neuroscientists record previously unobservable data (from freely moving, un-tethered animals, for example). In turn, this new knowledge of the brain is creating the need for even smaller, lower power, and more powerful electronics for brain-computer interfaces and neuroprosthetic devices. These systems will help restore motor function for the disabled, predict and suppress seizures, and facilitate sophisticated fundamental neuroscience research.

If the size of the system can be made small enough, further deployment possibilities emerge such as chronically implantable health monitors and even embedding active wireless biosensors on contact lenses. Like a Ham radio network on a very small scale, these tiny devices will form multi-hop networks and cooperate to move data efficiently across the body. Further advancements in wireless connectivity are key for turning these visions into reality, and designers will continue to look to the past for guidance and inspiration.

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Recent Developments in Antennas at the Communications Research Centre Canada

By Aldo Petosa and Michel Cuhaci

Abstract

This article surveys some of the latest antenna research and developments at the Communications Research Centre Canada. Various examples of dielectric resonator antennas, microstrip antennas, holographic antennas, reflectarrays, and Fresnel zone plate antennas are highlighted.

Introduction

The Research in Advanced Antenna Technology Laboratory (RAATLab) was established within the Communications Research Centre (CRC) in the early 1990s to investigate novel antenna concepts for both terrestrial wireless and satellite communication applications. The current team consists of twelve staff members and is complimented by numerous graduate students from various Canadian universities. Commercial and in-house software are used in the analysis and design process, while machine shop and board etching facilities at the CRC allow for in-house fabrication of all antenna prototypes. These antennas are then measured in the RAATLab test facilities, which include a far-field anechoic chamber (1-40 GHz), a planar near-field scanner (1-40 GHz), a compact range (2-100 GHz), and a quasi-optical test bench for material characterization (at 30 GHz). Various antenna technologies have been investigated over the years and this article presents a few examples in the representative areas where the RAATLAb has focused its attention.

Dielectric Resonator Antennas

Dielectric resonators have long been used in microwave circuits for oscillator and filter designs, but only in the early 1980s was it demonstrated that they could also be used as efficient microwave radiators [1]. Since then, these dielectric resonator antennas (DRAs) have been shown to be a viable alternative to microstrip technology, offering several advantages, the main one being design flexibility. RAATLab has been one of the pioneers in the characterization and development of DRA technology, especially in arraying DRA elements for high-gain applications. This article presents three of the more recent developments.

The first example is shown in Figure 1 and consists of a planar phased array of 320 multi-segment DRAs, designed at 8 GHz and containing a set of 16 four-bit digital phase shifters for electronic beam scanning ability in the azimuth plane [2, 3]. The multi-segment DRA is a wideband element specifically developed to be directly fed by a microstrip line, and thus facilitating the feed network for large arrays [4].

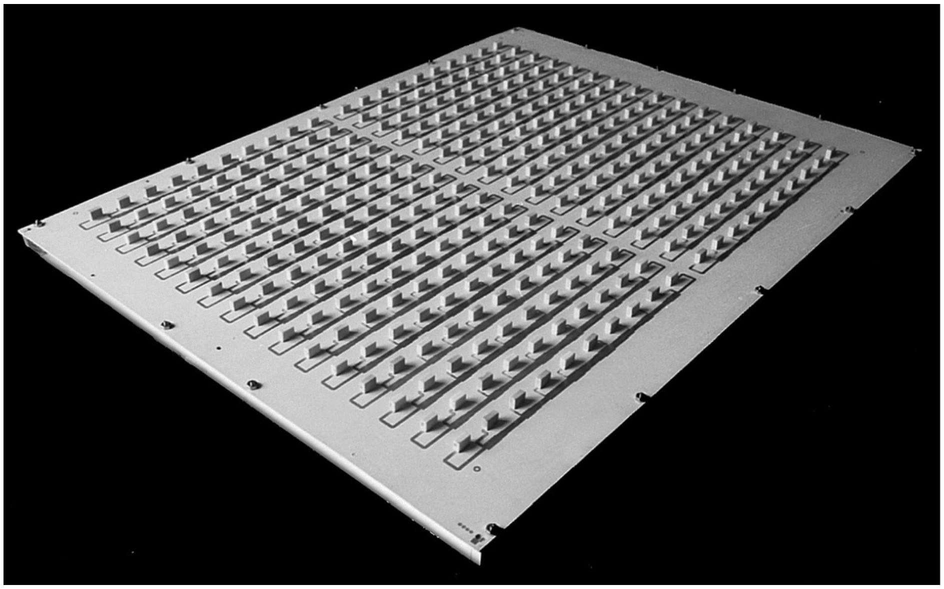

Figure 1. Phased array of multi-segment DRAs with electronic beam steering, designed at 8 GHz.

Figure 2 is an example of a hybrid antenna consisting of a monopole-DRA combination. This antenna produces monopole-like radiation patterns over extremely wide impedance bandwidths. Impedance bandwidth ratios of greater than 3:1 have been demonstrated, making this antenna is a good candidate for ultra wideband communications [5-7].

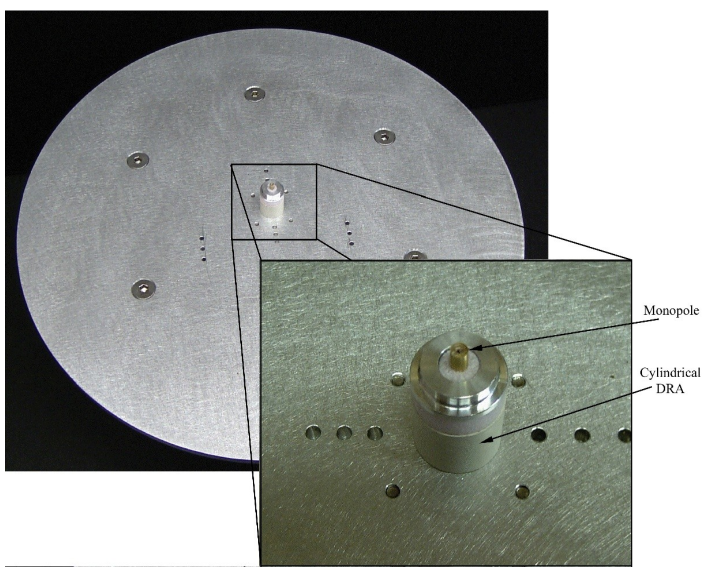

Figure 2. Monopole-DRA for ultra-wideband applications.

Figure 3 is an example of an array of 64 DRAs designed using a perforation technique [8]. Using perforations, the necessity for placing and bonding individual elements to form an array is removed, since the entire array is formed from a single substrate, which can simplify the fabrication process.

Figure 3. Array of perforated DRAs, designed at 24 GHz.

Comparisons of the perforated DRA array to a corresponding microstrip array at 24 GHz have shown improved bandwidth and gain performance [9]. An article published in 1998 contains several more examples of advances in DRA technology by the RAATLab, for the interested reader [10]. Further information on DRAs can be found in a recently published book [11].

Microstrip Antennas

Microstrip antenna technology was first introduced in the early 1970's and is now widespread in numerous commerical, medical, and military and applications, from cellular base stations to satellite-based radars. Microstrip technology offers several attractive advantages: it is easy to manufacture, relatively light-weight, potentially low cost and can be made conformal to numerous flat and curved surfaces. The emphasis at the RAATLab has been on low-cost, wideband microstrip antennas and arrays for terrestrial wireless and mobile satellite communication applications. Two examples are presented in this article. Figure 4 shows a 16-element array of microstrip stacked patches designed for a wideband terrestrial wireless base station (4.85-5.85 GHz).

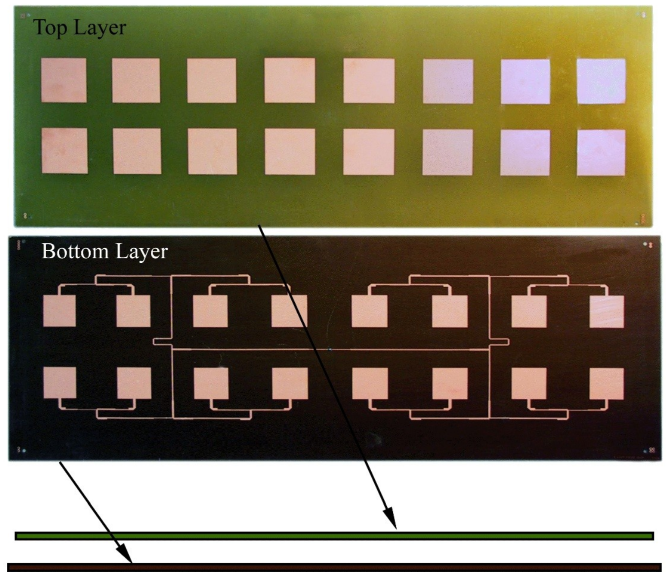

Figure 4. Stacked patch array for wideband terrestrial wireless applications (4.85-5.85 GHz).

The array is fabricated with low-cost Fiberglass boards using standard printed circuit board etching techniques and plastic spacers are used to maintain the required separation between boards.

A single-layer microstrip antenna is inherently narrow band (typically they have only a 1-2% impedance bandwidth), and the technique of vertically stacking two or more microstrip antennas significantly extends the operating bandwidth. A second example of this stacking technique is shown in Figure 5, which is a single antenna designed to radiate circular polarization and to be used in L-Band mobile satellite applications.

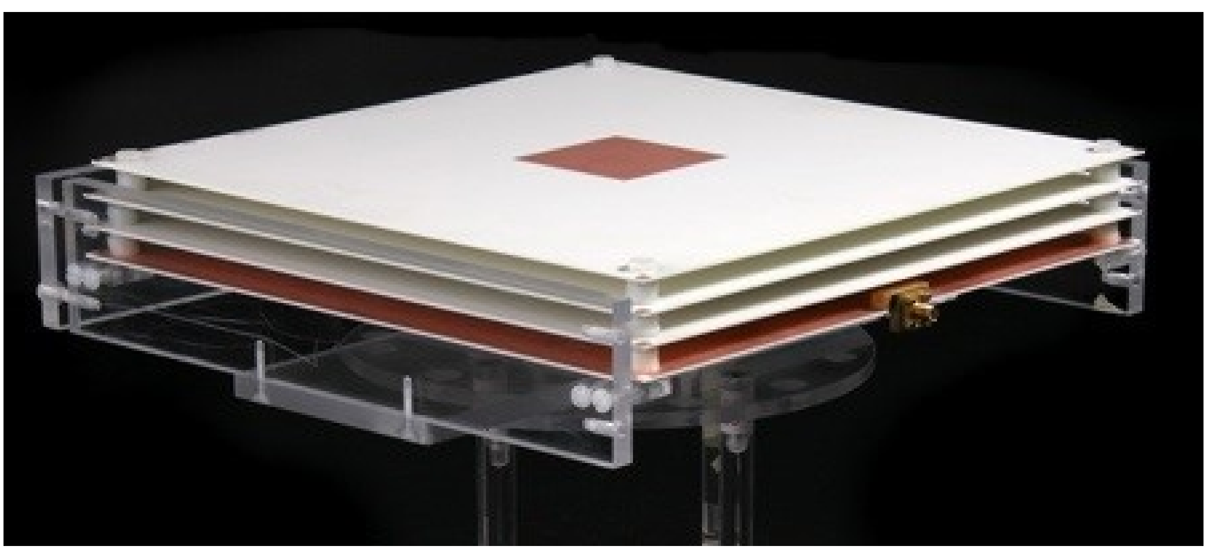

Figure 5. Stacked patch for wideband L-Band mobile satellite communications.

The four-layers of stacking were necessary to meet the requirements to simultaneously cover the L1 (1.575 GHz) and L2 (1.228 GHz) GPS frequency bands. Other examples of microstrip antenna designs can be found in [12], which includes arrays designed at 20 and 30 GHz for portable satellite communication terminals.

Reflectarrays

A class of flat reflector antennas, or reflectarrays, composed of microstrip technology was first developed in the late 1980s [13] Microstrip reflectarrays offer similar gain and efficiency performance to parabolic reflector antennas, while offering excellent cross-polarization performance. They can be fabricated using standard etching techniques and offer a lower profile than reflectors. Reflectarrays can perform numerous functions not possible by the dish reflector such as: distributed power combining; distributed phase shifting; and scanned beam operations. Unlike a phased array, a reflectarray does not require the use of a complex and lossy corporate feed network. Thus, it inherently has efficiency figures greater than that of a similarly sized phased array. In addition, the reflectarray is inexpensive to manufacture as compared to a phased array and perhaps to a parabolic dish.

Reflectarray technology has been investigated at the RAATLab since the mid 1990s, and few recent examples of reflectarray designs are presented in this article. Figure 6 shows a reflectarray designed in a Cassegrain configuration, for use as in a portable terminal for 20/30 GHz satellite communications.

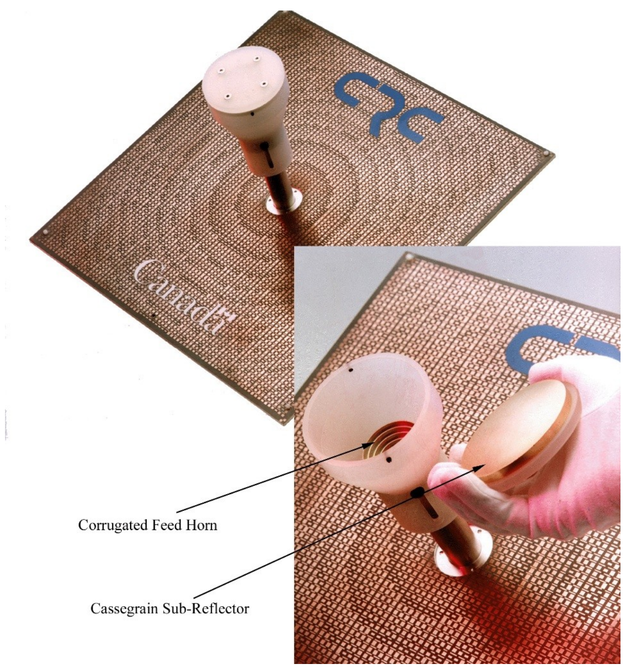

Figure 6. Dual-band (20/30 GHz) reflectarray with Cassegrain sub-reflector.

The conventional parabolic main reflector has been replaced by the flat reflectarray for a more convenient portable design. The reflectarray achieved significantly improved cross-polarization performance compared to the conventional reflector [14].

Unlike parabolic reflectors, reflectarrays can be designed with multiple focal points. Figure 7 is an example of a bi-focal reflectarray, which is designed to focus signals at different frequencies to separate feed horns.

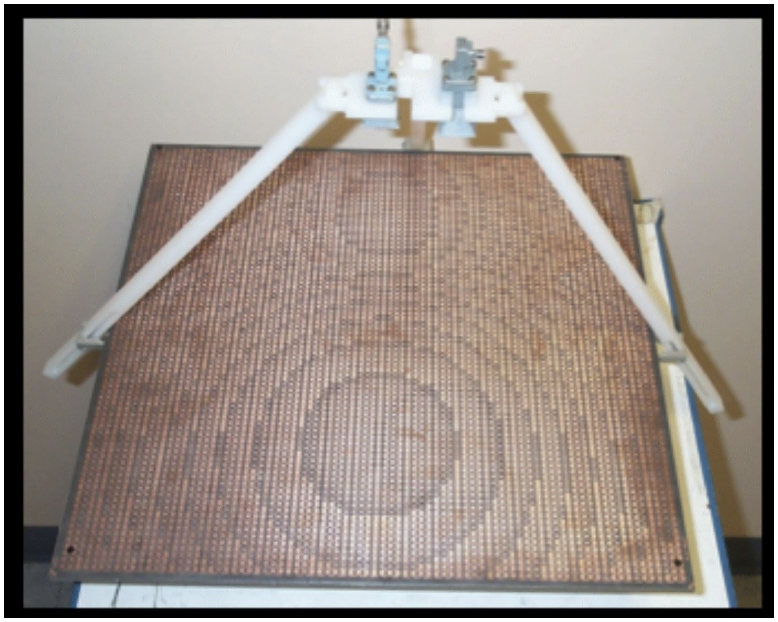

Figure 7. Dual-polarization bifocal reflectarray (20/30 GHz).

The advantages of this type of configuration include improved isolation between transmit and receive frequencies and a significant simplification of the waveguide feed components, since orthomode transducers are no longer required and the amount of isolation filtering is greatly reduced [15].

Finally, Figure 8 shows an example of a circularly polarized reflectarray.

Figure 8. Circularly polarization reflectarray (20 GHz).

Unlike the conventional reflector, this reflectarray uses a linearly polarized horn feed and it is the cross-shaped elements of the reflectarray which convert the linear polarization of the feed into circular polarization. This greatly simplifies for the feed design since complex waveguide polarizers can be eliminated, which also reduces the overall antenna costs. Articles summarizing the main contributions of the RAATLab to the reflectarray field are available for those who have further interest [16-18].

Holographic-Designed Antennas

Holographic principles are well known and have been applied to the optics field for many years for various applications such as microscopy, imaging, data storage, and interferometry. At microwave and millimeter-wave frequencies, holography has been adapted to such applications as synthetic aperture radar synthesis, imaging of hidden objects, and to the design of microwave and antennas [19-29]. The RAATLab has been applying holographic principles to the design of both low-profile high-gain antennas (using the theory of thin holograms) and to the design of microwave beam splitters or power combiners (using the theory of thick holograms) [30-35].

Two examples of low-profile antennas designed using holographic theory are shown in this article. Figure 9 is a printed antenna designed at 23 GHz to produce a high-gain broadside beam when fed by a small pyramidal horn in the plane of the antenna.

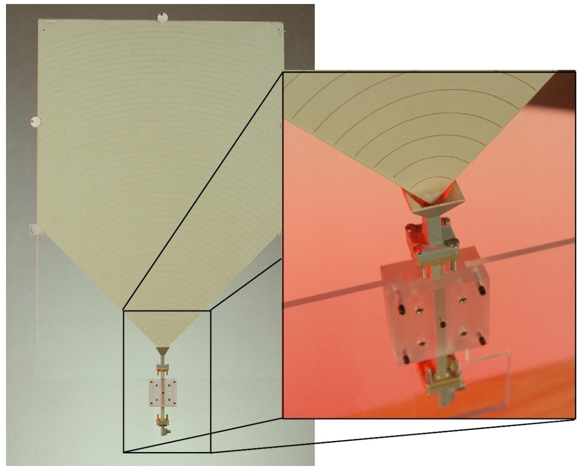

Figure 9. Horn-fed holographic-designed antenna.

Holographic theory was used to design the printed rings in such a way that the scattered fields from the horn feed result in a narrow pencil beam in the direction normal to the antenna surface. This type of antenna offers the low profile of a microstrip array without the associated feed network losses. A second version of this antenna is shown in Figure 10, where the waveguide feed is replaced with a printed dipole that is integrated onto the same substrate as the holographic ring pattern, resulting in a less complex and very low-profile design.

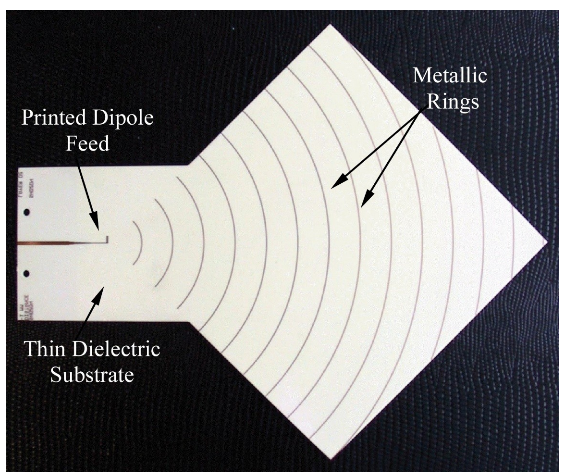

Figure 10. Integrated printed dipole feed and holographic-designed antenna.

Fresnel Zone Plate Antennas

A brief historical background on the use of Fresnel zone plate antennas at microwave frequencies is provided in [36]. The first mention of the use of Fresnel lenses designed at microwave frequencies appeared in US patents issued in the late 1930's and 1940's [37-39]. Since then, relatively little work was published until the late 1980's when satellite communications and direct broadcast satellite TV applications sparked renewed interest in Fresnel zone plates, and over the last two decades there has been a significant increase in research activity. Two books have also recently been published dealing primarily with Fresnel lenses at microwave frequencies [40-41].

Fresnel zone plate lenses offer certain advantages over conventional shaped lenses: they are thin and light weight and are easier to fabricate than conventional lenses. The research on Fresnel zone plate lenses at the RAATLAb has focused primarily on planar dielectric antennas operating at Ka-band. The majority of the prototype antennas fabricated have all been designed at 30 GHz. This research was initially intended to address applications for the then up-and-coming terrestrial wireless Ka-band LMCS (local-multipoint communications system) market, but most of the results of this research are applicable to other frequency bands and for many other applications requiring high-gain antennas [42]. The research and developments on Fresnel zone plate antennas are published in several articles [43-54]. Three examples are presented here.

Figure 11 is an example of a 30 GHz phase correcting Fresnel zone plate antenna, fabricated from Plexiglas and designed to with a radiation beam peak 23˚ away from boresight.

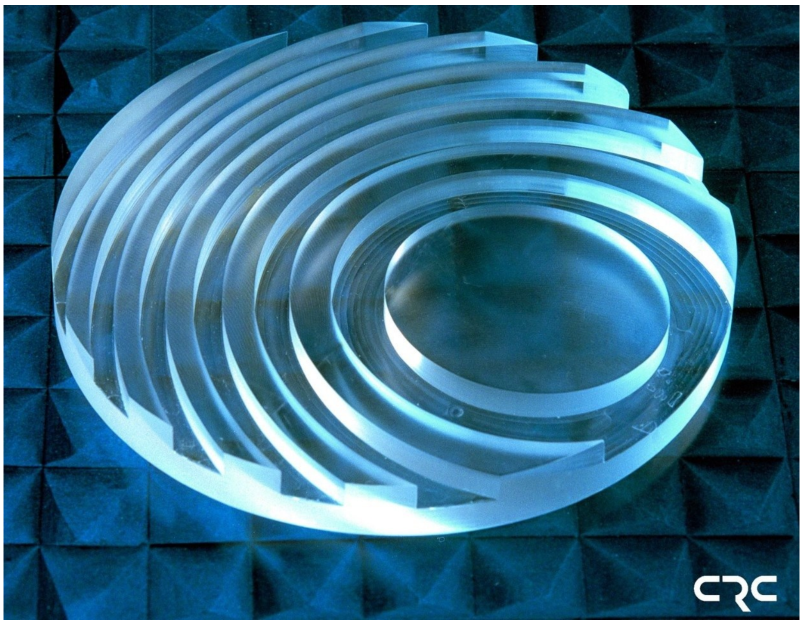

Figure 11. Phase correcting Fresnel zone plate antenna with offset beam, designed at 30 GHz.

The intended application would be for inter-building wireless communications where the two buildings might not necessarily be directly opposite each other and the offset beam design would allow the antennas to still be flush mounted on the walls or located inside offices behind windows.

A photograph of a high-directivity array of perforated dielectric Fresnel zone plate antennas is shown in Figure 12. The technique of perforating a single dielectric sheet with holes of different diameters was used to alter the intrinsic dielectric constant of the material.

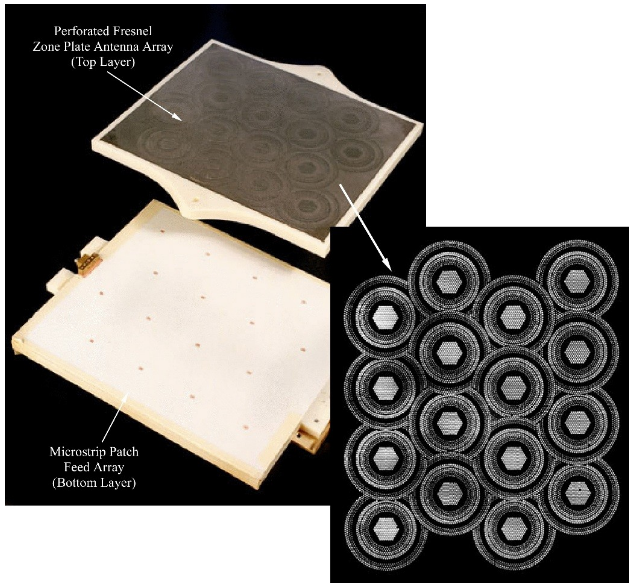

Figure 12. Array of perforated Fresnel zone plate antennas at 30 GHz.

These annular zones of different dielectric constants were used to design an array of 90˚ phase correcting Fresnel zone plate antennas [43,44,49]. The individual elements overlap in order to reduce the grating lobe levels which would otherwise have been unacceptably high. Each of the antennas is fed by a separate microstrip patch, located on a lower layer, as shown in Figure 12. This technique of combining an array of small-diameter Fresnel zone plate antennas, results in a significant reduction in the overall profile compared to a single large antenna whose diameter is equivalent to the total diameter of the array.

The third example is of a Fresnel zone plate antenna with beam scanning capability, shown in Figure 13. This antenna consists of a set of vertical narrow metallic shutters which can be individually opened or closed to either let through or block radiation.

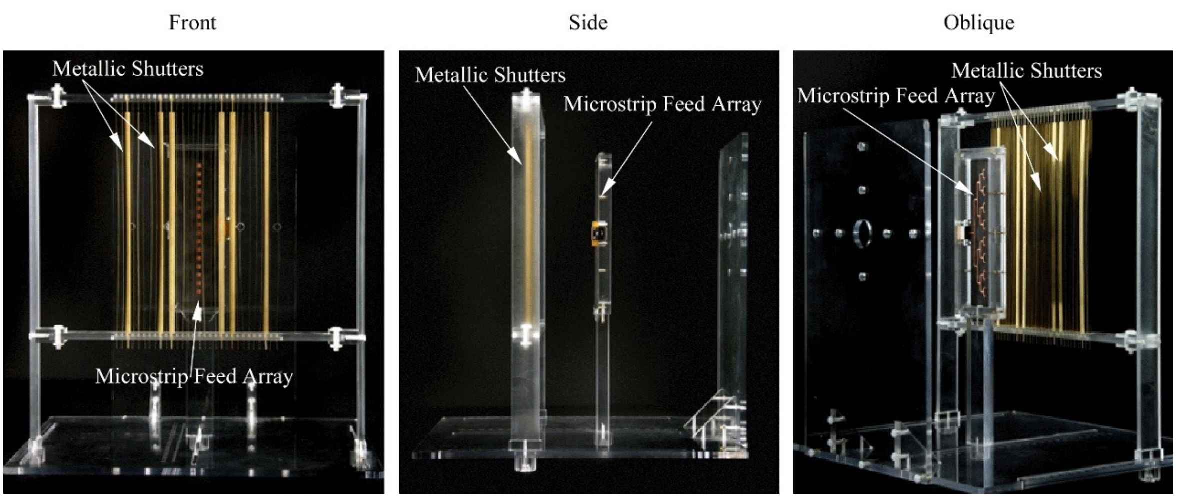

Figure 13. Fresnel zone plate shutter antenna with beam scanning capability.

By appropriately setting these shutters, the location of the beam peak can be scanned in azimuth (horizontal plane), operating, in principle, like a switched-beam array. Beam scanning of ±40˚ has been demonstrated with this antenna [54].

Summary

This article has presented an overview of the antenna technologies that are being investigated at the RAATLab. The scope of the activities has focused on improving performance, lowering the cost and complexity, or enhancing the capabilities of antennas designed between 1 and 30 GHz to address terrestrial wireless and satellite communications applications.

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Aldo Petosa received the B. Eng, M. Eng. and Ph.D. degrees in electrical engineering from Carleton University, Ottawa, Canada, in 1989, 1991, and 1995, respectively. From 1990 to 1994, he carried out research at CAL Corporation, Ottawa, on microstrip antennas for cellular and mobile satellite communication applications. In 1995, he joined the Communications Research Centre Canada, Ottawa, Canada, where he is presently the Project Leader for Antenna Design and Development in the Advanced Antenna Technology Lab. He is also an Adjunct Professor with the Department of Electronics at Carleton University.

Dr. Petosa has published over 150 journal and conference papers and is the author of the *Dielectric Resonator Antenna Handbook* (Norwood, MA, Artech House, 2007). His current research interests include: microstrip antennas, dielectric lenses, dielectric resonator antennas, and holographic antennas.

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Software Defined Radio - Signals You Can See
(and sound even better than on your old radio)

By Phil Harman, VK6APH, and Steve Ireland, VK6VZ

Those who read amateur radio journals and magazines closely over the last few years will have seen a large amount of references to software defined radios or 'SDRs'. If you are a traditionalist who likes their radios to fit onto the tabletop, have big knobs, meters and dials that glow, the idea of a radio made of software isn't going to be exactly appealing. However, it is in terms of old-fashioned radio values - such as sounding great and dealing well with weak signals in strong noise – that SDRs hold perhaps one of their two biggest advantages over conventional superheterodyne radios.

However, perhaps *the* biggest advantage is that SDR software lets you *see* radio signals – not just one at a time as you would hear them on a conventional radio, but all those that are present in a reasonable chunk of an amateur band. This is possible by means of highly-sensitive bandscopes which display signals down to the nano-volt level. Figure 1 nearby shows the view provided by the bandscope of Alex Shovkoplyas VE3NEA's free *Rocky* SDR software [1] of the 1.8MHz band on a personal computer screen, when coupled to SoftRock SDR receiver hardware [2].

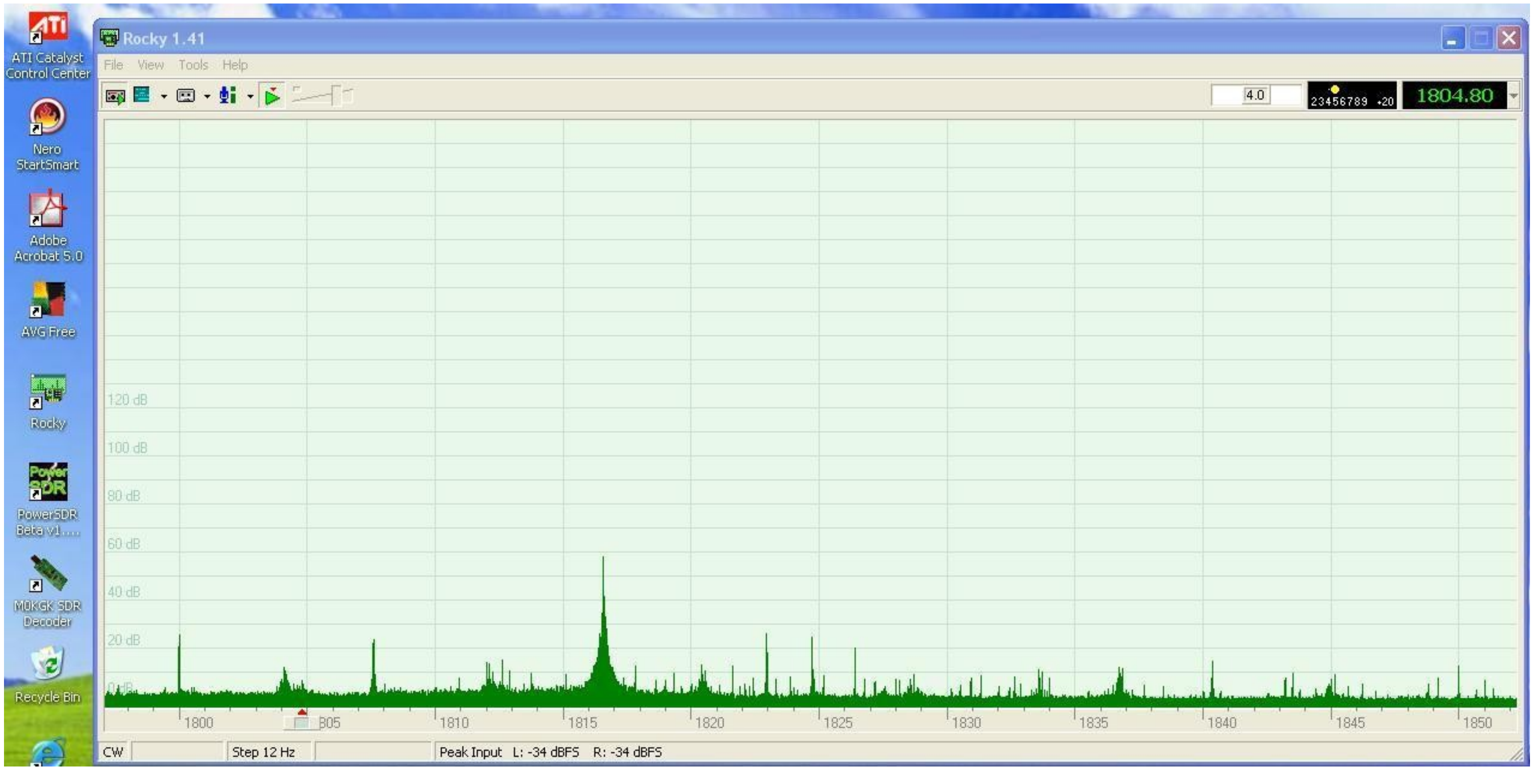

Figure 1 An SDR-view of the 1.8MHz CW band, using the band scope in VE3NEA's *Rocky* application software and a SoftRock v6 receiver, viewed on the screen of VK6VZ's Pentium IV personal computer. The signals you can see were recorded around local sunrise during the CQ 160 CW contest on 21 January 2006. The x axis of the band scope shows the frequency in kHz, whilst the y axis shows the amplitude of the signal in dB.

Not only are we talking about 'seeing' radio signals but this is done in 3D – signals can be seen in their amplitude, frequency and time dimensions. Very expensive conventional superheterodyne radios now can also do this, but arguably not as well as SDRs. Those who have seen the built-in bandscopes that are now standard on top-of-the line amateur radio transceivers costing several thousands of dollars will notice that, for example, *Rocky* offers a much bigger and more dynamic view of a piece of radio spectrum than the former.

Tuning for weak DX signals can be a pretty hit-and-miss affair, as Murphy's Law of DXing dictates that as soon as you are about to tune across that rare North Korean station that is calling CQ, he will cease calling. In contrast, with a SDR bandscope, rather than tuning your radio, with the right analogue-to-digital converter you can see all the stations in a 192kHz (or possibly larger) window and click your mouse (or similar) onto whichever station you desire to listen to. Often no tuning is often necessary to actually find a wanted station, as you can see such a large chunk of a typical amateur band.

In addition to a bandscope, which has a high resolution *in frequency*, most SDRs now offer a display which has a high resolution *in time*, known as a waterfall display (see Figure 2), owing to the way it 'flows' across the screen from left-to-right or top-to-bottom.

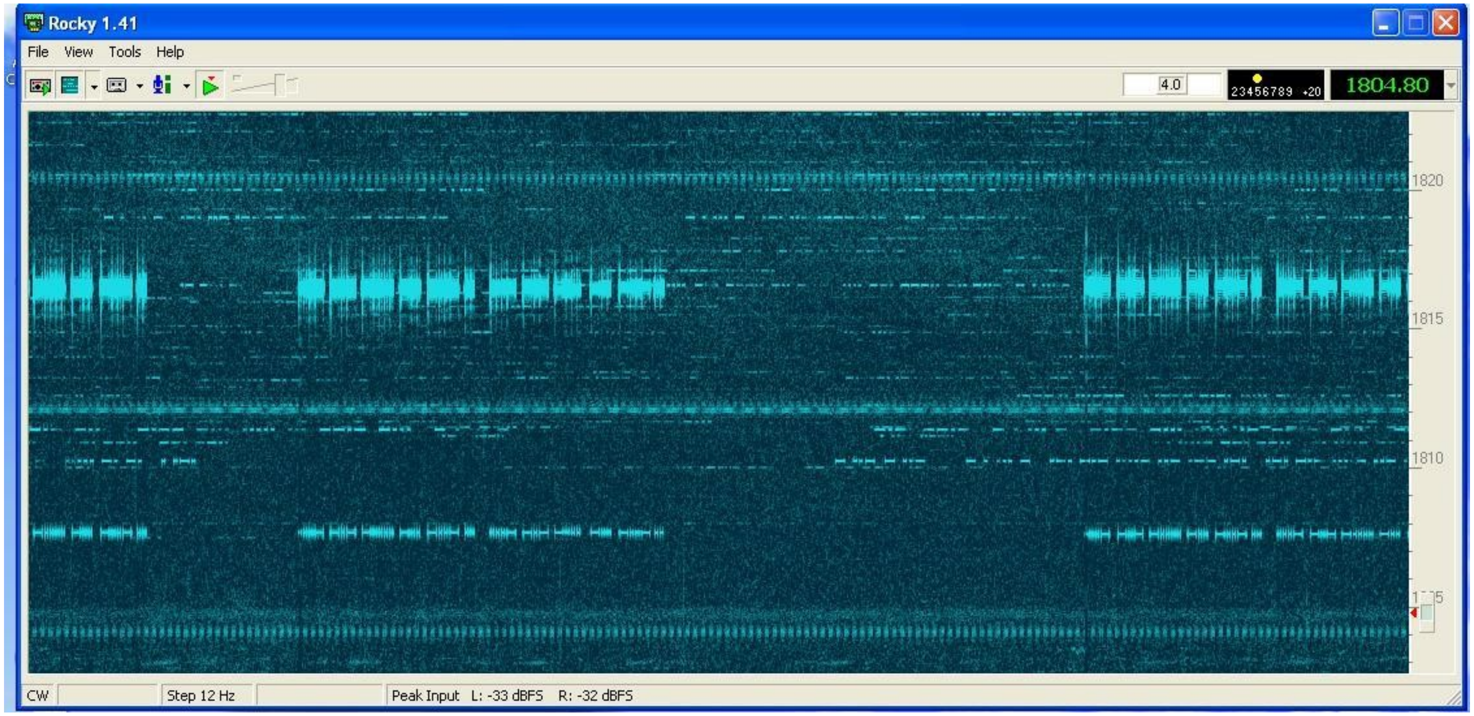

Figure 2   An SDR-view of the 1.8MHz CW band, using the waterfall display in VE3NEA's *Rocky* application software and a SoftRock v6 receiver, viewed on the screen of VK6VZ's Pentium IV personal computer. The signals you can see were recorded around local sunrise during the CQ 160 CW contest on 21 January 2006. The y axis of the band scope shows the frequency in kHz, whilst the x axis shows an image of CW signal in 'real time' (i.e. plotted against time). The images of the stronger signals received by the Softrock are much stronger/definite than those which are relatively weak. Using this waterfall display, signals that are barely audible will leave a distinct trace on the screen – in extreme cases, you can actually see a very weak signal when your ears cannot resolve it.

The waterfall display on *Rocky* even enables high-speed CW signals – up to about 40 words per minute - to be visually copied. Waterfall displays also show up flaws in the spectral purity of signals – in particular the key clicks generated by some modern transceivers. No more disputes as to how bad a friend's key clicks are – if you have *Rocky* or a similar program you can e-mail them a screen shot of their signal, captured from the waterfall display.

Over the last few years, some very significant developments have been made to SDRs, which has taken them out of the realm of the experimentally-minded and into the world of the hard-core radio operator – and these developments are the main subject of this article. However, before exploring them, let's look at a definition for a SDR that both the authors like – and have used several times in SDR-related articles.

> *"A software defined radio refers to wireless communication in which the transmitter modulation is generated or defined by a computer – and the receiver uses a computer to recover the signal intelligence. To select the desired modulation type, the proper programs must be run by the computer which controls the transmitter and receiver."*

It is in the recovery of the signal intelligence that the advantages of an SDR lie – in which an analogue signal is converted into a digital one, at which point essentially (almost) all the signal filtering and processing is carried out.

When VK6APH and VK6VZ first started writing about SDRs in the Radio Society of Great Britain's *RadCom* magazine three years ago, essentially all the SDR hardware designs intended for amateur radio were based on a quadrature switching detector (QSD) followed by an analogue-to-digital converter (ADC) which used a PC sound card or chip (see Figure 3). The highly popular SoftRock series of simple receiver and transceiver kits and the Flex-Radio SDR-1000 (and its successor) the Flex-5000 [3] uses this design.

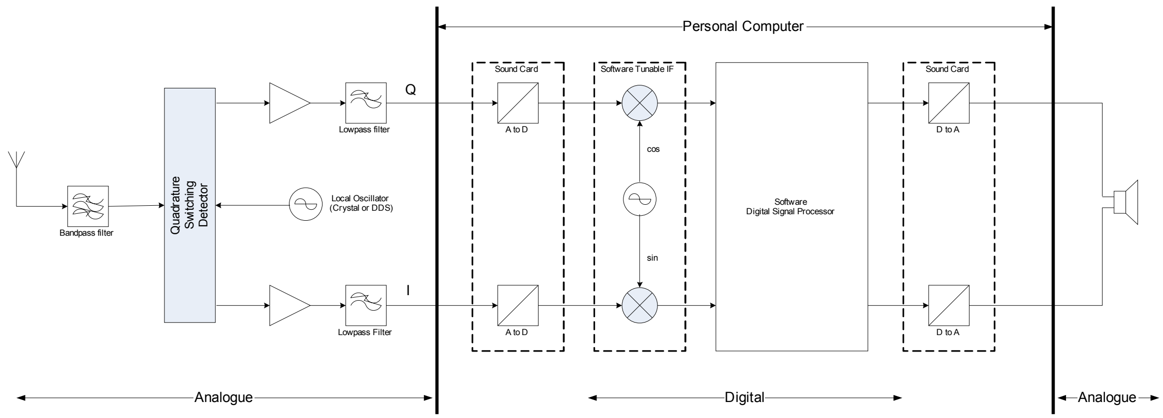

Figure 1 QSD based SDR

Figure 3   Block diagram of a QSB-based SDR receiver.

However, a second SDR hardware architecture of Digital Down Conversion (DDC)/Digital Up Conversion (DUC) is now emerging, where a high-speed ADC is connected directly to the receiver antenna – see Figure 4. Examples of receivers using the DDC technique are the Perseus [4], SDR-IQ [5], Hans Zahnd HB9CBU’s ADAT ADT-200A [6], the High Performance Software Defined Radio (HPSDR) Mercury [7] and the Quicksilver QS1-R [8].

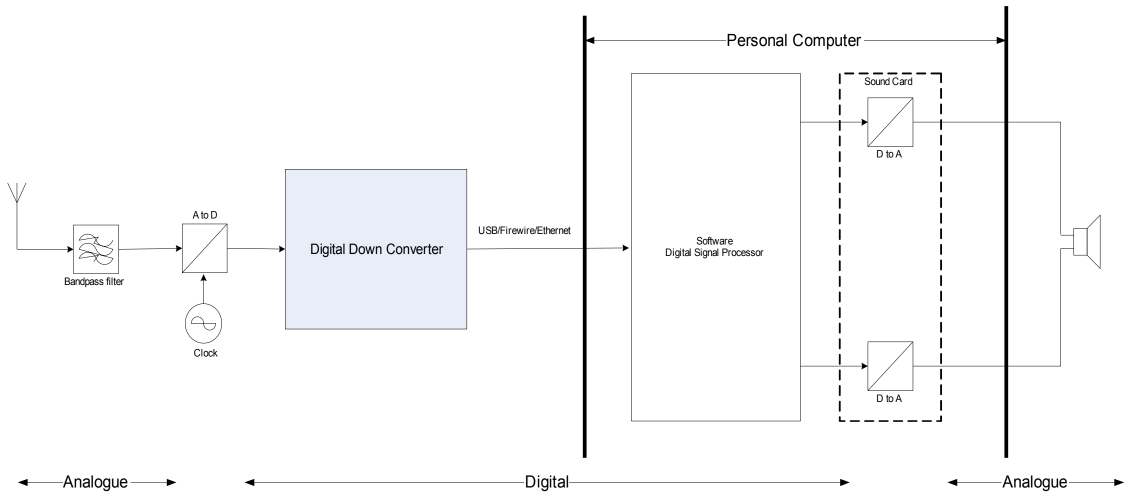

Figure 4 Block diagram of a DDC-based receiver.

VK6APH was converted to SDR from analogue radios through the purchase of an early version of the Flex-Radio SDR-1000, while both VK6APH and VK6VZ have been greatly enthusiastic about the SoftRock receiver kits. VK6VZ has used various Softrock receiver versions extensively on 1.8MHz and as the basis for an out-board bandscope for an FT-1000 transceiver and, latterly, an Elecraft K3. However, time has moved on and, right now, both us are primarily interested in the use of DDC hardware-based receivers and companion DUC transmitters, configured as a transceiver.

The reason for this ‘sea change’ is that direct sampling ADCs, such as the Linear Technologies LT2208, are now available that provide sufficient bits-per-sample so as to give blocking dynamic ranges over 100dB – comparable to, or better than, some top-of-the-range conventional HF transceivers. As an illustration of the high performance achievable, see Table 1. The prototype receiver is shown in Figure 5. This figure shows the final ‘alpha’ version of the open-source HPSDR Mercury DDC receiver, in which VK6APH has been involved in the design and the boards are now being produced by the not-for-profit Tucson Amateur Packet Radio (TAPR) organization [9]. As you can see from Table 1 below, Mercury has a BDR of 119dB, which is basically independent of frequency spacing.

Table 1 HPSDR Mercury DDC receiver performance figures

ADC overload	-12dBm (preamp on), +8dBm (preamp off)
MDS (500Hz) all amateur bands (1.8MHz to 50MHz)	-138dBm (preamp on), -118dBm (preamp off)
off)	
MDS (500Hz) on 50MHz via HPSDR Alexaires preamp	-146dBm
IP3 equivalent	+33dBm (preamp on), >50dBm (preamp off). Note the IP3 is independent of tone spacing.
Blocking Dynamic Range	119dB. Blocking Dynamic Range was measured at 100kHz and 5 kHz for 1dB gain compression with similar results.
122.88MHz clock phase noise	-149dBc/Hz at 1kHz spacing.

NOTE: The BDR is set by the overload point of the ADC rather than being phase-noise limited.

In the time that SDRs have moved towards DDC/DUC hardware architectures, the world of analogue transceivers has also moved on, with superb performance (assisted by digital signal processing and filtering) offered by radios such as the Ten Tec Orion, Icom IC-7800, Yaesu FT-2000 and, latterly, from the Elecraft K3. The Elecraft K3 currently tops Rob Sherwood NC0B's famous Receiver Test Data table (see http://www.sherweng.com/table.html) with a wide-spaced BDR of 140dB at 100kHz, but this falls to 101dB at 2kHz.

In contrast, although the HPSDR Mercury's BDR is about 21dB worse at 100kHz-wide signal spacing than the K3, the Mercury appears to be about 18dB better than the Elecraft K3 at a 2kHz spacing – which is obviously important if there is a very strong interfering signal near to the one you are listening to. On the other hand, if you have a very strong signal about 100kHz away from the signal you are listening to, then the K3 should cope with this better.

However, in general terms, the BDR of the new breed of analogue radios is similar to that achieved in DDC SDR hardware and the former also offer bandscope facilities and easily-updatable firmware – two of the major advantages that SDRs have had almost to themselves in the past. The analogue radios also offer a very familiar user interface – knobs and buttons, rather than a mouse and a keyboard. So why would users actually want to use a true DDC/DUC SDR, even given its superior bandscope facilities, rather than an up-to-the-minute analogue superheterodyne-type radio with a really good DSP back-end?

The answer is very simple and comes down to one of the most crucial features of any radio receiver – *because signals on a DDC SDR sound clearer and better*. There is also another reason – for those of us that use computers every day, keyboards, mouses, windows and pull-down menus are now even more familiar and intuitive to use than knobs and buttons.

Owing to the signal processing and selectivity of SDRs being provided digitally by a computer rather than crystal filters, you can provide continuously variable selectivity down to a few tens of Hz – properly designed digital filters don't ring like crystal ones. Similarly, noise filtering/blanking on SDRs are better than anything VK6VZ or VK6APH have experienced on analogue radios - or using the digital signal processors that are available as add-ons or fitted to the current generation of HF transceivers.

Both VK6VZ and VK6APH have owned Yaesu FT-1000MPs – a fine transceiver with a relatively good built-in DSP noise reduction and filtering – but the DSP processing available in today's SDR software such as the free and open source *PowerSDR™* [10], written mainly by Bob McGwier N4HY and Frank Brickle AB2KT, and VE3NEA's free *Rocky* is vastly superior to that available in the FT-1000MP in our opinion.

One of the best things about SDR digital filtering is that it is usually continuously variable. For example, by simply clicking with your mouse onto the filter bandwidth screen icon on the *Rocky* spectrum display and dragging it, you can vary the bandwidth of selected filter – in the case of the CW filter from 600Hz down to 20Hz.

This means the operator can actually optimise the bandwidth of the received signal, in terms of signal-to-noise ratio. As VE3NEA, the author of *Rocky*, notes on his website, for CW signals in white noise this is 1.5 times the words per minute of the CW signal you are listening to – which for a 30 wpm signal is about 45Hz. VK6VZ uses this control on *Rocky* (which he uses in conjunction with SoftRock receiver hardware) by simply dragging the filter bandwidth narrow/wider until the weak CW DX signal he is listening to sounds most readable, which on a noisy evening on 160m often seems to be around 150Hz.

Sounds better

Back in October 2008, three radio amateurs got together in the VK6APH workshop – VK6APH himself, VK6VZ and our friend Fred, VK6GE (an Elecraft K2 owner, very long-time radio amateur and retired professional radio operator). On the bench were an Elecraft K3 and a HPSDR Mercury (using the open-source *PowerSDR™* software), both connected to VK6APH's Moxon Claw HF beam antenna via an antenna switch. In this case, the bandwidth of the HPSDR was not being varied continuously to improve signal-to-noise ratio, but 'standard' filter bandwidths (i.e. 2.4kHz and 500Hz) were being selected in *PowerSDR™* that matched the filters that were available in the K3.

For 45 minutes or so, we sought-out weak SSB and CW signals on a noisy 14MHz band and switched the antenna from one radio to another – just simple A/B testing. The verdict was unanimous – whilst the Elecraft K3 was probably the best-sounding (and performing) analogue radio the three of us had ever used, the HPSDR sounded 'better' and weak signals were considerably easier to understand.

Why was this so? The performance figures for the two radios are very similar! The answer is actually very simple and relates to the crystal filtering ('roofing filters' in the case of the K3) that the K3 – and most analogue communications radios – use.

All the radio frequencies that amateurs use are covered in noise – some of which is atmospheric, some of which is ionospheric and the rest is man/machine made. When noise pulses/spikes pass through a crystal filter, the phase response of the filter changes, depending on the noise frequency. However, when noise pulses/spikes pass through an ADC with a linear response, the phase response stays the same, because the ADC treats them in a linear manner.

That's the theoretical explanation – what happens in practice is that on a DDC SDR any noise actually sounds mellow and easy-on-the-ear, in a manner that has to be heard to be believed. In the case of an analogue radio, even one stage of crystal filtering (such as is used on the K3) is enough to cause a phase response to noise that eventually irritates/tires the user and makes them want to switch the radio off.

In the case of the noise response of the DDC SDR Mercury, it was balm to the ears of VK6APH, VK6VZ and VK6GE. VK6VZ now tunes around 7MHz during the evenings listening to weak DX on his DDC SDR receiver hardware (based on the HPSDR Mercury and its companion Ozy communication board) and laughs cruelly to himself when other radio amateurs complain how noisy the band is…

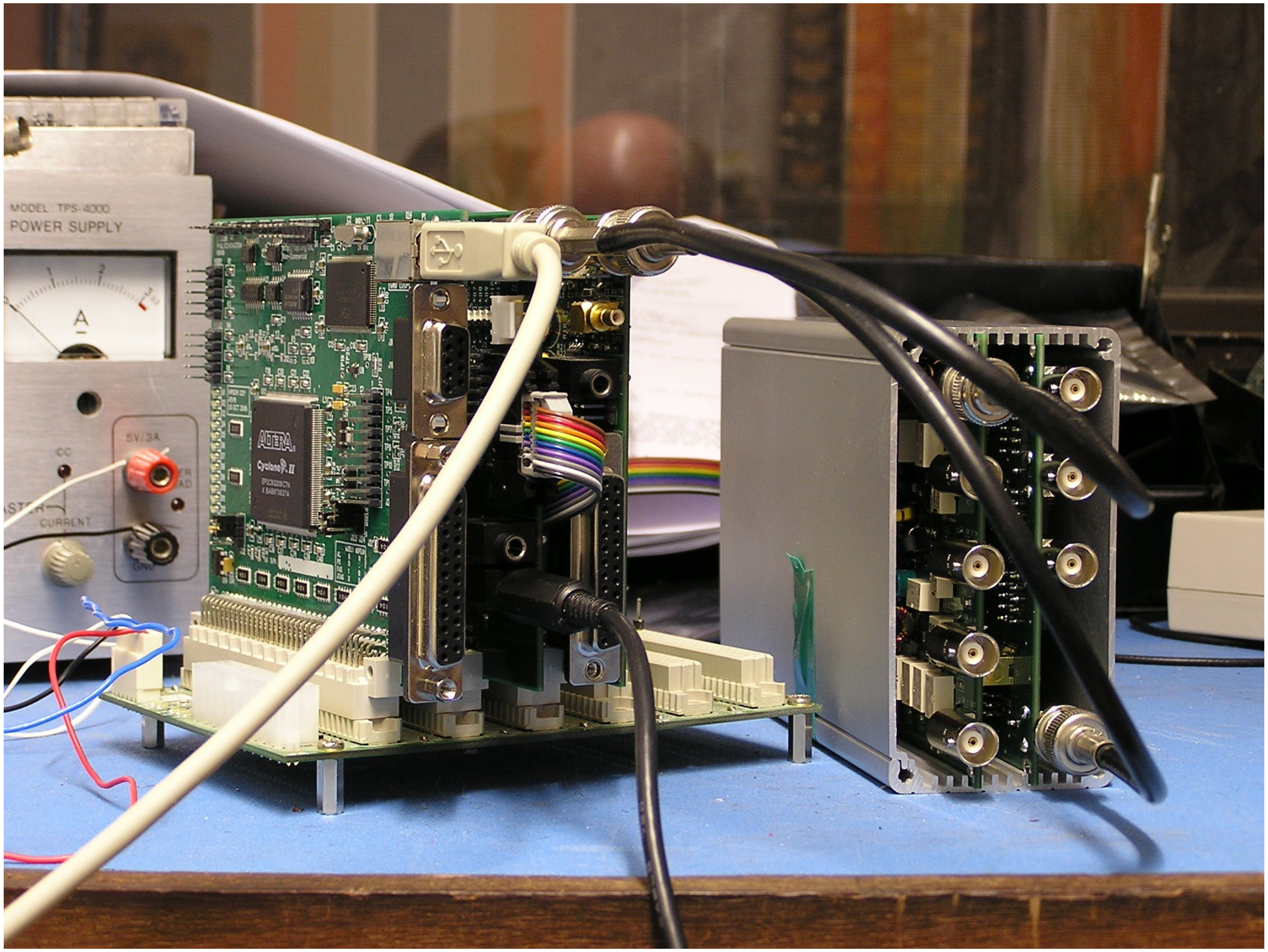

Figure 5   Photo of VK6APH's prototype transceiver. On the left (from left to right) you can see the Ozy, Mercury and Pentelope boards. On the right are prototype ALEX receiver bandpass filter and transmitter low pass filter, boards mounted in case.

VK6APH has been using prototype HPSDR transceiver hardware for over a year now and VK6VZ has moved onto converting his DDC receiver hardware into DDC/DUC transceiver hardware similar to that used by VK6APH, with the addition of the HPSDR Penelope DUC exciter/transmitter board and a 100W PA from a surplus commercial HF transmitter.

As we write in January 2008, a growing number of radio amateurs around the world are taking to the airwaves with 'home-made' transceivers, based on the Mercury, Penelope and the Ozy boards which are being sold by the TAPR.

VK6APH and VK6VZ hope to publish constructional details of a HPSDR-based transceiver during 2009 in the RSGB's *RadCom* magazine. A picture of an experimental version of the transceiver, in its prototype case, designed and built by our friend Bob Crowe, VK6CG is shown in Figure 6. Constructional details of the VK6CG case for the HPSDR are also planned to be published. The next major SDR project by VK6APH and VK6VZ is to write a handbook on the subject.

Figure 6   VK6VZ's partly-built HPSDR transceiver in VK6CG's prototype case.

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[1] The latest version of VE3NEA's *Rocky* software can be downloaded free from http://www.dxatlas.com/rocky
[2] The SoftRock series of receiver and transceiver kits are collated and sold by Tony Parks, KB9YIG. E-mail Tony directly at raparks@ctcisp.com to check kit availability. You can order from him by post or over the Internet/email by using PayPal. Please note that Tony sells the kits for fun and any profits go to fund the development of new SoftRock kits.
[3] www.flex-radio.com
[4] Perseus - http://www.microtelecom.it/perseus/
[5] SDR-IQ - http://www.rfspace.com/SDR-IQ.html
[6] ADAT ADT-200a - http://www.adat.ch/index_e.html
[7] HPSDR Mercury and other HPSDR boards – www.hpsdr.org
[8] QS1-R - www.philcovington.com/QuickSilver/
[9] TAPR – see www.tapr.org for current availability of the various HPSDR boards
[10] The *PowerSDR™* software can be downloaded free at: http://flex-radio.com/download_files/index.html

An ABC of SDR Abbreviations

ADC	Analogue-to-digital converter
BDR	Blocking dynamic range
DDC	Digital down conversion. The name given for receiver technology in which a received signal is converted from analogue to digital at the antenna socket.
DSP	Digital signal processing
DUC	Digital up conversion. The name given for transmitter technology in which a signal is converted from analog to digital before it reaches the antenna socket.
HPSDR	High Performance Software Defined Radio. See: www.hpsdr.org
I	In-phase signal
Q	Quadrature signal
QSD	Quadrature switching detector

About the Authors

Phil Harman, VK6APH, has a BSc (Hons1) in Electrical and Electronic Engineering from the University of Bath (UK). He was first licensed as G3WXO at the age of 16 and became VK6APH in 1980 upon migrating to Australia. First trained as an RF Engineer, Phil has also held a number of IT management positions. Over the last 12 years Phil has developed advanced video processing technologies for stereoscopic imaging and the conversion of 2D images to 3D and holds 23 patents relating to digital image processing. His main interests are receiver development, software defined radios, HEO satellites and HF DXing.

Steve Ireland, VK6VZ, has been a scientific journalist for over 25 years and is a former editor of the UK's *Ham Radio Today* magazine. He was first licensed as G3ZZD at the age of 16 and migrated to Australia in 1989, where he became VK6VZ. He has a BA (Hons2) degree in English from the University of North London and also holds an Ordinary National Certificate in Engineering. His main interests are low-band DXing (over 220 countries confirmed on 160 metres), software defined radio and writing technical articles about amateur radio (and coaching his daughter's soccer team).

Some of this material previously appeared in a different format in the authors' former SDR column in the Radio Society of Great Britain's *RadCom* magazine.

Postscript

The ARRL *QEX* magazine has begun a new column dedicated to software defined radio and digital signal processing, beginning in the January/February 2009 issue. If you have an interest in SDR, follow along to learn, or contribute to Ray Mack, W5IFS's column, who himself is learning as he writes this column. QEX is (or is intended to be) a forum for communications experimenters.

The Quest For Higher Frequency

Brian Justin, WA1ZMS

The author is one of only two or three radio amateurs worldwide who have had actual two-way radio contacts using the non-optical radio spectrum above 300 GHz. He is likely the only radio amateur thus far to achieve communications distances greater than a kilometer. The motivations, implementations and technical challenges of amateur operations in the millimeter wave spectrum are reviewed.

Background

The hobby of amateur radio gained its first dedicated and segmented millimeter-wave radio spectrum allocation as a result of the 1979 World Administrative Radio Conference (WARC-79) [1]. The new amateur allocations created included radio bands at: 47, 75.5, 120, 142, 241 GHz, and all above 300 GHz. Prior to WARC-79, all spectrum above 30 GHz was considered a single amateur radio band and no actual radio license was required for any operation in that region of spectrum, at least as far as operation in the United States was concerned. A result of WARC-79 was to "*raise the bar*" by replacing "all above 30 GHz" with the words "all above 300 GHz." At that point, the hobby entered a new and more challenging technical era.

With this change in allocations, it was then clear that an unofficial challenge had been issued to the amateur community to see who as a radio hobbyist could effectively design and construct radio hardware to establish radio communications in the upper regions of the radio spectrum.

It is interesting to note that, historically, radio amateurs as a whole have routinely been assigned by radio regulating bodies the "*useless short wavelengths*" that are often considered to be of little commercial interest. Although radio science has progressed greatly in the past 100 years, amateurs are still fortunate to have often unfettered access to the true "shortwaves," and it is in these regions with political and financial pressures removed, that the radio amateur is able to explore physical and natural laws of radio science as they apply to the nether region of radio spectrum.

Motivation

Although the author has been employed for over 20 years in the commercial RF industry as a circuit designer his personal interest in radio dates as far back as early childhood while chasing AM broadcast-band DX. In middle school the attraction of amateur radio lead him to the cementing a life-long love with radio. The freedom to design, construct and operate one's own radio equipment is unique to the hobby. Along with this freedom comes the ability to explore avenues of radio that otherwise might not be easily done in a commercial or military design environment where schedule, cost and reliability are key issues. In the amateur radio one is free to experiment with designs and radio operating techniques that may not result in positive success but yet the only costs incurred for failure are one's own personal time and effort.

It's with that framework in mind that the author in 1996 decided to embark on a project to explore the amateur radio band at 47 GHz. At the time, the goal was simple Gunn oscillator based radios that would allow for extra-earned points in VHF/UHF radio contests. After achieving that, it appeared only natural to take that success to the next higher amateur band, that being 75 GHz. With each ultimate successful radio contact over greater and greater distances grew the desire to continue to pursue yet higher and higher operating frequency.

As still the case today as it was in the 1990s, there is no complete of-the-shelf supplier of amateur radio equipment for the mm-wave, much less the sub-mm-wave bands. All equipment must be hand-built from scrounged and surplus commercial sources as well as home constructed assemblies such as mixers, phase locked loops, Gunn sources and antennas.

An additional challenge to the effort is the need to construct not only one transmitter and receiver, but the need exists to construct *two* transmitters and *two* receivers so there will be another station to communicate with. This necessitates the need for at least two of each sub-assembly to either be built or secured for a given project on a given amateur radio band. Needless to say, much personal effort is often required.

Equipment design challenges

The most difficult technical challenges facing any sub-millimeter wave radio system are the fabrication of the RF components and the need to address the inherent water vapor losses if non space-based communications are expected.

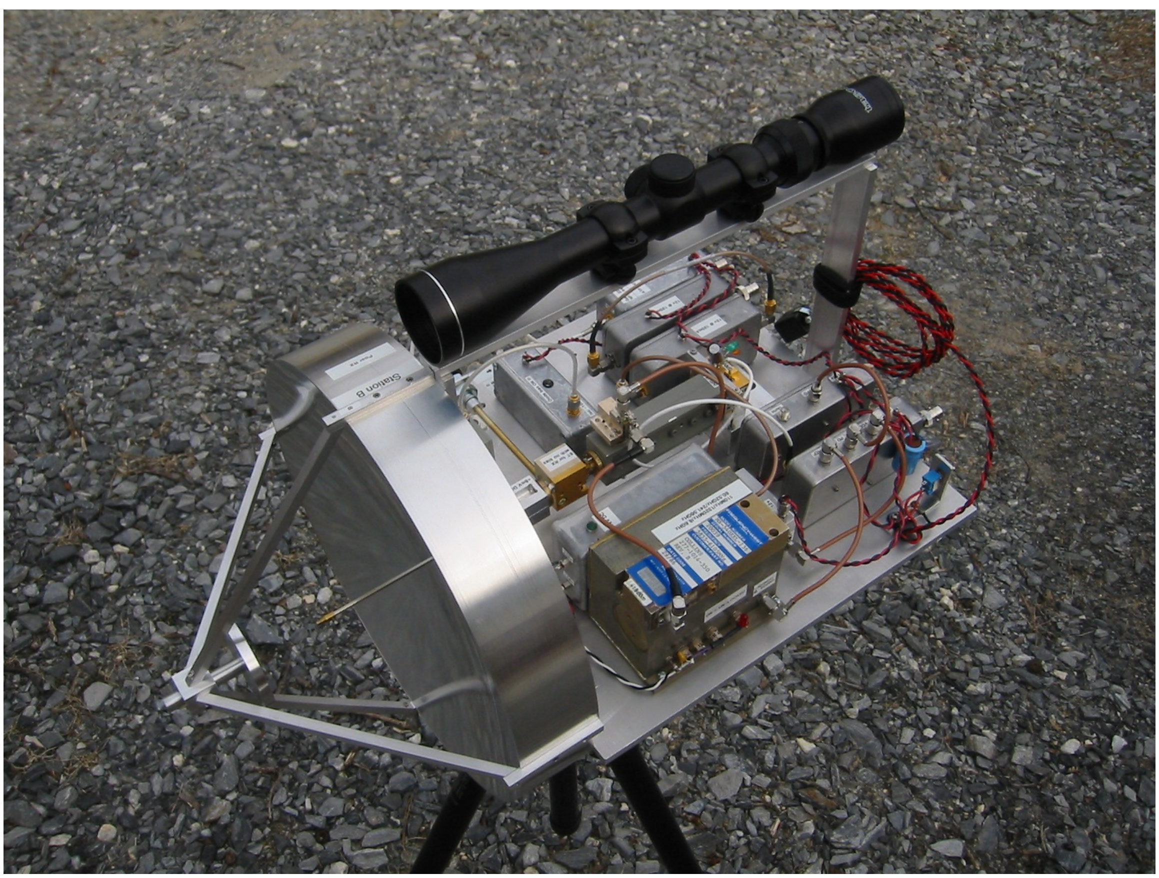
The first technical challenge has been overcome to a reasonable extent through the research and development work at the University of Virginia [2, 3] and its partner commercial company Virginia Diodes. [4] During the author's millimeter wave amateur radio projects in the late 1990's a strong partnership was created with several of the faculty and graduate students of the University of Virginia and their excellent R&D efforts in the area of planar Schottky diode mixers and multipliers. One of the key components of the author's collaborative work with the Virginia Diodes was a unique anti-parallel diode multiplier/mixer fabricated in a split-block assembly. [5] The anti-parallel diode pair is used in self-bias operation to act as an 80/240 GHz power tripler. Output power at 240 GHz is 1mW. The diode pair is further operated with active DC bias and requisite adjustments of LO drive power to place the diode pair in a single-ended harmonic mixer mode. It is this later mode of operation that is used to exploit higher order harmonics at multiples of the applied LO drive. In this specific case operation at 322 GHz and 403 GHz are both possible. Adjustment of DC bias and LO RF drive are used to optimize a given harmonic. Transmitted RF power out of the harmonic mixer is around 100uW for 322 GHz and around 10uW for 403 GHz. The mixer noise figures are estimated to be around 40 dB and 50 dB, respectively. In all cases, the mixer/multiplier is driven by a 40mW 80 GHz phase-locked Gunn source.

Since the TX carrier and RX LO carrier are in the sub-millimeter wave region, close-in phase noise of those carriers limit attempts to use very narrow receive demodulation bandwidths to improve received signal to noise ratio. Careful attention must be made to the selection of a primary frequency reference. In the case of phase-locking, the Gunn source, an ultra-low noise OCXO reference oscillator made by Wenzel Inc. was used for each station.

With such low transmitted RF power levels and high conversion loss receivers, simple CW (Morse Code or OOK) is used as the modulation type owing to its good performance with weak signal levels. PC-based FFT signal processing software is also used to help aid the radio operator in the direct copy of the CW signal at times when copy by ear was not possible.

Both radio set-ups are physically portable in design. This allows for easy transportation between hilltop locations as successful radio contact distances are increased over time. The portable nature requires that compact parabolic dish antennas be the antenna of choice and for each station a custom 30-cm-diameter parabola was machined through the assistance of a local trade-school instructor. A rifle scope is also used on each station to aid in pointing since the beam width of each antenna is less than 0.5 degree in both azimuth and elevation angle.

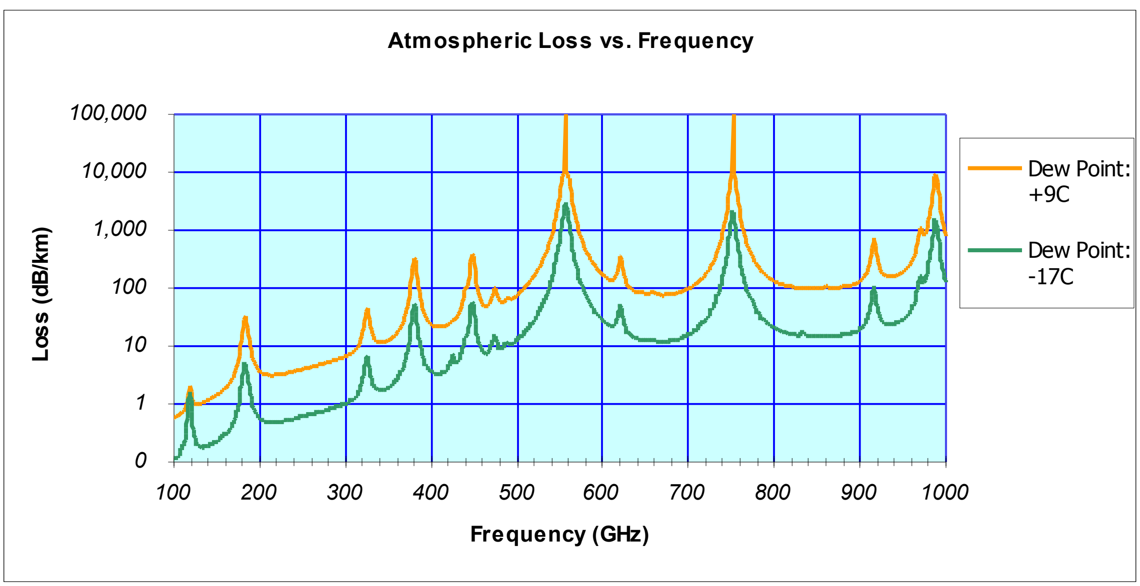
Figure 1 – Example of 241/322/403GHz portable Amateur Radio station



Atmospheric challenge
The next most difficult operational challenge is to understand and address the weather or atmospheric limitations that are placed on all terrestrial millimeter and sub-millimeter radio systems. Propagation losses from both oxygen and water vapor must be understood in order to extend radio communication distances. Since the radio amateur is often looking for anomalous modes of radio propagation to enhance communication distances, operation on millimeter-wave and sub-millimeter wave bands is almost exclusively limited to only days of lowest dew points when minimum water vapor exists in the atmosphere. The author has found that the Liebe atmospheric model [6] was indispensable for an intuitive understanding of atmospheric losses and for predicting when and where the best propagation conditions will take place based on local weather forecasts and atmospheric soundings data. Based on several years of practical, real-world use of the amateur millimeter-wave bands the author can confirm the accuracy of the Liebe ATM if even from semi-empirical perspective.

To provide some insight into the difficulty with millimeter-wave and sub-millimeter-wave propagation, refer to Figure 2.

Figure 2 – Graph Based on *Liebe* ATM showing atmospheric loss in dB/km as a function of frequency. Top curve represents warm weather with a dew point of 9° C, while lower curve represents cold weather with a dew point of -17°C. Both curves are for sea level height with a pressure of 1013 mb.

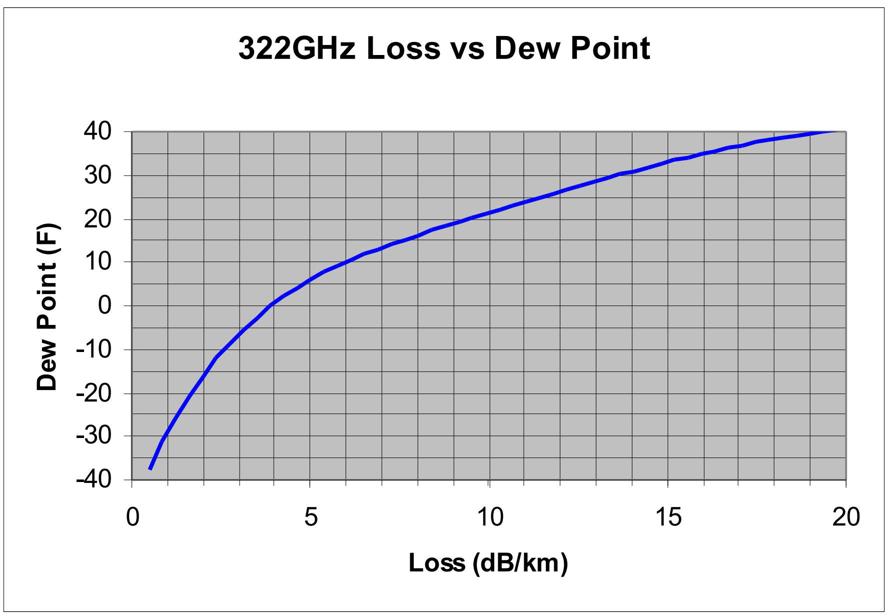


This graph shows the total atmospheric losses from both water vapor and oxygen as a function of operating frequency. When one locates the amateur millimeter wave bands on the graph (122, 134 & 241 GHz) it can be seen that there distinct advantages to operating at those frequencies due in-part to their distance from fixed molecular line resonances such as 119 and 183 GHz. This becomes even more of an issue when one considers operation in the 550 and mid-750 GHz regions. Near those frequencies, losses can be over 1,000 dB per km on even the driest of days in the Arctic when dew points are at extremely low values.

In the author's case, operation at 322 GHz was far from a closer optimum frequency such as 340 GHz, but since harmonics of lower frequencies were being exploited from existing equipment, it was considered a technical challenge that needed to be overcome.

Figure 3 is but yet another way to depict the effect of dew point on a given operating frequency. Graphs such as these have been made by the author for each of the amateur bands above 24 GHz and have shown to be excellent tools to help gauge potential communications distances by only considering the dew point of the current weather conditions.

Figure 3 – Chart based on Liebe MPM giving total atmospheric loss *vs*. dew point for operation at 322 GHz at sea level



Looking forward at even higher operational frequencies, one much face the fact that atmospheric losses will even be that much great and modern DSP receiving techniques that involve very long integration times must be considered if even the slightest value of received carrier-to-noise is to be expected.

Geographic challenge

Finding highway overlooks, clear hilltops, open parking lots and sides of roadways with views in particular directions are critical requirements that must be completed to incrementally extend ones communications distance. For example, if communication for a given radio frequency has been established under certain dew point conditions then in order to extend that distance a combination of accessible locations and new lower dew point values but be found. A new easy to access site that is but several more kilometers away might be just too far to communicate over unless the dew point reaches impossibly low values given a specific geographic region of the earth. In that case, one must either wait for a very rare weather even to produce the needed dew point value or a closer intermediate distance over which to operate must be found.

Operational results

Several years of time have been spent by the author operating on 241, 322 and 403GHz using the pair of stations described above. Successful communications distances with fellow amateurs operating the station on the other end have been slow. The primary restriction is due to the requirement for very dry atmospheric conditions that might only occur on a handful of days per year during the winter months. As distances have slowly been extended through equipment optimization and refined operating techniques, it has been found that the number of useful dry days reduces in quantity per year. Some winter seasons have not yielded any days that were dry enough to extend the previous year's distance records.

Table 1 - Table of author's distance records for 241GHz and above

Operational Frequency	Date	Distance
241 GHz	Jan. 21, 2008	114 km
322 GHz	Dec. 9, 2006	7.3 km
403 GHz	Dec. 21, 2004	1.4 km

Summary

It is in all likelihood that as radio science progresses and more commercial interests eye today's sub millimeter-wave spectrum the bar will be raised even higher possibly to 3THz and beyond for the radio amateur. Hopefully, the hobby spirit will continue and the relaxed environment will lead other amateurs to continue to explore portions of the radio spectrum that are often labeled "useless shortwaves" as was the amateur's original situation back in the early 1900's.

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2 - www.phys.virginia.edu
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About the Author

Brian Justin (WA1ZMS) received his first amateur radio license in 1976 at age 12 and has held the same call sign, WA1ZMS, since then. The photograph shows Justin operating his gear on 403 GHz out of the back of his van on a cold winter evening in 2003!

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Ultra-Wide Bandwidth Systems

By Mohammad Ghavami and Xiaoli Chu

The demand for higher data rate transmission in wireless communication systems can never be satisfied. The only constraint is the availability of required technologies at an acceptable market price. In recent years, wireless personal area network (WPAN) has become a popular topic. It requires wireless high data rate transmission over a distance ranging from several meters to hundreds of meters with low power consumption. New technologies have appeared to try to satisfy the demand. The low-power Bluetooth standard is designed to provide a maximum data rate of about 700 kb/s over a distance of up to 10 meters, which can only support file and music transfer. The IEEE 802.11b standard was established to offer a data rate of around 5.5 Mb/s over a distance of up to 100 meters, while the IEEE 802.11a standard promises a data rate from 24 Mb/s to 35 Mb/s over a distance of up to 50 meters. Although the latter two can provide enough data rates to support video transmission, the large power consumption restricts their broad applications on small portable devices.

Ultra-wideband (UWB) has been one of the most popular topics in wireless industry and academia since the early 1990s. With a transmission power below the noise level, it promises to accommodate data rates from hundreds of Mb/s to several Gb/s over a short range from one meter to tens of meters, with a trade-off between link distance and data rate. Working with such a low transmission power, UWB systems require a large bandwidth to maintain a high-transmission data rate. A large bandwidth of 7.5 GHz has been assigned by the Federal Communications Commission (FCC) in 2002 for future UWB applications in the USA. This decision has instigated greater speed in the process of bringing new UWB devices to the market.

This chapter starts with a short introduction to UWB systems. Then UWB communications and standards will follow. Moreover, propagation of UWB signals and interference problems related to them will be briefly investigated.

1 Introduction

UWB is a wireless communications technology that has attracted a lot of attention in recent years in both academia and industry due to its attractive features and capabilities. Although UWB wireless communications is considered to be a recent advancement, however, in fact UWB has been around for many decades.

Through these years, due to technical difficulties facing commercial use of UWB systems, narrowband communications were preferred to them, and UWB systems could only enjoy the attention of military organizations for communication purposes. This trend was changed when the initial step towards commercial UWB was taken by the FCC and its famous ruling. The ruling essentially dedicated a very large portion of the frequency spectrum from, 3.1 to 10.6 GHz, for unlicensed employment of the UWB signals at the noise floor. For a signal to be considered as UWB it has to occupy at least 500 MHz of bandwidth or posses a fractional bandwidth of more than 20 percent. The fractional bandwidth is defined as the 10 dB bandwidth of the signal divided by the center frequency. The FCC has also released a spectral mask to ensure the coexistence of UWB systems with other narrowband systems and devices sharing their bandwidth with UWB systems.

2 UWB Communications and Standards

Distinguished from narrow band communication systems, basic UWB impulse radio employs a baseband signal with a pulse width usually in the order of sub-nanoseconds and with signal energy spreading over a wide spectrum.

2.1 Impulse Radio UWB

One of the advantages of UWB impulse radio is its potential for carrier-free transmission, which can reduce the manufacture cost considerably. In this case, the signal is radiated by the transmitter antenna, propagates through the channel, and is then detected by the receiver antenna. The received signal energy is finally forwarded to the decision circuit.

Several wave shapes have already been proposed and investigated for UWB impulse radio systems including Gaussian pulses and its derivatives of different orders, modified Hermite functions, Rayleigh, Laplacian, and prolate spherical wave functions [1]. The bandwidth and spectral shape of UWB signals are determined by the pulse width, rise time of the leading edge of pulse and the frequency response of radiating antenna, while centre frequency is determined by the pulse shape.

For a single user transmitted waveform $s(t)$ can be given as:

$$s(t) = \sqrt{E}\sum_{n=0}^{\infty} a\left(\left\lfloor \frac{n}{N_f} \right\rfloor\right) p\left(t - nT_f - c^{\mathrm{TH}}(n)T_c - b\left(\left\lfloor \frac{n}{N_f} \right\rfloor \Delta\right)\right) \tag{1}$$

where E is the energy per pulse at the transmitter side, N_f is the number of frames in a symbol, T_f is the frame length, T_c is the slot duration, and $p(t)$ represents the applied pulse. Moreover, $N_c = T_f/T_c$ is the number of slots in a single frame and $c^{\mathrm{TH}}(n) \in \{0, 1, \ldots, N_c - 1\}$ represents the time hopping (TH) code during the n^{th} frame. By using various forms of a and b, different types of modulation schemes can be modeled by this equation.

2.2 Modulation Schemes

Commonly used modulation methods for UWB impulse radio systems include pulse position modulation (PPM), pulse amplitude modulation (PAM), binary phase shift keying (BPSK) and on-off keying (OOK) modulations. Assuming that an M-ary information symbol is given by $q(k) \in \{0, 1, \ldots, M - 1\}$, $a(k) = 1$ and $b(k) = q(k)$ represent PPM, $a(k) = 2q(k) - 1$ and $b(k) = 0$ implies BPSK and $a(k) \in \{0, 1\}$ and $b(k) = 0$ denotes OOK. Modulations can be achieved on more than one dimension to effectively increase the information bits conveyed on the pulse waveforms.

The large bandwidth occupied by the impulse radio UWB communication systems results in both frequency selectivity in the propagation channel and a large number of resolvable multipath components at the receiver side. This frequency-selective propagation channel can be modeled as a tap delayed line, and the optimum demodulator can be constructed by employing a sequence of matched receivers with proper time delays for all delay taps. This kind of demodulation structure is called Rake demodulator. The target of a Rake receiver is to collect the signal energy that is carried over selected multi-path components. Templates with proper time delays are called fingers of the Rake receiver, and are provided by the channel estimation part of the Rake receiver.

2.3 UWB Antennas

When an antenna is considered for UWB systems, it is crucial to ensure that the antenna will not cause the pulse to spread when it is transmitted. Furthermore, it is important to make sure that the antenna will be highly efficient in radiating electromagnetic energy because transmit power used in UWB systems is very low. In addition, the antenna needs to be broadband enough to handle the bandwidth requirements for (a fractional bandwidth of at least 20%).

The radiation characteristics of the impulse radio UWB signals from an antenna is significantly different compared with the radiation produced by long-duration narrowband signals. The development of new UWB sources and antennas has shown significant progress in recent years. In order to meet FCC spectrum requirements, considerable band-pass filtering will need to be done. Classical antennas have proven their use in different wireless applications, however, none of them can be used for UWB applications and there is a need to look for new types of antennas. The antenna must be able to radiate or receive fast electromagnetic transients with frequencies between 3.1 GHz and 10.6 GHz. These antennas should be able to be used off ground, not only for safety reasons but also to improve the mobility of the sensor. Another criterion to guarantee high mobility is the dimensions and weight of the antenna. Small antennas are also better for handheld applications. Finally, UWB antennas must be cheap to produce.

2.4 UWB Standardization Efforts

The standardization activities of WPANs take place in IEEE 802.15, which is an international working group within IEEE [2]. The group is responsible for creating a variety of WPAN standards, and is divided into four major task groups from which two of them are related to UWB systems:

a) The IEEE 802.15.3 task group is developing WPANs with data rates up to 55 Mbps. The standard should operate on five 15 MHz channels in the unlicensed 2.4 GHz ISM band.
b) The IEEE 802.15.4 task group is focused on low-data-rate, low-power WPANs. IEEE 802.15.4 members are investigating low-data-rate WPAN solutions with a battery life ranging from months to several years, with very low device complexity.

2.4.1 IEEE 802.15.3a

In 2001 802.15.3 SGa study group was set up to serve the requirements of companies wishing to deploy very-high-data-rate applications, such as video transmission, with data rates greater than 110 Mbps at a distance of 10 m. Probably the best candidate for definition of a new alternative was the UWB technology. The purpose of this study group was to provide a higher speed physical layer enhancement for applications involving imaging and multimedia. The main expected characteristics of this alternative were coexistence with all IEEE 802 wireless physical layers, data rate in excess of 100 Mbps, robust multipath performance and location awareness capability.

The IEEE 802.15.3a study group was considered as the main standardization organization for UWB. Since it began hearing proposals in March 2003, many companies continuously improved and merged their ideas, and collaborated to form coalitions. In June 2002, a UWB startup company had already introduced the first UWB device under the new rules for wireless connectivity applications using its direct-sequence (DS) UWB technology. On the other hand, the UWB Multiband OFDM Coalition supported a multiband OFDM approach which employed pulsed modulation.

2.4.2 IEEE 802.15.4a

The IEEE 802.15.4a task group was charged with developing an amendment to the current IEEE 802.15.4-2003 for an alternate physical layer. The primary interest in developing this physical layer was to provide communications and high-precision ranging and location capability, high aggregate throughput, and ultra low power. The group was also looking at adding scalability to data rates, longer range, and lower power consumption and cost. These additional capabilities over the existing IEEE 802.15.4 standard were expected to enable significant new applications and market opportunities.

IEEE 802.15.4a became an official task group in March 2004. The committee actively drafted an alternate physical layer specification for the applications identified in accordance with the project timetable. In March 2005, the baseline specifications were selected and approved. It consists of two optional physical layers consisting of a UWB impulse radio (operating in the unlicensed UWB spectrum) and a chirp spread spectrum (operating in the unlicensed 2.4 GHz spectrum). The 802.15.4a compatible UWB impulse radio is able to deliver communications and high-precision ranging.

2.4.3 DS-UWB Proposal

DS-UWB is one of the 802.15.3a proposals and uses DS-CDMA with variable code lengths to provide data rates of 28 to 1320 Mbps over a spectrum of 1.8 GHz in the range from 3.1 to 4.9 GHz [3]. Information bits are first scrambled and forward error correction (FEC) code is provided by convolutional codes with a coding rate of one half. An additional coding rate can be achieved by puncturing the encoder output. Encoded bits are then interleaved using a convolutional interleaver. Two types of modulation may be used, BPSK and 4-BOK (binary orthogonal keying). In the BPSK mode, 1 bit is used to determine the polarity of the spreading code which will be transmitted, while in the 4-BOK mode 2 bits are used to choose one of the two spreading codes as well as its polarity. Variable length codes combined with different chip rates as well as center frequencies are used to enable several devices to operate in the same band. Pulse shaping is then performed using a root-raised cosine low pass filter with 30% excess bandwidth.

Compared with the other proposal, DS-UWB can provide larger fractional bandwidth signals in two different bands and benefits from low fading due to the wide bandwidth of greater than 1.5 GHz. It also provides a combination of high performance and low complexity for WPAN applications. It supports scalability to ultra-low-power operation for short-range, very high rates using low-complexity implementations.

2.4.4 MB-OFDM Proposal

The MB-OFDM proposal uses OFDM along with time-frequency codes to provide data rates of 55 to 480 Mbps over three frequency bands of 3.168 to 4.752 GHz. Data bits are first scrambled and then encoded using a convolutional encoder, next they are interleaved in a block interleaver and mapped into modulated symbols, using QPSK modulation [4]. Modulated symbols are then mapped to 100 OFDM sub-carriers, along with 12 pilot and 10 guard tones, using a 128 point inverse fast Fourier transform (IFFT). Pilot tones are used for channel estimation and carrier-phase tracking at the receiver. Time-frequency codes are used to interleave OFDM symbols over three frequency bands, each 528 MHz wide. This is done to enable the system to utilize more than one band for the given OFDM waveform and to enable simultaneous operation of multiple users over the three frequency bands by assigning different time frequency codes different users.

The popularity of the multiband OFDM specifications is due to several advantages it provides over other approaches. For example, spectral flexibility, ability to be built low-cost CMOS semiconductor processes, narrow-band interference management capability, and the controllability of the out-of-band emissions.

3. UWB Channel Models

The performance of a communications system is limited by the channel that it operates in. Since last decade, measurements and modeling of UWB channels have attracted a lot of research interest from both academia and industry.

3.1 Generic Channel Representation

A UWB channel has distinct features as compared with conventional narrowband channels, e.g., the number of multipath components (MPC) that fall into each resolvable delay bin is much smaller due to the fine delay resolution, and each MPC can be distorted by its frequency-selective interactions with the propagation environment. Accordingly, the impulse response of a UWB channel is given by [5]

$$h(t,\tau) = \sum_{l=1}^{L} a_l(t)\chi_l(t,\tau) \otimes \delta(\tau - \tau_l) \qquad (2)$$

where $a_l(t)$ and τ_l are the amplitude and delay of the l^{th} MPC, respectively, and $\chi_l(t, \tau)$ denotes the distortion on the l^{th} MPC. This expression shows that adjacent delay bins are likely affected by the same MPC, thus invalidating the wide-sense stationary uncorrelated scattering (WSSUS) assumptions [6]. The resulting power-delay profile (PDP) may appear “dense” or “sparse”, depending on the channel bandwidth and the environment. In a sparse channel, MPCs arrive at time intervals that are larger than the delay resolution, and not each delay bin carries a significant amount of energy. In a dense channel, the inter-arrival times of the MPCs are less than the resolvable bin-width. Usually the larger the bandwidth, the more likely that the channel is sparse, but an environment with lots of reflecting and diffracting objects can lead to a dense channel even for an extremely large bandwidth [7]. UWB channels were also characterized in the frequency domain by using low-order autoregressive models [8].

A lot of investigations have shown that UWB MPCs tend to arrive in clusters, which can be mathematically reflected by the Saleh-Valenzuela (SV) model [9]. The number of clusters depends both on the channel bandwidth and the environment [5]. Different models have been proposed for the inter-arrival times of MPCs within a cluster, such as regularly spaced arrivals for dense channels [7], Poisson distribution [5], or a mixture of two Poisson processes [10]. For small-scale fading in UWB channels, unlike narrowband channels, where the central limit theorem can be applied on the many MPCs that fall into each resolvable delay bin to give a Rayleigh distribution, alternative distributions, such as Nakagami [11], Lognormal [12], POCA (for NLOS) and NAZU (for LOS) [13], and Rice [14], have been suggested.

Time variations of a channel can be characterized by the Doppler power spectrum if the channel impulse response $h(t, \tau)$ is a WSS process of t [15]. The WSS assumption is approximately true in a UWB channel if only the transmitter and/or receiver move, but not if the objects in the environment move, because moving objects can make the channel switch between LOS and NLOS characteristics. For the latter case, a geometrical model (blocking off rays from a certain angular range) for simulation [15] and real-time measurements in a specific environment [16] have been reported.

3.2 UWB Channel Measurements

The main concept of UWB channel measurements is to probe the channel with a proper UWB signal. The impulse response can be measured by exciting the channel with a short pulse and recording the received signal with a sampling oscilloscope [17], but this technique is sensitive to impulsive interference [5]. More robust measurements can be made by using a wideband signal with low peak-to-average power ratio [18]. UWB channel measurements can also be performed by using a vector network analyzer to scan the channel through small frequency steps [19], but modeling of the impulse response is made difficult by the transformation back to the delay domain.

Most measurement reports in the literature present results for the concatenation of the UWB channel with the antenna used, because it is hard to deconvolute the antenna effects from the channel effects. Haneda *et al*. [20] tried to separate the antenna effects from the UWB sounding results by using the double directional concept [21], which involves direction-of-departure and direction-of-arrival measurements at both ends of the link, but the number of samples was not sufficient for stochastic modeling.

3.3 Standardized Channel Models

3.3.1 The 802.15.3a Model

The IEEE 802.15.3a channel model was developed for UWB high-data-rate WPANs, so only indoor office and residential scenarios with ranges less than 10 m were considered. The model follows the SV format based on measurements of [12] and [22], without considering the frequency-dependent distortions. Both large-scale and small-scale fading are modeled by lognormal distributions. Each cluster undergoes independent shadowing.

3.3.2 The 802.15.4a Model

The IEEE 802.15.4a channel model (3.1–10.6GHz) was developed for UWB systems with low data rates and high-precision ranging capabilities. The model includes indoor residential, indoor office, industrial, outdoor suburban, and farm environments [23]. The path gain is a function of distance and frequency. The impulse response is given by a generalized SV model, where the number of clusters is Poisson distributed, the cluster decay time constants are delay-dependent, the small-scale fading is Nakagami distributed, and the path arrival rates follow a mixed Poisson distribution (for indoor residential and office environments). For the industrial environment, the impulse response is given by a tapped-delay-line model with regular tap spacing. Figure 1 depicts an instantaneous PDP in an industrial NLOS environment, showing that the first arriving MPC is strongly attenuated.

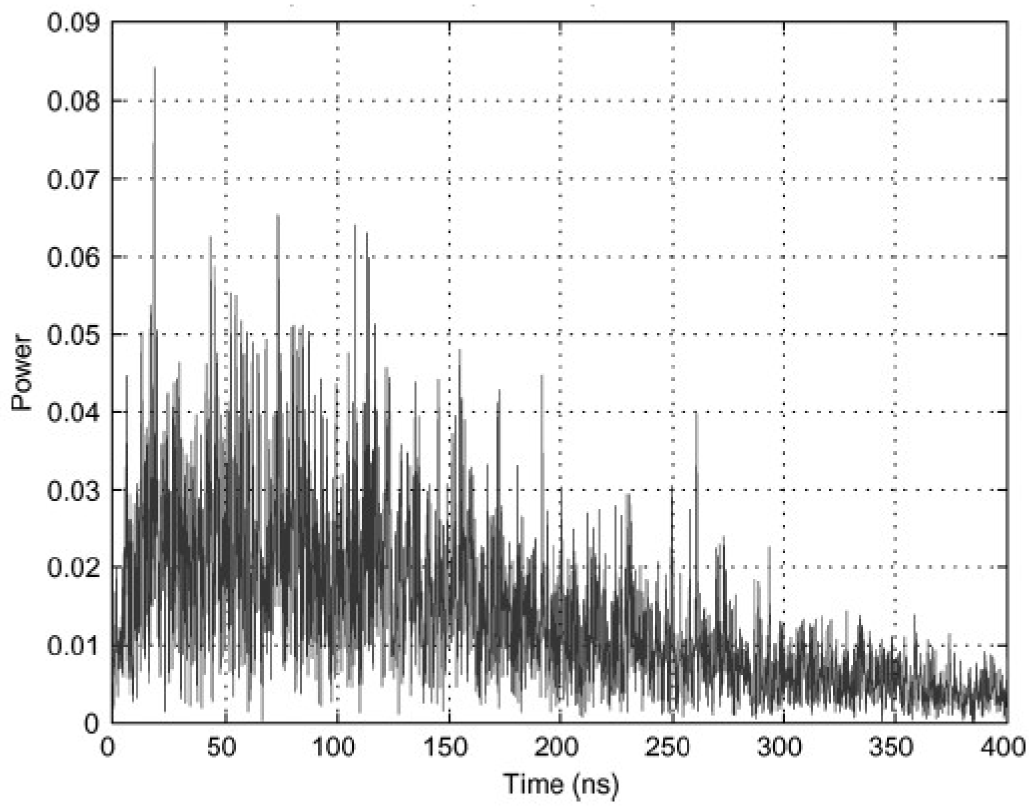

Figure 1. A channel impulse-response realization in the industrial NLOS environment [23].

This could be a problem in ranging applications, which need to determine the absolute delay of the first arriving MPC. The IEEE 802.15.4a group also developed a channel model in the 100–960MHz band for the indoor office scenario, based on the dense model with a single exponentially decaying cluster [11].

A channel model for communications between sensors on the human body (a.k.a. body area networks) was developed based on finite-difference time-domain simulations in the 2–6GHz band [23]. Because propagation through the body is negligible in the gigahertz band [24], the link distance is defined as the distance around the perimeter of the body. The impulse response contains two clusters of MPCs due to the initial wave diffracting around the body and a reflection off of the ground [23]. Measurements [25], [26] that include the surrounding environment showed more clusters of MPCs reflecting off of objects in the room.

3.3.3 Limitations of the Current Models

The 802.15.4a models are more general than the 802.15.3a model, but there are still issues that might limit their applicability. The number of measurements that form the basis of the models in different environments is very small, with a single campaign of only 10 to 20 measurement points in some cases [23]. No description is given for the channel temporal variations, due to insufficient experimental results. Different frequency dependences of the channel and the antennas in different directions are neglected. The model assumes that all MPCs experience the same propagation distortion.

3.4 Impact on System Design

According to the UWB channel impulse response in (2), the matched-filter receiver needs to match to the convolution of the transmitted waveform with the distortion functions $\chi_l(t,\ \tau)$. This is not practically feasible, especially if $\chi_l(t,\ \tau)$ are different for different MPCs. Alternatively, the receiver can use several Rake fingers spaced at the Nyquist sampling interval for each MPC [27], but the resulting number of Rake fingers becomes very large. Several simplified Rake structures have been proposed, e.g., selective Rake that combines the strongest MPCs and partial Rake that combines the first-arriving MPCs [28], the performance of which depends on whether the channel is dense or sparse. The impact of distorted received-waveforms on Rake receiver performance was analyzed in [29]. For incoherent receivers and transmitted-reference UWB systems [30], the SNR penalty increases significantly with the delay spread, especially for sparse channels.

The regulations for UWB emission specify that the transmit power spectral density (PSD) must be limited in every direction [31], implying that both non-isotropic antenna patterns and beamforming at the transmitter would require a reduction of the total emitted power. The situation is similar for MB-OFDM [32], where higher-frequency subbands undergo severer attenuations, but increasing power for higher frequencies is not an option. A lot of research remains to be done before we will possess complete knowledge of the UWB channel and its impact on system design.

4. Interference and Coexistence

Despite its merits, UWB radio has been under debate regarding potential interference with existing or future wireless systems using the same or neighbor bands at close range.

4.1 Impact of Interference

4.1.1 Interference Caused by UWB Transmissions

Studies of the coexistence between UWB and UMTS [33], [34] showed that the current FCC UWB regulations could affect the UMTS downlink performance when multiple UWB devices coexist in proximity with UMTS handsets. The aggregate interference posed by the UWB devices is related to the environment, the spatial separation, and the UWB device activity factor (AF) [35]. It was also shown that a large number of UWB devices or a UWB device with high AF and high duty cycle (DC) can degrade the acquisition performance [36] and positioning accuracy [37] of global positioning systems (GPS). On the other hand, optimistic conclusions on the coexistence between UWB and FWA, UMTS, GPS and DCS were drawn in [38].

The 802.11a WLAN systems operate in the 5GHz bands [39]. When UWB devices are close to the 802.11a receiver, severe performance degradation of the 802.11a system was observed [40]. If the UWB DC is high, the AF has a significant impact on the victim WLAN link; otherwise, the UWB impact is insignificant regardless of the AF [41]. Fortunately, the practical AF of UWB devices is relatively low (less than 5% [41]), because UWB terminals are in sleep mode for a large percentage of time and do not emit constantly at the maximum allowed power level.

The target bands for 802.16d/e WiMax deployment are the 2.4GHz, 3.5GHz and 5.8GHz bands. Operation of WiMax in the 3.5GHz band is susceptible to interference from UWB devices in band-group one (3.168–4.752GHz) of the WiMedia specification [32], particularly in Europe, Korea and Japan, as illustrated in Figure 2.

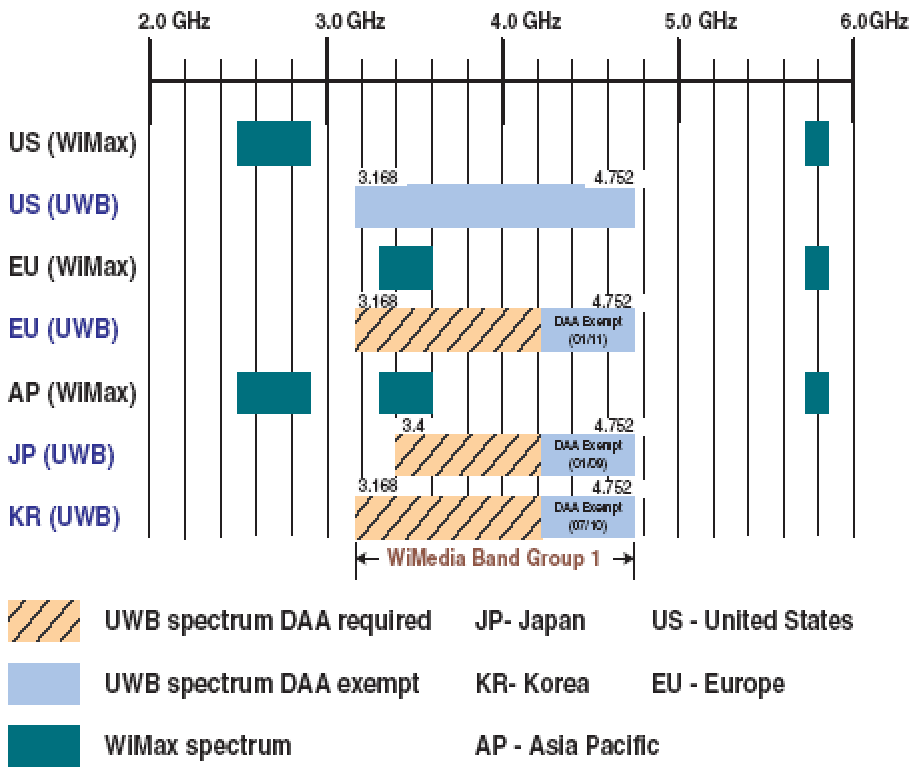

Figure 2. Overlapped frequency allocations of UWB and WiMax in various countries [54].

The results in [42] showed that UWB interference will not destructively affect the 3.5GHz WiMax system performance, in terms of cell radius reduction and outage of active users.

4.1.2 Narrowband Interference against UWB

Due to the very low PSD, strong narrowband interference (NBI) becomes a crucial issue to UWB systems. According to the current FCC regulations on UWB, it is almost certain that UWB will be affected by 802.11a WLAN transmissions, which are up to 20dB higher in power than UWB transmissions [43]. UWB system performance was also studied in the presence of GSM900 multitone jamming [44] and pulsed jamming at the UMTS bands [33]. Different NBI characteristics due to different NBI center frequencies and different UWB DC were reported in [45]. A UWB system suffers most from NBI if the NBI band and the nominal center frequency of the UWB signal overlap [46].

4.2 Interference Mitigation

The ability of the UWB receiver to reject NBI and the ability of the UWB transmitter to avoid interfering with other radio systems both depend on the PSD of the UWB signal [46]. To mitigate the interference from other radio systems to impulse radio, notch filtering of the UWB signal at the 5.15–5.825GHz 802.11a band was proposed in [46], and a multicarrier template waveform that is composed of several subbands excluding the NBI bands was developed in [47]. For NBI mitigation in DS-UWB systems, schemes in conjunction with Rake receivers were proposed in [48], and a method employing receive diversity with space-time adaptive processing was proposed in [39]. Power control was proposed in [49] to reduce the mutual interference between MB-OFDM and DS-UWB systems.

In order to protect the 3.5 GHz WiMax system, the regulation authorities in regions such as Europe, Korea and Japan define the UWB emission limit approximately 35 to 40 dB lower than the –41.3 dBm/MHz FCC limit over the 3.1–3.8GHz band if there is no mitigation technique used [50], however, with such a low PSD, UWB devices may not be able to establish communications with adequate data rates. Detection and avoidance (DAA) techniques are required in both Japanese and European regulations for a PSD of –41.3 dBm/MHz at the 3.1–4.2 GHz band [51], [52]. With DAA, a UWB device can reveal the presence of a victim terminal by power measuring and regulate its transmission to reduce interference [53]. An on-chip implementation of basic DAA functionality based on energy detection was developed in [54]. The minimum keep-out distance between WiMax and UWB terminals and the DAA sensing threshold were suggested based on interference measurements [55]. However, the DAA functionality is obtained at the expense of reduced efficiency/capacity of UWB networks. Ideally in a cooperative scenario, the UWB devices and the victim devices can exchange some basic information, and the UWB devices can broadcast the victim status information to other UWB devices in the area. Such cooperative DAA is able to provide better coexistence performance and improved UWB network throughput [56]. Besides, low duty cycle at the 3.4–4.8 GHz band was suggested by the European regulation [52].

5 Summary

In this chapter we studied the basic principles of UWB signals and systems in communication engineering. This presentation started with a brief explanation of the impulse radio modulation schemes and antenna design issues. Standardization activities of IEEE 802.15 on WPAN systems with two main proposals of DS UWB and multiband OFDM UWB were explained. Channel modeling for UWB communications systems based on measurement and analytical investigation was also considered. Finally, interference caused by UWB transmitters on existing communication systems and ways to mitigate this interference were briefly explained.

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Weak Signal LF Experimentation in Newfoundland

By Joe Craig, VO1NA

Introduction

The relatively low efficiency (less than 1 percent) of practical transmitting aerials coupled with high levels of atmospheric and man-made noise makes amateur LF experimentation inherently weak signal work. For the remaining technical aficionados of the amateur service, low frequency experimentation has become a refreshing challenge. It is hoped this paper will help motivate others to pursue experimentation in this portion of the radio spectrum.

The author's interest in LF was first sparked in the early 1970's when listening to the static and utility stations below 500 kHz on his father's National HRO-50 receiver. Interest in transmitting long waves followed after reading about the US 160-190 kHz LF experimenters' band in Robert Schrader's "Electronic Communication" text for the Amateur Radio course in which the author was a young student in 1975-1976. Within a short time, an oscillator was constructed to produce a carrier on a frequency of about 180 kHz. Unfortunately, the signals would not be radiated; an official with the Department of Communications was not optimistic about authorising transmissions below the 1.8 MHz amateur allocation and so the LF transmitter project remained dormant for 16 years. The interest in LF transmitting was further inspired by a chapter written by Belrose (1983).

In 1992, while employed at the Physics Department at Memorial University, the author learnt from academics on the internet news groups that Canadian amateurs had recently been experimenting on the 160-190 kHz band and by April 1992, authority to transmit in this portion of the spectrum was received from Communications Canada. A transmitter was constructed, signals were received by amateur stations about 10 km away and experimentation with reception and transmissions continued for about a decade.

In the late 90's amateurs in Europe began experimenting on the 4000m and 2200m bands and new methods of weak signal reception were developed. In 2003, the author was authorised to transmit between 135.7 and 137.8 kHz. The 1992 LF transmitter was tuned to this new band and additional transmitters were constructed. Audible amateur LF signals were, for the first time, transmitted across the Atlantic. The 137.777 kHz transmitter featured high frequency stability and ultimately operated with 1.2 kW input power. Although it was decommissioned in June of 2007 when the authorisation expired, experimental work resumed near 185 kHz and continues to this day.

Transmitter Design

The LF oscillator built in 1977 had a tank circuit comprising a 15 μH coil and a 0.05 MFD capacitor. A 6C4 triode and junction transistors were used as the active components and sustained oscillations were achieved once the bypass capacitors were properly scaled: the 0.001 μF bypass capacitor, common in the amateur radio literature, was of little use on 1600 metres, whereas 0.2 μF proved much more effective. LF signals were finally produced on about 180 kHz, measured with a frequency counter and heard on the HRO receiver.

A new transmitter for 1600 metres was constructed in 1992 *(Figure 1)***.**

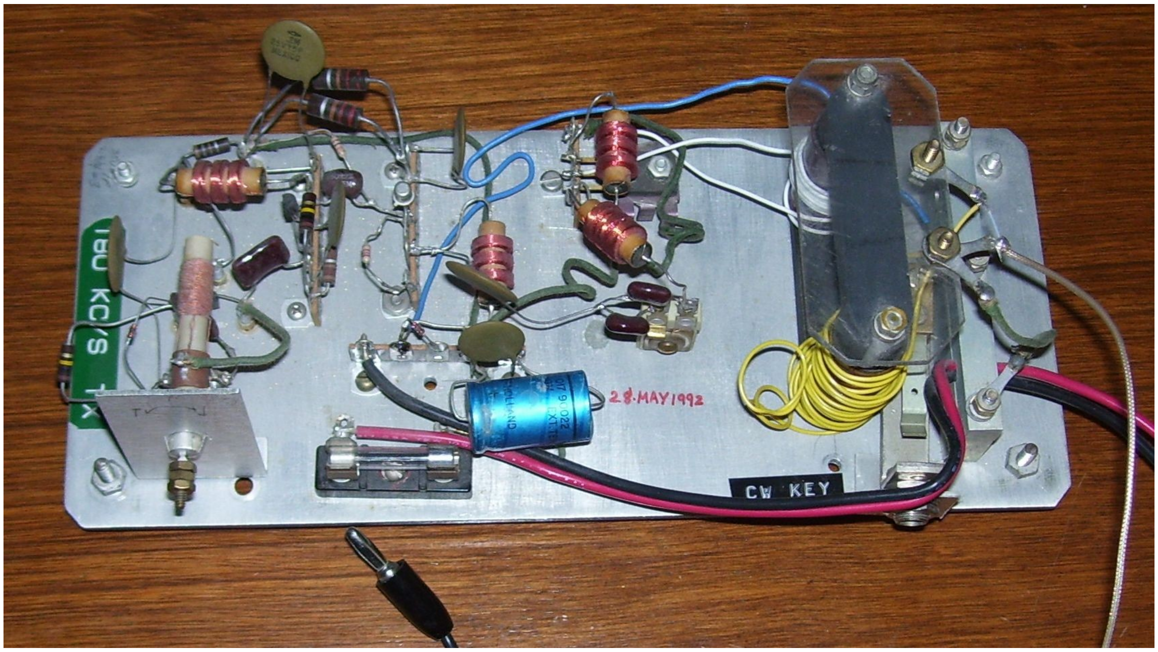

Figure 1 180 kHz Transmitter

This was a conventional but primitive design that started with a field effect transistor Hartley oscillator. The frequency was set by a tank circuit comprising a tapped Miller 40-240 µH variable inductor and a 10 nF polystyrene capacitor. This was followed by an FET buffer, BJT keying and PA stages. The output was 3 watts with spurii down at least 30 dB as measured with a spectrum analyser. A more modern design with 15 watts output from a highly efficient Class E stage was constructed for 2200 metres and was followed by a 125 watt version which operated on a supply of about 40 volts *(Figure 2 and Figure 3)***.**

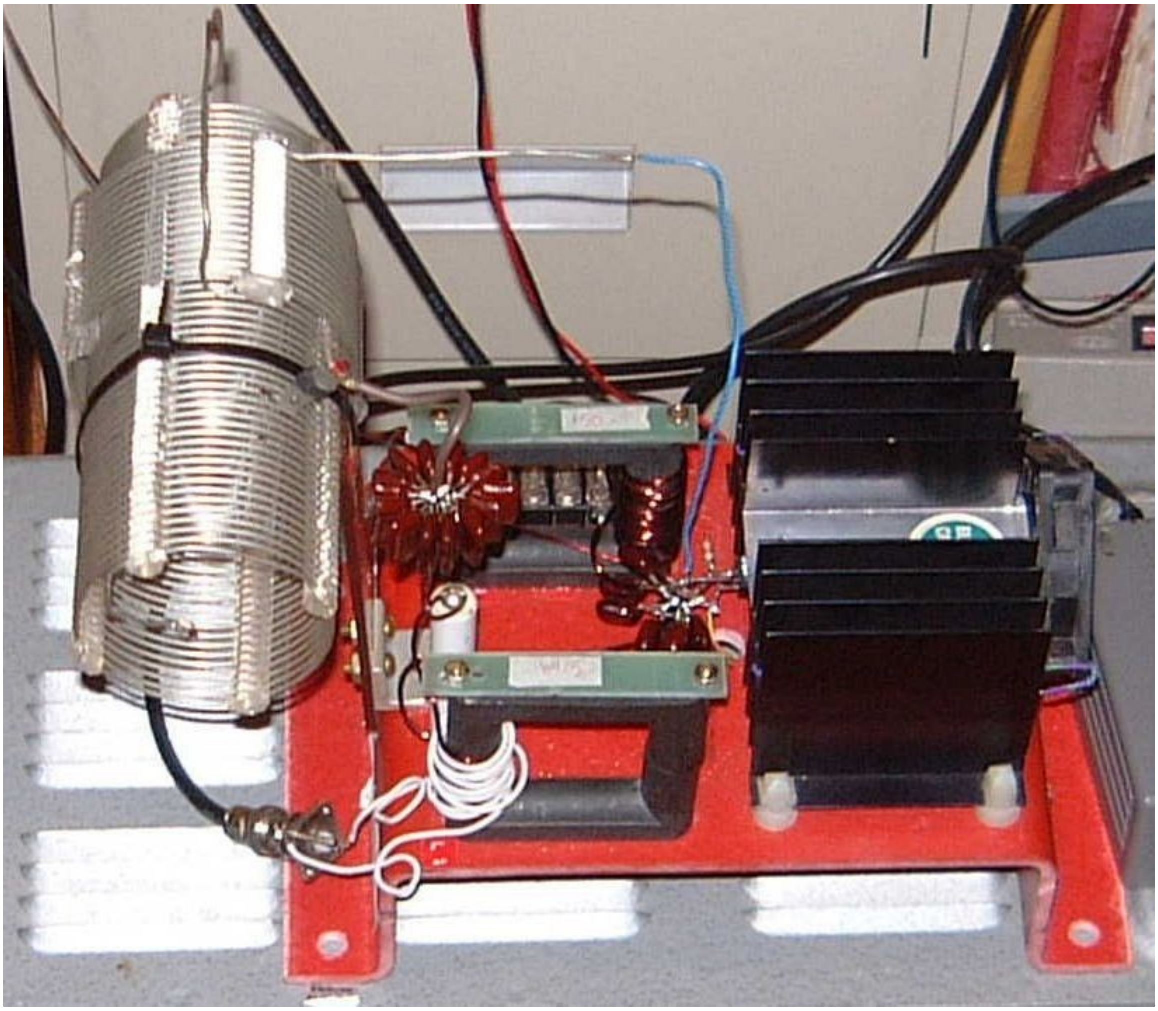

Figure 2 RF deck of the 137 kHz 125 watt transmitter

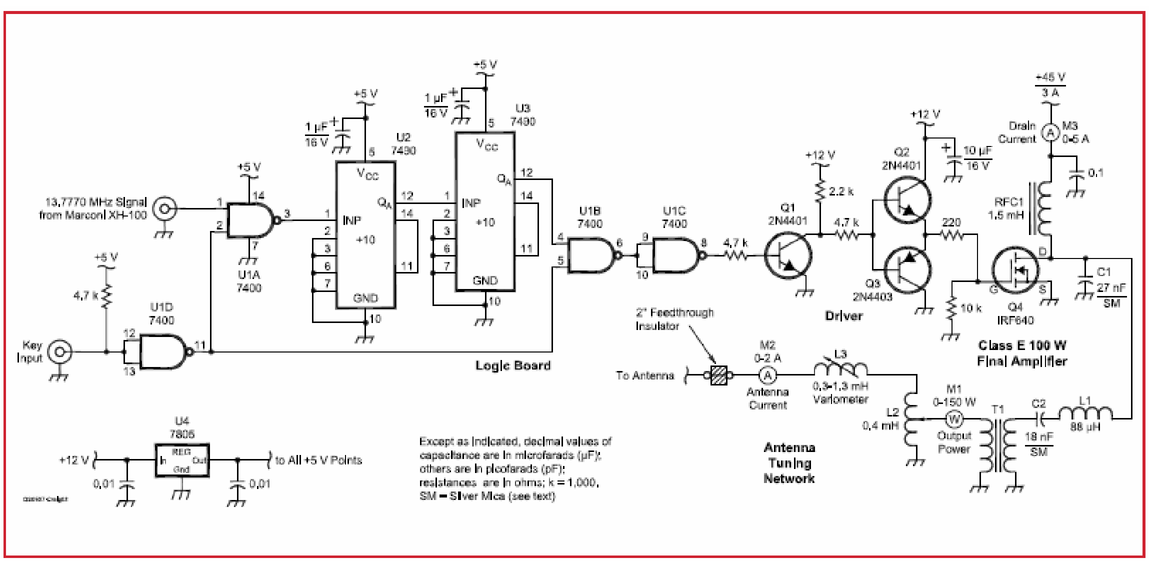

Figure 3 137 kHz transmitter schematic. From July 2005 QST, reprinted with permission. Copyright ARRL.

This used a crystal oscillator in an oven of a modified Canadian Marconi XH100 receiver and digital circuitry to divide the oscillator frequency to 135.830 or 137.777 kHz and to perform the keying of the carrier as described by Craig and Melia (2005). Provisions were made to permit the frequency to be shifted for FSK experiments as authorised by Industry Canada along with CW transmissions. The remaining parameters of the special authorisation were an ERP of 1.0 watt and a bandwidth of 100 Hz over 135.7 to 137.8 kHz. A 1200 watt Decca transmitter *(Figure 4)* was obtained and deployed for the final phases of the 2200m experiment.

Figure 4 The 1200 Watt Decca transmitter, from the United Kingdom

The Monopole Aerial

An insulated 25.3m triangular lattice tower with a 30 cm face originally used on the 30-160m amateur bands as a monopole was deployed for 1600 metres and various experiments were conducted. The ground system comprised a 1000 cm^2 square brass plate buried below the water table to provide a low resistance path in case of a lightning strike, and 16 radials, 20 metres in length. Extending 4 of the radials by 20 metres and connecting the ground plate to the RF ground did not significantly increase the ground current nor improve the signal strength.

Different methods of coupling the transmitter to the aerial were attempted. These included the traditional tuning helix and matching transformer approach and the L network.

Some effort was made to determine the impedance of the antenna system and this was facilitated with the generous assistance from officials of Navigation Canada at St. John's Aeroport who provided technical manuals for the aeronautical beacons. This was very useful in designing and constructing the instrumentation, in particular an SWR bridge and an RF current meter.

Estimates of the theoretical impedance of the monopole were calculated using expressions provided by Belrose (1983) as follows.

The surge impedance of a monopole of height h and cross sectional area a is:

$$Z_0=60[\ln(h/a)-1] \qquad (1)$$

Various means of estimating the effective cross section area of towers of differing shapes have been developed and as cited above however a reasonable guess would be to let a=0.2m so that h/a=125, hence $Z_0 = 230\ \Omega$. We note here for h/a>15, which is satisfied for a monopole of realistic geometry, that 100 ohms may be taken as a lower limit the surge impedance.

The base reactance for a short monopole can be estimated as:

$$X_b=-Z_0 \cot\theta \qquad (2)$$

Since $\lambda = 1600$, $l/\lambda = 25/1600 = 0.016 = 0.098$ radians, hence $X_b = -2.3\ k\Omega$.

The value of the ground resistance was largely a matter of speculation. From the turns ratio of the matching transformer and tuning values for the monopole at 180 kHz, estimates of 200 Ω and 1.8 mH were obtained, corresponding to an impedance of 200-j2000 Ω. We note the reactive component is in fair agreement with Eqn.(2).

The radiation resistance can be estimated by an expression in the aforementioned reference as:

$$R_r = 10G^2 = 0.09\ \Omega \qquad (3)$$

where G is the electrical height of the aerial in radians.

Using this and the value of the ground resistance, the efficiency, neglecting losses in the tuning network, ohmic and other losses was

$$\eta = R_r /(R_g + R_t + ...) = 0.09/200 = 0.05\% \qquad (4)$$

Hence, a 1 watt input would yield an ERP of 0.5 mW.

Impedance matching with an L network was attempted. The design equations for the shunt and series elements are found by simultaneously solving the real and imaginary equations for the impedance of the network and load as:

$$X_s = \pm(R_0X^2/R + R_0R - R_0^2)^{1/2} \qquad (5)$$

$$X_p = (RX_s - R_0X)/(R_0-R) \qquad (6)$$

for an L network with the shunt element across the load. Eqns. (5) and (6) requires that

$$X^2 > R_0/R - 1 \qquad (7)$$

Where R+jX is the load impedance and R_0 is the line characteristic impedance.
The inequality (7) is valid for the monople under consideration, whose impedance is dominated by a high capacitive reactance. The elementary design equations assume lossless elements. For R +jX=200-j2000 ohms they yield 860pf and 577 uH respectively for the series and shunt elements. The series element is placed between the junction of the shunt element with the base of the monopole and the centre conductor of coaxial feed line. An impedance match was achieved for the actual monopole, as indicated on an SWR meter, with elements of 1000 pF and 500 uH. These are in reasonable agreement with those calculated from the design equations and the impedance as estimated from the tuning and matching values.

More generally, using expression (2) for X_b and $10G^2$ for R in eqn. (7) for which we assume no losses, we have

$$[-Z_0 \cot(G)]^2 > R_0/10G^2 \qquad (8)$$

For small θ, tan(θ)≈θ so cot(θ)≈1/θ and we may write, noting $X^2 >>1$ and
$R_0/R >> 1$,

$$Z_0^2 > R_0 \qquad (9)$$

As noted above, the minimum surge impedance for a monopole is 100 and for a typical transmitter and transmission line characteristic impedance of 50 ohms, this condition is always satisfied. Hence, the L network described above can be used to match any short monopole, no matter how small, provided the ground and network and other losses are sufficiently small. Additionally, these results show the antenna and tuning systems to be operating properly and demonstrate quantitatively the assertion of the L network utility as made by Craig (2005) and confirmed by Belrose (pers. com. 2005) to be valid.

This somewhat detailed analysis followed observations of unexpectedly weak signal strengths outside the near zone of the aerial. Although the 180 kHz signals were received by amateurs about 10 km away in May of 1992, it was determined much later as outlined by Craig (2005a), that the problem was with noise levels of the portable monitoring receiver used by the author and not the transmitter, tuning networks nor the aerial.

The Wire Aerial

In the early spring of 2003 preliminary transmitting experiments commenced on 135.83 kHz using an aerial comprising two wires run from the station to the top of the 25 metre tower, spanning about 150 meters. This arrangement was for convenience to preclude accessing the tower base in the deep snow. The wires were insulated from the tower with large 30cm Steatite insulators. The variometer and to a lesser extent the matching transformer required frequent adjustment to peak the aerial current and to keep the SWR low with changing environmental conditions. Other arrangements, such as a single wire at a reduced height of 10 metres were made necessary by violent wind and ice storms which frequently felled the wires and eventually the 25 metre tower. This provided opportunities to investigate the performance of other antenna configurations. Field strength measurements at 3.5 km and signal reports from stations in England and Europe appeared to support Eqn. (3) when the height was taken as the maximum height of the far end of the antenna. For instance, if we assume that the efficiency of the antenna varies with its radiation resistance, all other factors being equal, then Eqn. (3) yields a ratio of efficiencies of 6.25 for antenna heights 25 and 10 metres. The corresponding differences in relative field strength were about 10 dB and the reports from Europe showed that roughly equal signal strengths were had when using 100 watts with a 25 metre high antenna and 1000 watts with the antenna at 10 metres high, again a factor of 10 dB. The Decca amplifier (*go back to Figure 4*) yielded just over 5 amperes (*Figure 6*) of aerial current to the 100 metre wire at 10 metres height.

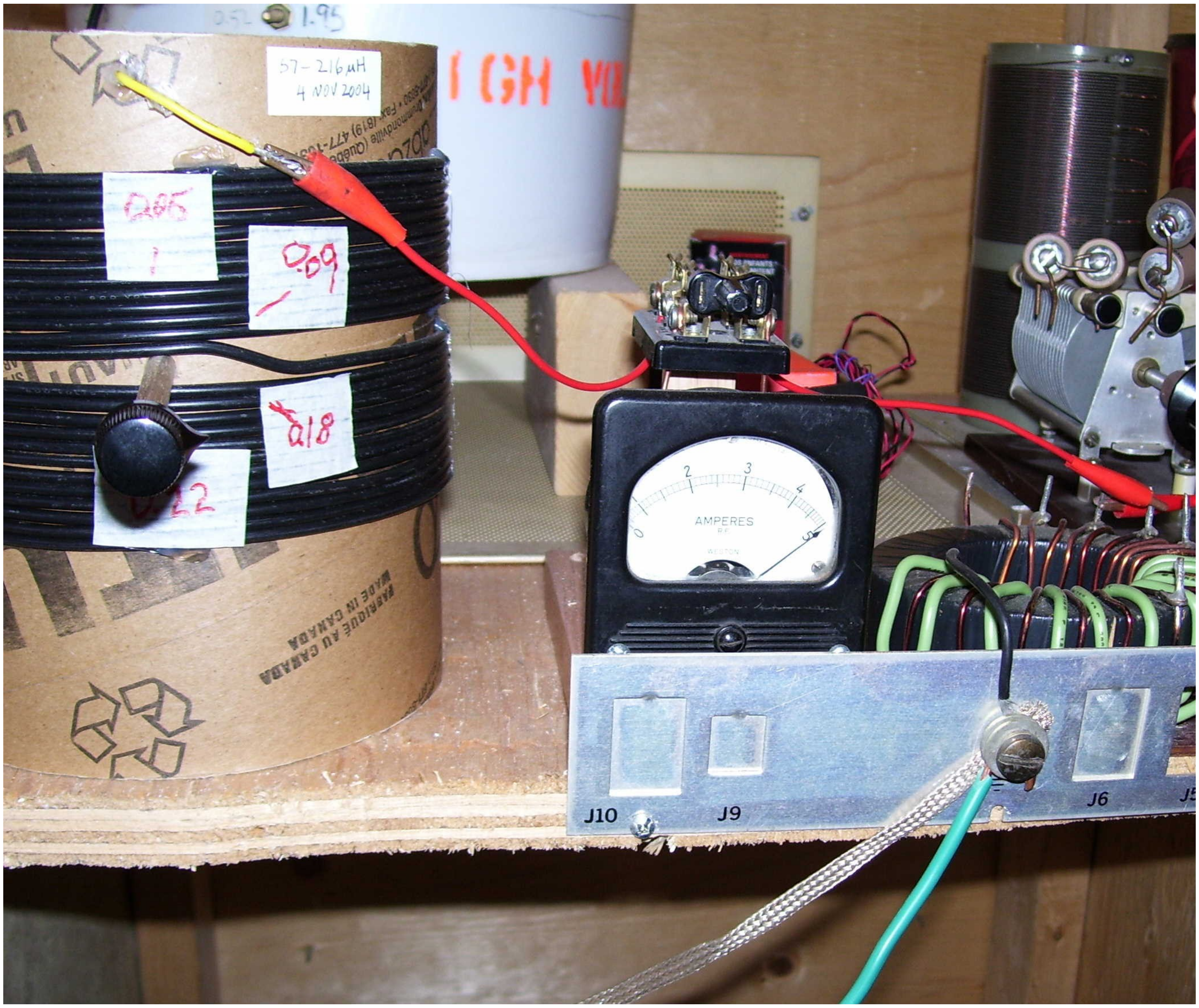

Figure 6 Aerial ammeter: just over 5 amperes to a 100 metre wire

Digital Signal Processing

Recent advances in digital signal processing have enhanced the extraction of weak signals from high noise levels. This is achieved by increasing the signal to noise ratio at the expense of effective bandwidth and the signalling rate. An effective and practical method of doing this is to implement fast Fourier transforms whereby a signal in the time domain is transformed into the frequency domain. The resolution of the frequency domain depends on the how long the signal is sampled before it is transformed, hence there is an inverse relation between signalling rate and realisable bandwidth. The upper limit of the frequency domain is limited by the rate at which the received analogue signal is sampled, being one half this rate.

The deconvolution of a signal to its sine wave constituents requires not only their frequency, but also their phase and amplitude. The latter is limited by the dynamic range of the analogue to digital conversion. Very practical implementations of this spectral deconvolution have been developed for amateur radio use such as Spectrum Lab(DL4YHF)and Argo(I2PHD and IK2CZL). Both are straight forward to use and tailored for amateur LF communications and experimentation. Spectrum Lab uses the PC soundcard to analyse spectra of audio input signals and digitised audio, its time series, and to perform filtering and decoding of other experimental communications modes. ARGO has been used in several notable long distance transmissions and receptions over the past decade. ARGO uses various sampling times and associated bandwidths. For instance with QRSS10 for Morse code dots which are 10 seconds long, the update time on the computer screen is about 1 second and 25 Hz of spectrum can be displayed. The FFT uses 65536 samples at a rate of 5512 Hz, yielding a windowed bandwidth of about 0.1 Hz. De Bene uses a large overlap by reusing previous samples with new data so that the time resolution is of the order of 10 seconds. The overlap allows for flexibility in the refresh rate. A longer update time is used for slower speeds; for instance it is 12 seconds Morse code with 120 second dots. Only about 1.7 Hz of spectrum can be displayed at this speed but the signal to noise ratio is about 20 dB better than that possible with conventional aural Morse code reception at 20 words per minute.

By plotting the frequency against time as pixels on a computer screen, a carrier of sufficient stability and intensity can be distinguished from the background noise as a horizontal line. If the carrier is interrupted or frequency shifted in a periodic fashion as by Morse code, a practical reception system can be realised as dots and dashes across the computer screen or series of segments with the dots on one frequency and dashes on another *(Figure 7)*.

Figure 7 Dual Frequency CW transmission (DE VO1NA) received by H. Wolff in Germany

The signal to noise ratio is limited by the integration time and the carrier frequency stability. The trade off is the rate of intelligence transmission, in accordance with Shannon's law. For example, using the 12 second integration time of QRSS120 would require almost 2 hours to receive "VO1NA". De Bene has enhanced the visibility of the signals by mapping the intensity of the pixels by the signal to noise ratio, rather than the absolute value of the signal. The FFT algorithm is based on assembly routine hand optimised library functions from the Intel Signal Processing library.

The "Z" axis of the ARGO, the pixel intensity, has a large dynamic range and numerical values are available. These are relative and depend on the time series of the amplitude of the corresponding frequency, but also on the computer sound card and its settings. Practically, a range of 60 dB or more can be achieved before nonlinearities associated with compression in the computer sound card can start to affect the accuracy. This can be overcome by using attenuators before the input to the sound card.

There are many other modes of communication employed and being developed by amateur LF experimenters. They use advanced error correction techniques, modulation methods and implementations of the internet for disseminating and archiving received signal and signal to noise levels at remote sites. This makes it possible to monitor transmitter performance at distant stations in near real time.

The future of receiver technology is also undergoing a revolution with software defined radio technology and several instances of spectacular receiver performance have been cited in the current literature.

Transmission

High stability of the carrier was necessary for weak signal work so that even carefully designed LC tank circuits were not suitable. Instead the carrier was generated from a 13.7777 MHz crystal in a thermostated oven. This was digitally divided by 100 to 137.777 kHz and then fed to the class E transmitter or Decca amplifier. Digital signal processing also played a role in the generation of carriers with the use of frequency synthesisers. By using a stable reference oscillator, which may be disciplined by a reference from the Global Positioning System (GPS) to within 1 part in 10^{11}, any arbitrary frequency may be generated below about one third of the reference oscillator with a resolution of about 1 part in four billion. These devices are in the form of very tiny integrated circuits and are normally controlled by a microprocessor chip. A more versatile approach is to use a computer hardware port, (MRCN 2007). In this case, the desired frequency is converted into a ratio of the reference oscillator frequency. This ratio is then coded as a binary word of typically 32 bits and fed into the DDS chip via the hardware port. Other bits may be assigned to adjust the phase of the DDS output so that with two DDS circuits and single reference oscillator, accurate quadrature signal sources may be realised. The DDS chip then uses the reference oscillator signal as a clock and, using a lookup table, digitally constructs a sine wave at the specified frequency. There are high frequency components in the output which must be removed by external filtering. The filtered output is then followed by amplification stages to bring the signal to the required level.

Direct digital synthesis is in wide spread use in communication systems and has been used experimentally by amateurs for a number of years. In addition to carrier generation, DDS systems have been used in reception applications, for example as an HFO in an experimental LF receiver, (Craig, 2007). This uses a simple program to generate the appropriate binary word corresponding to the desired frequency and to set the data lines of the RS232 port to load this data into the registers of the DDS. For frequencies substantially smaller than the clock frequency, the quality of the sine wave is excellent.

Reception Measurements

The utility of the computer FFT DSP was highlighted by two experiments. These were the measurement of relative signal intensity with distance from transmitter and its variation with aerial height at a fixed distance.

In the spring of 2004, the transmitter that was used in the transatlantic experiments was deployed to determine the variation of signal strength with distance from a receiver on a ship. The receive aerial comprised 14 turns on a 60 cm square frame which was resonated with a variable capacitor. There were two pickup loops in parallel with resonant loop connected to coaxial cable to the receiver. The loop antenna was oriented so that its plane was parallel with a radial to the transmitter with 125 watts output to a 100m wire.

Signal strengths were measured as AC voltages in a 0.1 Hz bandwidth after an FFT on the receiver audio. Aural tests were conducted with the aid of a 500 Hz filter but were limited by the electrical noise from the ship and by atmospheric noise at night. The signal levels were measured with an estimated uncertainty of 1.5 dB. Measured noise was at least 30 dB below the signal. Distances were determined by GPS and were accurate to within 1 km. Aural detection was possible at distances of up to 450 km and intelligible signals were heard at 400km. They became consistently readable at 300 km. The measured signal levels were plotted against distance, Fig. 5.

We expect the LF ground wave signal strength to follow the inverse distance relation (Belrose et al., 1959)

$$E = mE_0/r \qquad (10)$$

where m is the attenuation coefficient and E_0 is the field at unit distance r. Taking the logarithm of both sides, we can rewrite this as

$$Y=A-\log Br \qquad (11)$$

where y is the relative field strength in dB. Treating A and B as arbitrary constants, this equation was fitted to the observed data *(Figure 8)* solid line, using the constant values of 75 and 12 respectively.

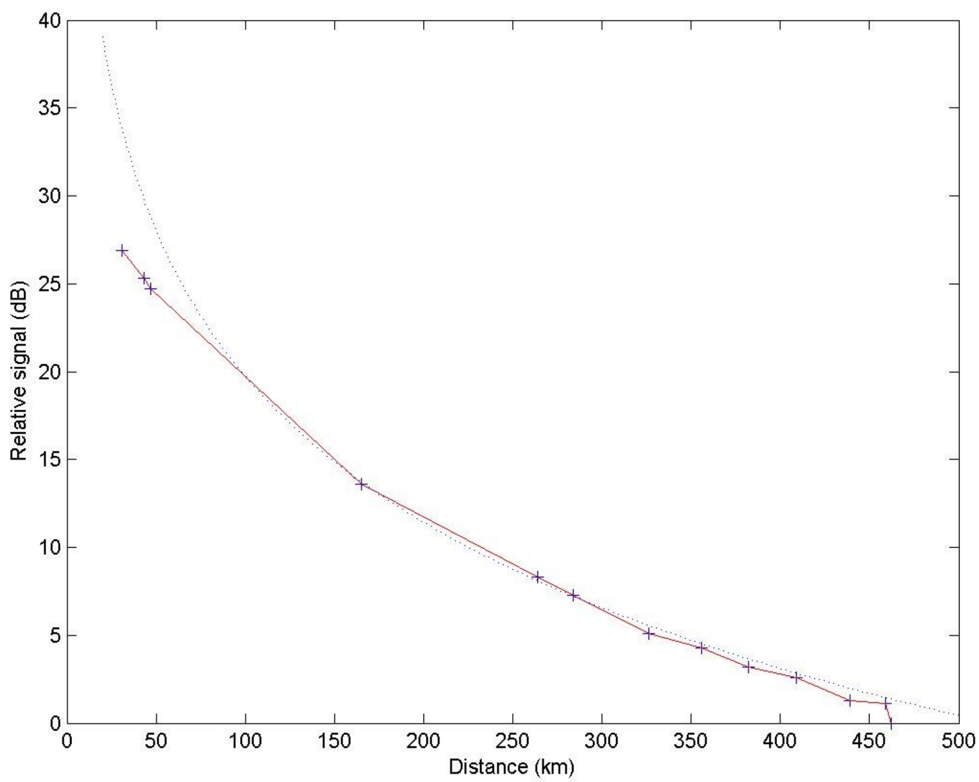

Figure 8 Plot of signal strength vs. distance. The solid line is a plot of observed levels. The broken line is from Eqn. 10.

The crosses indicate the measured values. If we neglect the apparent discrepancy at the smaller distances where the received signal is more sensitive to the orientation of the aerial, the fit is quite good. Further experimentation may be directed to improving the accuracy of the measurements, calibration and estimation of the constants A and B from the measured field strength of the transmitting station and published values for the attenuation coefficient.

These measurements did not show any evidence of diurnal variation and we conclude that propagation over salt water is predominantly by ground wave at distances up to 500 km. Measurements have shown the propagation over land is substantially lower and subject to seasonal variability.

To determine the performance of the transmitter antenna, a remote site along a road about 3.5 km from the station was selected. There were no overhead wires near this location and repeatable measurements were routinely achieved. A small ferrite rod about 8 cm long was wound with wire and resonated at 138 kHz. This was affixed outside a car parked at a marked location. The rod was rotated for maximum signal strength. The line output of a receiver, which is independent of the volume setting, was connected to the sound card input of a portable computer which was running ARGO. The receiver AGG was disabled and other settings were maintained.

Additional measurements were made to ensure that the signals were not being reradiated by the power lines and that the lines were not being used as a ground connection for the antenna system. This was facilitated by measuring the signal strength perpendicular and parallel to power lines at 7km from the station at points where the lines were perpendicular and parallel to a radial to the station.

Amateur Communication Experiments

Although local reception up to 10 km had been achieved on 180 kHz, it was not until the start of experimentation on 135.84 kHz that long distance transmission was seriously attempted. In early 2003, transatlantic amateur signals were detected for the first time in Newfoundland when an amateur station in Portugal (CT1DRP) was copied with the aid of FFT processing of the audio from the receiver. Amazingly, these signals could be copied using an indoor 30 cm resonant loop antenna. Shortly after authorisation was received to transmit on 2200m, signals from a 15 watt transmitter on 135.83 kHz were received in Boston, 1000 miles away by W1TAG. Transatlantic experiments commenced on 137.777 kHz with a power of 125 watts and succeeded with a reception of a full call sign by G3NYK and a 2-way contact M0BMU. Several other transatlantic experiments followed, resulting in additional contacts (Craig et al. 2004). Audible LF signals were transmitted across the Atlantic for the first time in late April of 2004 when 5 WPM CW was heard by H. Wolff in Germany. The signals were also heard in Ireland and France. The best distance for FFT copy was 6600 km by RN6BN.

In August of 2004, a conventional CW radio contact was established between VO1NA and VO1HP who was operating VO1MRC using the 1992 transmitter with his 160 metre inverted L about 10 km away. This was the first amateur LF contact in Canada to be completed without computer assistance. Earlier, amateurs VA3LK and VE3OT in Ontario had succeeded earlier in achieving a contact using computer aided FFT reception. Attempts to link the antipodes were not successful from this station even with the 1200 watt Decca amp. Signal reports in near real time were made possible by a wireless internet connection to a remote receiver connected to an FFT processor whose output was broadcast in the internet. The signals could be monitored using a portable computer which was set up in the transmitter shed *(Figure 5)*.

Figure 5 Interior of the tuning hut, aerial tuning apparatus

It was receiving the wireless internet on about 2.4 GHz to monitor transmissions from the shed on 2200m. The high power 137.777 kHz station was decommissioned in June of 2007 and experiments resumed on 189 kHz with 10 watts output with many aural reception reports at sea including one east the Flemish Cap at 650 km over an all-water path and one in St Pierre over a mixed land-sea path. The latter reception required excitation of the receiving loop using about 30 metres of wire stretched out on the ground on a hill away from the interference in the town. No signals were heard in Gander, or Salvage but they were copied on Blue Hill in Terra-Nova National Park in 2008. Although Salvage was somewhat closer and the path was over a greater portion of water, Blue Hill was about 200 metres higher suggesting an increase in signal strength with height.

The first reception of transatlantic low power signals on 160-190 kHz band took place in 2005 (Craig et al, 2005) and reports have been received from France, Holland, America and Portugal.

Experiments continue today and focus on promoting LF experimentation and attempting amateur ground wave receptions up to 1000 km (*Figure 9*).

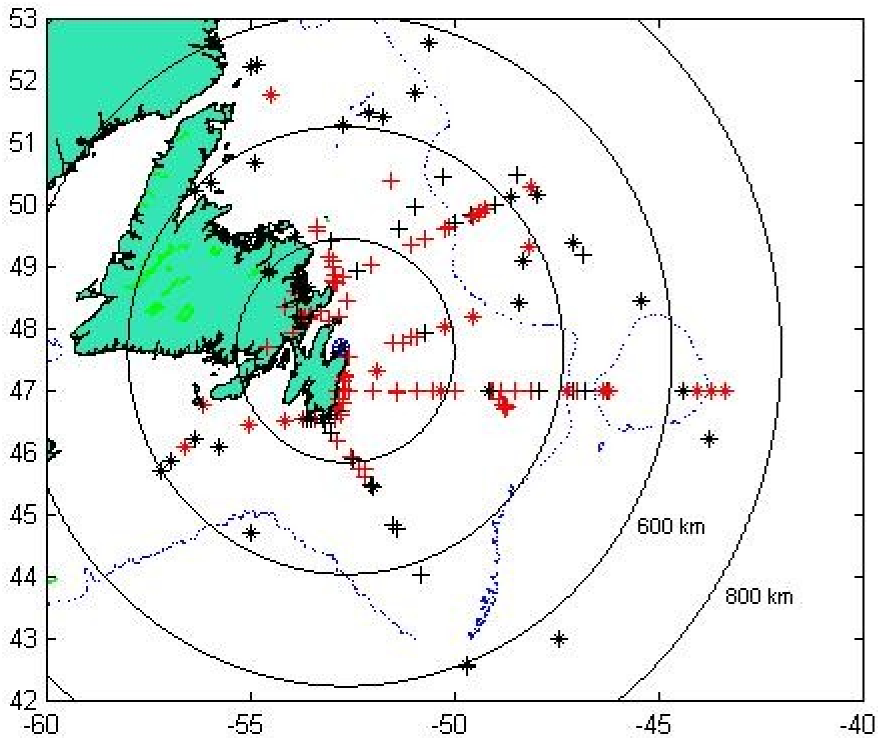

Figure 9 Receptions of the 10 watt 187 kHz beacon. Red symbols indicate readable signals, black symbols indicate no signals heard. Note how a reception path over the ocean extends farther than those over the land.

Plans for the future include experimentation with GPS disciplined oscillators, experimental transmission modes and attempting additional 2 way contacts using traditional. It is anticipated that these activities will be augmented when the 2200m band is made available to Canadian amateurs in the future.

About The Author

Joe Craig, VO1NA, was first licensed in 1976. He is the son of VO1FB, husband of VO1RL, and father of Julia. Joe completed his undergraduate and graduate degrees at Memorial University of Newfoundland and works with the Government of Canada as a physicist. He has lectured at the University and at conferences in radio and physical science and has authored dozens of technical and research papers including several in the primary literature. Joe is a member of many radio groups including the Poldhu Amateur Radio Clubs and the Marconi Radio Club of Newfoundland, and is a life member of the Quarter Century Wireless Association. He has both CW and 160 meter DXCC and WAZ.

The photo shows Captain Ed Turner of the CCGS Teleost *(left)* and the author copying the CW beacon on 187 kHz in Smith Sound Trinity Bay, Newfoundland.

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The author wishes to acknowledge the Jack Belrose for his many inspirational publications, reviewing portions of this and other manuscripts, the many radio amateurs (previously acknowledged in the Final Report of LF experimentation in Canada, see VO1MRC web page) who contributed to the author's knowledge and the members of Marconi Radio Club of Newfoundland.

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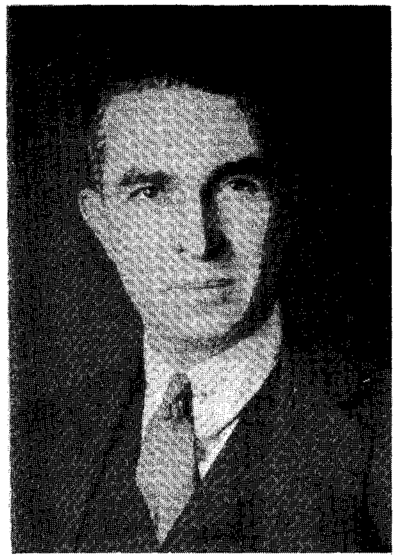

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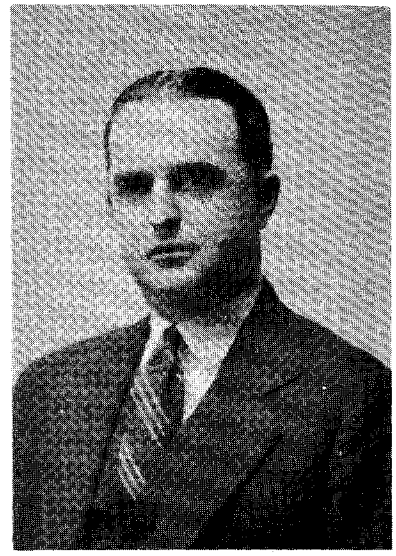

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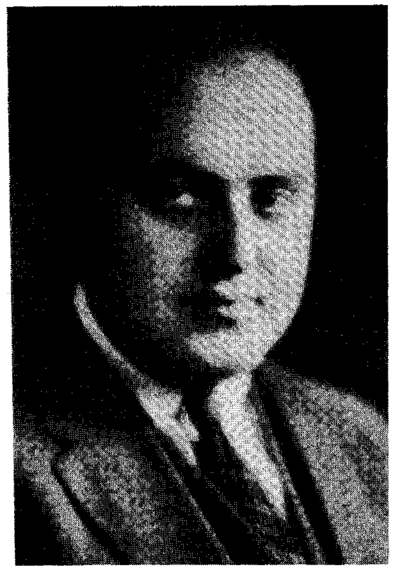

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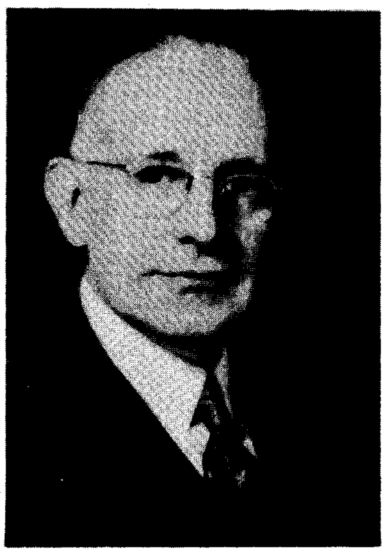

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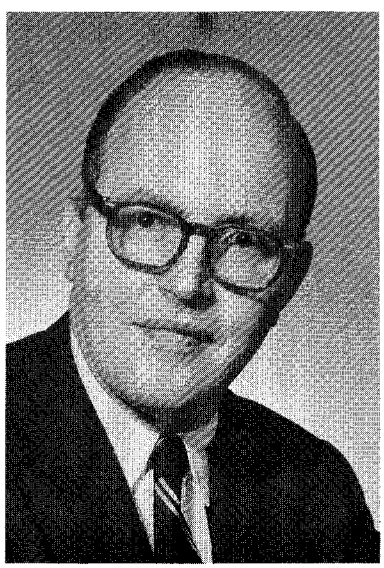

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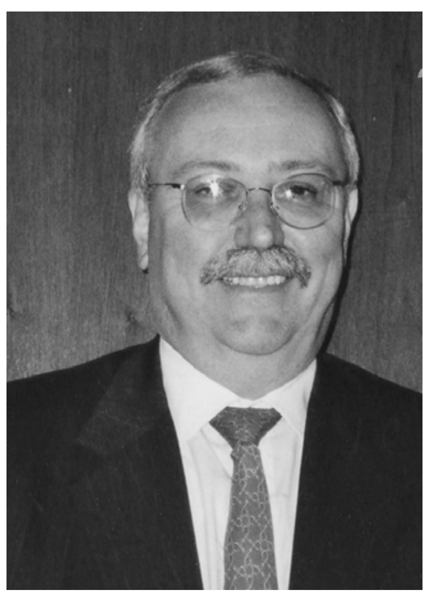

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Azle TX 75020-0807

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San Angelo TX 76904-4087

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Honorary Members

RCA by-laws state that "an honorary member (selected by a vote of The Board of Directors) shall be a person of high professional standing who is interested in the activities of the Club." It is the highest distinction given by The RCA. Altogether (1909 to present), RCA has had 28 honorary members. John V.L. Hogan, Robert H. Marriott and John Stone Stone were among the first, becoming honorary members in 1915, when RCA was but six years old. They were among founders of the Institute of Radio Engineers in 1912 and had extensive technical achievements. Hogan started a New York radio station that became WQXR. In February 1907, Stone founded a radio communications society that pre-dated the Radio Club: the Society of Wireless Telegraph Engineers. He was president of IRE in 1915.

Hogan

Marriott

Stone

The Radio Club lobbied President Calvin Coolidge to appoint Marriott as an initial commissioner of the Federal Radio Commission when it was being assembled in 1926, to begin operations in 1927. Coolidge didn't. That was back in the days when a more homogeneous membership made it easier for RCA to take positions on regulatory and legislative matters.

The Diamond Jubilee Yearbook lists 24 Honorary Members. During the past 25 years RCA has selected for honorary membership four more. The late Mildred Link, widow of RCA's perennial president — as he called himself — was made an honorary member in 1998, shortly after Fred passed away. Lorraine Poppele Flower, lived in Morristown, NJ, was elected member and honorary member in 1992, died on 20th July 2001. Walter Cronkite (now deceased), was made an honorary member in July 2007. Cronkite is best known as the anchor of the "CBS Evening News" program from 1962 to 1981 and as America's eyewitness to history. In November 2007, Andy Rooney was named an honorary member of the Radio Club of America. In that year Andy delivered the keynote speech at the Club's annual banquet. Andy is best known for essays that he presents on the CBS News program "60 Minutes," where he has worked for the past 30 years.

June P. Poppele joined the Club in 1981 and was made an honorary member the same year (her name is listed in the Diamond Jubilee Yearbook). June is a member of RCA's Executive Committee and is chairman of the Club's Good & Welfare Committee. Poppele family members have been active supporters of RCA activities for decades.

Link

Rooney

Cronkite

The Radio Club of America
List of Awards

1909-2009

The Armstrong Medal

Initiated in 1935. Bestowed by the board of directors upon any member who shall have made in the opinion of the board of directors and within the spirit of the Club, an important contribution to radio art and science.

Testimonial Scroll Establishing The Armstrong Medal

1935 - Edwin H. Armstrong

Medalists

1935 - Maj. Edwin H. Armstrong
1937 - Louis Alan Hazeltine
1938 - Harold H. Beverage, D. Sc
1940 - Greenleaf Whittier Pickard
1941 - Harry W. Houck
1945 - Carman Randolph Runyon, Jr.
1946 - Charles Stuart Ballatine
1947 - John V.L. Hogan
1950 - Ernest V. Amy
1950 - Maj. Edwin H. Armstrong
1950 - George E. Burghard
1950 - Minton Cronkhite
1950 - Paul F. Godley
1950 - John F. Grinan
1950 - Walker P. Inman
1952 - Capt. Henry J. Round
1953 - Raymond A. Heising
1956 - Melville Eastham
1959 - John H. Bose
1962 - Paul Ware
1964 - Harold A. Wheeler
1965 - Ernest V. Amy
1967 - John Bertrand Johnson
1968 - Jerry B. Minter
1969 - Francis H. Shepard, Jr.
1970 - Frank A. Gunther
1972 - Renville H. McMann, Jr.
1974 - Lewis M. Hull
1975 - Henri G. Busignies, D. Sc., Ph.D., D. Eng
1976 - Capt. William G. H. Finch
1977 - Arthur A. Collins

1978 - Murray G. Crosby
1980 - Leonard R. Kahn
1981 - Arthur V. Loughren
1983 - Edwin P. Felch
1986 - George H. Brown, Ph.D
1987 - William W. Eitel
1988 - Luther G. Schumpf
1991 - E. King Stodola
1992 - Paul M. Gruber
2003 - Morris Tischler
2007- Walter Cronkite
2007 – John S. Belrose, Ph.D

The Special Recognition Award

Initiated in 2000. Awarded by the board of directors in appreciation to individuals for their dedicated service to the Club.
2000 - Jerry B. Minter
2003 - Maurice H. Zouary
2005 - Emmett B. "Jay" Kitchen Jr.
2008 - Gilbert R. Houck
2008 – Eric D. Stoll Ph. D

The Sarnoff Citation

Initiated in 1973. Established by the board of directors to be awarded to individuals for significant contributions to the advancement of electronic communications.

1973 - Barry M. Goldwater
1974 - Jack R. Poppele
1975 - Edgar F. Johnson
1976 - Fred M. Link
1977 - William P. Lear
1978 - William W. Eitel
1979 - Donald G. Fink
1980 - Monte Cohen
1981 - Jerry S. Stover, P.E.
1982 - Julian Z. Millar
1983 - William F. Halligan, Sr.
1984 - Robert M. Akin, Jr
1985 - Dana W. Atchley, Jr
1986 - Kenneth M. Miller
1987 - William J. Weisz
1988 - Mal Gurian
1989 - William E. Endres
1990 - John D. Goeken
1991 - Lt. Gen. Walter E. Lotz, Jr.
1992 - Ake L. Lindqvist

1993 - Ben Tongue
1994 - Jack McCullough
1995 - Jai P. B'hagat
1996 - Emmett B. Kitchen, Jr.
1997 - William O. Hunt
1998 - James A. Dwyer, Esq.
1999 - Sidney Topol
2000 - Theodore S. Rappaport
2002 - William F. Baker
2004 - Hubert Schlafly, Jr.
2007 – C. Dennis Bodson
2008 – Paul E. Jacobs Ph. D
2008 – Brian Williams

The Edgar F. Johnson Pioneer Citation

Initiated in 1975. Designated by the Board of Directors to be awarded to long-time members who have contributed substantially to the success and development of the Club, or to the art of radio communications.

1975 - Richard W. Konter
1976 - Harold H. Beverage, D.Sc.
1977 - William E.D. Stokes, Jr.
1978 - Lewis M. Clement
1979 - Clair L. Farrand
1980 - Frank King
1981 - James J. Lamb
1982 - J. Keith Henney
1983 - F.X. Rettenmeyer
1984 - Harold A. Weeler
1985 - George C. Connor
1986 - O. James Morelock
1978 - Edward Sieminski
1988 - Francis H. Shepard, Jr.
1989 - Capt. W.G.H. Finch
1990 - Alexander A. McKenzie
1991 - William G. Russell
1992 - George J. Apfel
1994 - Chandos A. Rypinski
1997 - Norman L. Chalfin
1998 - John E. Balint

The President's Award

Initiated in 1974. Awarded at the discretion of the president of the Radio Club of America for unselfish dedication to support of the Club.

1974 - George W.Bailey, Pd.D
1975 - Ernest V. Amy

1978 - Joseph L. Stanley
1980 - Jack Poppele
1981 - Jerry B. Minter
1982 - Vivian A. Carr
1983 - Stuart F. Meyer
1984 - Joseph F. Walker, Sr.
1985 - Fred Shunaman
1986 - Archibald C. Doty, Jr.
1987 - Gaetano (Tom) Amoscato
1988 - David Talley
1989 - Joseph E. Sims
1990 - Joseph W. Morrisey, P.E.
1991 - Connie M. Conte
1992 - June Poppele
1993 - Don Bishop
1994 - Frank A. Gunther
1994 - Jerry B. Minter
1994 - Francis H. Shepard, Jr. *
1995 - Gilbert R. Houck
1996 - Fred M. Link
1997 - Steven L. Aldinger
1998 - Richard G. Somers
1999 - Vivian A. Carr
2001 - Mercy S. Contreras
2004 - Patrick E. Buller
2005 - Eric D. Stoll, Ph.D., P.E.
2006 - Raymond C. Trott P.E.
2008 – Ronald J. Jakubowski
2009 – Carole J. Perry
* Awarded posthumously

The Allen B. DuMont Citation

Initiated in 1979. Awarded by the Board of Directors for important contributions in the field of electronics to the science of television.

1979 - Thomas T. Goldsmith, Jr., Ph.D
1980 - P. Samuel Christaldi, Pdh.D
1981 - Horace Atwood, Jr
1982 - William Fingerle
1983 - Fred M. Link
1984 - Jack R. Poppele
1985 - John W. Morrisey
1986 - William H. Sayer
1987 - Kenneth A. Hoagland
1988 - William D. Kelly
1989 - Kenneth A. Chittick
1990 - Donald G. Fink
1991 - Loren F. Jones
1992 - William F. Bailey
1993 - Andrew F. Inglis

1994 - William E. Good, Pd. D
1995 - Renville H. McMann, Jr
1999 - William E. Endres
2003 - William E. Glenn

The Ralph Batcher Memorial Award

Initiated in 1975. Presented to a member who has assisted substantially in preserving the history of radio and electronic communications.

1976 - Morgan E. McMahon
1977 - John F. Rider
1978 - Bruce L. Kelley
1979 - Robert W. Merriman
1980 - Edward G. Raser
1981 - Ernest A. DeCoste
1982 - Louise Ramsey Moreau
1983 - Joseph R. Pavek
1984 - William A. Breniman
1985 - Donald G. Fink
1986 - Donald K. deNeuf
1987 - John D. Ryder, Ph.D
1988 - Ralph W. Muchow, D.D.S.
1989 - James E. Brittain, Ph.D
1990 - Brother J. Patrick Dowd, F.S.C.
1991 - Ralph O. Williams
1992 - Thomas S. W. Lewis, Ph.D
1993 - Hugh G.J. Aitken, Ph.D
1995 - Max C. de Henseler, Ph.D
1999 - Maurice H. Zouary
2000 - Raymond Minichiello
2006 - Ronald E. Frisbie
2008 - Jerry B. Minter
2009 - Bart Whitehouse

The Special Service Award

Initiated in 1975. Awarded at the discretion of the Board of Directors to individuals who have contributed substantially to the support and advancement of the Club.

1975 - Ernest V. Amy
1975 - William H. Offenhauser, Jr.
1976 - David Talley
1982 - Connie M. Conte
1986 - Mal Gurian
1987 - John W.Morrisey, P.E.
1988 - Jerry S. Stover, P.E.
1989 - Eric D. Stoll, Ph.D., P.E.
1990 - Jay R. Huckabee
1991 - Maurice H. Zouary
1992 - Joseph S. Rosenbloom, Esq

1993 - Raymond C. Trott, P.E
1995 - David E. Weisman, Esq
1996 - Mercy S. Contreras
1997 - Stanley Reubenstein
1998 - Maxine Carter-Lome
1999 - June Poppele
2001 - Loren R. McQueen
2002 - Karen J. Clark
2003 - Andrew A. Conte
2004 - Debra Baker Wayne
2006 - Richard J. Reichler
2009 – Richard P. Biby P.E.
2009 - Carroll L. Hollingsworth

The Henri Busignies Memorial Award

Initiated in 1981. Awarded by the Board of Directors for contributed substantially to the advancement of electronics for the benefit of mankind.

1981 - William H. Forster
1982 - James O. Weldon
1983 - David Talley
1984 - Frank P. Barnes
1985 - Jerry B. Minter
1986 - Frank A. Gunther
1987 - Renville H. McMann, Jr.
1988 - Francis T. Cassidy
1989 - Avery G. Richardson
1990 - William G. Donaldson
1991 - Raymond E. Lafferty
1992 - Stuart F. Meyer
1994 - Eric D. Stoll, Ph.D., P.E.
1997 - Leslie A. Geddes
1998 - Reed E. Fisher
2000 - Stephen M. Meer
2003 - Leonard R. Kahn

The Fred M. Link Award

Initiated in 1986. Awarded by the Board of Directors to those who have contributed substantially to the advancement and development of land mobile radio and communications.

1986 - Fred M. Link
1987 - Frank A. Gunther
1988 - Stuart F. Meyer
1989 - Mal Gurian
1990 - Raymond C. Trott, P.E.
1991 - Gaetano Amoscato
1992 - Al Gross
1993 - Jerry S. Stover, P.E.
1994 - Robert L. Mattingly

1996 - Martin Cooper
1997 - John E. Brennan
1998 - Henry B. Kreer
1999 - Roger R. Block
2000 - Manuel A. Alvarez
2001 - Peter Mailandt, Ph.D
2002 - James W. Campbell
2003 - Arthur E. McDole
2005 - William F. Lieske Sr.
2006 - Sir Angus Tait
2008 - Michael W. Hunter
2009 – Terry G. Daniels

The Alfred H. Grebe Award

Initiated in 1994. Awarded by the Board of Directors to those who have achieved outstanding quality in the design and manufacture electronic components and equipment.

1994 - Frank A. Gunther
2001 - Amar G. Bose, Sc D
2002 - Gilbert R. Houck
2005 - Jerry B. Minter
2007 – Louis J. Meyer P.E.
2009 – Larry Conlee

The Frank A. Gunther Award

Initiated in 1996. Awarded by the Board of Directors for major contributions to the advancement of military electronic communications systems.

1996 - Frank A. Gunther
1998 - Seymour Krevsky, P.E.
1999 - Thomas H. Traynor, P.E.
2001 - Paul M. Gruber
2002 - Kenneth A. Hoagland

The Jerry B. Minter Award

Initiated in 1996. Awarded by the Board of Directors for significant contributions to the electronics art through innovation in instrumentation, avionics, and electronics.

1996 - Jerry B. Minter

The Lee De Forest Award

Initiated in 1983. The award was established concurrently with the joining of the De Forest Pioneers with The Radio Club of America, and is made in memory of the many contributions of Lee De Forest, Ph.D. to the radio communication industry. Awarded by the Board of Directors to a person for significant contributions to the advancement of radio communications.

1983 - D.E. Replogle
1984 - William G. H. Finch
1985 - Austin G. Cooley
1986 - Maurice Zouary
1987 - William Storm Halstead
1988 - Fred M. Link
1989 - Fred Shunaman
1990 - Marguerite E. Warshaw
1991 - Louis Rabinowitz
1992 - Louise Ramsey Moreau
1995 - Edward Dervishian, P.E
1999 - Joe Franklin
2001 - Leslie A. Geddes, Ph.D
2006 - Sean Maloney
2008 – Joe Vestal

The Jack Poppele Broadcast Award

Initiated in 1989. Awarded by the Board of Directors for important and long-term contributions to the improvement of radio broadcasting.

1989 - Leonard R. Kahn
1990 - Robert M. Morris
1991 - Frank L. Marx
1992 - George Jacobs, P.E.
1993 - Robert L. Everett, Ph.D
1994 - Capt. John B. Knight
1995 - Carl E. Smith P.E
1997 - Charles A. Higginbotham
2000 - John R. Gambling
2003 - Skitch Henderson
2005 - Gordon B. Bishop
2008 – Barry M. Farber
2009 – George Woodard

The Barry Goldwater Amateur Radio Award

Initiated in 1994. Awarded by the Board of Directors for major contributions to the amateur radio service.

1994 - Stuart F. Meyer*
1995 - Archibald C. Doty
1996 - Carole J. Perry
1998 - Joseph J. Fairclough
2000 - Jim C. Hirchman, M.D
2006 - Anthony J.F. Clement

2009 – Ralph A. Haller
* Awarded posthumously

The RCA Centenarian Award

Initiated in 1989. Awarded by the Board of Directors to any member attaining the age of 100 years.
1989 - Hugo Cohen
2007 – Harry J. Mills

NPSTC'S Richard DeMello Award

The National Public Safety Telecommunications Council ("NPSTC") (www.npstc.org) developed this award in 2006. NPSTC plans to grant this award annually, and present it at RCA's Annual Awards Banquet, to an individual in public safety communications who has demonstrated the highest levels of personal and professional conduct and performance in the local, state and national public safety communications arena. This award was created to honor the achievement of Richard DeMello, one of the founding fathers of NPSTC and a member of The Radio Club of America. DeMello was instrumental in bringing all of the frequency coordinators together to form NPSTC.

2006 - Harlin R. McEwen
(The 2006 Award was funded by Sponsors, Richard Nowakowski, Motorola, and M/A-Com.)

2007 – John Powell
(The 2007 Award was funded by Sponsors, Geo-Comm and Motorola).

2008 - Charles Werner
The 2008 award was funded by sponsor Ericsson.)

2009 – Donald E. Root, Jr.
(The 2009 award was funded by sponsors, EADS COR^{P25} and The Jack Daniel Company ·)