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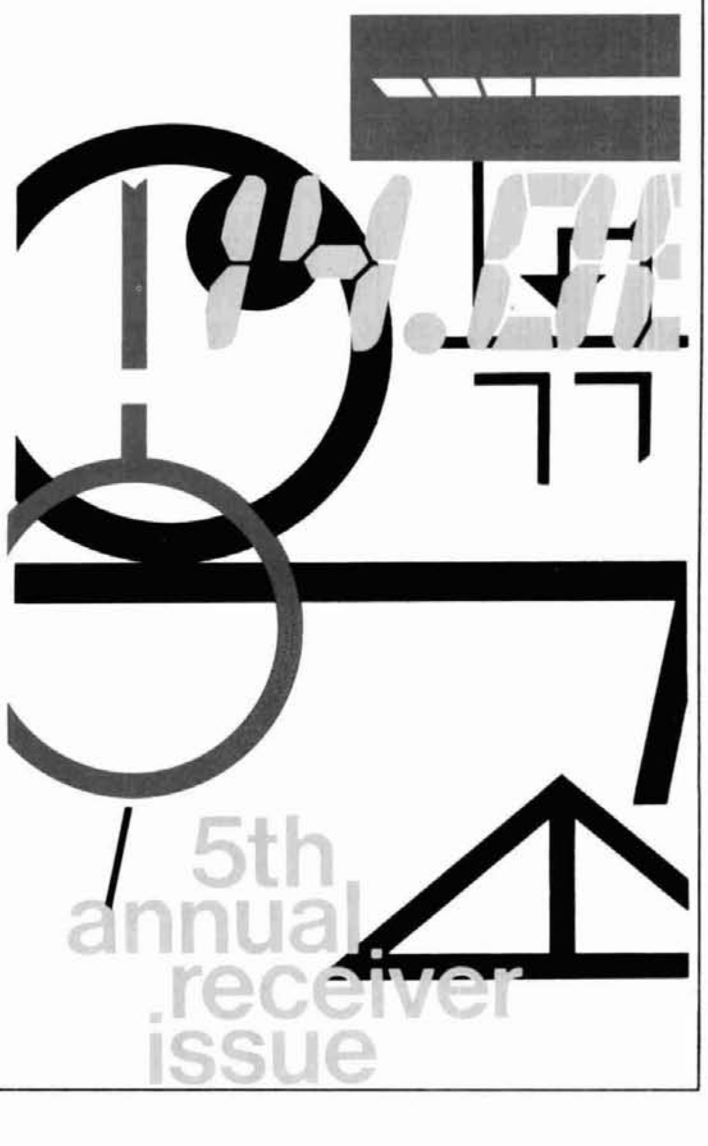
ham radio magazine

NOVEMBER 1979



TEMPO
FM Transceiver
S2

More Details? CHECK—OFF Page 118

ham radio magazine

NOVEMBER 1979

volume 12, number 11

ham radio magazine
is published monthly by
Communications Technology, Inc
Greenville, New Hampshire 03048
Telephone: 603-878-1441
Address all editorial and
advertising correspondence to
Greenville, New Hampshire 03048

subscription rates

United States: one year, $15.00
two years, $26.00; three years, $35.00

Canada and other countries (via Surface Mail)
one year, $18.00; two years, $32.00
three years, $44.00

Europe, Japan, Africa (via Air
Forwarding Service) one year, $25.00

All subscription orders payable in
United States funds, please

foreign subscription agents

Foreign subscription agents are
listed on page 99

Microfilm copies
are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles
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919 Walnut Street, 8th Floor
Philadelphia, Pennsylvania 19107

Second class postage
paid at Greenville, N.H. 03048
and at additional mailing offices
ISSN 0148-5989

**Subscription inquiries and changes of address should be directed to *ham radio* magazine, Greenville, New Hampshire 03048
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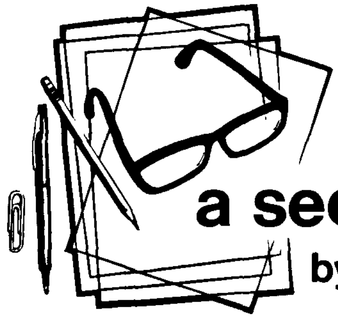


a second look

by Jim Fisk

As I was tuning around 40-meters one evening earlier this fall, I overheard a contact between two old-time Amateurs who obviously felt that Amateur Radio just isn't as exciting, inviting, and mysterious to today's youth as it had been to them when they first got started back in the 1920s and 1930s. But just as the old timer of today would like to return to the homebuilt receivers and transmitters of his youth, the old timer of 1930 probably wished to return to the days of his beloved spark transmitter and galena detector — and the old timer of 2001 will no doubt reminisce about the "good ole days of 1979." The cast of characters is different, but the basic argument never changes: "Modern technology is ruining Amateur Radio." That kind of thinking is as old fashioned and out of place as a-m on 20 meters; if anything, Amateur Radio offers more opportunities now than ever before, and the number and variety of those opportunities increases with each major advance in technology.

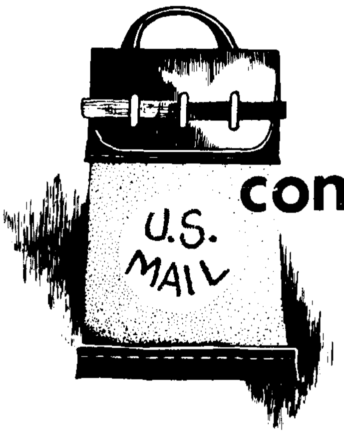
As just one example, consider the opportunities available through satellite communications. Rather than wishing for a return to the "good old days," we should appreciate the possibilities of intercontinental communications when we want it, rather than at the whim of the ionosphere. The Radio Amateur's traditional communications expertise, inquisitiveness, patience, and resourcefulness must again come to the fore in the exciting field of satellite communications.

Many old timers also worry that fewer and fewer amateurs now build their own equipment. Although the homebuilt receivers and transmitters of yesteryear have given way to vastly superior (and less expensive) commercial equipment, today's Radio Amateur is still building some of his own gear — speech processors, automatic SWR meters, digital dials, memory keyers — sophisticated accessories that weren't available ten years ago at any price!

There are even those who complain that the thrill of working DX is gone — anybody with enough money and a big antenna can work all the DX he wants. That's always been true, so I guess what they're really saying is that DX is no longer the private province of a small, select group. With the proliferation of high-performance transceivers and high-gain antennas, the competition for rare DX is probably more intensive now than ever before. If that's not challenge enough, there's always the world of QRPp, now growing by leaps and bounds as experienced kilowatt-wielders leave their high-power linears to marshal four or five watts to chase DX around the world.

Modern solid-state technology and manufacturing techniques have provided us with equipment which has fostered the Amateur spirit — perfecting the art of getting the message through in spite of conditions or power limitations. Rather than making more "appliance" operators, high quality commercial amateur equipment offers new challenges and opportunities for fun and training to help Radio Amateurs better serve the public interest. The sophisticated equipment now available also gives us all the ability, and indeed, the *responsibility*, to truly communicate with our fellow Radio Amateurs. And if that still isn't exciting, or challenging, or rewarding, or as new and vital as *today*, then I don't know what is.

Jim Fisk, W1HR
editor-in-chief



comments

biquad band-reject filter

Dear HR:

The article on the biquad bandpass filter for CW in the June, 1979, *ham radio* (page 70) is very interesting; the biquad active filter is a very versatile circuit. With little modification it can be made into a highpass, lowpass, bandpass (as in the article) or band reject (notch) filter. The latter may be of great interest to CW fans who want to try to remove interference near a rare DX signal. The only modifications needed are a 1.5k resistor from the input to the second op-amp inverting input (pin 2) a 1.5k resistor from the input to the third op-amp inverting input (pin 2) and R1 and R2 must be the same value. This gives an out-of-band gain of 1. To vary the Q of the filter, both R1 and R2 must be adjusted. Note that R3 still sets the filter's center frequency. The only problem I've noticed in this circuit is that if R3 is too low, the circuit will oscillate.

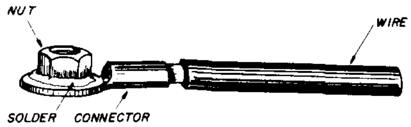
The depth of the notch depends upon how well resistors R1 and R2 and the 1.5k resistors are matched. There is probably no point in being too fussy about this since most audio amplifiers generate some harmonic distortion, so no matter how deep the notch is, some of the harmonics will still come through. Using 10 per cent resistors for R1 and R2 I routinely get rejection notches of about 25 dB; 3 dB bandwidths can be less than 50 Hz.

Dwight Sipler, KB3EH
Pittsburgh, Pennsylvania

electronic paddle

Dear HR:

The "Simple Paddle for Electronic Keyers" in April, 1978, *ham radio* proved to be a very timely article. One small point may help someone else building the paddle. It was a little



difficult starting the nut on the screw inside the plug shell. However, if you solder the nut on a spade lug, the job becomes a snap.

Edward Chromczak, WB2MGY
Somerset, New Jersey

anodizing aluminum

Dear HR:

The article on anodizing aluminum in the January, 1979, issue offers some interesting material. It also proffers some remarks which I feel need some clarification. The statement is made early in the article that the natural surface of aluminum breaks down, causing it to be unsuitable for applications where a long-term, stable surface is needed.

In contrast to this, let me quote a statement by the American Society for Metals:* "Aluminum, a member of Group III of the periodic table, is stable in air because of the presence of an extremely thin, but remarkably tight and adherent, transparent oxide film. Growth of this natural oxide film on aluminum is self-limiting." The two points of view seem to be widely divergent, to say the least.

Other statements in the article refer to ". . . an otherwise easily corrodible metal." Now, all metals are corrodible; in fact, stainless steel depends on a somewhat similar oxide film mechanism to achieve its corrosion resistance. Look around and you'll see bare aluminum performing in such long-term applications as electric transmission lines, culverts, and many others. In most instances the metal chosen for these applications was aluminum because of its ability to resist corrosion.

The photo on page 64 has a caption which speaks of ". . . a carbon speck or other alloying constituent." Granted that the cause of such an anomaly is difficult to ascertain since only the void exists, usually at the time of discovery. But a carbon-alloying constituent it is not. Over seventy-five commercial alloys are presently available in the United States, and carbon is not recognized as an alloying agent in one of them.

On page 66, the author says: "The cathode must be constructed of lead." Cathode materials may be of aluminum, stainless steel, or lead. Some precautions must be considered in the way of cathode placement, but there's a choice of materials to use.

Furthermore, I could not reconcile the current density quoted with that employed by commercial anodizers in this country. Most H_2SO_4 (sulfuric acid) anodizing in the U.S. is done at 12 amperes per square foot. Small pieces may be calculated at 0.0833 amperes per square inch but in either case keep in mind that both sides of the piece are treated at the same time. Thus one square foot of sheet metal will represent two square feet of anodizing surface when calculating current density.

Even thickness should be considered, since it's easy to see that a panel 6 × 12 × 1/16 inch thick will have 2.25 square inches of surface area exposed to the bath along the edges alone. Total surface area then is

$$2(L \times W) + t(2L + 2W)$$

(Continued on page 81)

**Aluminum*, volume 1, page 22, American Society for Metals.

KENWOOD ...pacesetter in amateur radio

...for the discerning Amateur who demands quality.

TR-7600

TR-7625

The TR-7600 and TR-7625 are Kenwood's popular synthesized 2-meter FM mobile transceivers. Combined with the RM-76 Microprocessor Control Unit, several memory and scanning capabilities are provided.

TR-7600/TR-7625 FEATURES:

- One memory channel.
- Mode switch for simplex or repeater operation. Repeater mode shifts the transmit frequency + 600 kHz or − 600 kHz or to the memory frequency.
- Full 5-kHz coverage from 144.000 to 147.995 MHz.
- Adaptable to any one MARS simplex or repeater channel between 143.7 and 148.3 (with modification kit).

RM-76

ADDED FEATURES WITH RM-76:

- Six memories.
- Automatic memory scan.
- Automatic scan up the band in 5-kHz steps, with selectable upper and lower frequency limits.
- Manual scan up or down the band in single or fast continuous 5-kHz steps.
- ± 1 MHz transmitter offset as well as ± 600 kHz and memory offset for repeater operation.
- MARS operation on 143.95 MHz simplex.
- Versatile digital display of transmit and receive frequencies, and operating functions.

KPS-7

The KPS-7 is a matching AC power supply for the TR-7600 and TR-7625. Output is 13.8 VDC at 7 A ICS (50% duty cycle).

TR-2400

The TR-2400 synthesized 2-meter hand-held transceiver features a large LCD frequency readout, 10 memories, scanning, and much more.

TR-2400 FEATURES:

- Large, illuminated LCD digital frequency readout. Readable in direct sunlight, and a lamp switch makes it readable in the dark. Shows receive and transmit frequencies and memory channels, and indicates "ON AIR", memory recall, battery status, and lamp switch on.
- 10 memories, with battery backup.
  - Automatic memory scan, for "busy" or "open" channels.
  - Mode switch for simplex, ± 600 kHz transmit repeater offset, and memory-frequency ("M.O") transmit repeater offset.
  - REVERSE momentary switch.
  - Built-in 16-button Touch-Tone generator.
  - Keyboard selection of 5-kHz channels from 144.00 to 147.995 MHz.
- Up/down manual scan and repeater or simplex operation from 143.900 to 148.495 MHz in single or fast continuous 5-kHz steps.
- Two lock switches to prevent accidental frequency change and accidental transmission.
- Subtone switch (subtone module not Kenwood supplied).
- More than 1.5 W RF output.
- High-impact plastic case and zinc die-cast frame.
- BNC antenna connector.
- Standard accessories included with the TR-2400 are a flexible rubberized antenna with BNC connector, ni-cad battery pack, and AC charger.

ST-1

OPTIONAL ACCESSORIES:

- Attractive leather case.
- Model ST-1 base stand, which provides 1.5-hour quick charge, trickle charge, and base-station operation with microphone connector and impedance-conversion circuit for using MC-30S microphone.
- Model BC-5 DC quick charger.

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A DEADLOCK ON CONFERENCE CHAIRMAN selection marred the opening of the World Administrative Radio Conference September 24th; the conflict was between the nonaligned and developed nations, with some opinion that the orchestration was developed at the nonaligned summit meeting in Havana. A compromise chairman from Argentina was finally selected on the 27th, putting the conference almost a week behind schedule. If the opening deadlock is any indication, WARC 79 could be an extremely difficult, drawn-out, and frustrating exercise.

Amateur Radio's Outlook from the WARC isn't too promising, according to an A.D. Little study just completed for the Senate Committee on Science, Commerce, and Transportation. Proposed increases in Amateur HF allocations will probably be defeated, Little said, because of low demand for new frequencies outside the United States and the desire to protect fixed services already in the desired slots. Though Canada, Japan, the United Kingdom, Brazil, India, plus possibly some of Western Europe should support an increase, most of the rest of the world will not.

3.5-3.9 MHz Also Has Problems, with the U.S. proposal to increase the Amateur exclusive allocation opposed by some Region 2 neighbors as well as the rest of the world.

New 10, 18, 25 MHz Amateur bands don't appear to have enough support to be sustained, either. Despite firm support from New Zealand, Australia, and Japan, opposition from most of the rest of the world will prevail.

Exclusive 7.10-7.25 MHz Amateur allocations in Regions 1 and 3 as well as Region 2 are a distinct possibility. A close vote is expected, with both developing nations and the free world supporting the argument for non-interference and standardization. Opposition is expected from the USSR and her satellites, much of Western Europe, and China.

No Other Amateur Radio problem areas were cited in the report, indicating that the 14, 21, and 28 MHz HF bands as well as the VHF/UHF spectrum do not appear seriously threatened.

DESIGN OF THE AMSAT PHASE III SATELLITE'S two-meter omnidirectional antenna is complete and the patterns have been run. The wiring harness which interconnects the modules in the spacecraft has been installed in the spacecraft structure. The flight connectors are now being assembled onto the harness. The auxiliary battery unit is complete, and the Integrated Housekeeping Unit (IHU) computer design has been debugged and completed.

The Russians May Launch one or two new Amateur Radio satellites before the end of the year, with transmitting downlink frequencies between 29.3 and 29.5 MHz, according to unsubstantiated reports reaching AMSAT. No real verification is available, and so we'll simply have to wait to see what happens.

THE "IONOSPHERIC HOLE" had a relatively minor and short-lived effect on HF propagation, according to a review of the more than 100 reports already received from participating Amateurs. The giant Atlas Centaur rocket went up at 0528Z September 20th, and its launch had no apparent effect on the signals from either the 3.6- or 7.1-MHz beacons. The 14.1-MHz signal dipped several dB for most observers, starting just after launch, and some also noted rapid flutter just after the exhaust-induced disturbance began. Unfortunately, an equipment failure took the 14.1 beacon off the air from 0536 to 0542, but no other beacon problems occurred and all stayed on until dawn.

The 21.2-MHz Beacon signal also showed a noticeable drop to observers monitoring that frequency. At press time there had been no reports on 28 MHz, but one northerly observer reports hearing the 50.1-MHz beacon, weak and watery, for two short periods between 0536 and 0538 — coincidental with the final rocket burn. All propagation effects seem to have ended by 0550Z, 22 minutes after launch.

Analysis Of The Report sheets by Boston and Stanford Universities and the USAF Geophysical Laboratory should be a lengthy process, but a detailed report will be forthcoming.

KILLER HURRICANE DAVID emphatically proved Amateur Radio's value for disaster service, as the slow-moving but violent storm trailed death and destruction through the Caribbean islands into the southeastern U.S. Active nets on 80 through 15 meters handled a wide range of traffic as David made its way west and north, leaving many communities and some entire islands devastated and cut off from the world.

The One Negative Note in an otherwise outstanding Amateur Radio performance was the too frequent presence of jammers, including several "carrier throwers," the usual too-vocal critics, at least one apparent drunk, and — unbelievably — a station in the mid-central U.S. who actually retransmitted music several times! Fortunately the net was able to function reasonably well despite these irrational activities, but it would be nice, as one net operator suggested, if each of these misguided souls were given the opportunity to observe the next major hurricane while sitting on a small Caribbean island with only a low-power 20-meter transceiver for company!

THE NATIONAL TELECOMMUNICATIONS CONFERENCE, sponsored by the IEEE, will be held on November 27th, at the Shoreham Americana Hotel in Washington, D.C. Guest speaker will be Ulrich Rohde, DJ2LR, discussing "Recent Developments in Shortwave Communications Receiver Circuits."

The following are excerpts from unsolicited letters and registration cards received from owners of the new TEN-TEC OMNI transceiver.

"I sold a Yaesu to buy this and am very impressed" —WB5ULA

"My first QSO with OMNI-A was LA1SV on CW and second was EA8SK on SSB." —N2CC

"Excellent rig, just as advertised." —WB5TMD

"Very pleased with performance. QSK feature very slick." —WB0ELM

"This is my 5th TEN-TEC transceiver in less than 2 years. I loved them all and still have 3." —WB0VCA

"Through the years I have had complete Drake and Collins stations. I tried a 544 Digital and liked it the best so decided to purchase the 546 OMNI-D Digital." —WA4NFM

"Your OMNI is the best rig I have had in 20 years of haming." —K4IHI

"As a owner of Collins rig, your OMNI-D is the best." —K9JJL

"I already have an OMNI-A, 544 and a TRITON IV. You may ask why I own so many TEN-TEC rigs. In case there is a great RF famine, I want to be ready!" —WD4HCS

"You guys really know how to turn on an old timer!" —K8ELS

"Best operating & most conveniences of any transceiver I've ever used." —W6LZI

"I like CW. Compared OMNI against IC701 (rcvr) and OMNI won hands down. XYL WD6GSB really enjoys rig on SSB. Finds rig is very stable and digital readout accurate." —AC6B

"Have checked it out on both modes from "top band" (160) all the way to 29 MHz. Terrific!!!!" —W4DN

"Works well, parts layout and design much better for any possible servicing than other ham gear. The Japanese hybrid sets can't compare to TEN-TEC for audio. Audio reports excellent without special speech processors, etc., to distort the signal." —AG8K

"I have been using the S-Line over 15 yrs and never thought anything could outperform it. I got the biggest surprise and THRILLED with this OMNI-D even though I have been a ham since 1936." —KV4GD

"This must be the greatest. I've spent enough money on final tubes to almost pay for this." —KA4BIH

"This transceiver was recommended to me by old time hams (Xtras) whom I have known for 40 yrs. Has excellent break-in." —N6AVQ

"Best package job I've ever seen! First licensed 6AAV in 1926. Now in operation—a sweetheart!" —W7LUP

"From a 32V2/SX115 to an OMNI is a big step!" —K6YD

"Receiver prominent—transmitter likewise—working comfortable—pleasing design." —OE1FAA

"First new rig for me in 10 years but seems to be very good." —W5GBY

"The best transceiver I ever used or owned." —W3TS

"I wouldn't swap my OMNI for anything on the market, regardless of price." —WD0HTE

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All solid-state; 160-10 meters; Broadband design; Standard 8-Pole 2.4 kHz Crystal Ladder I-F Filter + Optional 1.8 kHz SSB Filter & 0.5 kHz 8-Pole CW Filter; 3-Bandwidth Active Audio Filter; Choice of readout — OMNI-A (analog dial), OMNI-D (digital); **Built-in VOX and PTT, Selectable Break-in, Dual-Range Receiver Offset Tuning, Wide Overload Capabilities, Phone Patch Interface Jacks; Adjustable ALC; Adjustable Sidetone; Exceptional Sensitivity; 200 Watts INPUT; 100% Duty Cycle, Front Panel Microphone and Key Jacks; Zero-Beat Switch; "S"/SWR Meter; Dual Speakers; Plug-In Circuit Boards; Complete Shielding; Easier-to-use size:** 5¾"h x 14¼"w x 14"d; **Full Options:** Model 645 Keyer $85; Model 243 Remote VFO $139; Model 252MO matching AC power supply $139; Model 248 Noise Blanker $49; Model 217 500 Hz 8-Pole Crystal Ladder CW Filter $55; Model 218 1.8 kHz 8-Pole Crystal Ladder SSB Filter $55.

Model 545 Series B OMNI-A . . . $949
Model 546 Series B OMNI-D . . . $1119

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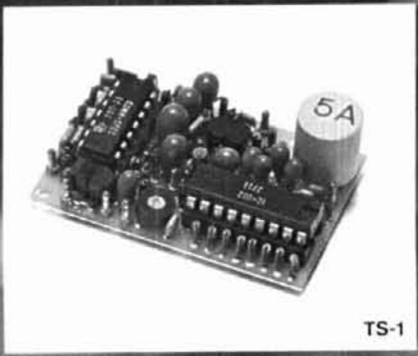
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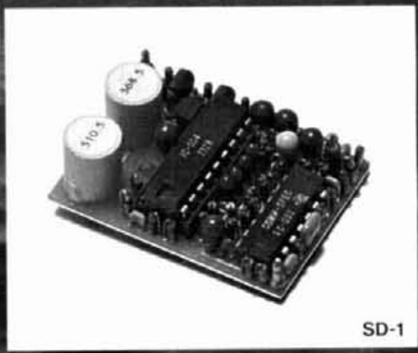
TS-1JR


PE-2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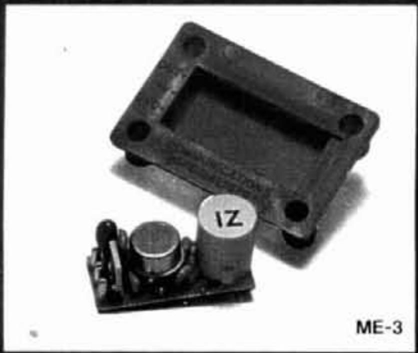
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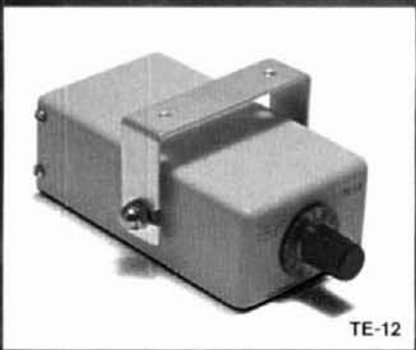
TE-8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TS-1JR Sub-Audible Encoder-Decoder • Microminiature version of the TS-1 measuring just 1.0" x 1.25" x .65", for hand-held units • **$79.95** complete with K-1 element.

ME-3 Sub-Audible Encoder • Microminiature in size, measures .45" x 1.1" x .6" • Instant start-up • **$29.95** complete with K-1 element.

TE-8 Eight-Tone Sub-Audible Encoder • Measures 2.6" x 2.0" x .7" • Frequency selection made by either a pull to ground or to supply • **$69.95** with 8 K-1 elements.

PE-2 Two-Tone Sequential Encoder for paging • Two call unit • Measures 1.25" x 2.0" x .65" • **$49.95** with 2 K-2 elements.

SD-1 Two-Tone Sequential Decoder • Frequency range is 268.5 - 2109.4 Hz • Measures 1.2" x 1.67" x .65" • Momentary output for horn relay, latched output for call light and receiver muting built-in • **$59.95** with 2 K-2 elements.

TE-12 Twelve-Tone Sub-Audible or Burst-Tone Encoder • Frequency range is 67.0 - 263.0 Hz sub-audible or 1650 - 4200 Hz burst-tone • Measures 4.25" x 2.5" x 1.5" • **$79.95** with 12 K-1 elements.

ST-1 Burst-Tone Encoder • Measures .95" x .5" x .5" plus K-1 measurements • Frequency range is 1650 - 4200 Hz • **$29.95** with K-1 element.

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how to design broadband jfet amplifiers

to provide top performance from VLF to over 100 MHz

A discussion of broadband jfet amplifier design, with special emphasis on IMD performance and matching

Broadband rf amplifiers are becoming increasingly useful in hf/vhf receiving applications. A modern wideband upconverting high-frequency receiver, for example, often employs a broadband rf amplifier as the first active stage. The rf stage improves the receiver noise figure and reduces undesirable LO-to-antenna conduction. Broadband amplifiers are also useful in a wide variety of other Amateur applications ranging from antenna preamplifiers to home-constructed test equipment. This article deals with some of the considerations involved in the design and construction of broadband jfet rf amplifiers. The circuits presented can be easily duplicated with readily obtainable components.

Other than to provide selectivity, a broadband rf amplifier must do everything that a narrowband amplifier does. Thus gain, noise figure, stability, and most other parameters must be comparable. There is, however, a major additional requirement. Since the broadband amplifier responds to signals over a very wide bandwidth, it is important that the amplifier have exceptionally high resistance to overload and intermodulation distortion (IMD).

With respect to overload, there are potentially many more signals over the larger bandwidth (in comparison with a narrowband amplifier) that might drive the amplifier into its gain compression (overload) region. With respect to IMD, there are many more combinations of frequencies at which these strong signals can cause the amplifier to produce intermodulation products that could interfere with

By **Alex Burwasser, N6DC,** 5022 Artesian Street, San Diego, California 92117

signals we are trying to receive. The intermodulation problem is compounded by the fact that unlike the narrowband amplifier, which is vulnerable only to odd-order IMD, both odd- and even-order IMD can produce interfering intermodulation products in the broadband amplifier. The narrowband amplifier is relatively immune to second-order IMD because its bandwidth is much less than an octave. Within this sub-octave bandwidth, there is no combination of frequencies at which in-band signals can produce second-order intermodulation products that also fall in-band (that is, second-order intermodulation products that are capable of interfering with in-band signals we might be trying to receive).[1,2]

Thus, in broadband receivers, it is very important to employ rf amplifiers that have extremely high resistance to both odd- and even-order IMD. These same considerations also apply to mixers.

broadband jfet amplifier

When considering an active device to be employed as a broadband amplifier, you must look for certain qualities. High transconductance is desirable. Input, output, and feedback capacitances should be low. The device should exhibit good noise performance and high signal handling capability.

High-quality jfets satisfy all of these requirements (with the exception of low feedback capacitance)

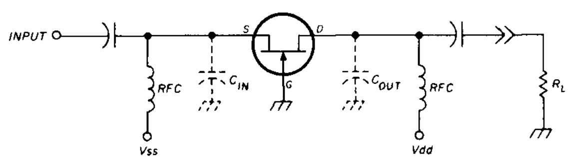

fig. 1. Schematic diagram of the simplified grounded-gate jfet amplifier.

reasonably well. By operating a jfet in the grounded-gate configuration, you can effectively reduce its otherwise high feedback capacitance to a very low level. Earlier, I mentioned that one of the desirable features of rf amplifiers in receivers is reverse isolation, or more specifically, the amplifier's ability to attenuate LO energy from the mixer to the antenna. The grounded-gate/base/grid configuration yields the best reverse isolation of any of the three possible amplifier configurations.

A simplified circuit of a grounded-gate jfet amplifier is shown in **fig. 1**. You can gain some insight into the operation of this circuit by applying some fundamental (and somewhat simplified) relationships. A more general and rigorous presentation of these relationships may be found in reference 3. The first relationship defines the input impedance of the amplifier. Disregarding the imaginary (reactive) component, the approximate input impedance is given by the expression:

$$R_{in} \approx \frac{1}{G_m} \qquad (1)$$

where R_{in} is the real component of the input impedance and G_m is the device transconductance. A grounded-gate jfet with a transconductance of 10,000 micromhos, for example, would have an approximate input impedance of 100 ohms.

The second relationship defines the voltage gain of the amplifier. This relationship is:

$$A_v \approx G_m \times R_L \qquad (2)$$

where A_v is the voltage gain

G_m is the device transconductance

R_L is the load resistance

Rearranging **eq. 1** to solve for G_m produces:

$$G_M \approx \frac{1}{R_{in}} \qquad (3)$$

and substituting this expression of G_m into **eq. 2** produces:

$$A_v \approx \frac{R_L}{R_{in}} \qquad (4)$$

That is, the approximate voltage gain is simply the ratio of the load resistance to the device input impedance.

Referring back to **fig. 1**, observe that the driving source, the jfet, and the load are all in series. Disregarding the input and output capacitances for the moment, it is evident then that the current gain, A_i, of this amplifier must be equal to unity because the current in a series circuit is everywhere the same. Power gain, A_p, is given by the expression

$$A_p = A_v \times A_i \qquad (5)$$

Since A_i equals unity in a grounded-gate jfet amplifier, then

$$A_p = A_v \qquad (6)$$

In other words, the power gain equals the voltage gain.

It would seem then that to obtain high power gain out of this amplifier, all that is necessary is to make R_L large. This is true up to a point, but even if you disregard the inherent output conductance of the jfet (which could be represented as an equivalent conductance from the drain to the source), you would find that C_{out} (the jfet output capacitance) would limit the output impedance and device gain at high frequencies. Assuming a constant transconductance over the frequency range of interest, and disregarding C_{in},

$$f_{3dB} \approx \frac{1}{2\pi R_L C_{out}} \quad (7)$$

where f_{3dB} is the high-end frequency at which the amplifier gain is 3 dB down from its low frequency value.

To obtain the widest bandwidth, then, **eq. 7** indicates that you should employ a jfet with a very low output capacitance driving a low value of R_L. You can arbitrarily select a low value for R_L, but to maintain high power gain, **eq. 4** says that you will need a low value of R_{in} (the jfet input impedance). However, since $R_{in} = 1/G_m$ from **eq. 1**, this is actually just another way of saying that you need a jfet with high transconductance.

Given the above, it is evident that a useful figure of merit for a jfet in broadband operation is the ratio of device transconductance to output capacitance. A jfet with an exceptionally high transconductance to output capacitance ratio is the Siliconix U310.[4]

U310s are rather expensive, but a plastic economy version (the J310) is also available with performance characteristics that are substantially the same. The J310 is manufactured by Siliconix and National Semiconductor. Siliconix also offers a matched pair of J310-type jfets in an epoxy package. This device is the E430.

By the time this article is published, the E430, in all probability will have been phased out in favor of the U430. The U430 will employ the same chip geometry as the E430, but will use an 8-pin metal package similar to the TO-5 package.

The J310 is described in the *Siliconix FET Data Book*[5] as a low-noise, wide-dynamic-range device capable of high power gain at frequencies up to at least 450 MHz. The typical transconductance is listed at 12,000 micromhos at a drain current of 10 mA. The amplifiers presented in this article employ J310s and E430s.

The input impedance of a J310 or E430 grounded-gate amplifier can be made close enough to 50 ohms so that a reasonable input VSWR can be achieved without any matching network. The signal can simply be capacitively coupled to the jfet source. The disadvantage of this convenient technique is that the input impedance may not be optimum for best noise figure.

As previously mentioned, the load impedance (R_L) must be high compared with the jfet input impedance to obtain high power gain. Since the required value of R_L is much higher than the assumed 50-ohm load the amplifier is ultimately driving, broadband autotransformers can be employed to convert the 50-ohm load impedance to the higher level of R_L required to achieve reasonable gain in the jfet amplifier. Fifty ohms is selected as the desired ultimate load impedance since this is the nominal impedance level of most broadband mixers that might follow the amplifier.

jfet biasing

In biasing a jfet, there are three general requirements. The first is that the jfet maintain the desired bias current level over the anticipated temperature range. The second requirement is that the biasing circuit should not be device-sensitive. That is, if you design an amplifier employing a J310 biased at 18 mA of drain current, this drain current should be close to 18 mA for *any* J310. The third requirement is that the bias current should be insensitive to changes in supply voltages.

The first requirement is not too difficult to meet. Even with a poor biasing circuit, the bias current will remain fairly constant over a reasonably wide temperature range.

The second requirement can be relaxed somewhat where repeatability isn't so important. Since Amateur home projects are usually built in very small quantities, there is no particular problem with using pot or selecting resistors to achieve the desired bias current (especially if doing so permits the use of simpler circuitry or reduces power consumption).

The third requirement is also easy to meet. If the jfet is operated from a single supply voltage (V_{dd}), the inherent constant-current characteristics of the jfet will automatically stabilize the bias current, provided that the drain-to-source voltage is at least 6 volts or so (depending upon the particular jfet). If the jfet is supplied by both positive and negative voltages (V_{dd} and V_{ss}, respectively), the bias current may be somewhat sensitive to changes in V_{ss}. However, the situations where dual supply voltages are available will also be the situations where these supplies are *most likely to be regulated.*

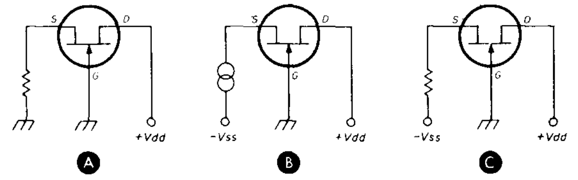

fig. 2. Diagrams of the three jfet biasing configurations with only the relevant dc circuitry shown. Schematic (A) shows the simplest, and poorest, configuration. The circuit is very device-sensitive, in that it is necessary to select the bias resistor for the desired current. Diagram (B) illustrates the use of a constant-current source to bias the jfet. The best overall compromise is shown in (C), where a negative voltage and large-value resistor act as a pseudo constant-current source.

Fig. 2 illustrates three commonly used jfet biasing circuits. For simplicity, only the relevant dc circuitry is shown. **Fig. 2A** shows the most commonly used (and poorest) jfet biasing configuration. Although its performance over a temperature range is adequate in most cases, it tends to be very device-sensitive. It is therefore necessary to select the resistor (or make it variable) to secure the desired bias current. On the plus side, overall power consumption is lower than that of the other two configurations and no negative supply is required. In **fig. 2B**, the jfet is biased by a constant-current source. If the constant-current source (usually a bipolar transistor with a temperature compensating diode) is temperature stable, this biasing scheme is nearly impervious to temperature, device, and supply voltage variations, and is thus an excellent biasing configuration.

A compromise configuration is shown in **fig. 2C**. This circuit is very similar to that of **fig. 2A** except that the resistor is larger and is returned to a negative supply. The negative voltage and large resistance act as a pseudo constant-current source. The larger value of the resistor and the magnitude of V_{SS}, the closer this biasing circuit comes to approximating a true constant-current source. If the negative voltage supply is available, this circuit offers the best performance for the number of components required. Temperature stability is very good, and the circuit is reasonably insensitive to device variations. As a brute-force test, this circuit was constructed with a J310 biased at a nominal current level of 18 mA using ± 12 volt supplies. Ten different J310s were tried in the circuit. The measured bias currents were all well within a 10 per cent window. Heating the devices for 10 seconds by applying a 25-watt soldering iron of less than 10 per cent. Similarly, chilling the devices with an aerosol spray coolant for a period of 10 seconds also resulted in a bias current change of less than 10 per cent.

Although the amplifiers described in this article all employ the biasing configuration of **fig. 2C**, substanany of these bias configurations. More detailed information on the subject of jfet biasing can be found in reference (3).

basic jfet broadband amplifier

Fig. 3A shows a simple broadband amplifier. Although this circuit is presented primarily for purposes of illustration, it nonetheless has many practical applications. The circuit is a grounded-gate jfet amplifier employing a single J310 biased at 18 mA of drain current. The output employs a peaking inductor and a 4:1 bifilardwound auto-transformer (detailed winding information is presented later in this arti-

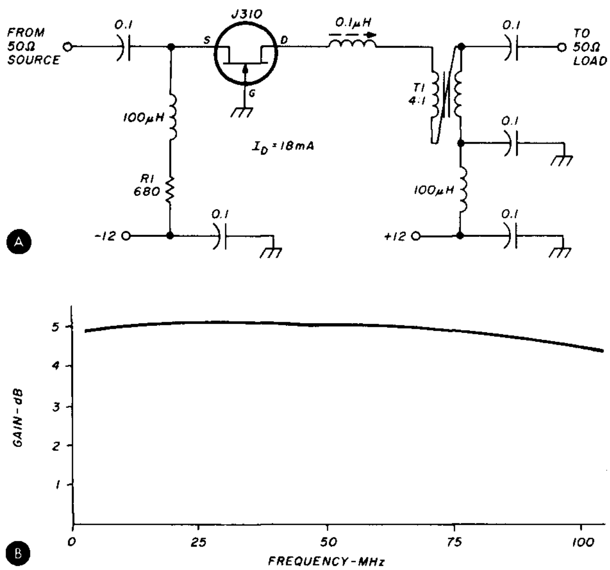

fig. 3. Schematic diagram of the basic broadband jfet amplifier. R1 sets I_D at 18 mA. (B) shows the frequency response of this basic amplifier.

cle). The peaking inductor extends the frequency response. **Fig. 3B** shows the frequency response when L_1 is set for optimum gain flatness with respect to frequency. The setting of L_1 is not particularly critical, although it does substantially affect the high-end frequency response. Other performance characteristics are as follows:

1 dB gain compression level	+ 13 dBm
2nd-order intercept point	+ 28 dBm
3rd-order intercept point	+ 22 dBm
30-MHz noise figure	4.5 dB
input VSWR	1.3:1 from 1.8-100 MHz
reverse isolation	38 dB or better to 30 MHz; 25 dB or better to 200 MHz

The intermodulation and overload specifications for all amplifiers presented in this article are referenced to the amplifier input. The + 13 dBm specification for the 1 dB gain compression level, for example, is the *input* (rather than output) level at which 1 dB of gain compression occurs. When evaluating the intermodulation and overload performance of a device, it's very important to know whether the specifications are referenced to the input or output. Unfortunately, many manufacturers specify their devices without providing information as to whether the specification ferred method is to reference the specification to the input.

The output referenced specification is simply the input referenced specification plus the device gain. For example, an amplifier having an input referenced 3rd-order intercept point of + 20 dBm and a gain of 10 dB has an output referenced 3rd-order intercept point of + 30 dBm.

Some clarification is in order concerning this amplifier. First, the good input VSWR trades off against optimum noise figure. With a 1:1 input VSWR you would have "power match" and best amplifier gain. However, the noise figure in this case could be no better than 3 dB. "Noise match" (optimum drive source impedance for best noise figure) occurs when the driving impedance is considerably higher than the amplifier input impedance. The second point is that although you can specify a 50-ohm output load, the actual output impedance of this amplifier is much higher than 50 ohms (the jfet output is essentially a high-impedance current source). This fact is very important if a filter must follow the amplifier. Where low output VSWR is important, refer to the circuits of **fig. 6** or **7**. All the other circuits in this article have a high output impedance. Finally, the gain of this amplifier is load-sensitive; that is, if the actual value of R_L is greater than 50 ohms, amplifier gain will be higher. Load impedances other than 50 ohms will also require that the value of L_1 be changed for flattest frequency response. If the amplifier is to be used only below 30 MHz, however, L_1 may be omitted entirely. Amplifier gain may vary somewhat depending upon the characteristics of the particular J310 employed. If a negative supply is not available, return R_1 to ground (instead of − 12 volts) and select (or adjust) R_1's value for 18 mA of drain current.

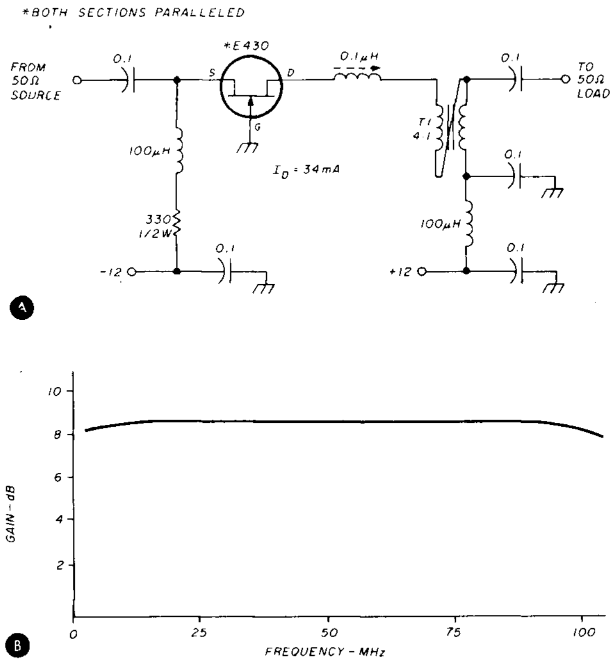

fig. 4. Diagram of the improved broadband jfet amplifier with improved gain, lower noise figure, and better IMD performance. The higher transconductance from the paralleled fets results in a higher gain and better input noise match. Graph (B) shows the overall frequency response of this improved amplifier.

improved jfet broadband amplifier

The amplifier shown in **fig. 4A** is very similar to the one just described, but with higher gain, a lower noise figure, and superior IMD performance. **Fig. 4B** shows typical amplifier gain as a function of frequency. Other performance characteristics are as follows:

1 dB gain compression level	+ 14 dBm
2nd-order intercept point	+ 38 dBm
3rd-order intercept point	+ 29 dBm
30-MHz noise figure	<2.5 dB
input VSWR	1.8:1 from 1.8-200 MHz
reverse isolation	36 dB or better to 30 MHz
	30 dB or better to 175 MHz

This amplifier employs the E430 dual jfet as the active device, with individual sections connected directly in parallel (source 1 tied to source 2, gate 1 tied to gate 2, and drain 1 tied to drain 2) to achieve an equivalent ultra-high transconductance jfet. The higher transconductance (≈36,000 micromhos) accounts for the higher gain of this amplifier as compared with that of **fig. 3**. This higher conductance also causes the input impedance to drop to approximately 28 ohms, which accounts for the 1.8:1 input VSWR. Although you no longer have an optimum input power match you're now much closer to an optimum input noise match, which accounts for the improved noise figure. As far as improved IMD performance is concerned, the easiest way to rationalize

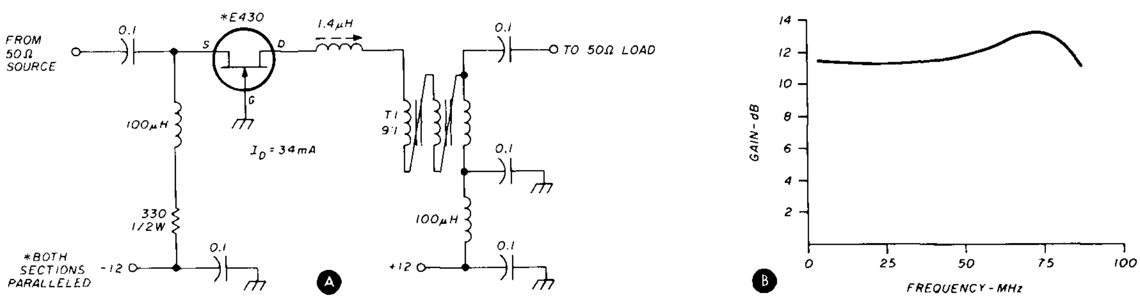

fig. 5. Schematic of a jfet amplifier which exhibits approximately 12 dB gain, though with a narrower bandwidth. In this case, the bandwidth has been sacrificed to produce the higher gain. A plot of the gain vs frequency is shown in (B).

that is to simply say that two devices are carrying the load instead of just one (keeping in mind that you now effectively have two J310s in parallel).

The same considerations with regard to load sensitivity, device variations, and output VSWR are equally applicable to this amplifier as to the one in **fig. 3**. Again, for operation below 30 MHz, peaking inductor L_1 may be omitted. Since the E430 gets quite warm with 34 mA of drain current, it would probably be a good idea to use a heatsink. T_1 is the same 4:1 bifilar-wound transformer as the one shown in **fig. 3**.

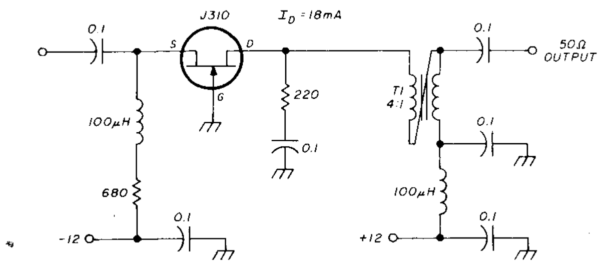

fig. 6. Schematic of a broadband 50-ohm driver where the output impedance is set to 50 ohms. In this case, the 220-ohm resistor loads the collector, leading to the 50-ohm output through the transformer. Gain in this example is approximately unity.

higher-gain jfet broadband amplifier

From **eq. 4**, you know that amplifier gain can be increased by raising the effective drain load impedance as seen by the jfet. Therefore, if you replace the 4:1 autotransformer of **fig. 4A** with a 9:1 autotransformer, gain should increase. **Eq. 7**, however, tells you that this will also decrease the bandwidth. Since the amplifier of **fig. 4A** has a bandwidth in excess of 100 MHz, you probably can trade off some of this bandwidth for higher gain in many applications. **Fig. 5A** shows the circuit for such an amplifier. **Fig. 5B** shows the gain as a function of frequency. As predicted, gain has increased at the expense of bandwidth. Other performance characteristics are as follows:

1 dB gain compression level	+10 dBm
2nd-order intercept point	+36 dBm
3rd-order intercept point	+24 dBm
30-MHz noise figure	<2.5 dB
input VSWR	1.6:1 from 1.8-100 MHz
reverse isolation	34 dB or better to 100 MHz

Winding details of the 9:1 autotransformer are presented later in this article. L1 cannot be omitted from this circuit for high-frequency operation unless substantial gain roll off (2-3 dB at 30 MHz) can be tolerated.

jfet broadband drivers

There may be occasions where a better-defined amplifier output impedance is required. **Fig. 6** illustrates a broadband driver circuit designed to present nominal 50-ohm impedances to both the source and load. Since this driver produces somewhat less than unity gain, it is intended only to follow one of the previously discussed amplifiers rather than to stand alone. The circuit is nearly identical to the "basic" jfet broadband amplifier of **fig. 3**. Notice, however, that the drain is ac loaded by a 220-ohm resistor to establish the amplifier output impedance (at the autotransformer output) near 50 ohms. This reduces the gain for two reasons. First, you have lowered the impedance as seen by the J310 drain by a factor of two, thus reducing voltage and power gain by the same factor. Additionally, half the output power is now consumed in the 220-ohm resistor. Thus, the power available to the load is cut by a total factor of 4, or 6 dB. The measured gain of this amplifier is −1 to −2 dB from 1.8 to 100 MHz, or 6 to 7 dB lower than that of the "basic" jfet broadband amplifier of **fig. 3**. Other performance characteristics are as follows:

1 dB gain compression level	+13 dBm
2nd-order intercept point	+36 dBm
3rd-order intercept point	+24 dBm
30-MHz noise figure	4-5 dB (estimated)
input VSWR	1.3:1 from 1.8-100 MHz
output VSWR	1.3:1 from 1.8-100 MHz
reverse isolation	35 dB or better to 100 MHz

Fig. 7 shows another broadband driver circuit

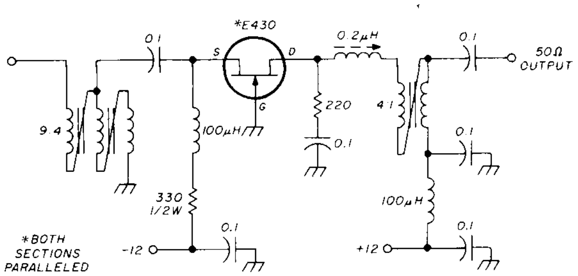

fig. 7. Schematic diagram of another broadband 50-ohm driver which has the input impedance matched by the 9:4 transformer. The gain, in this case, is 1-2 dB.

which provides some gain rather than loss. It is very similar to the "improved" jfet broadband amplifier of **fig. 4A**. Again, the drain is ac loaded by a 220-ohm resistor to establish the amplifier output impedance. Also, the input signal is impedance matched to the jfet source through a 9:4 autotransformer. This transformer is wound identically to the 9:1 autotransformer employed in the "higher gain" jfet broadband amplifier of **fig. 5A**, but is turned "upside-down" to provide a 9:4 impedance ratio. The gain of this amplifier is 1-2 dB from 1.8-100 MHz. Other performance characteristics are as follows:

1 dB gain compression level	+14 dBm
2nd-order intercept point	+30 dBm
3rd-order intercept point	+29 dBm
30-MHz noise figure	4-5 dB (estimated)
input VSWR	1.3:1 to 30 MHz
	1.8:1 to 100 MHz
output VSWR	1.3:1 to 30 MHz
	1.6:1 to 100 MHz
reverse isolation	40 dB or better to 100 MHz

In both driver circuits, it is important to connect the 220-ohm resistor as closely as possible to the jfet drain with very short lead lengths. If this is not done, oscillations may occur.

winding the autotransformers

The 4:1 autotransformer consists of five turns of bifilar-wound wire on a single-hole ferrite bead. The bifilar wire is made by paralleling and twisting together two dissimilar colored (red and green, for example) of strands of no. 32 AWG (0.2-mm) magnet wire. This is easily done by attaching one end of the paralleled wires in a vice and placing the other end in the chuck of a portable power drill. Maintaining suitable tension on the wires, turn on the drill until the wires have twisted together. Four twists per centimeter (10 twists/inch) is suitable, but this is not at all critical. The only real requirement is that there be enough twists to prevent unraveling but not so many as to cause kinking. The ferrite bead is an FB 43-801. To wind the transformer, wind the bifilar wire through the bead five times, keeping the winding tight to the core. This will result in four strands of bifilar wire against the outside of the bead. Cut off the excess wire, leaving 2-3 cm (approximately 1 inch) or so at each end. Untwist the two ends and bend the green wire of either end and the red wire of the other end toward each other until they meet halfway along the outside wall of the bead, completing the fifth turn. Tin and twist these wires together. Similarly, tin the remaining red and green wire ends. The net result is that the red and green wires are connected *series-aiding*, with their junction being the autotransformer center tap. This 2:1 turns ratio yields a 4:1 impedance ratio. **Fig. 8A** shows an outline drawing of the completed autotransformer along with the corresponding schematic representation.

The 9:1 autotransformer is constructed on the same type of ferrite bead as the 4:1 autotransformer, but is wound with no. 32 AWG (0.2-mm) trifilar wire. The trifilar wire consists of three colored strands, (red, gold, and green, for example) of no. 32 AWG (0.2-mm) wire twisted together in the same manner as the bifilar wire. Wind five turns of the trifilar wire through the ferrite bead and connect the wires series-aiding (see **fig. 8B**). If the input signal and ground connections are reversed, the 9:1 autotransformer then becomes a 9:4 autotransformer.

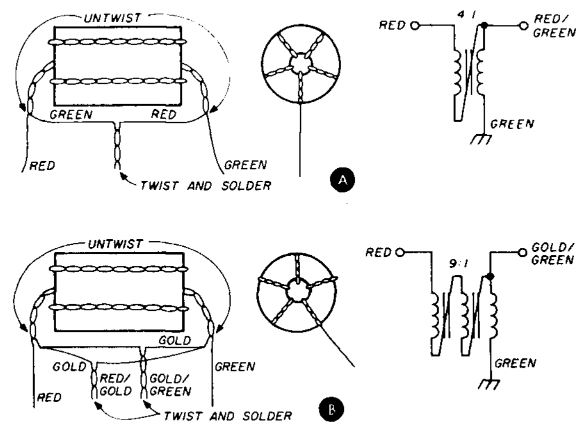

fig. 8. Winding information for the 4:1 and 9:1 transformers. Each transformer uses a ferrite bead, FB 43-801, as the core.

Although the FB 43-801 beads are satisfactory in broadband autotransformer applications, they were selected primarily on the basis of their availability to Amateurs rather than for optimum performance. Two-hole balun cores seem to perform somewhat better.

The FB 43-801 beads may also be used to construct the rf chokes. The 100-μH rf chokes used in the broadband amplifiers may be constructed by winding nine turns of no. 28 AWG (0.3-mm) wire through the beads.

measurement procedures

Swept gain, VSWR, and reverse isolation measurements were made using a Wiltron Model 640 RF analyzer. Noise-figure measurements were made using a calibrated temperature-limited diode-noise generator, a 6-dB pad, a broadband Avantek amplifier, a Heath SB-303 receiver, and an RMS ac VTVM as shown in **fig. 9A**. The noise factor of the pad/amplifier/receiver combination was first measured. The jfet amplifier under test was then inserted between the noise generator and the 6-dB pad, after which the overall system noise factor was measured. The noise factor of the jfet amplifier alone was then calculated using the well-known gain-noise factor equation in rearranged form:

$$F_1 = F_T - \frac{F_2 - 1}{G_1} \quad (8)$$

where F_1 is the noise factor of the jfet amplifier
F_2 is the noise factor of the pad/amplifier/receiver combination

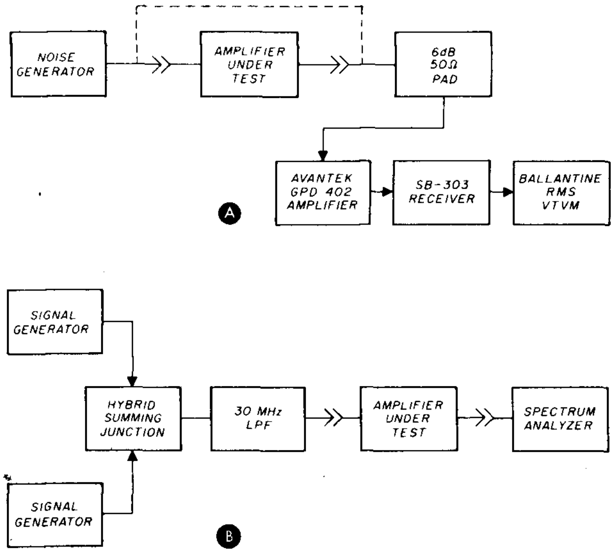

fig. 9. Test setup for the noise-figure and IMD measurements.

G_1 is the power gain factor of the jfet amplifier

F_T is the overall system noise factor

The noise *figure* is then simply $10 \log_{10}$ noise factor.

Gain compression level measurements were made with an HP-8654B signal generator and an HP-8558B spectrum analyzer. Intercept point measurements were conducted using two HP-8645B signal generators, a 3-dB hybrid junction, a 30-MHz lowpass filter, and an HP-8558B spectrum analyzer. **Fig. 9B** shows the test setup. Second-order intercept point measurements were made by first setting the signal generator outputs to +3.5 dBm (or 0 dBm input to the amplifier after accounting for the 3.5-dB loss at the hybrid junction) at frequencies of 14 and 15 MHz. The difference in amplitude between the 14/15 MHz signal levels and the 29-MHz sum product as observed on the spectrum analyzer was then added to the 0 dBm 14/15 MHz amplifier input signal level to compute the sum product second-order intercept point. The signal generators were then tuned to 27/30 MHz, and the second-order intercept point was again calculated, this time for the 3-MHz difference product. The amplifier second-order intercept point (referenced to the amplifier input) was then taken as the lesser of the two measurements.

Third-order intercept measurements were accomplished by again setting the signal generators to 14/15 MHz at 0 dBm input levels to the amplifier under test. Third-order intermodulation products appeared at 13 and 16 MHz. The difference in amplitude between the 14/15 MHz signals and the greater of the intermodulation products was divided by two and added to 0 dBm to arrive at the third-order intercept point (referenced to the amplifier input).

summary and conclusion

Broadband amplifiers for receiving applications require superior odd- and even-order intermodulation performance due to their greater bandwidths. Jfets make excellent low-noise broadband amplifiers in the high frequency and low vhf range, providing moderate gain and unsurpassed third-order intermodulation performance for the amount of current drawn. Second-order intermodulation performance is good, but may not be as good as that of certain bipolar transistors, particularly when these bipolar transistors are connected in push-pull.[6]

Other devices for consideration as low-noise broadband high-intercept point amplifiers include the Siliconix VMOS[7] and the Signetics DMOS fets.[8] The VMOS fets are capable of performance superior to that of E430s in terms of gain, bandwidth, and dynamic range. To secure maximum gain and linearity, however, it is necessary to run hundreds of milliamperes of current through the device, impractical for most receiving applications. A test of a Siliconix VN33AK VMOS fet at 50 mA of drain current (in the device square-law region) resulted in significantly poorer bandwidth and dynamic range than that of an E430 running at 34 mA. A test of the Signetics SD202 DMOS fet at 20 mA of drain current resulted in a gain somewhat greater than that of a J310 and a third-order intercept point comparable to that of an E430. The extremely low output capacitance of the SD202 resulted in improved bandwidth as well.

Both VMOS and DMOS fets characterized for rf applications are still rather expensive, but both technologies are rapidly advancing in terms of performance and manufacturability. As a result, prices are certain to come down while performance improves (some Siliconix VMOS fets characterized for switching applications already sell for under one dollar in large quantities). In the months ahead, we undoubtedly can look forward to exciting developments in both of these expanding technologies.

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ham radio

the Hallicrafters story

A fascinating account of one of Amateur Radio's great names. How it grew, what it produced, and its demise in today's Amateur market. But is Hallicrafters really dead? Of course not

prologue

The unmarked car pulled up in front of the small factory. It was a sultry, humid day in Chicago in August of 1941. The driver got out of the vehicle and strode purposefully into the office of the little company. He displayed his credentials and, after a short pause, was ushered into the office of the president.

The president, young Bill Halligan (W9WZE, now W9AC), greeted his visitor and quickly found what was wanted.

"Mr. Halligan," the visitor said in self-assured voice, "we need an HT-4 transmitter."

Bill Halligan shook his head. "I'm sorry, we haven't one in the place. And we don't even have one in production now."

The visitor looked around the office and glanced out the door to the small production line.

"How about a used one, or one that you keep for test purposes?"

"None available at all, sorry."

The visitor leaned forward across Bill's desk. "Do any of your dealers have one? I mean anywhere in the U.S.? How about sending some telegrams?"

Bill Halligan produced a wad of letters and telegrams from his desk. "It's the other way around," he replied. "They're all cleaned out and are asking for more HT-4 transmitters."

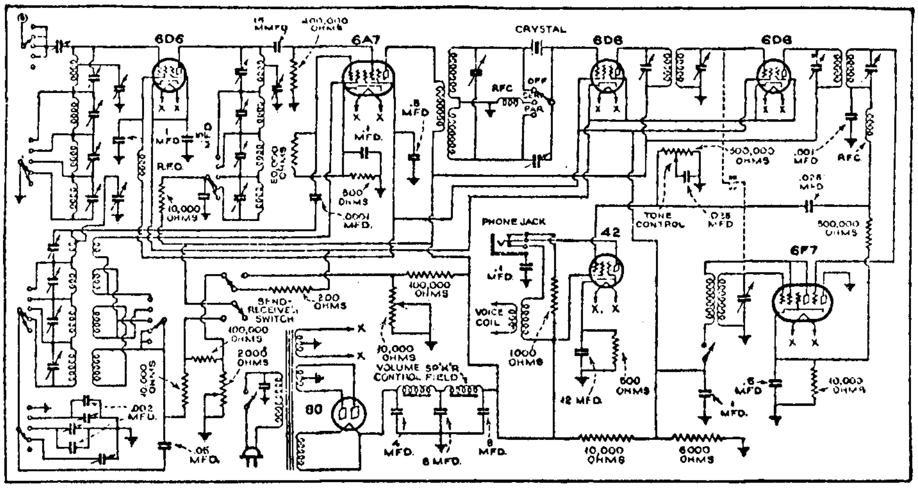
"You don't seem to understand," said the visitor. "This is important and urgent. We must have a transmitter. At once. It is of the highest priority!"

Bill sighed. "Well, how about my HT-4 transmitter? It's at home in my shack . . ."

The transmitter was immediately brought to the factory, an old red brick building on Indiana Avenue. That weekend Bill and an engineer went over the HT-4, checking it out, and on Sunday an Army bomber roared away from Chicago Municipal airport with W9WZE's supreme sacrifice aboard — his own personal HT-4 transmitter. Not even the persistent, close-lipped visitor knew of its ultimate destination, but it was bound for a rendezvous with history (see epilogue).

Bill Halligan received an early start in the world of wireless. As a high-school student before World War I, his homemade spark transmitter cut a broad swath in the 200-meter band, causing great anguish to the Navy radio operators in the Boston area. And after marine and Navy radio work in the Great War, he immediately went into radio as a profession in the Boston/New York area. But by 1931 he was a manufacturer's agent in Chicago, just in time for the depths of the depression. It was a challenging time for an energetic fellow who wanted to build high-quality ham equipment — something he'd never done but always wanted to do. Perhaps now was the time. What did he have to lose?

By William I. Orr, W6SAI, 48 Campbell Lane, Menlo Park, California 94025



Schematic of the Super-Skyrider, the first Hallicrafters short-wave superheterodyne receiver.

"I've just the name for you," said Lloyd Back, Bill's good friend in a local advertising agency. "Why don't you call your new company The Hallicrafters? I got the idea from an outfit called the Roycrafters, a printing company in New York that produces fine printing under the leadership of Elbert Hubbard. You'll be the artisans of the new science of radio communications. How do you like that?"

the coveted RCA license

The whole idea caught fire like wet leaves. It was 1933, and hams were broke too. No one seemed interested in the simple *Sky Rider* receiver that Bill had designed. Another serious problem was also at hand: The little company was unable to secure a license to manufacture sets under patents held by the Radio Corporation of America. RCA was virtually a patent pool, holding patents on almost every basic radio circuit that existed. True, a licensing system existed for those well-heeled outfits that could pay the price. But it was too high for Hallicrafters. The company went into low gear, and Bill Halligan had to go to Silver-Marshall Company — a licensed competitor — to produce sets of his own design.

It was a tough road. Bill would take a briefcase full of wiring diagrams, drawings, and photographs to ham dealers and secure orders for nonexistant receivers. When he had 50 or 100 orders, he'd deposit the orders with Silver-Marshall and the sets would be produced — for cash only.

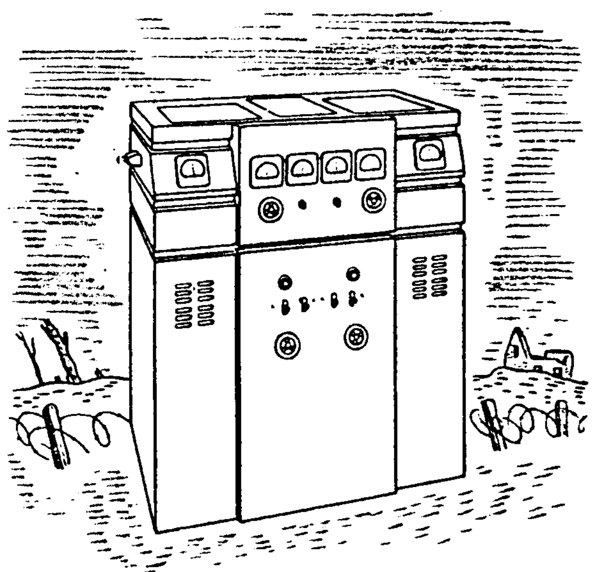
"I've got to get an RCA license of my own," Bill told his wife. He knew that security and a future depended upon an RCA license. And he was going to get one.

harsh days in Chicago

Difficult days were ahead for Bill Halligan. He finally heard of a new, ultra-modern radio factory in Marion, Indiana, which was closing for lack of business. It had an RCA license! Hurrying to Marion, he sold the Hallicrafters' idea to the owner. Shortly thereafter the Hallicrafters' name appeared above the factory entrance. But the two partners lacked the money to produce anything, and the grim specter of bankruptcy loomed on the horizon. Both partners were deep in debt. Bill now had the RCA license, but he could do nothing with it!

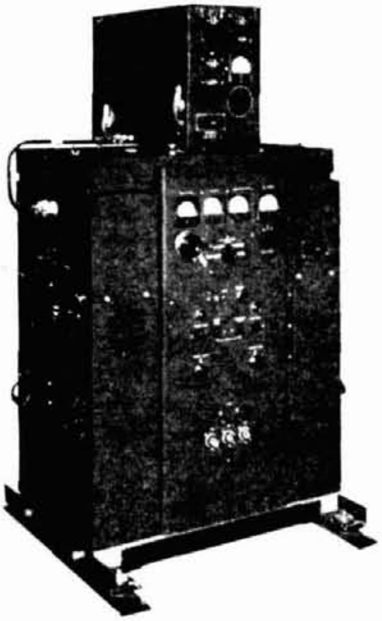
By one of those fascinating turns of fate, Bill Haligan chanced to meet Ray Durst. Ray was the credit manager for the Ecophone Company in Chicago, which has a large account with the plant in Marion. Ray felt that if he could collect the debt Marion owed to Ecophone, he might not be fired by that company.

Bill and Ray got together to see if they could solve their immediate problems. The upshot of these discussions was that Bill and his partner agreed to dis-



The Hallicrafters HT-4 transmitter.

HALLICRAFTERS BC-610 Xmtr
450 WATTS C.W.
325 WATTS PHONE
now available to the amateur!



NET PRICE complete $500.00

This high-power transmitter, famed for its *performance in the SCR-299 mobile* radio station, is ready now for YOU. Includes all regular features of the familiar HT-4E . . . plus battle-tested improvements that make it better than ever. Furnished complete with speech amplifier, tubes, 3 sets of coils (1.5 to 18 mc.), and simple modification instructions for operation on 10 meters. Like new — used only slightly. Fully guaranteed.

The BC-610 was a three-stage transmitter using plug-in coils. Tube line up was: 6V6 crystal oscillator, parallel 807s buffer, and 250TH final amplifier. The modulator used p-p 100THs. A separate speech amplifier and antenna tuner were a part of the transmitter package. Pre-war ham price was about $750. Post-war surplus price was $500. The BC-610 was a popular ham transmitter up to 1948 when it was killed off because of excessive TVI. Tuning units and coils for this famous transmitter are occasionally found on the surplus market today.

solve their contract. Bill and Ray then went to Chicago. There Bill met Clem Wade, the inventor of the *Eskimo Pie* ice cream stick and sole owner of the Ecophone Company's equally frozen assets. Would it be possible that some kind of agreement could be reached whereby Bill could make use of the facilities at Ecophone? Perhaps some kind of cross-licensing?

Yes, it was possible. After a tangle of lawsuits with creditors, contracts, licensing agreements, incorporations, and expensive paperwork, Bill Halligan and Ray Durst emerged with a company. Now, perhaps, the Hallicrafters dream would come true.

before Pearl Harbor

Hallicrafters was in business. It made radio receivers and phonograph combinations for Capehart, Magnavox, and other Chicago radio companies. And it wasn't long before handmade Hallicrafters shortwave receivers were being made. At long last, Bill Halligan had his factory and was in the ham radio business.

Hallicrafters entered the ham market like a rocket. The *Super Sky Rider* receiver was announced in early 1935. Modern marketing techniques and joint advertising with distributors was tried — a new approach to the staid market of Amateur Radio. Bill Halligan's earlier work as a manufacturer's agent began to pay off. Within months Hallicrafters was a household word in Amateur Radio. Hallicrafters fielded a whole series of radio receivers and probably had more models on the market than all the other receiver manufacturers combined. Yearly model changes were made, high-style cabinets and attractive panels were used, and the massive volume of receiver production held the costs low — a Hallicrafters receiver existed for every purse.*

the Hallicrafters HT-4 transmitter

"Why not build a modern ham transmitter," Bill Halligan asked himself one day. With the aid of Bob Samuelson, the design for a powerful ham transmitter was drawn up — target price: less than $800.00.

Bill Halligan and wife, Katie, with the very first model Sky Rider receiver of long ago. Receiver was a trf job, soon to be supplanted by the Super Skyrider, a superheterodyne.

Bill hoped that the Radio Amateur, now accustomed to buying a receiver rather than building it himself, to buying a receiver rather than building it himself, might be ready for a factory-assembled rig.

The ham transmitter of 1938 was a sight to behold. The ham kilowatt then was a massive and awesome contrivance that towered in one or more relay racks to a height of six or seven feet — and with all the mobility of a grand piano.

Early Hallicrafters television receivers are a collector's item now. This model had a push-button tuner that included TV channel 1, now the Amateur 6-meter band.

Starting with a typical high-power transmitter design, Bob Samuelson and his engineers spent months over wiring diagrams and layouts, reducing the design to a height of 37 inches and decreasing the conventional seven power supplies to three. Complex switching circuits were simplified. Plug-in tuning assemblies were designed. The heavy steel relay rack construction was scrapped for a light steel frame using the "stressed skin" technique developed for airplane fuselages. Transmitter weight was reduced from over a ton to about 500 pounds!

The final design was a 450-watt phone and CW transmitter that contained no aluminum. It was made of automobile sheet steel, and, with the exception of the heavy transformers, it was easy and inexpensive to produce.

mass production — a real problem

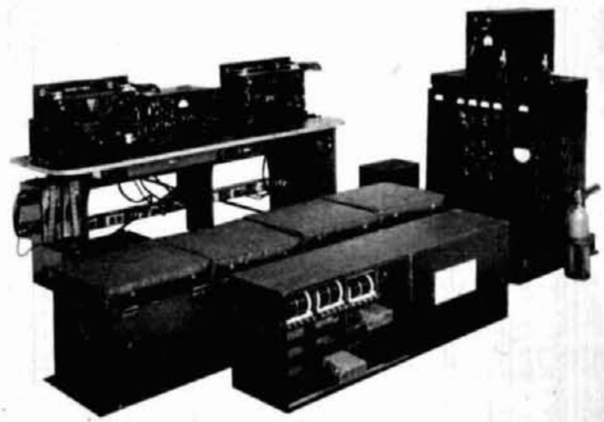
Bill Halligan had no way of knowing that a war was about to start and that his HT-4 transmitter would be a mainstay for World War II communications. After all, he had built only twenty of them by the fall of 1940. He was soon to be surprised. Suppose America got into the war? Would anyone be interested in the HT-4? Could production be stepped up to the unheard-of rate of one a day? What if someone wanted more?

Less than a year later these questions became real when a delegation of French and British purchasing commissioners ordered more transmitters than Bill Halligan had built in the eight years his company had been in existence. Deliveries were a matter of life and death. And how about SX-28 receivers? Did he need money? Would cash in advance help speed things up? The heat was on. It was quite a shock to realize that Hallicrafters had a sold-out factory. Now, instead of selling people on the idea of buying Hallicrafters radio equipment, Bill had to sell other people on making them!

Hallicrafters was well on the road by the time of Pearl Harbor. Production was the all-absorbing passion. The factory was geared to devise faster, more efficient assembly techniques. Three shifts were started, and by the fall of 1941, a steady stream of radio equipment was being shipped to the British (who had taken over the French commitments). On the morning of December 7, 1941, Colonel George H. Sparhawk of the Army Air Force telephoned Bill Halligan and told him that the Armed Forces were commandeering the British transmitters and that they were to be packed and out of Chicago by air that very night.

the war years
the SCR-299 is born

Hitler's stunning victories in Poland, France, and the low countries revealed his secret weapons: speed, fluidity of attack, and *instantaneous commu-*



Radio equipment installed in the famous SCR-299 or SCR-399 communication truck. At the right is the BC-610 transmitter and antenna tuner. At rear is the operating desk with two BC-342 short-wave receivers, speech amplifier, and control panel for the transmitter. In the foreground are the chests that contained extra transmission coils, tuning boxes, and spare parts.

*I still have my Hallicrafters S20R, purchased with paper-route money in the 1940s. Wouldn't sell it for any price. Editor, W6NIF

Hallicrafters won five Army-Navy E awards during World War II for excellence in production. This photo shows BC-610 transmitters in final inspection before they were mounted in the communications vans in the background.

nications. The U.S. military service saw the need for a mobile radio station capable of communications over a wide range of frequencies, even while en route over rough terrain. The rough design for such a communications center was worked out at Fort Monmouth, New Jersey, under the direction of Colonel Roger B. Colton. Known as the SCR-299, the system consisted of a 1½-ton panel body truck with four-wheel drive coupled to a heavy-duty, two-wheel trailer. In the truck body was a complete short wave receivers (BC-342s). In the trailer was a gasoline-driven generator that was used to supply power for the mobile station. A rugged whip antenna was mounted onto the truck.

After long deliberation and tests, the ham-type HT-4 transmitter was selected for the SCR-299 communications truck. It was chosen because of its simplicity, small size, light weight, and ruggedness. And it had good, clear audio. Special military tuning units and handles were added to ensure quick and easy equipment removal from the truck. With some other minor changes, the ham rig was just right for military service.

the SCR-299 in military service

Production was now rolling. The SCR-299 was in service on every Allied battlefront from Alaska to China. SCR-299s were airlifted to Guadalcanal, North Africa, and Sicily. Among the first units to roll ashore at Normandy on invasion day was the SCR-299. Each SCR-299 carried a mile of telephone cable on a drum, permitting telephone lines to be set up for communications with distant areas. This enhanced the value of the SCR-299 where mobility was limited.

the Sebold incident

Finally, there was the celebrated case in which a German-American citizen, William Sebold, helped the FBI to apprehend a ring of Nazi spies. Sebold had returned to Germany to visit his family in 1939. Through coercion and intimidation, Sebold was forced to go through the great spy school in Hamburg. When he left Germany in 1940, Sebold had instructions and authority to establish a short wave radio station in the United States for direct communications to Hamburg.

Upon arriving in New York, Sebold went straight to the FBI, which helped him establish a secret station on Long Island, equipped with a Hallicrafters HT-4 transmitter. He did a fine job of putting carefully doctored misinformation into the hands of the spy chiefs at Hamburg.

after the war

By 1946 the war was over, and Hallicrafters turned to the future. The Hallicrafters transmitter (known by the military label BC-610, part of SCR-299) was being released on the surplus market for as little as $500, complete with tubes, antenna tuner, and speech amplifier — only slightly more than the manufacturing cost. As far as Hallicrafters was concerned, there was no ham future in the HT-4 design.

To get peacetime production rolling, Bill Halligan brought out the S-38 and S-40 receivers (revamped versions of pre-war models) and started to plan ahead. By late 1946 he proudly announced the SX-42, an advanced superheterodyne receiver that tuned from 540 kHz to 110 MHz in six bands.

Always on the go! The SCR-399 communications truck was used to negotiate the surrender of Rommel, the "Desert Fox," in north Africa. The SCR-399 was present at the D-day invasion of Europe and accompanied General McArthur during his historic conquest of Leyte Island in the Philippines. Gasoline-powered generator is in trailer. Truck was supplied with three whip antennas for transmitting and receiving while in motion.

The famous Hallicrafters SX-28 receiver. Over 50,000 were produced for the Allied Forces. High styling and good performance made the receiver a favorite among pre-war Amateurs. Receiver incorporated two rf stages and tuned up to 43 MHz. In 1946 it was replaced by the SX-42.

A simple television receiver was also in the works. Hallicrafters had heard about single sideband transmission. Yes, the future looked bright indeed in 1947 as Hallicrafters settled down to profitable, post-war production of modern radio equipment. They had the know-how.

More than fifty thousand SX-28 receivers had been built, and more than eighteen thousand SCR-299 (BC-610) transmitters had been built, as well as nearly ten thousand S-29 receivers. And now single sideband, television, and high-fidelity fm lay ahead, as well as CB radio on the distant horizon. The world looked good to Bill Halligan in 1947. He had really arrived in style!

The problem was conversion from a war-time to a peace-time industry. Hallicrafters was spread over fourteen plants, some as small as a garage. The first matter of business was to consolidate operations. A new facility was built, and two other locations were retained for growth.

Returning GIs remembered the name Hallicrafters. The company decided that, in addition to building ham gear, they would expand into the entertainment field. Television receivers, hi-fi equipment, and the Lowery organ were built by Hallicrafters. The company continued to build military electronic gear, particularly counter-measure equipment.

But all was not smooth sailing. The home radio and television market was cutthroat. By 1956 Bill Halligan was fed up. He couldn't compete and retain the high standards he'd set for Hallicrafters. The crisis of this uncomfortable situation was reached in the fall of 1957, when Bill Halligan sold out to the Penn-Texas Company. While Bill gave up ownership of Hallicrafters, he still retained management. This operation was even less satisfactory, and late the following year Bill bought the company back from Penn-Texas. Management of Hallicrafters was turned over to Bill's son, Bob Halligan. Bill remained chairman of the board.

epilogue

Over the years, Hallicrafters contributed many firsts to the electronics industry and to Amateur Radio. Some of these were the first use of silk-screened panels in place of expensive engraving, the use of smooth paint in place of black-crackle paint, the calibrated S meter, the dual-diversity receiver, the automatic noise limiter, the temperature-compensated, high-frequency oscillator, the battery-portable, all-wave receiver, the dual AVC system, the bridge-T notch filter, and commercial production of an electronic keyer.

W9AC is still active on the air, mostly on 7 and 14 MHz CW. On occasion Bill can be found on 20 meter SSB. During the summer months he's on the air from W4AK in Florida.

Keep your ears open for this pioneering Amateur! Bill's interest in Amateur Radio is as keen as ever. Even though he's not manufacturing ham radio equipment, he can still use it along with the best of today's operators.

In 1950, J. Edgar Hoover of the FBI told Bill Halligan that the HT-4 transmitter Bill had sold to the FBI agent in August, 1941, had been flown to Pearl Harbor and that it had been installed in the hills above Honolulu. It was the only active communications link to the mainland during the Japanese attack, because saboteurs had cut telephone lines in Honolulu. The old W9WZE transmitter served its country well during those painful hours of need.

Large numbers of the Hallicrafters S-36 (BC-787B) receiver were sold during wartime. Tuning range was from 27 MHz to 140 MHz, which included vhf communications ranges of Allied, German, and Japanese ground and air forces. Receiver worked on both a-m and fm.

ham radio

phaselocked up-converter

Last of
a three-part series
on a frequency synthesized
local-oscillator system
for the
high-frequency
Amateur bands

In the first article of this series, I described the basic VCO synthesizer, or "first loop," which covers 100-1600 kHz in 10-Hz steps.[1] Part 2 covered the phaselocked 9-MHz BFO system.[2] This article describes the phase locked up-converter, which translates the 100-1600-kHz output of the first loop to the LO frequencies required for each of the Amateur bands between 160 and 10 meters.*

*Parts kits and circuit boards will be available from the author if there is sufficient interest. Send a self-addressed, stamped envelope for information.

For coverage of the high-frequency Amateur bands in 500-kHz segments, the VFO signal must be translated to a higher frequency for each band without degrading the phase noise performance. The output frequency is the sum of the first loop[1] output frequency and that of a stabilized crystal oscillator. This frequency plan is shown in **table 1. Fig. 1** is a block diagram of the up-converter. The output loop works by first mixing the VCO signal with that of the crystal oscillator (XO) then phase comparing the 1100-1600-kHz result with the first loop output to produce the VCO control voltage. The presteering system ensures that the loop acquires lock and remains locked despite large temporary differences between the VCO and XO frequencies caused by bandswitching or sudden large frequency changes. Crystal-oscillator frequency accuracy is guaranteed by a simple divide-by-n loop, with the phase detector operating at 50 kHz.

Crystal-oscillator section (fig. 2). Each 500-kHz band segment is selected by activating a crystal oscillator operating at a frequency 1100 kHz lower than the bottom end of the required LO frequency range. The collectors and the control voltage inputs of the nine oscillators are connected in parallel. The bandswitch, S1, applies base bias voltage to the selected oscillator, leaving the others cut off. Common-base

By Raymond C. Petit, W7GHM, Post Office Box 51, Oak Harbor, Washington 98277

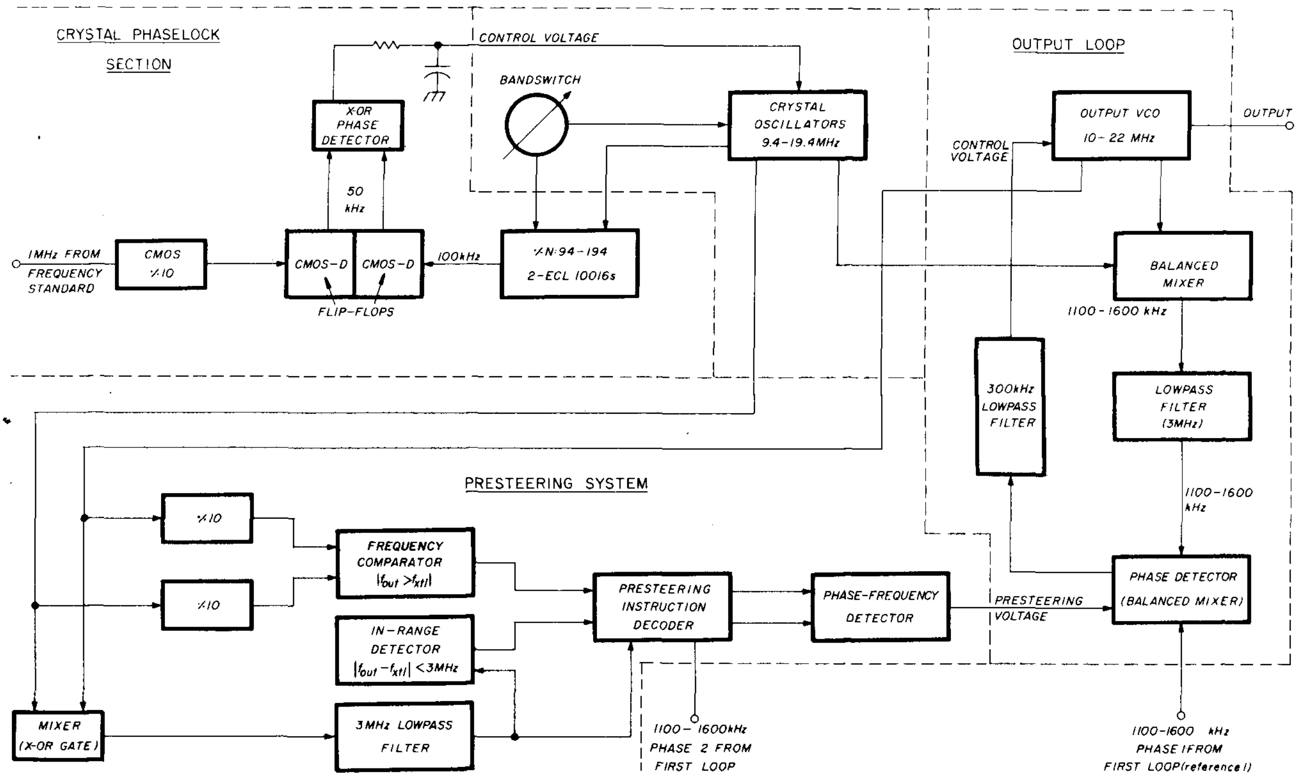


fig. 1. Up-converter block diagram.

buffer Q2 provides about 50 dB isolation between the *rf* output and the inputs to U2. The additional isolation provided by U2 and the PNP differential pair, Q3-Q4, effectively eliminates reverse signal-flow from the ECL and TTL circuits they drive.

Phaselock section (fig. 3). The ECL output of the crystal oscillator section is divided to 100 kHz by 8-bit programmable binary counter U6-U8. The diode matrix controlled by S1 sets the division ratio; the desired division ratio plus the binary number preset by the diode matrix must always equal 256. Because the phase detector requires symmetrical square-wave inputs for best performance, the 100-kHz outputs of the counter and reference divider U3 are first divided by two in U5. The combination of very low VCO gain in the crystal oscillators and the high reference frequency used in the phase detector make it possible to suppress reference-frequency modulation of the VCOs by more than 100 dB.

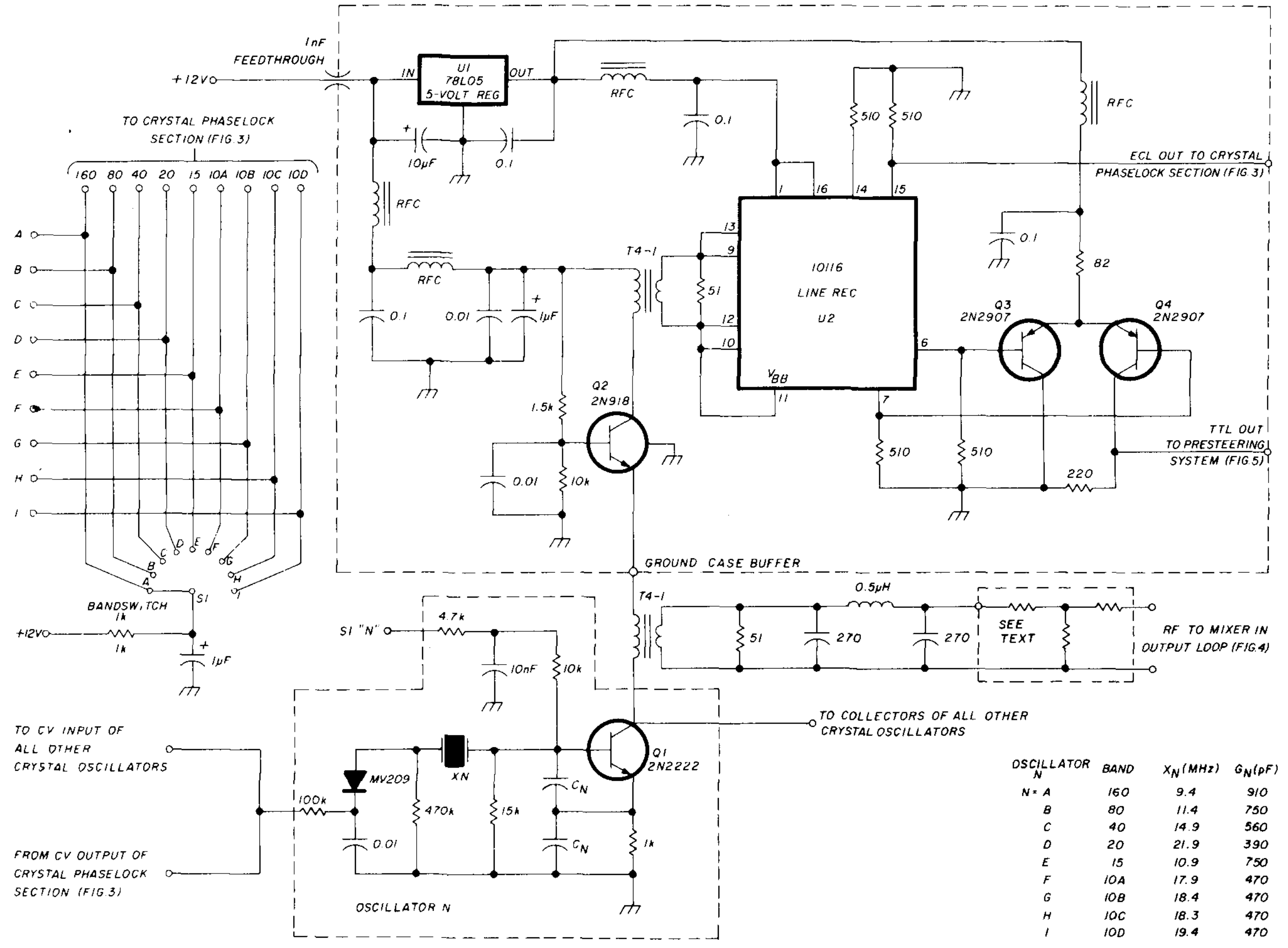
Output loop (fig. 4). With care and good layout, the loop of **fig. 4** will suppress the reference-frequency sidebands by at least 100 dB and reproduce the superb phase-noise performance of the first loop within about 6 dB.

Accompanying these advantages are some special problems. The capture range of the loop is about 250 kHz, and there are two frequencies where the unassisted loop could lock for each bandswitch setting and first-loop output frequency.

Assume the first loop has an output of exactly 1500 kHz and the bandswitch is set for 40 meters. Then the output of the down-mixer can be exactly 1500 kHz when output oscillator Q7 is set for 16.4 MHz (desired frequency) or 13.4 MHz (image). The phase detector alone produces a maximum of about ±100 millivolts. This is good for only about ±200 kHz of VCO tuning range. Because the i-f port of the double-balanced mixer is dc isolated, a presteering voltage can be added to the phase-detector output voltage to put the output oscillator frequency within correct locking-frequency capture range.

table 1. Frequency relationships for the frequency synthesized LO system.

crystal-oscillator frequency (MHz)		system output frequency (MHz)	±i-f (MHz)	frequency band covered (MHz)
9.4		10.5-11.0	−9	1.5- 2.0
11.4		12.5-13.0	−9	3.5- 4.0
14.9		16.0-16.5	−9	7.0- 7.5
21.9	1100- + 1600 = kHz	23.0-23.5	−9	14.0-14.5
10.9		12.0-12.5	+9	21.0-21.5
17.9		19.0-19.5	+9	28.0-28.5
18.4		19.5-20.0	+9	28.5-29.0
18.9		20.0-20.5	+9	29.0-29.5
19.4		20.5-21.5	+9	29.5-30.0



OSCILLATOR N	BAND	X_N(MHz)	C_N(pF)
N = A	160	9.4	910
B	80	11.4	750
C	40	14.9	560
D	20	21.9	390
E	15	10.9	750
F	10A	17.9	470
G	10B	18.4	470
H	10C	18.3	470
I	10D	19.4	470

fig. 2. Crystal-oscillator section schematic.

Presteering system (fig. 5). Two conditions must be met to guarantee correct lock. The first is that output oscillator Q7 frequency must be greater than that of the crystal oscillator. Call this condition **B**. This ensures that the system will not lock onto the image frequency. The second condition is that the difference between the two frequencies must be less than the 3-MHz cutoff of the lowpass filter following the mixer (condition **A**). A phase-frequency discriminator can take over at this point and bring output oscillator Q7 frequency to within capture range.

The presteering system is basically a crude down-mixing loop (such as the output loop), except that it can detect when either — or both — of the above conditions are not being met, and will steer the output frequency in the proper direction until these conditions are met. U9-U12 test for condition **B**. The 4044 phase-frequency detector doesn't work reliably above a few MHz, so both inputs must first be divided by ten. Condition **A** is tested by the lowpass filter, ac peak detector, time-delay filter, and U17. If both conditions are met, the down-mixed signal from U16 and the first-loop signal through U20 are passed to U19 by instruction decoder U18. Phase-frequency discriminator U19 and amplifier U21 bring the system into lock at exactly the correct frequency.

If condition **A** is not met and condition **B** is met, the output oscillator frequency is more than 3 MHz above that of the crystal oscillator. U18 interrupts the normal signal flow and places U20 output on the **R** input of U19, causing U21 to pump down the presteering-voltage U17 signals.

If condition **B** *is not met, regardless of condition* **A**, the output oscillator frequency will be below that of the crystal oscillator. Thus U18 interrupts the signal from the downmixer while leaving the first-loop signal intact. This action causes the presteering output to pump up. Since, in this case, the output-oscillator frequency is below that of the crystal oscillator, these signals must pass through zerobeat in the downmixer before correct lock is possible.

But a zerobeat condition will give no ac signal for

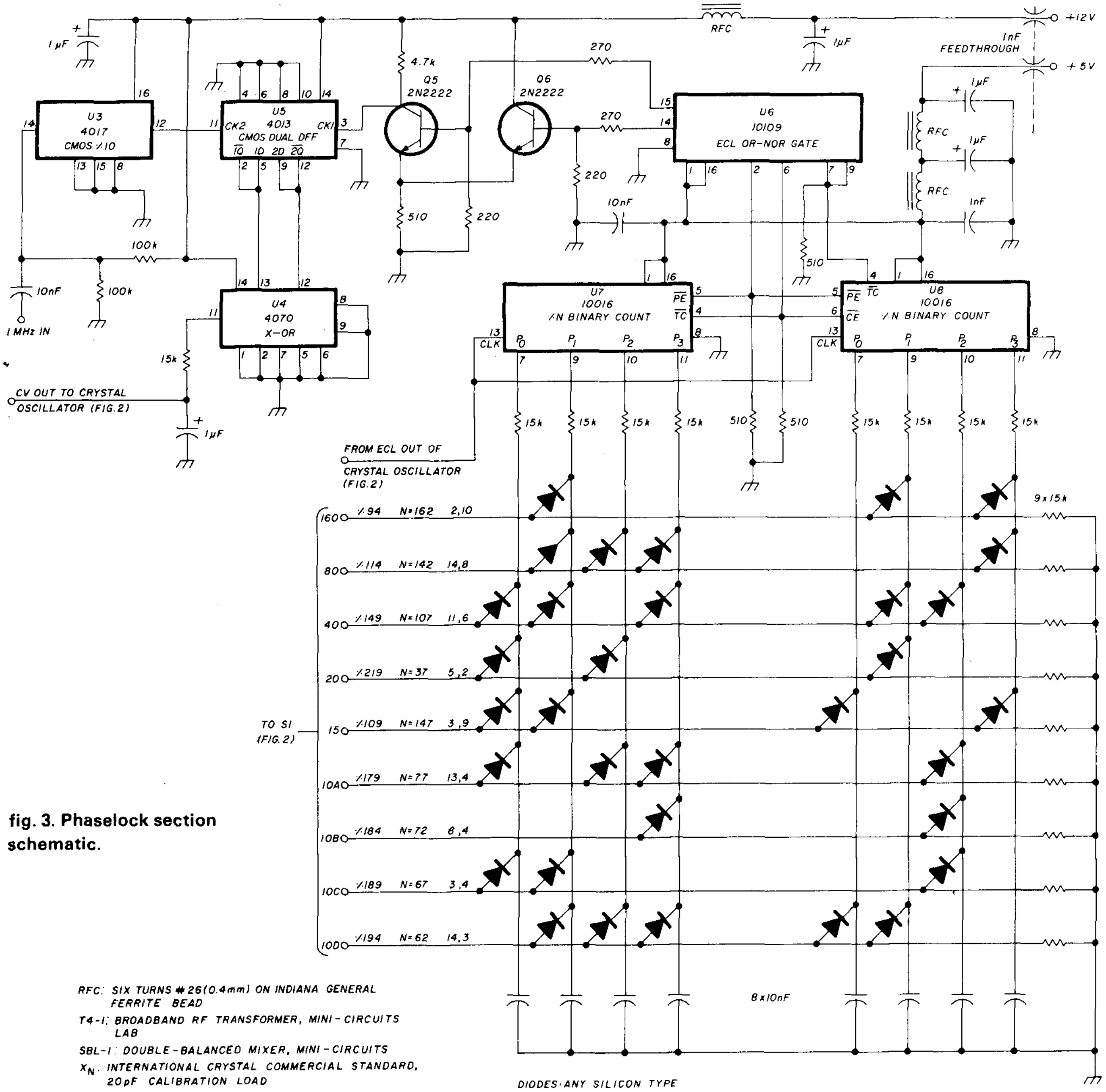


fig. 3. Phaselock section schematic.

the peak detector. This action would give a false alarm on condition **A**, except that the time-delay filter at U17 input keeps the input high until the beat returns. (Without this provision, the presteering system goes into a "dither" condition, which holds the output oscillator frequency close to that of the crystal oscillator.)

test procedures

For simplicity it's desirable to check out each section before connecting them. Sections already checked out can be used as test generators for successive sections.

Crystal oscillator. Set bandswitch S1 to 160 meters. The dc voltage at the base of Q-1 (the 9.4-MHz oscillator) should be about 6 volts. Check for the 9.4-MHz signal with a scope or counter connected to the collector. With a potentiometer, vary the control voltage to check that it oscillates over the entire range and that it is exactly 9.4000 000 at some setting near midrange. Check the ECL and TTL outputs for the 9.4-MHz signal. Repeat this procedure for each oscillator.

Crystal phaselock section. Connect the oscillator ECL output to the clock input of the programmable

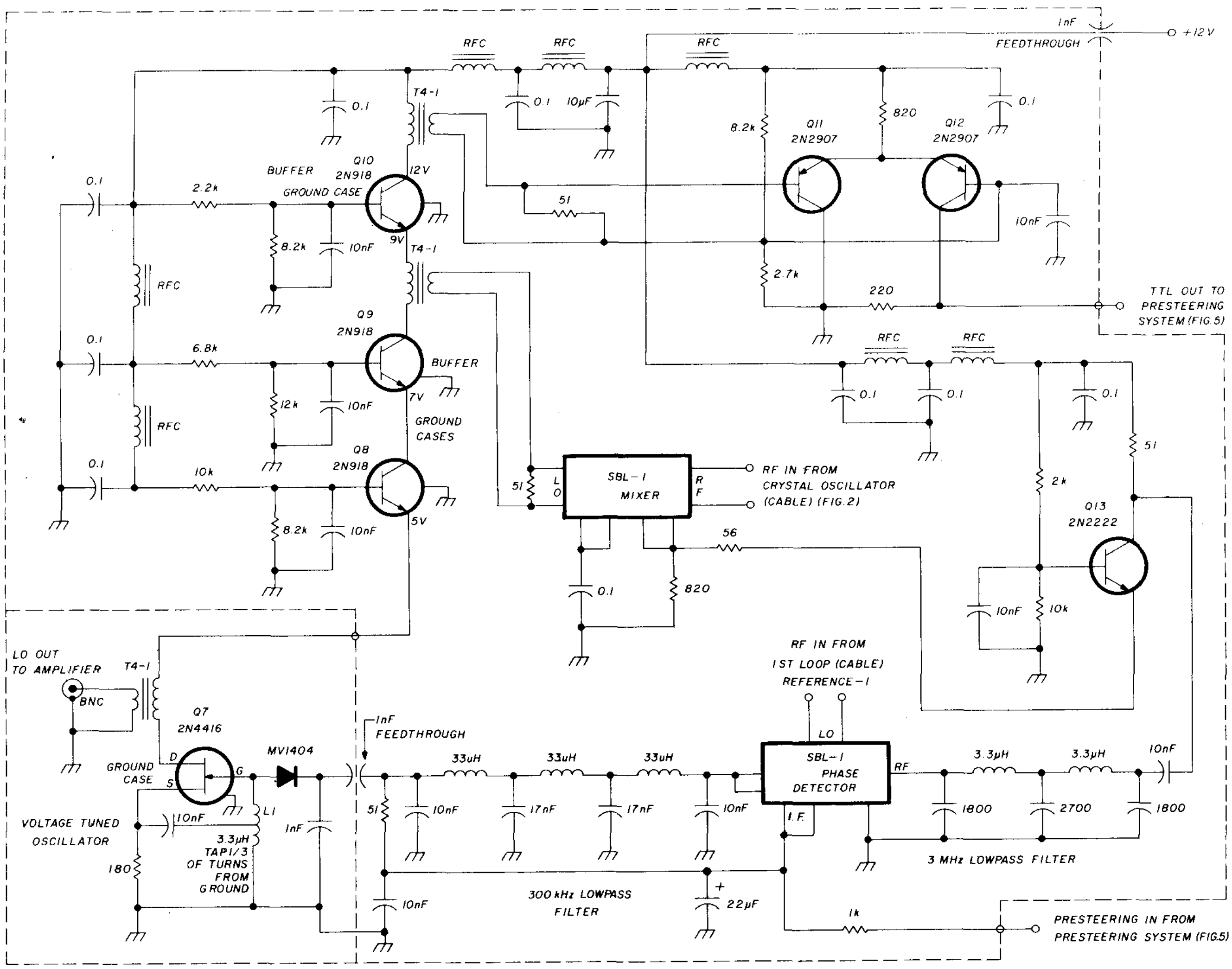


fig. 4. Output loop schematic.

divider, and make the connections to S1. Connect a counter to the collector of Q5. For each setting of the bandswitch, it should be possible to adjust the control voltage (as before) so that the counter reads exactly 100 kHz. This checks the diode matrix and programmable counter. Connect a 1-MHz frequency standard to the reference input. U3 pin 12 should show 100 kHz. U4 pin 12 should be exactly 50 kHz, and U4 pin 13 should be very close to 50 kHz.

Check the CV output with a scope. As the CV input of the oscillator is varied, the phaselock section CV output should be a very-low-frequency triangle waveform, which goes through zero beat as the CV input voltage is brought through the middle of its range. Now close the loop by connecting the CV terminals of the two sections and removing the potentiometer. Put the counter on the oscillator-section TTL output and keep the scope on the (connected) CV terminals. Switch through all bands and check that the counter reads exactly the intended frequency and that the control voltage quickly settles to a constant dc level.

Output loop. Connect only the voltage-varying potentiometer to the presteering input and the counter to the rf output. Adjust L1 to obtain a frequency of approximately 15 MHz when the presteering voltage is 6 volts. Check for the TTL-level signal at the same frequency from the TTL output. Connect the crystal-oscillator section rf output to the downmixer rf port input. This signal level should be approximately 200 mV rms. A 50-ohm T-pad on the oscillator output should be used to reduce the output to this level and provide a suitable termination for the mixer.

Set the bandswitch for 40 meters. Connect a scope to the 3-MHz lowpass filter output, which drives the phase detector. Vary the presteering voltage to observe the difference signal (zero to about 3 MHz) at a level of about 100 mV rms. Connect the first-loop rf output to the phase detector and set

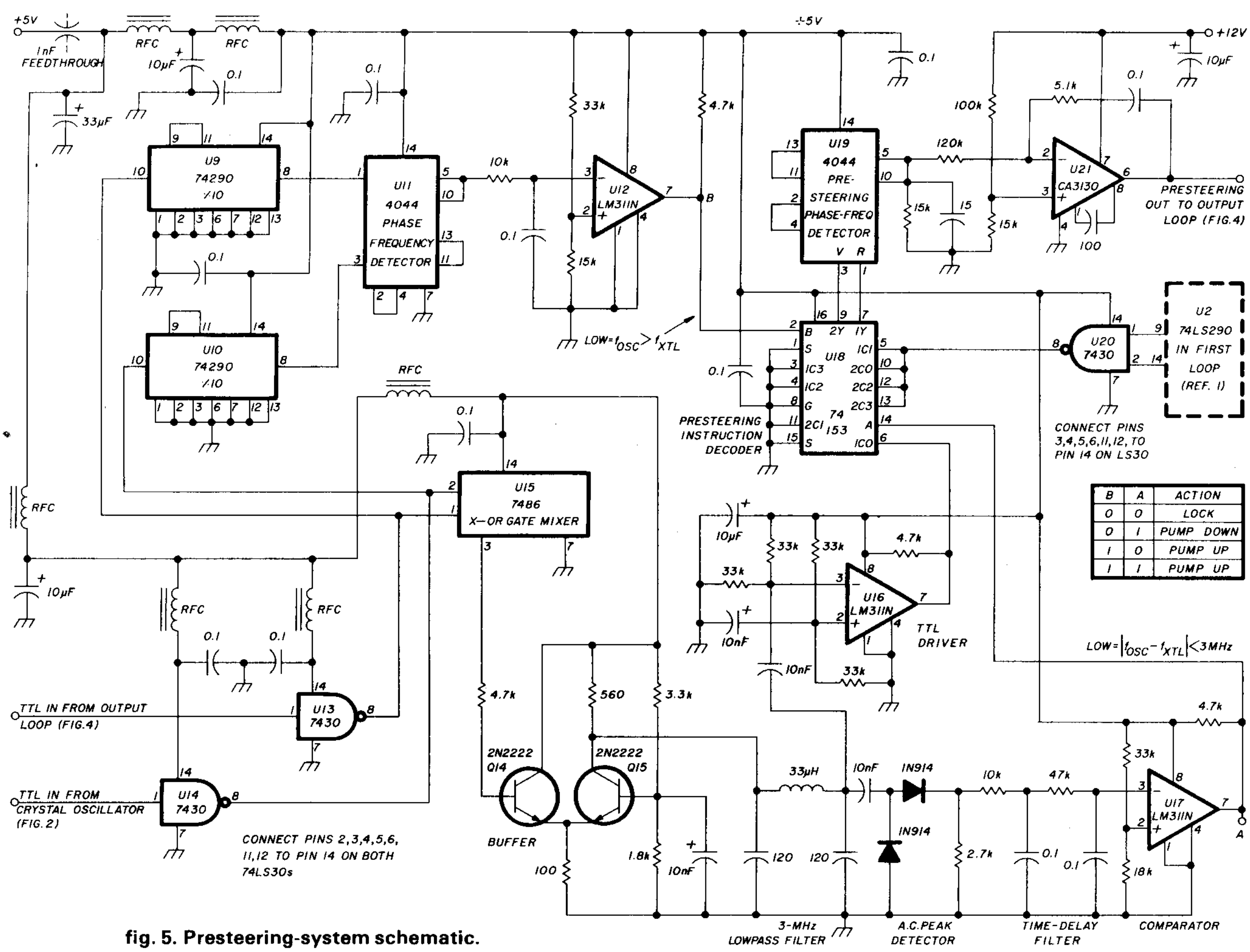


fig. 5. Presteering-system schematic.

the first loop for 1100 kHz (all switches zero). Adjust the presteering voltage so that the frequency is 16 MHz. For a small range of presteering voltage variation, the output frequency should remain at exactly 16 MHz.

Presteering system. Connect everything except the presteering output. Keep the potentiometer on the output loop presteering input. As you vary the output oscillator frequency slightly above and below 14.9 MHz, voltage **B** (U12, pin 7) should switch between zero and 5 volts. The output should be near zero volts when the output VCO is above 14.9 MHz.

Put the counter on U16, pin 7. It should show a square wave at the difference frequency. As this difference frequency goes above 3 MHz, approximately, voltage **A** (U17, pin 7) should jump from zero to 5 volts.

Now connect a voltmeter to the presteering output. When the VCO frequency is below 14.9 MHz, this output should increase to nearly 12 volts. When the VCO frequency is above 18 MHz it should drop to near zero volts. Remove the test instruments, connect the presteering output to the presteering input of the output loop, and then operate the system.

note on phase detectors

The phase detector in **fig. 4** yields its best performance when the two input signals are more than 30 degrees out of phase. Phase-frequency discriminator U19 in the presteering system requires that the two signals be *exactly* in phase. If both are operating from the same set of input signals, they work against each other, producing chaos. This may be eliminated by driving U19 from a separate phase-shifted output of the first loop. Thus, while U19 sees a zero phase difference, the SLB-1 mixer sees its inputs shifted by at least 60 degrees, resulting in stable operation. U20 delivers the required shifted output.

references

1. Raymond C. Petit, W7GHM, "Frequency Synthesized Local-Oscillator System for the High-Frequency Amateur Bands," *ham radio, October,* 1978, pages 60-65.

2. Raymond C. Petit, W7GHM, "Phase-Locked 9-MHz BFO," *ham radio,* November, 1978, pages 49-51.

ham radio

Stalking the Ultimate DX.
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More Details? CHECK—OFF Page 118

wideband amplifier summary

A powerful tool for designing wideband amplifiers using transformer feedback — features include low intermod distortion and low noise figure

Feedback amplifiers have been used in solid-state circuits for many years. Applications include wideband amplifiers for undersea cables, instrumentation amplifiers, and antenna amplifiers. For receiver front ends it's essential to combine good input impedance matching, low noise figure, sufficient gain, and a high intercept point. Good linearity can be achieved by using resistive feedback while sacrificing noise. A new circuit is presented combining all these advantages. It can be produced at very low cost.

feedback intermod, and noise figure

Bipolar transistors have a number of inherent nonlinearities:

1. Exponential base-emitter diode characteristics
2. Current-dependent diffusion-layer input capacitance
3. Voltage-dependent depletion-layer output capacitance

The distortion is highly dependent on the generator source impedance. If the generator source impedance is very small compared with the transistor/input impedance, the input voltage will be directly converted into an output current. This exponential transfer characteristic is responsible for all current nonlinearities.

The only cure for this type of distortion is current feedback. But current feedback provides two unpleasant side effects: it increases the device input and output impedance and therefore creates a mismatch. If the transistor is driven by a current-source generator of infinite impedance, distortion will depend mainly on the current-gain linearity. Since the output is converted into a voltage gain, voltage distortion will result. The only cure for voltage distortion is voltage feedback. Voltage feedback has the disadvantage of reducing the device input and output impedance.

The standard technique for current feedback is to use an unbypassed emitter resistor. This emitter resistor adds a significant noise contribution to the circuit, which is not phase correlated to the transistor internal noise sources. The resulting noise figure is typically between 6 and 10 dB. An amplifier with such performance cannot be considered a low-noise circuit.

Voltage feedback is accomplished by using a resistor feeding voltage from the collector to the base. Again we find resistive losses resulting in noise,

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which appears amplified as a product of the transistor gain at the output and which further reduces amplifier performance. Typically the noise figure of a wideband amplifier using this type of feedback as the sole source is at best 4 dB when ultra-low-noise transistors such as the Siemens BFT66 are used. The noise figure of the same circuit, at the same dc operating point without any feedback, is about 1 dB. An attempt should therefore be made to maintain the 1-dB noise figure while increasing the dynamic performance.

The intermodulation distortion as well as the noise figure is dependent on the emitter current. **Fig. 1** shows the two-tone test performance for two carriers of zero dBm at the input as a function of the dc current. It's obvious that the performance is not improved above 10 mA, which also indicates that the cutoff frequency peaks around 10-15 mA. This performance will vary from transistor to transistor. A

fig. 1

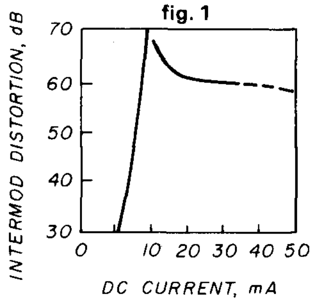


fig. 2

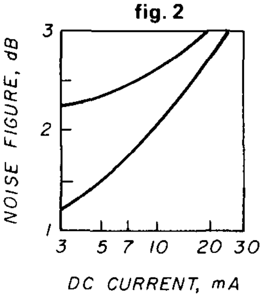


fig. 1. Two-tone test results (left) for two carriers of zero dBm at the input of a wideband amplifier as a function of dc emitter current. Improvement is limited above 10 mA.

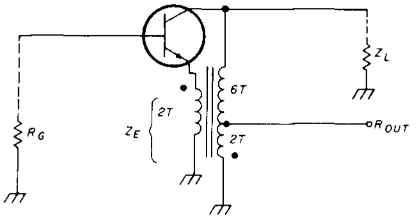
fig. 2. Noise figure (right) of a wideband CATV transistor amplifier versus emitter current. The transistor is a BFT65 used in a recent design for wideband antenna amplifiers.

typical CATV transistor, such as the 2N5109, has a flat curve of constant intermodulation distortion produced between 20 and 80 mA.

Fig. 2 shows the noise figure of a wideband CATV transistor as a function of dc current. This transistor (a BFT65) is a recent design for wideband antenna amplifiers. However, similar performance can be achieved with the less-expensive 2N5109. It's obvious that until the amplifier is driven to a level that the output voltage swing gets close to the collector dc voltage, the distortion and intermodulation is caused by the *exponential transfer function*.

noiseless feedback

If we use a feedback system as shown in **fig. 3**, in which the collector resistor is transformed back in series with the emitter by a transformer, the emitter will be grounded through a resistance depending upon the collector load. It's apparent that the voltage



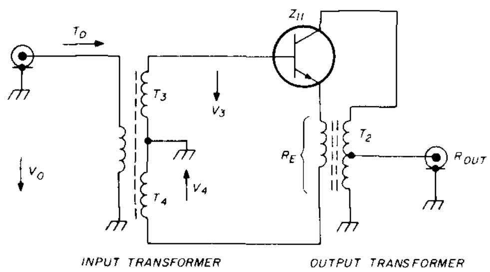
$$\frac{Z_L}{R_E} = \frac{Z_L}{Z_E} = \left(\frac{N_1}{1}\right)^2 ; \frac{Z_L}{R_{OUT}} = \left(\frac{1}{N_3}\right)^2$$

fig. 3. Feedback circuit in which the collector resistor is transformed back in series with the emitter by a transformer. Transistor emitter will be grounded through a resistance depending on the collector load, thus voltage gain is independent of load changes. The core is a Siemens B62152-A0004-X001.

gain is independent of any load changes, which results from the definition that the voltage gain is equal to the collector load resistor values divided by that of the unbypassed emitter resistor. Since this emitter resistor is derived by feedback, it adds no noise contribution. Therefore, this type of feedback is called "noiseless feedback."

Let's assume that the transformer collector-to-emitter turns ratio is three to one. Then the impedance ratio is nine to one, and the 450-ohm collector load will result in a 50-ohm emitter-current feedback impedance. Ideally this impedance is resistive. If the transistor is operated at 20 mA, the differential output impedance from emitter to ground will be about 1 ohm, assuming a current gain of fifty and a generator impedance for the transistor stage of 50 ohms. Therefore, we have a voltage division whereby the input voltage between base and ground is divided by forty-nine parts across the emitter impedance and one part across the base-emitter junction. The amount of current feedback is fifty and the linearity improvement is also roughly fifty, or 33 dB. The third-order intercept point, as shown previously without feedback, was about 30 dBm and has now been increased by 33 dB, resulting in about 63 dB.

The power gain of this stage can be calculated



$$I_4 = I_2 = I_1 ; V_4 = -V_3 N_2 ; V_3 = I_1 \cdot Z_{11} - I_4 R_e + V_4$$

$$I_4 = -I_3 N_2 ; V_0 = V_3 ; I_0 = I_1 + I_3 ; I_2 = -I_1 B^{-jF/F_T}$$

fig. 4. Schematic diagram of a bridge-type circuit which adds voltage feedback in order to lower the circuit's input impedance.

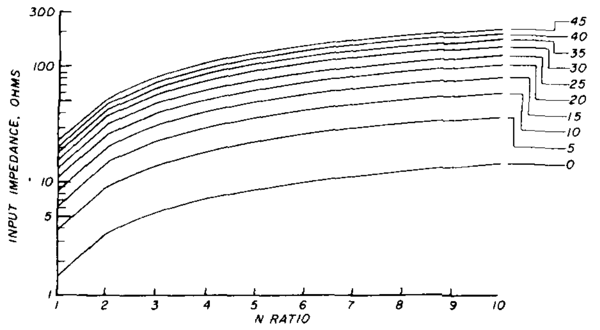


fig. 5. Voltage and current feedback amplifier using a 2N5109. Shown is input impedance (ohms) as a function of transformer turns ratio with R_E as a parameter.

from the voltage gain, which would be ten divided by the impedance scaling at the output, from 450 ohms to 50 ohms. Therefore a voltage gain of ten divided by three results in a power gain of about three. This power gain is defined by the input and output, whereby the transistor input impedance has become fairly high in value.

As stated earlier, the second source of distortion is voltage distortion. We will now apply voltage feedback to decrease the input impedance to a suitable value, such as 50 ohms.

voltage feedback using a transformer

Fig. 3 shows a bridge circuit, which transforms the transmitter emitter-to-ground impedance to a value determined by the bridge transformer turns ratio and puts it in parallel between base and ground. This feedback reduces the output impedance and is therefore counteractive to the current feedback. For developing the mathematical equations, R_E is the emitter and bypassed resistor value, which has been obtained by using a collector transformer. The various feedback network voltage and currents are included. While the mathematical derivation of this circuit takes a few minutes, only the results are shown.

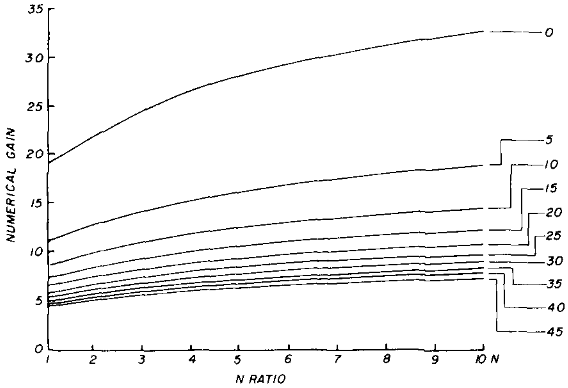


fig. 6. Same amplifier as in fig. 5. Gain as a function of transformer turns ratio is shown with R_E as a parameter.

The circuit input impedance is:

$$Z_{in} = \frac{Z_{11} + R_E \beta C^{-jF/F_T}}{\left(1 + \frac{1}{n_2}\right)\left(1 + \frac{1}{n_2}\beta e^{-jF/F_T}\right)}$$

$$= \left(\frac{n_2}{\left(1 + \frac{1}{n_2}\right)}\right)\left(R_E + \frac{26\,mV}{I_e}\right) \quad (1)$$

and the output impedance is:

$$Z_{out} = \left(\frac{R_G + Z_{11}}{\beta}\right)\left(\frac{n_1}{n_3}\right)^2$$

$$\approx \left(3\Omega + \frac{26\,mV}{I_e}\right)\left(\frac{n_1}{n_3}\right)^2 \quad (2)$$

The power gain has been determined as:

$$P_G = \left(\sqrt{\frac{Z_L}{Z_{in}}}\right)\left(\frac{\left(1 + \frac{1}{n_2}\right) Z_L}{\left(R_E + \frac{26\,mV}{I_e}\right)}\right) \quad (3)$$

$$and\ R_E = Z_L \left(\frac{1}{n_1}\right)^2$$

$$Z_L \approx 500\Omega, from\ Z_L = \frac{(V_{BAT} - V_{SAT})^2}{2P_{OUT}}$$

test data

Figs. 5 and **6** are the results of computer runs showing test data obtained with an experimental wideband amplifier using a 2N5109 transistor. **Fig. 5** shows input impedance (ohms) as a function of transformer turns ratio, N, with R_E as a parameter (ohms). **Fig. 6** shows amplifier numerical gain as a function of transformer turns ratio, N, again with R_E as a parameter. To obtain a 50-ohm input impedance with $R_E = 10$ *ohms*, for example, a transformer turns ratio, N, of about eight is required. For $R_E = 50$ *ohms*, the required turns ratio is about two.

conclusion

It's apparent that this circuit in its final form, providing an intercept point for third-order distortion of more than 70 dBm, is a very powerful tool in designing new wideband amplifiers. Because of transformer feedback, the noise figure is only about 2 dB. In a pushpull version, this circuit has shown a second-order intercept point of more than 120 dBm. These numbers appear to be much better than those for previously published amplifiers.

ham radio

improved GaAs fet preamp

for 144-432 MHz

Experiments with a new mesfet from NEC featuring simplified bias and amplifier circuits

Since its publication in the April, 1978, issue of *ham radio*, my article describing a 432-MHz low-noise preamplifier using a NE24406 GaAs fet[1] has resulted in many inquiries from readers. These inquiries have prompted some experiments with a new device, the NE24483 GaAs mesfet (metal semiconductor fet). The NE24483 has characteristics identical to those of the NE24406, but it costs less. This article presents the results of my experiments with the new device, which include

1. bias-circuit simplifications for the 432-MHz preamp;

2. applications of the NE24483 to 144-MHz amplifiers; and

3. circuit simplifications for the 432-MHz preamp.

simplified bias circuit for 432-MHz preamp

Fig. 1 shows the preamp circuit in reference 1. Separate power sources are arranged for the gate circuit (minus voltage) and the drain circuit (plus voltage). (This circuit is discussed later.) When EME communications (*i.e.*, high-power systems) are considered, this is the safest bias circuit for fets. However, with GaAs fets, if the drain voltage is applied first, a current will flow that reaches I_{DSS} (saturation current when the gate voltage is zero); in some low-noise transistors this current may reach 100 mA. Therefore, it's desirable that a method be used that always switches on the minus voltage to the gate. However, it's difficult to provide such a minus voltage.

Fet bias circuits. Fig. 2 shows five methods for supplying bias to fets.[2] Each method has its advantage, and no method can be said to be the best; however, the method easiest to use (considering component mounting and operation) has been employed.

Although the method shown in **A** of **fig. 2** is a bother to implement, it's a superior bias method for fets at extremely high frequencies, as in an 18-GHz amplifier. This is because, with this method, the source can be directly grounded, and the grounding inductance can be maintained smaller than with any other method. So this method will be significant when high gain at the high-frequency bands, or a low-noise amplifier, is desired.

In all methods other than **A**, a bypass capacitor is inserted in the source. Of these methods, **D** and **E** require only one power source. If a sudden increase in supply voltage occurs, series resistor R_S is connected to the source (D and E, **fig. 2**) so that a voltage, E, will appear across the R_S terminals and will automatically suppress the voltage increase between drain and source:

$$E = (R_S)(\Delta I_D) \qquad (1)$$

where ΔI_D is the increment of drain current caused by a sudden increase of supply voltage

Transistor protection is thus automatic.

Although circuit E (**fig. 2**) has this feature, circuit

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E is inconvenient to implement because a minus power supply must be used. In general, circuit D should be used.

Design. Generally, about 15 per cent of I_{DSS} is optimum as the recommended biasing point of these transistors for low-noise applications. Characteristics are shown in **table 1. Table 1** shows 60 mA as a typical value for I_{DSS}, so the bias circuit design is based on this value. A value of 20 milliohms is typical for the gm (transconductance) when $V_{DS} = 3\ volts$ and $I_D = 10\ mA$.

To determine R_S when $I_D = (0.15)(I_{DSS}) = 9\ mA$:

$$R_S = \left(\frac{I_{DSS}}{I_D} - 1\right) / gm \quad (2)$$

R_S is determined as:

$$R_S = \left(\frac{60\ mA}{9\ mA} - 1\right) / 20\ mmho$$
$$= 5.67/0.02$$
$$= 283\ ohms$$

If a drain current, I_D, of 9 mA flows when $R_S = 280\ ohms$, the voltage across R_S will be:

$$R_S I_S = (280)(0.009) = 2.52\ volts \quad (3)$$

If the voltage, V_{DS}, between drain and source is set to 3 volts, it will be sufficient for the bias if the power supply delivers $V_{DS} + (R_S I_D)$:

$$V_{DS} + (R_S I_D) = 5.52\ volts$$
$$= 3 + [(280)(0.009)] = 5.52\ volts$$

The bias circuit is now complete; its design is shown in **fig. 3. Fig. 4** shows the fet amplifier of reference 1 in which the bias circuit has been arranged to that described above.

Practical considerations. If a 5-volt, three-terminal voltage regulator is used in the power supply, further protection against damage is provided. Needless to say, in this case the voltage between drain and source will be somewhat lower than 3 volts, but absolutely no change will be noticed in actual use.

Attention should be paid to the value of R_S when the fet gm, V_p (pinch-off voltage), or I_{DSS} is irregular. R_S should be set to a value between 210 and 280 ohms at which the drain current, I_D, is the specified value.

With a preamplifier employing this biasing method (self-bias), supplying bias will be very easy, even when the amplifier is mounted directly under the antenna.

144-MHz band preamplifier employing GaAs fets

The impedance characteristics of the NE24406 in the 435-MHz band were shown in reference 1. These characteristics are shown in **fig. 5**.

Γ_{FOPT} indicates the impedance at which the noise figure, NF, becomes minimum when the transistor input circuit is matched to this impedance. Theoretically, this value has the following meaning. It shows what noise figure, NF, will be obtained when a certain impedance is connected externally to an element having an intrinsic minimum noise figure of F_0.

$$NF = F_0 + \frac{R_N}{G_S}\left[(G_S - G_0)^2 + (B_S - B_0)^2\right] \quad (4)$$

Here, G_0 and B_0 are the conductance and susceptance, respectively, when the noise figure is minimum. They have the following relationship:

$$\Gamma_{FOPT} = G_0 + jB_0 \quad (5)$$

From **eq. 4** it can be seen that the minimum noise figure will occur when $G_S + jB_S = Z_S$ becomes:

$$\Gamma_{FOPT}(G_0 = G_X;\ B_0 = B_S) \quad (6)$$

When any other impedance is connected, a noise figure is obtainable that's always worse than the case where $Z_S = \Gamma_{FOPT}$.

table 1. Typical electrical characteristics of the NE24406 and NE24483. $Ta = 25C\ (32F)$.

	symbol	conditions		min.	typ.	max.	unit
drain current	I_{DSS}	$V_{DS} = 3.0\ V$,	$V_{GS} = 0$	30	60	100	mA
pinch-off voltage	V_P	$V_{DS} = 3.0\ V$,	$I_D = 100\ \mu A$	−1.5	−3.5		V
maximum oscillation frequency	f_{max}	$V_{DS} = 3.0\ V$,	$I_D = 30\ mA$		55		GHz
transconductance	Gm	$V_{DS} = 3.0\ V$,	$I_D = 10\ mA$		20		mV
maximum available power gain	MAG	$V_{DS} = 3.0\ V$, $I_D = 30\ mA$	f = 4.0 GHz		17		dB
			f = 8.0 GHz	10	12		dB
			f = 12.0 GHz		9		dB
noise figure	NF	$V_{DS} = 3.0\ V$, $I_D = 10\ mA$	f = 4.0 GHz		1.5		dB
			f = 8.0 GHz		2.7	3.8	dB
			f = 12.0 GHz		3.7		dB

Now take another look at **fig. 5**. Γ_{FOPT} is at the edge of the Smith chart in a position where it is a predicted value for the 144-MHz band. In any case, a matching circuit for this value seems feasible.

The experimental 144-MHz GaAs fet schematic is shown in **fig. 6**. The pi network in the output is a 3-dB attenuator. (When these transistors are used in the 144-MHz band they may oscillate.)

A Johanson air trimmer is in series with the input, since only 4 to 5 pF is required. An inexpensive Philips trimmer capacitor could also be used. **Fig. 7** shows assembly and simple structural drawings of the preamplifier.

Incidentally, an $NF \leq 0.7$ *dB* and a *gain* ≥ 22 *dB* were obtained with this amplifier. These component values are approximately the same as those of the 430-MHz preamplifier previously described. They show that, at frequencies in this range, no improvement in noise figure occurs as a result of lower frequency, and the noise figure has a flat characteristic.

BNC connectors have been used in the input and output, but type N connectors would probably be better. The preamp shown in **fig. 6** employs self-bias. The bias circuit described previously can be used.

further simplification of the 432-MHz system

At the beginning of this article I described a simplified method for supplying bias (**fig. 4**). However this circuit employs four expensive air trimmer caps. I've received some comment about the difficulty of adjusting these air trimmers, so further simplification is in order.

The idea was to match the input circuit using a single fixed capacitor for *C1 instead of the air trimmer* (**figs. 4** and **6**). Theoretically it should be possible to replace the variable cap with a fixed cap of the correct value to obtain minimum noise figure.

Take another look at **fig. 5**. For minimum noise figure in the 430-MHz band, the impedance should be $50+j400$. This means that a $j400$ reactance should

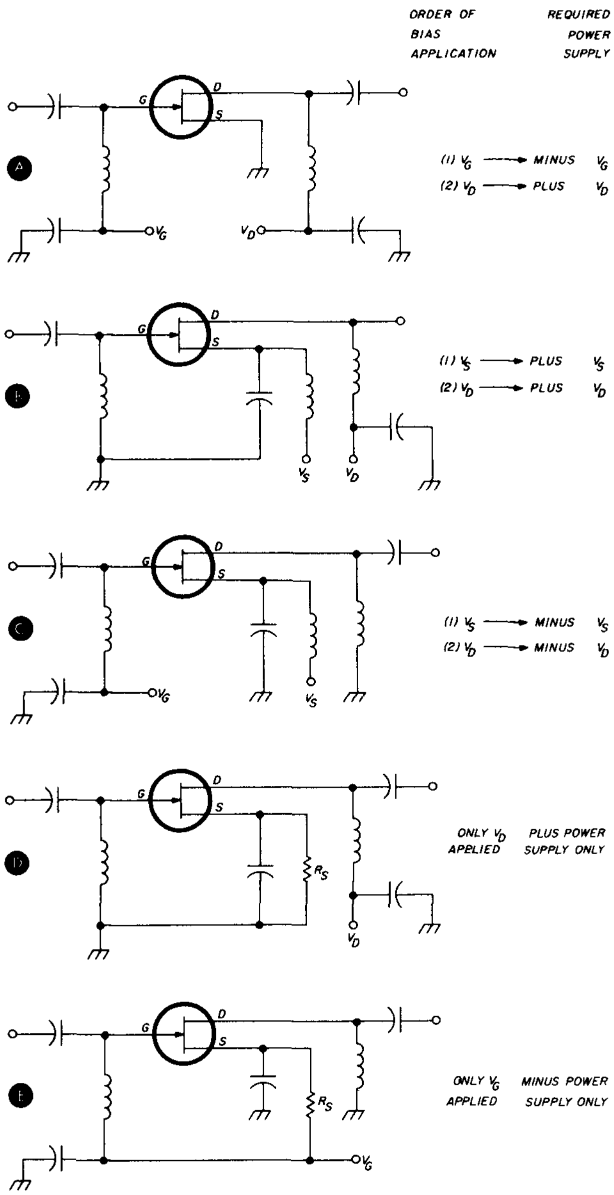


fig. 2. Five methods for supplying bias to GaAs fets (from reference 2).

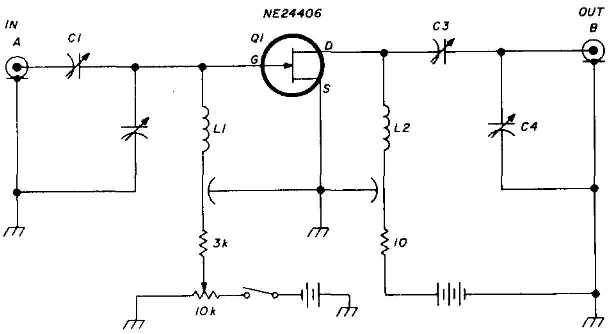


fig. 1. The low-noise 432-MHz preamp described in reference 1. An improved self-bias circuit has been designed (fig. 4).

be connected to the 50-ohm line. Close examination of **fig. 5** shows that an impedance of $50+j400$ is situated on the 50-ohm impedance line at a point in a counterclockwise direction when seen from the center of the Smith chart. A reactance element that gives a trace moving in a counterclockwise direction on the impedance line is a series capacitance. With this information, it can be seen how the GaAs fet preamplifier is designed.

The $j400$ impedance is expressed by:

$$\frac{1}{2\pi fC} = j400 \tag{7}$$

where $f = 435\ MHz$

$$C = \frac{1}{400 \times 2\pi f}$$

$$= \frac{1}{400 \times 2\pi \times 10^6}$$

$$= 0.915 \times 10^{-13}$$

$$= 0.915\,pF$$

Therefore, it can be seen that, matching for a minimum noise figure, *NF*, can be accomplished by employing a 0.915-pF series capacitor.

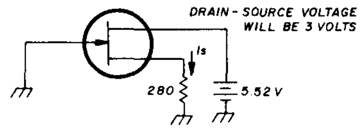


fig. 3. Self-bias circuit for the NE24406/NE24483.

In practice, the circuit will be affected by the circuit series inductance. However, since a series inductance produces a trace which moves in a clockwise direction on the impedance line, the capacitance of the series capacitor must be increased to compensate this inductance.

As seen from the size of the chassis used, the inductance of the capacitor leads can be estimated to be several tens of nH. About 1.2 pF can be considered optimum. Therefore, it will be ideal if the air trimmer in the input circuit and the single-turn coil resonate at the desired frequency in the 432-MHz band and they are employed only as an infinitely large impedance.

The circuit is shown in **fig. 8**. In this circuit the number of air trimmers has been reduced by one.

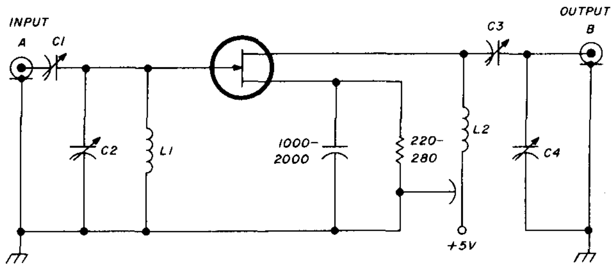


fig. 4. GaAs fet preamp using self-bias. Reference 1 shows component values.

With the method of connecting a 1.2-pF fixed capacitor in series with the input, a noise figure of $NF \leq 0.7$ *dB* was obtained, as were characteristics identical to those of the preamplifier presented before.

system sensitivity

All these preamps have a noise figure, *NF*, less than 1 dB; thus they are candidates for receiving systems of tremendous sensitivity, but this isn't easy to attain. In a high-sensitivity receiving system, thought must be given to the system *as a whole*, including the antenna and coaxial cable.

Noise at receiver terminals. Here the relationship between antenna and receiver sensitivity is discussed. In **fig. 9**, a "no-loss" bandpass filter with a bandwidth of *B* is assumed. A load resistor is connected across the output terminals, and a resistor equal to the filter input impedance, within the passband range, is connected to the filter input terminals.

In this state, when the resistor connected to the filter input is maintained at absolute temperature, *T* (*degrees Kelvin*), thermal noise will be generated by

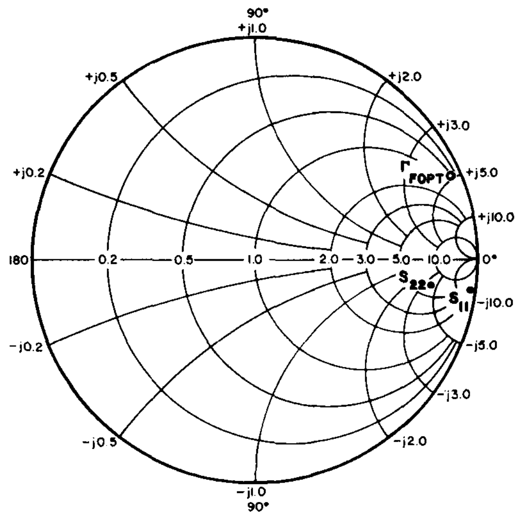


fig. 5. NE24406/NR24483 impedance characteristics.

this resistor and will flow into the filter output load.

The noise power, *N*, flowing into the load resistor is:

$$N = \frac{hfB}{e^{hf/kT} - 1} = kTB\,(hf << kT) \qquad \textbf{(8)}$$

where

h = Planck's constant $(6.62 \times 10^{-34}\,joules/sec.)$
k = Boltzmann's constant $(1.38 \times 10^{23}\,joules/deg.)$

Eq. 8 shows that the noise generated by the resistor is proportional to the *absolute* temperature.

Accordingly, this absolute temperature is called the noise temperature. The magnitude of the noise can be expressed by the noise temperature, *T*; the noise power, *N*, can be expressed as $N = kTB$.

In the example above, I've shown the results of thermal noise generated within a typical receiver input circuit. The resistor connected at the filter input

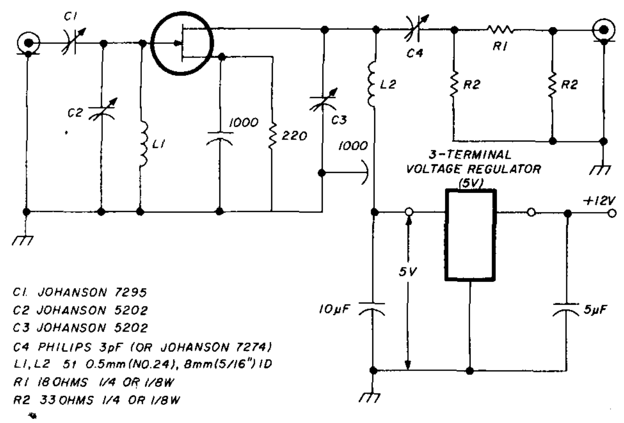


fig. 6. GaAs fet preamp for 144 MHz using self-bias.

represents this noise. But what about other noise, such as that entering the receiving antenna from space?

In this case, the receiving-antenna output terminals are connected to terminals 1 and 1′ (**fig. 9**) instead of the resistor.

Noise coming from space or artificial (manmade) noise will appear at the antenna output. Connect a noise-power meter of N watts to the bandpass-filter output. Determine:

$$Ta = \frac{N}{kB} \qquad \textbf{(9)}$$

which is the antenna noise temperature. This temperature is the same as that of the resistor in **fig. 9**, whose thermal noise exactly replaces the noise coming into the antenna.

Receiving-system noise characteristics. As shown in **fig. 10**, the antenna is connected to the receiver through a transmission line (coaxial cable). In this case, a) the noise coming into the antenna, b) the thermal noise generated by the resistive loss of the transmission line, and c) the noise generated inside the receiver are compounded. Let's convert all of these noise powers to their equivalent at the receiver input terminals.

Antenna noise. If the antenna noise temperature is assumed to be Ta, then, as described before, the noise power flowing into the transmission line from the antenna output will be $kTaB$. Now, if the transmission-line insertion loss (coaxial cable) is taken as $10 \log_{10} L$ (dB), the antenna noise power flowing into the receiver input terminals will be:

$$\frac{kTaB}{L} \qquad \textbf{(10)}$$

where L is the cable insertion loss.

Transmission line noise. The transmission-line absolute temperature is assumed to be T_0K, and a matching load resistor is connected in place of the antenna in **fig. 10**. Then a load resistance is connected, and the load resistance and transmission line are maintained at a temperature of T_0K.

The noise power occurring at the receiver input terminals will be kT_0B. Of this noise power, the portion generated by the matching load resistor, which appears at the receiver input terminals, will be kT_0B/L. Therefore, the actual thermal noise power generated by the transmission line will be:

$$kT_0B\left(1 - \frac{1}{L}\right) \qquad \textbf{(11)}$$

If the line has no loss, L will become 1; therefore, from **eq. 11**, noise generated by the line will become zero. This is a natural result, considering the principle that thermal noise is produced by resistance.

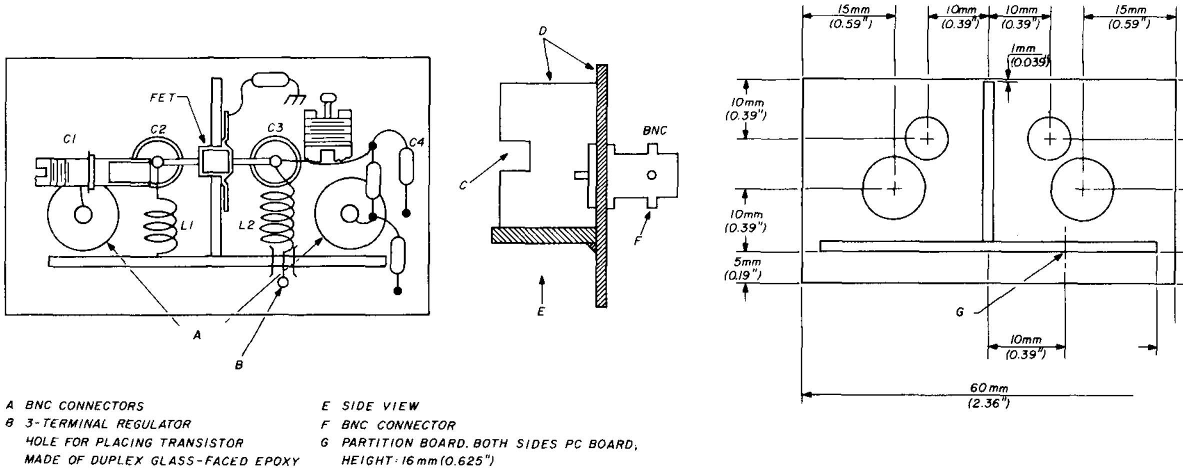
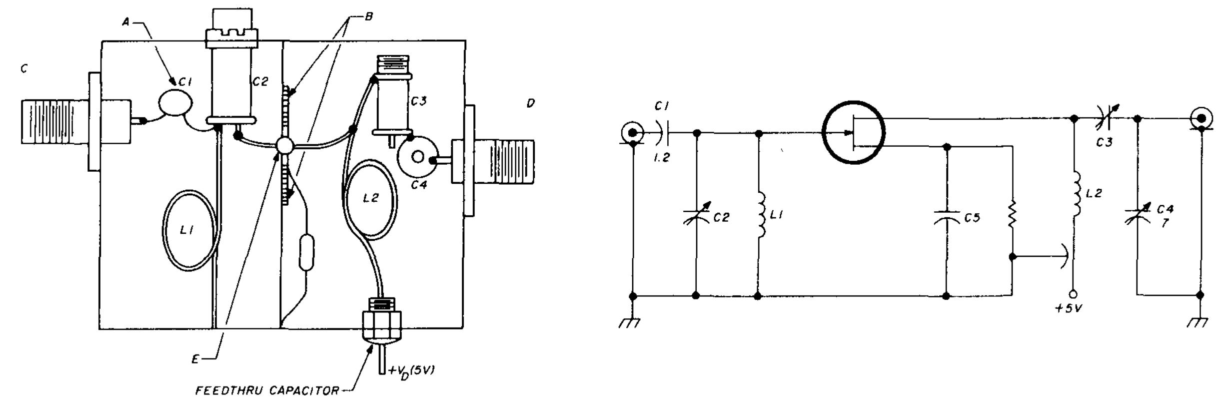


fig. 7. Parts layout and assembly drawings for the 144-MHz preamplifier.



A FIXED CAPACITOR, 1.2pF
B 1000pF SOLDER CAPACITORS ATTACHED TO PARTITION BOARD
C INPUT
D OUTPUT
E NE24483 OR NE24406

fig. 8. Simplified 144-MHz preamp using a fixed capacitor for the input circuit. A noise figure of 0.7 dB was obtained, as well as characteristics identical to those of the preamp in fig. 6.

Receiver-generated noise. Whatever noise figure an amplifier has, when an attempt is made to obtain gain, the noise figure will always be degraded compared with the $SN(S_{in}/N_{in})$ of the input signal.

When a preamplifier having a noise figure NF_1 and gain G_1 is connected in front of a receiver having a noise figure NF_2, the overall system noise figure is:

$$NF = NF_1 + \frac{NF_2 - 1}{G_1} \qquad \textbf{(12)}$$

In this case, if $NF_1 << NF_2$ and $G_1 >> 1$, the receiver noise figure will be improved.

As previously mentioned, noise power can be converted into temperature; this relationship is:

$$T_e(290)\,[(NF-1)] \qquad \textbf{(13)}$$

When considered in terms of power:

$$N = kT_eB \qquad \textbf{(14)}$$

and this amount of noise power will appear at the receiver output.

Over-all noise characteristics. The sum of **eqs. 10, 11,** and **12** is the overall noise power at the receiver input terminals. When this is taken as N:

$$N = kB \quad \frac{T_a}{L} + T_0 - \frac{T_0}{1} + T_e \quad = kTB \qquad \textbf{(15)}$$

Therefore:

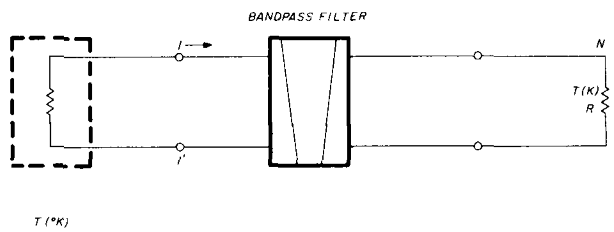
$$T = \frac{T_a}{L} + T_0\left(1 - \frac{1}{L}\right) + T_e \qquad \textbf{(16)}$$

T is the receiving system over-all noise temperature.

The smaller the value of T, the better. (Note that the coaxial-cable loss, L, always has a value larger than 1.) The noise at the receiver output is always the sum of a) the noise coming into the antenna, b) the noise generated in the coaxial cable, and c) the noise generated in the receiver. So the receiving system should be constructed with the distribution of these noises in mind.

When the receiver noise, including the coaxial cable loss, is higher than the antenna noise temperature, it will be necessary to obtain a signal that will override this noise. In such cases a preamplifier ahead of the receiver will be effective. But since the over-all noise temperature won't become lower than the antenna noise temperature there may not be much effect, even when the receiver noise temperature is extremely low compared with the antenna noise temperature.

Preamplifiers and receiving systems in practice. The relationship between the equivalent temperature of natural noise and frequency is shown in **fig. 11.** Using this relationship as a datum, let's discuss receiving systems using GaAs fet preamplifiers. (Understanding will be made easier if actual numerical values are inserted into **eq. 16.**)



N NOISE POWER
R LOAD RESISTANCE
T(K) ABSOLUTE TEMPERATURE OF NOISE SOURCE IN DEGREES KELVIN

fig. 9. Explanatory diagram for noise-temperature discussion.

An ideal antenna is assumed, whose noise temperature in the 432-MHz band is determined solely by natural noise. Then, from **fig. 11**:

$$T_a = 48K \text{ at } 435\ MHz$$

A system as shown in **fig. 12** is used as an example. Let's consider a state when the temperature is 17C:

$$\textit{loss of coaxial cable, } L = 3\ dB$$

$$\textit{noise figure of receiver} = 1\ dB$$

The over-all noise temperature, T, for this case is determined from **eq. 16**. First, the loss, L, of the cable is converted into an antilog:

$$log^{-1}\, 3\, dB = 1.9 \tag{17}$$

Next, the $NF = 1\ dB$ of the receiver is converted to noise temperature, T_e, using **eq. 13**. For this, $NF = 1\ dB$ is converted into an antilog:

$$log^{-1}\, 1\, dB = 1.3 \tag{18}$$

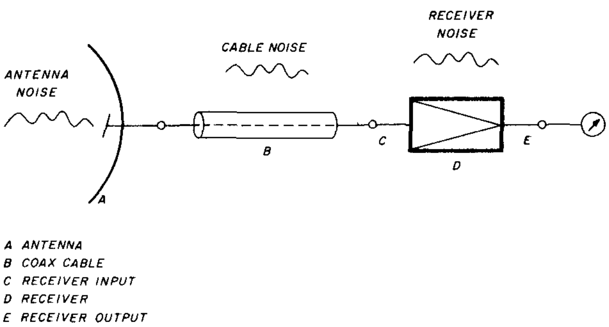


fig. 10. Noise-generating points in a receiving system.

Substituting this value into **eq. 13** yields:

$$T_e = 290 \times (1.3 - 1) = 87K \tag{19}$$

$$T_0 = 273\ degrees + 17 = 290K \tag{20}$$

Calculation of **eq. 16** yields:

$$T = \frac{48K}{1.9} + \left[290K\,(1 - \frac{1}{1.9})\right] + 87 = 249K \tag{21}$$

If a coax cable with absolutely no loss can be used, L in **eq. 16** will be $L = 1$ and will be sufficient if:

$$T = T_a + T_e \tag{22}$$

is calculated.

In this case:

$$T = 48 + 87 = 135K \tag{23}$$

will be obtained.

Let's take another look at **eq. 16**, which shows the over-all noise temperature of the receiving system. Suppose you have a receiver with a noise figure of

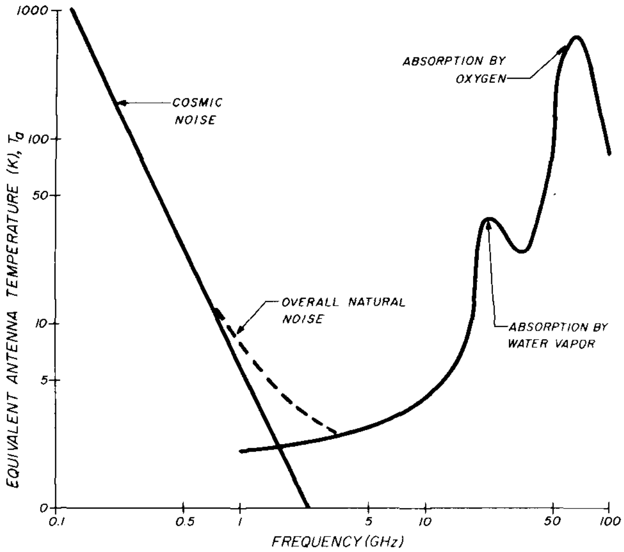


fig. 11. Antenna equivalent temperature as a function of frequency with natural noise as a parameter.

$NF = 1\ dB$ connected to a coax cable with a 3-dB loss. According to **eq. 21**, the over-all noise figure, NF, will be:

$$\begin{aligned} NF &= 10\,log_{10}\,(1 + \frac{249}{290}) \\ &= 2.7\ dB \end{aligned} \tag{24}$$

This can be explained as follows. An antenna having a noise temperature of $T_a = 0K$, and a receiver having a noise temperature of $T_e = 0$ are assumed. When a 3-dB attenuator is connected to the receiver input, what will become of receiving-system noise figure? The noise figure should be 3 dB. But according to **eq. 16** the noise temperature is about 145K, and the noise figure, NF, will be 1.8 dB. When thinking about a receiver, the signal-to-noise ratio should be considered. When a 3-dB attenuator is connected

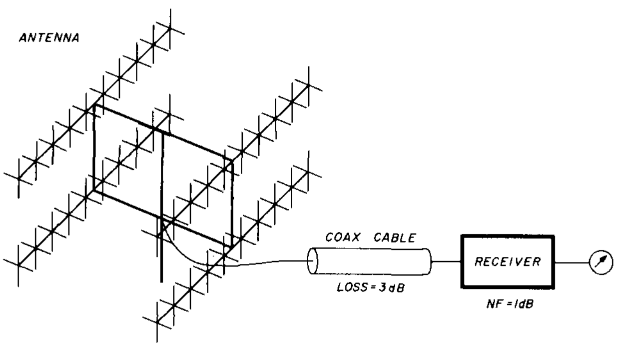


fig. 12. 432-MHz receiving system used as an example for showing the relationship between natural noise and frequency. Antenna noise temperature, T_a (from fig. 11), is 48K at 432 MHz.

to a receiver having 0-dB noise figure, the noise figure will be 3 dB (noise temperature 290K).

signal-to-noise ratio

With regard to the signal entering the receiver input, the transmitting-antenna gain is expressed by G_T; the power output by P_T, and the receiving-antenna gain by G_R. A loss occurs between the transmitting point and receiving point, which is expressed as L_S. Furthermore, when the coaxial-cable loss from the antenna is expressed as L, the strength of the signal entering the receiver will be:

$$S = P_G G_T G_R \frac{1}{L_S L} \quad \textbf{(25)}$$

To calculate the signal-to-noise ratio, **eqs. 15** and **16** are added to **eq. 25**. Then:

$$SN = P_T G_T G_R \frac{1}{L_S L} \quad /kTB$$

$$= \frac{P_T G_T G_R}{L_S} \times \frac{1}{[T_a + T_0(L-1) + LT_0]\, kB} \quad \textbf{(26)}$$

Only the second term of **eq. 26** is the portion in which the receiving-system sensitivity is shown. Therefore, from **eq. 26**, it can be understood that, when a 3-dB attenuator is connected to an amplifier of $NF = 0\ dB$, the system noise figure will be degraded by 3 dB, as well as the signal-to-noise ratio, SN.

$$T_r = T_a + T_0(L-1) + LT_e \quad \textbf{(27)}$$

is defined as the noise temperature of the receiving system including the coaxial cable. When the above example is calculated again using **eq. 27**:

$$T' = 48 + [290(1.9-1)] + [1.9 \times 87] = 474K \quad \textbf{(28)}$$

This value has the surprising amount of 339K difference compared with the value when the coaxial-cable loss isn't considered.

This difference is more than 3 dB, so if an amplifier or preamplifier of good noise figure and ample gain is placed directly after the antenna, without any coaxial cable, the noise figure may be improved more than the loss (3 dB, in this example) of the coaxial cable. This occurs because the coaxial cable has resistance and generates some noise.

points for EMErs

To perform EME in the 432-MHz band in Japan, a maximum output of 500 watts is sometimes permitted. However, in such cases, when transmitting, some power may detour and damage the GaAs fet amplifier.

Consider **fig. 13**. What degree of isolation should the coaxial switch have on the input side of the preamplifier to be adequate?

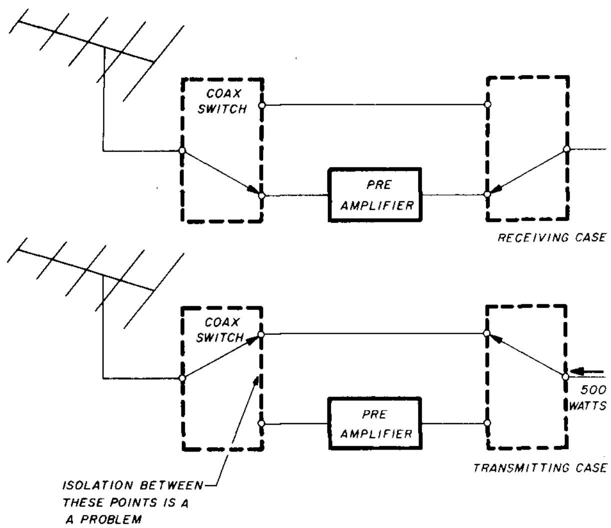


fig. 13. When using high power, isolation in the coax switch is important to protect the fets in the preamp.

Here, a transmitting power output of 500 watts is expressed as 57 dBm. If the coaxial-switch isolation is 30 dB in the 432-MHz band, the power that will detour to the preamplifier input during transmission will be 27 dBm (500 mW). Will the fet be protected at this level?

Table 2 shows the power level at which the GaAs fet approaches breakdown in the 432-MHz band when the input power is gradually increased. These are values determined by my experiments in the 432-MHz band. Answers to such questions as "How long will the fets withstand a level 1 dB lower than these values?" are, I regret to say, not yet available.

The power differences in **table 2** occur because of the difference in the biasing methods, and are of great interest. Let's consider why this difference occurs.

Fig. 14 shows two biasing methods. When the input power is inceased in method **A**, at a certain

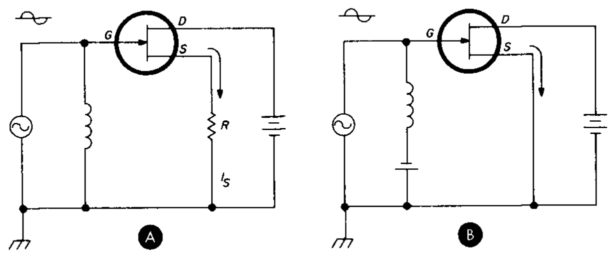


fig. 14. Allowable maximum input power is smaller for the self-bias method (see text).

moment the gate-source span will become forward biased, the current I_S will increase. However, when current I_S increases, a potential drop $I_S \times R$ is created; and in time, the source potential will rise, impeding current flow in a forward direction in the fet. Then, only a voltage in the reverse direction will be applied between gate and source; and when this voltage exceeds the reverse breakdown voltage between gate and source, it will bring about fet breakdown.

However, in the case of **B** of **fig. 14**, the gate voltage is always maintained lower than the source potential by the application of a constant potential. This constant potential prevents the gate voltage from being more greatly negatively biased (reverse direction) through the rising of the source potential by the input voltage. From this, it can be seen that method **B** is strong against breakdown.

From the standpoint of construction and adjustment, method **A** of **fig. 14** is very stable. However, there is the contradiction that this stability is hard to obtain under actual operating conditions. It's imperative that the maximum input power of the preamplifiers described in this report be designed to have a value 3 dB *lower* than the values shown in **table 2**.

table 2. Allowable maximum input of GaAs fet preamplifiers.

fet	CW	ssb
with two bias circuits:		
NE24483 NE24406	23 dBm (100 mW)	28 dBm (158 mW)
with self-bias circuit:		
NE24483 NE24406	20 dBm	25 dBm

Therefore, when a self-bias circuit is employed, an isolation of 40 dB will be required to transmit at 500 watts (7 dBm). Furthermore, although these values have been determined experimentally, I've found that when input power is applied without applying bias, breakdown will occur at values 1-2 dB lower than those shown. Thus, when high-power operation is attempted, it will be safer to keep the bias applied during transmission.

Finally, it's desirable to consider using a delay circuit that will ensure transmitting power is always cut off before the coaxial switch is moved to the receiving position. This will ensure further safety of operation.

references

1. S. Sando, JH1BRY, "Very Low-Noise GaAs fet preamp for 432 MHz," *ham radio*, April, 1978, pages 22-27.
2. G.D. Vendelin, "Five Basic Designs for GaAs Amplifiers," *Microwaves*, February, 1978.

ham radio

More Details? CHECK—OFF Page 118

diversity reception:

an answer to high frequency signal fading

Diversity reception techniques are discussed with ideas on how they can be implemented with today's equipment

Signal fading is one of the principal problems confronting Amateurs in the high-frequency or shortwave bands. This seems strange, because fading was one of the earliest high frequency problems to be investigated. A 1927 *QST* article[1] shows that a worthwhile reduction in the adverse effects of fading can be obtained by using diversity reception.

What is diversity reception? With diversity reception, two or more different, or diverse, antenna/receiver combinations are used to receive the same signal. A two-channel system is known as dual diversity; a three-channel system, triple diversity. Diversity reception is widely and effectively used in commercial high frequency installations but has never been popular with Amateurs. One wonders why. Considering what the development of stereo did for the hi-fi industry, I'm surprised that the receiver manufacturers didn't push diversity reception years ago.

In this article I discuss fading and explain how diversity reception can minimize signal loss due to fading. I then discuss equipment considerations for a diversity reception system.

diversity reception

Although it's not apparent to a listener with one receiver and one antenna, fading is not uniform over the surface of the earth. If the listener had several antennas separated by between two and ten wavelengths, with each antenna connected to its own receiver, he'd find that the signal received by the various antennas faded more or less independently of one another. The probability of all receivers being in a fade at the same time is very small. So, if several receivers are connected so that the receiver with the strongest signal can be chosen, the effect of fading can be greatly reduced.

Fig. 1 is a strip-chart recording of a CW signal received on 19 MHz using a triple space-diversity system. The first three rows show each channel individually, while the bottom row shows the combined signal. Note the reduction in fading of the combined output.

The fading characteristics of the two signals of a dual-diversity system may be described mathematically by what is known as the correlation coefficient of fading, R. This coefficient may have any value between -1 and $+1$. When $R = +1$, the two signals will vary in the same direction; *i.e., both signal will be either above or below a reference "minimum usable signal level" (MUSL) at the same time. In this case, diversity operation will obviously not provide any improvement.*

When $P = -1$, the two signals will always fade in opposite directions; when one signal is above the MUSL, the other will always be below it. In this situation, diversity operation will provide fade-free reception, since one of the signals will always be above the MUSL. Unfortunately, negative correlation factors are seldom found in practice.

When $R = 0$, the two signals will fade completely independently of each other. In this case, the proportion of time that both signals spend below the MUSL simultaneously is equal to the product of the proportion of time that each signal will be below that MUSL individually.

The advantage of diversity reception is measured by what is called "diversity gain" and is given in dB. Diversity gain is the increase in average signal level obtained from a diversity receiving system compared with the level obtained from a single-channel receiver averaged over a period of time, usually 5 to 10 minutes. Diversity gains of between 3 and 20 dB are typical in commercial practice, and gains approaching these values are probably obtainable in Amateur practice, a worthwhile improvement in average received signal level.

By John J. Nagle, K4KJ, 12330 Lawyers Road, Herndon, Virginia 22070

Commercial stations using high frequency propagation commonly use three antenna/receiver combinations; the law of diminishing returns applies for more than three. A substantial improvement can be obtained, however, using only two receiving systems, and it's doubtful if more than two channels are justified for Amateur applications.

fading

To understand how diversity reception improves reliability, it's necessary to understand the fading phenomenon. Fading in the high frequency, or shortwave, bands is basically of two types: path failure and multipath.

Path failure occurs when the ionosphere can no longer reflect the transmitted frequency back to earth. A good example of this is the way signals on 10, 15, and 20 meters fade out at night: The signals just gradually disappear into the noise. This type of fading is also known as "flat fading," since all frequencies over the usual information bandwidths fade together. Nothing can be done to overcome this type of fading except to change frequency; if the signal is not there, two receivers are not going to hear it any better than one. Path failure isn't a serious problem anyway, because propagation forecasts can generally predict which frequencies will fade and when, so that you can arrange your operating plans accordingly.

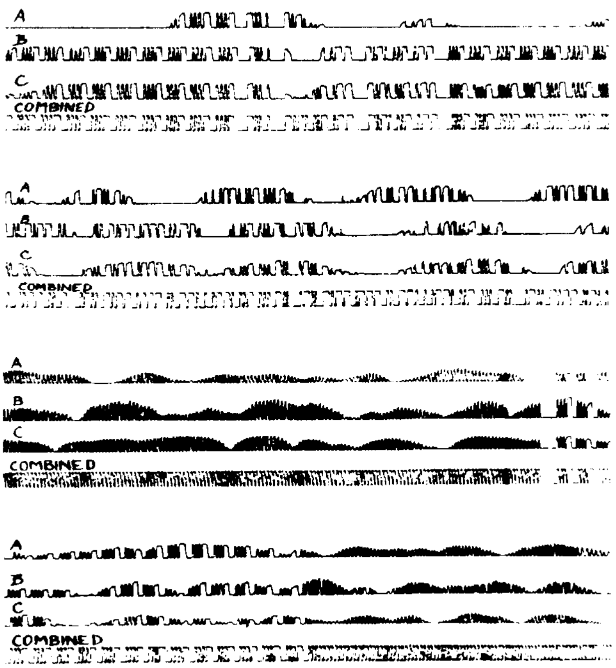


fig. 1. Strip chart recording of keyed CW signals from the output of the three separate channels of a triple-diversity receiver is shown in rows A, B, and C. The combined output is shown in the bottom row, illustrating the reduction in fading possible with this type of system (from reference 2, page 543).

Multipath fading is much more annoying and is the result of two or more waves from the same transmitter traveling over different paths and arriving at the receiver with different phase relationships. If the length of these paths differs by an odd multiple of a half wavelength, which is only about 10 meters (35 feet) at 14 MHz, the two waves will arrive out of phase, and a fade will occur at that frequency. If their path lengths differ by one wavelength, the two waves will arrive in phase, and a "fade-up" will occur.

The distance from the East Coast to the West Coast of the United States is about 5000 km (3000 miles), and the radio path is slightly longer because of its round trip to the ionosphere. A path difference of only 10 meters (35 feet) represents a very small percentage difference between the two, so it isn't any wonder that multipath fading occurs and creates the problem it does.

types of diversity reception

The ionosphere is not stationary but dynamic — more so at some times than others. Paths are constantly changing in both number and length. Therefore signals fade in and out randomly at different locations, at different times, and on different frequencies, all depending on the signal polarity and its angle of arrival. This phenomenon gives rise to five different types of diversity reception: space, polarization, angle of arrival, time, and frequency.

Space diversity. The most common form of diversity reception used by commercial high-frequency stations is space diversity. In commercial practice triple diversity is usually used, with the three antennas spaced at the corners of an isosceles triangle measuring two to ten wavelengths on a side.[2] Increasing the spacing beyond this amount doesn't materially improve reception, nor does using more than three antennas. Many experimenters, including Amateurs, have found that a worthwhile diversity gain can be obtained on the 20-meter band by using only two antennas spaced about 15 meters (50 feet) apart. Therefore, space diversity can be practical for Amateur stations restricted to a modest suburban lot. With correlation coefficients of fading as high as 0.6, space diversity can still provide a significant diversity gain.

Polarization diversity. Where space is a limiting factor, as it is at many Amateur locations, a considerable reduction in the effects of fading can be obtained from polarization diversity; that is, using one horizontal antenna and one vertical antenna, each connected to its own receiver. The same tower that supports the horizontal antenna, or one end of it, can also act as the vertical antenna. Polarization diversity is possible because the vertical and horizontal components of the received signal do not usually fade simultaneously, even at the same location.

Some Amateurs report an unusual effect when using polarization diversity: The ionosphere gets hung up on one polarization for extended periods of time, often several days. When this happens, a single-receiver channel using the wrong polarization would report that conditions were bad, whereas a polarization diversity system would report good conditions.

The advantages of space over polarization diversity, if any, are not clear. Grisdale *et al.*[3] report more diversity gain with space than with polarization diversity under some conditions, and *vice versa under* other conditions; the *differences are too detailed to* list here. In any event, significant diversity gains are obtainable with either type of diversity, with the difference between the two usually limited to 2.5-3 dB.

Angle-of-arrival diversity. This method uses one or more antennas with lobes at various vertical angles of arrival. Experiments have shown that waves arriving at vertical angles differing by as little as two degrees will give significant diversity gains. Close control of the vertical radiation pattern requires a vertical antenna many wavelengths tall; therefore this type of diversity system doesn't appear to be practical for most Amateurs.

Frequency diversity. Two separate frequencies are used to transmit the same message, because different frequencies don't necessarily fade at the same time. By transmitting the same message simultaneously on different frequencies and listening to the stronger of the two, circuit reliability can be improved. Frequency separations as small as 400 Hz will give considerable improvement on long-haul, high-frequency paths. It therefore appears possible to receive the two sidebands of an a-m or DSB signal, demodulating each sideband separately with two different SSB receivers, thus receiving frequency diversity. (I will discuss this later.)

Time diversity. Time diversity uses two channels, usually with the same transmitter, antennas, and receiver. Imagine a transmitter capable of transmitting two teletype signals simultaneously. Start a message on channel A and a minute or so later restart the same message on channel B. At the receiving end, match the messages received on the two channels. The probability of the circuit fading out during the same portion of each message is much lower than the probability of a fade on only one channel, so that an improvement in circuit reliability can be obtained. Delay times of between 0.05 and 95 seconds, depending on conditions, have been found to give improvement.

Note that both frequency and time diversity improve reliability by sacrificing channel capacity, *i.e.*, by halving the number of messages that can be transmitted over the circuits in a given period of time. If there were no fading, two different messages could be transmitted over the same two circuits. Space, angle of arrival, or polarization diversity, however, don't reduce the channel capacity.

diversity transmission?

Diversity reception has been shown to increase the average signal level, so one might reasonably ask if additional improvement could be obtained by transmitting over two or more antennas. The answer is no. Because fading is caused by multipath, using two transmitting antennas with either space or polarization diversity would double the number of possible different signals reaching the receiver, thereby increasing the possibility of multipath fading.

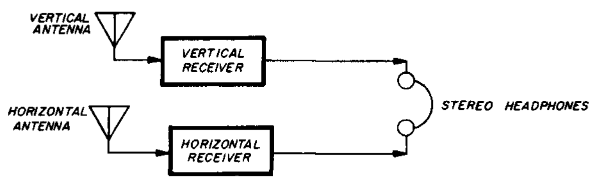


fig. 2. A simple polarization diversity receiving system.

The best thing that the transmitter can do is to concentrate its available energy in as small a beam as possible, *i.e.*, use an antenna with as much gain as is practicable. This is standard practice anyway, so no changes are necessary at the transmitter.

diversity receiving techniques

If we assume polarization diversity, which appears to be the most practical for Amateur use, the simplest form of a diversity receiving system consists of two separate receivers, one connected to a vertical antenna and the other to a horizontal antenna. The output of each receiver is connected to separate headphones, such as are commonly sold for stereo use; see **fig. 2**. This is a simple and effective method, but it has the disadvantage that the receiver whose input signal is "down" generates noise, making it difficult for the operator, since the noise changes from ear-to-ear.

This problem can be easily corrected by tying together the agc circuits of the two receivers. In this way the agc of the "up" receiver will tend to mute the "down" receiver, minimizing the noise in the down channel; see the sketch in **fig. 3**.

The next obvious step is to combine the audio output of the two receivers in a common amplifier, as shown in **fig. 4**. However, this technique can only be used for phone reception, a-m or SSB; not for CW. The reason is that for CW the audio-tone output of each receiver has a phase that depends upon the phase of the rf signal received by the respective antenna. As the relative phases of each rf signal vary in a random manner because of multipath effects, the phase of each audio tone will vary randomly, too, and there will be times when the audio tones will be 180 degrees out of phase. A fade will then occur in the receiver combined output, even though the signal in each receiver is strong. This is just what we are trying to avoid!

There are two solutions to this problem. The first, used by the commercials, is to take the second-detector output as a dc pulse and add the pulses in a simple summing network. The resulting pulses will be relatively fade-free and are used to key an audio oscillator, which the operator hears in his headset.

The second technique uses what is called a "heter*otone*"[4] oscillator, which is simply a multivibrator operating at about 400 Hz generating two square waves 180 degrees out of phase. These are used to alternately gate each diversity i-f channel. This signal modulates the CW signal at the intermediate frequency.

Tuning a CW signal using a hetero*tone* oscillator is definitely different from tuning one with a heterodyne oscillator, or BFO; with the heterotone no change occurs in pitch as you tune through the signal.

early diversity receivers

Considering all the advantages of diversity reception, there have been surprisingly few attempts to develop diversity techniques for Amateur use. The earliest attempt of which I am aware was in 1936 by Carll Roland,[5] who used two antennas 183 meters (600 feet) apart connected to two short wave broadcast receivers. Even with such primitive equipment and many trials and errors, Roland's results were good. The final sentence in his article reads: "If the

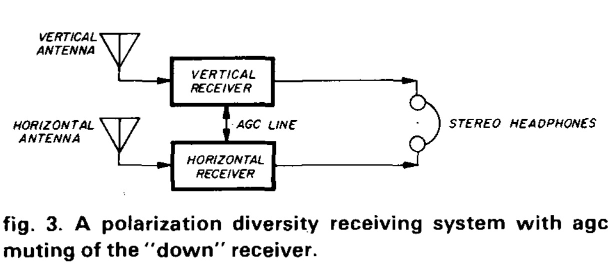


fig. 3. A polarization diversity receiving system with agc muting of the "down" receiver.

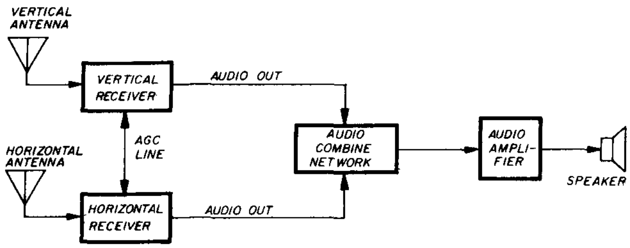


fig. 4. A full dual-polarization diversity receiver for phone work.

broadcast listeners had not wanted their receivers back, we would have kept on using diversity reception."

The second step was taken by James J. Lamb and J. L. A. McLaughlin,[6] who designed what is probably the first single-tuning-control diversity receiver. They developed this receiver specifically for Dr. James M. B. Hard, an American who will be remembered by old timers as XE1G in Mexico City.

QST for December of 1937 describes the third step in an article by J. L. A. McLaughlin and Karl W. Miles.[7] They refer to the May, 1936, receiver (my reference 6) and say, in part:

> It has conclusively demonstrated the practicability and desirability of diversity reception for amateur and experimental communications work. Even with two antennas spaced but 50 feet apart, good diversity action has been obtained, especially on the 14-Mc band. Dr. Hard reports that many times when fading conditions and heterodyne interference became so bad as to make his other single receivers useless, the dual diversity still brings in an intelligible signal.

This receiver was considerably improved over the earlier version, mostly in a simplified mechanical design and an improved i-f amplifier. Apparently it was also built specifically for Dr. Hard and became the prototype of the Hallicrafters dual diversity receiver model DD-1. It contains many unique and advanced engineering features, even by today's standards. I'll not go into detail now; see the photograph of my model in **fig. 5**. It's a very impressive piece of equipment!

With diversity reception it's not necessary to use specially made receivers or even identical receivers. Taylor[8] describes a 10-meter diversity system using a Hallicrafters SX-17 and a Skyrider 5-10 receiver. His antennas were a horizontal 10-meter dipole and one-half of a vertical 5-meter beam. One end of the 10-meter dipole was attached to the pole that held the 5-meter beam.

As an example of his results, Taylor describes the 10-meter reception of a GM6 late one afternoon:

> . . . most of the Britishers had already passed out of the picture. With a single receiver and antenna his signal was

so hashed up by a fast fade from S9-plus down into the mud that only about one word out of five was understandable. On switching in the other half of the diversity combination his signal was brought up and smoothed off at a level which rarely fell below S-8; a solid and completely intelligible signal . . .. We will guarantee a thrill the first time you see one of the "S" meters . . . drop down to the bottom of the scale with the signal still pouring out of the 'phones in fine style.

A slightly different approach to diversity reception has been suggested by Bartlett.[9] Bartlett connects each antenna to a separate rf preamplifier; the output of each of the two preamplifiers is connected in parallel to a single receiver of conventional design; this would be the normal station receiver. The preamplifier stages are switched on and off, 180 degrees out of phase, at an audio rate usually between 300 and 1000 Hz. A block diagram is shown in **fig. 6**. In this manner only one antenna at a time is connected to the receiver so that phase relationships between the two antennas are not important. The receiver output is proportional to the strongest signal present in either antenna at any instant of time.

Because the incoming signal is modulated at the switching frequency this method is useful only for CW. This method also has an unusual effect on the receiver output. If the signal in one antenna is up and the other completely down, the signal reaching the receiver is modulated at the switching frequency. If both antennas receive equal signal levels, the signal reaching the receiver is modulated at twice the switching frequency.

If one antenna has a strong signal with the signal from the other antenna fading in and out, the effect on the output is a changing tone that depends on the strength of the fading signal. Bartlett claims this effect is "very pleasing" to most CW operators; I haven't tried it myself. It sticks in my memory that a device similar to this was advertised in *QST* right after World War II, but I've not been able to find the advertisement in my old magazines.

fig. 5. A Hallicrafters dual-diversity receiver, Model DD-1. This is the only commercially made receiver intended for diversity reception, circa 1939.

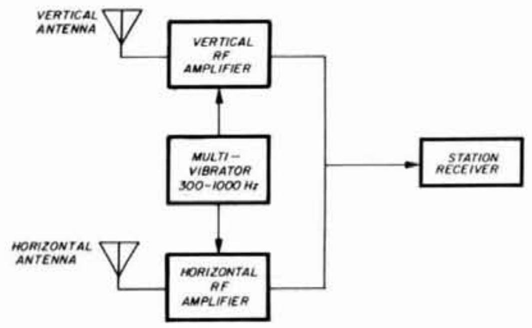


fig. 6. Block diagram of Bartlett's dual-diversity preselector/adapter for CW work.

Bartlett[9] also states that when using polarization diversity, there may be "days at a time" when the vertical signal is 10 to 15 dB lower than that of the horizontal signal. I don't know if this is true in general, or if it results from the use of a smaller vertical antenna than horizontal antenna.

equipment considerations — receivers

By now you may be wondering what changes are needed to equipment designs to make diversity reception practical. The design of a diversity receiving system is not that difficult. At one time a diversity receiver was a truly substantial piece of equipment in both size and cost; fortunately, the development of modern semiconductor devices has reduced both the size and the cost of receiver components. And, since the second receiver will be a duplicate of the first, there will be no additional engineering costs.

As the details of different receivers vary considerably, and as each receiver designer/builder has his own ideas as to what a good receiver should be, I'm not going to discuss a detailed receiver design. The characteristics required of a good diversity receiver are the same as those needed for a good single-channel receiver: sensitivity, stability, low noise figure, low intermodulation response, good shielding, and so on. The only difference is that you build it twice! Numerous articles on this subject have been published by *ham radio*; I need not repeat that information.

Good shielding is very important. First, it's necessary to keep the horizontal and vertical channels electrically separate. Leak-through from one to the other before final detection will cause a loss in diversity effectiveness. With two separate receivers, using separate local oscillators, leak-through of one oscillator to the other mixer will cause birdies, because the two oscillators will, in general, not be on exactly the same frequency.

There are several ways of minimizing the oscillator leak-through problem other than the use of shielding.

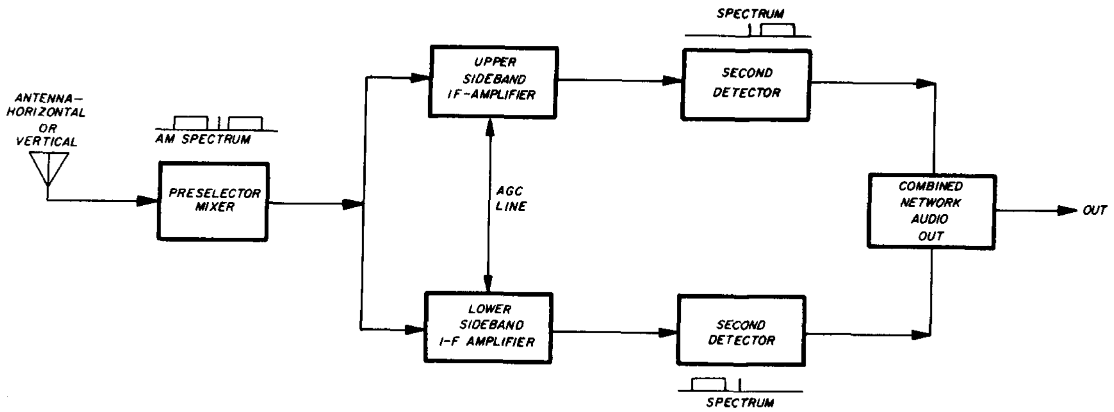


fig. 7. Simple frequency diversity receiver for independent demodulation of the upper and lower sidebands of an a-m signal.

One is to use receivers with different i-fs. Taylor[8] used a Hallicrafters SX-17 with a 465-kHz i-f and a Skyrider 5-10 with a 1600-kHz i-f with good results.

If receivers with the same i-f are used, one oscillator can be realigned to put it on the high side, with the other oscillator on the low side, of the signal. (This may have an adverse effect on tracking in the modified receiver.)

Probably the best arrangement is to use the same oscillator for both channels. Even here, though, considerable care must be used in mixer design to ensure that the received signal from one channel doesn't leak through the common oscillator bus into the other channel. What has been said concerning the local oscillator applies equally well, of course, to all local oscillators in a multiple conversion or SSB receiver.

adapting current transceiver designs

Because the current trend in Amateur equipment design is toward the transceiver, I'll present some general ideas on adapting current transceiver designs to diversity reception. As pointed out earlier, there's nothing the transmitter can do to improve diversity reception, thus the transmitter portion of a transceiver will remain unchanged. Most of the bulk, weight, and cost of a modern high frequency transceiver is in the transmitter section, the transmitter power supply, and the frequency control unit (synthesizer); the receiver itself is very small. And this is the only portion of the transceiver that must be duplicated.

Probably the single most important thing that transceiver manufacturers can do to aid in diversity reception is to make the various oscillator injection voltages and agc bus available, suitably buffered, on the *back apron of the transceiver.* This will permit an external adapter, either commercially manufactured or homemade, to be easily attached. It will then be practical to add an external diversity adapter containing the rf, i-f, audio, and combining circuits necessary to complete the diversity receiving system.

In the preceding material I've assumed a simple summing network for combining the output of the two receivers, as this appears to be the simplest and most appropriate for Amateur use. Actually, the subject of an optimum combining law for two (or more) signals has occupied many, many pages in various journals.

Combining laws can vary from a hard-switching law (*i.e.*, switching to the receiver with the strongest signal) to more sophisticated and beneficial laws. Leonard R. Kahn[10] has asked this question: "For a given ratio of diversity signal levels, how much of the weaker signal and its noise should be added to the stronger signal and its noise to obtain the optimum signal-to-noise ratio?" He then answers his own question by showing that a square-law is best. That is, the ratio of the two signal levels should be squared, then summed.

The method I've sketched, summing the detected signals and tying the agc buses of the two receivers together, will have a combining law that depends on the agc characteristics of the receivers. The most desirable law for Amateur purposes probably can be determined only after considerable experimentation.

The types of combining described so far are known as "post-detection combining." The combining is accomplished after detection, when the rf/i-f phase information has been removed. Additional diversity gain is possible by using "predetection combining," combining the signal before detection. This method requires that the signals be added in phase and is much more difficult to achieve.

equipment considerations — the antenna

Assuming polarization diversity, it's essential that

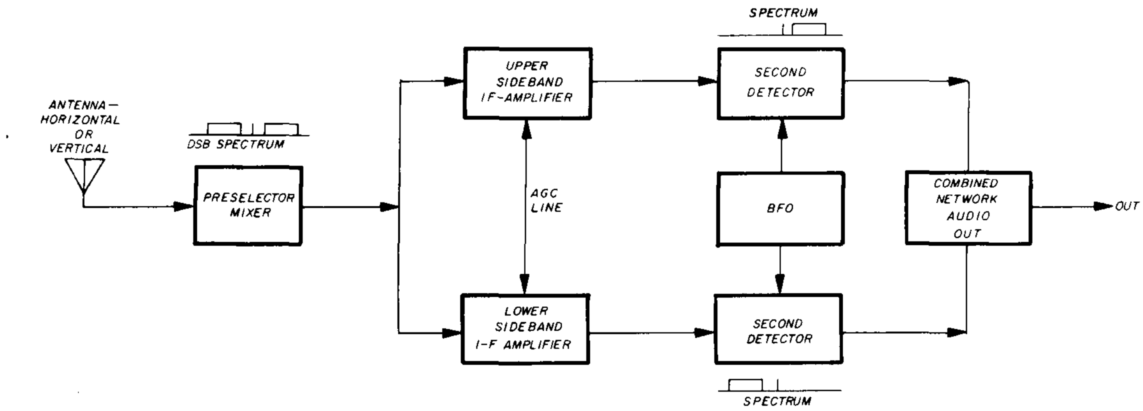


fig. 8. Simple frequency diversity receiver for independent demodulation of the upper and lower sidebands of a DSB signal.

the horizontal antenna *and its transmission line* respond only to the horizontal component of the received signal. Similarly, the vertical antenna and its transmission line should respond only to the vertical component of the received signal.

In both cases, the transmission lines are probably the biggest problems. For the horizontal antenna, the vertical down-lead is the problem area. With the vertical antenna, horizontal runs away from the antenna are potential trouble spots.

If coaxial cable is used, it should have a tight shield braid, or, better yet, be double-shielded.* A high-grade balun should certainly be used in both antennas.

frequency diversity

In describing frequency diversity, I mentioned that frequency separations as small as 400 Hz could be used to provide diversity gain. Since audio frequencies below about 300 Hz are usually filtered out in a voice transmitter, the two sidebands in an a-m or DSB signal will be at least 600 Hz apart, giving rise to the possibility of using frequency diversity.

The simplest embodiment of a frequency diversity receiving system for a-m or DSB signals is shown in **fig. 7.** Here a single antenna, receiver front-end (rf amplifier, mixer, and local oscillator) drives two i-f amplifiers. One i-f amplifier has a filter that covers the carrier and upper sideband; the other i-f amplifier covers the carrier and lower sideband. Each amplifier output is separately detected, then combined in a common audio amplifier. The agc bus of the two amplifiers may be tied together. In this way, the two sidebands are independently received and detected, then combined. Summation does not take place until after the rf phase information has been removed from both sidebands, so that multipath effects between the upper and lower sidebands will not cause fading.

This system gives a surprising amount of diversity gain, except when the carrier itself is in a fade; then the two sidebands don't have anything to beat against, so that demodulation is not possible. The receiver output sounds like a DSB signal with the BFO off.

The next obvious improvement is to provide a locally generated, fade-free, noise-free carrier to demodulate the two sidebands. This scheme is shown in **fig. 8.** Since the carrier is no longer needed to demodulate the sidebands, why transmit it? Put the carrier energy into the sidebands to increase talk power and transmit a DSB.

As I write this, I can imagine *ham radio* readers coming to a full stop! Didn't we fight the SSB vs DSB battle 25 years ago and decide on SSB?

The answer, of course, is, yes, we did. DSB lost for three basic reasons:

1. When the two sidebands of a DSB signal are demodulated in the same detector, the stability required of the locally generated carrier is extremely critical.

2. Multipath effects between the upper and lower sidebands cause fading.

3. Extra bandwidth is required in an already overcrowded spectrum.

In a frequency diversity receiver, items **1** and **2** don't apply because the two sidebands are demodulated in separate detectors — not in the same detector. The frequency stability required of the inserted carrier may be somewhat higher than for SSB; if it gets too far off, one sideband sounds like Smokey the Bear, the other like Squeaky the Squir-

*A point well taken. Many Amateurs tend to take coaxial transmission lines for granted. Many types of coax cable are offered for sale. Most are marginal as far as shielding is concerned. If you're interested in diversity receiving systems, it's well worth obtaining good-quality coax cable. The *ARRL Handbook* describes problems that can occur when using marginal-quality coaxial transmission lines. **Editor.**

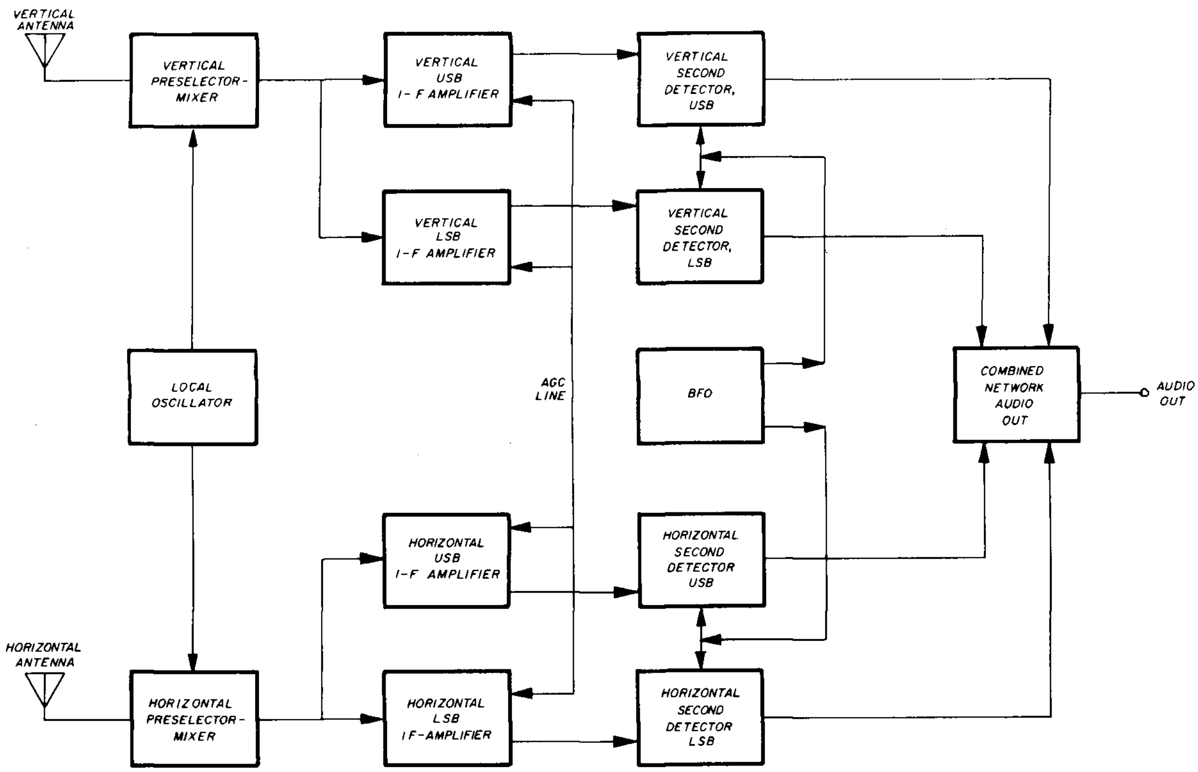


fig. 9. Simplified block diagram of a compound diversity receiver using both frequency and polarization diversity to receive an a-m or DSB signal.

rel. The stability, however, is only on the order of a few hertz instead of a few degrees.

Detecting the two sidebands separately also eliminates fading caused by the two sidebands being 180 degrees out of phase because of multipath. Furthermore, since the probability of *both* sidebands being below the MUSL simultaneously is considerably lower than that of *either* sideband being below the MUSL separately, fading should be considerably less of a problem with the sidebands independently demodulated.

The additional bandwidth will still be with us and may be considered the price paid for diversity gain.

With present-day technology, it's not impractical or expensive to build a compound diversity receiver, using both frequency and polarization diversity. A block diagram of such a receiver is shown in **fig. 9**.

conclusion

I've described the advantages of the variious types of diversity reception and shown how they can be implemented with Amateur equipment. Because of space limitations I have hit only the highlights. Anyone who's going to pursue this type of work should become familiar with the references cited. Much of the original work on this technique was done 40 years ago, so I am, admittedly, reinventing the wheel. I firmly believe, however, that diversity reception will be the next step in advanced Amateur receiving techniques. I hope this article helps to start Amateurs experimenting with diversity reception and encourages manufacturers to supply equipment for this purpose.

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ham radio

measuring receiver dynamic range

How to determine receiver performance using simple test equipment and procedures

Receivers with limited dynamic range really have a tough time surviving in my neighborhood, where signals of 100 mW at the antenna are common. When the time came to shop for new equipment, my primary objective was to find a rig with good immunity to some of the problems that might affect its front-end stages. Of primary importance is information on the dynamic range[1,2] and blocking specifications for the rig in question. This information isn't usually supplied by manufacturers, so the scheme was to build some simple test equipment to measure this data and make some comparisons between different rigs available on the new and used equipment markets. An added bonus is that once the test equipment is available it may be used for other tests.

test setup

Two crystal oscillators were constructed, one for operation at 14.02 MHz and the other at 14.04 MHz. Other frequencies could have been used[3] although, in general, it's convenient to retain the 20-kHz spacing. The crystals used are ICM* units designed for OX-series oscillators. That oscillator wasn't suited to this application, so I designed a circuit that has a known power output and minimum second-harmonic content, **fig. 1**. I built identical circuits on opposite sides of a piece of double-clad PC board and placed them in a tight-fitting aluminum box. I brought separate power leads through feedthrough capacitors so that the oscillators could be operated independently.

About 60 dB of isolation between the two circuits was achieved, which is adequate for the task. When two-tone signals are needed, a hybrid combiner[2] couples the oscillator outputs together with minimum interaction; a step attenuator adjusts the amplitude of the tones simultaneously (**fig. 2**). This equipment plus a 9-volt battery and a few short pieces of coax and connector adaptors is all that's needed to perform the tests. Everything fits nicely into a small box, which may be easily carried to any location where tests are to be run.

Because the signal sources are high level (0 dBm), shielding of test oscillators, coax cables, and attenuators is inadequate to allow testing the sensitivity or noise floor of the receiver. Fortunately this information, although needed to calculate dynamic range, is not absolutely essential in this situation, as the input power that causes an undesired response may be

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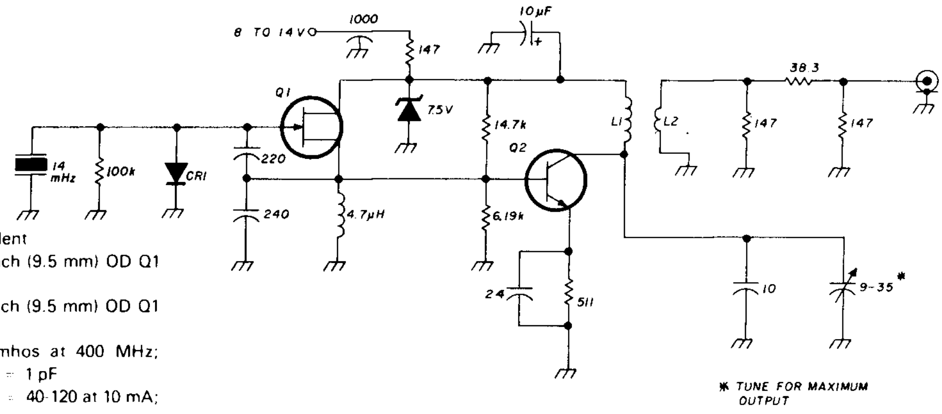
part of fig. 1



CR1 Schottky diode, HP 5082-2810 or equivalent
L1 11.5 turns 24 AWG (0.5 mm) on 3/8-inch (9.5 mm) OD Q1 ferrite core
L2 1 turn no. 24 AWG (0.5 mm) on 3/8-inch (9.5 mm) OD Q1 ferrite core
Q1 2N5245 or equivalent, G_{FS} = 4 millimhos at 400 MHz; I_{DSS} = 5-15 mA; C_{ISS} = 4.5 pF; C_{RSS} = 1 pF
Q2 2N2369 or equivalent, f_T = 500 MHz; β = 40-120 at 10 mA; C_{OB} = 4 pF

fig. 1. Test oscillator schematic. The crystal is an ICM (International Crystal Manufacturing Co.) with a capacitance of 100 pF. Output is zero dBm at 14 MHz. Two oscillators are required for receiver tests: one at 14.02 and one at 14.04 MHz. The oscillators were built on opposite sides of a double-clad PC board, which was placed in an aluminum box.

compared directly. This assumes that each receiver has sufficient sensitivity to perform its task, which is normally not a problem on the high-frequency bands; on the contrary, it's common for excessive sensitivity to contribute to reduced strong-signal-handling capabilities.

procedure

Each receiver is evaluated with the agc on, normal SSB filter selected, rf gain at maximum, preselector peaked at 14.04 MHz, noise blanker and rf attenuation off, and audio set for a comfortable level. Turn on both tones, set the attenuator at zero, and tune the receiver to the third-order intermodulation-distortion product at 14.06 MHz.

No calibrated audio voltmeter was available, so my "calibrated ear" was used to determine when the undesired signal could just be heard in the receiver noise output. I've achieved good consistency with this method, although it results in a more conservative number than that obtained by using a voltmeter for measuring a 3-dB change in the audio output. However, all results obtained by this technique may be compared with the others obtained in the same manner by the same person.

Reduce the amplitude of the two tones with the attenuator until the third-order intermod at 14.06 MHz is just detectable. One convenient way to do this is to leave the 14.02-MHz oscillator running and slowly key the 14.04-MHz oscillator on and off with its battery lead while adjusting the attenuator for this just-discernible signal. Subtract the losses of the hybrid combiner and attenuator from the 0-dBm output of the test oscillators to find the input power to the receiver. This number is listed in **table 1** as the **two-tone input** power and is the receiver input power that causes a just-detectable third-order intermodulation product.

gain compression test

A second test may be performed to find the input power that causes gain compression (blocking) in the receiver. This test is usually run with one weak signal and one strong signal, but it's possible to gather some useful data by using the receiver's own internal noise as the weak signal.

An interesting thing can happen when running this test. If gain compression occurs with a strong out-of-passband signal, the noise level heard in the output will decrease. This noise originates in the first stage of the rig. Gain compression of this stage or a succeeding stage will cause a drop in the noise level. However, many times the noise output will increase when the strong out-of-band signal is present. This action is caused by reciprocal mixing with noise sidebands in the receiver local oscillators (commonly heard as a keyed hiss with a strong local CW station on a nearby frequency). A mixer really doesn't care whether it sees a strong LO and weak rf signal or a

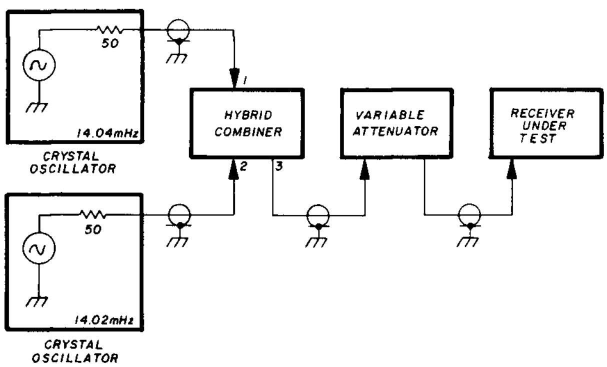


fig. 2. Test setup for making the tests described.

*International Crystal Manufacturing Co., Inc., P.O. Box 32497, Oklahoma City, Oklahoma 73132.

table 1. Test results from many popular receivers using the equipment and procedures described.

receiver	two-tone input (dBm)	gain compression input (dBm)	bandwidth (kHz) at a rejection of 60 dB	70 dB	80 dB	90 dB	S-meter (S9 μV, linearity)	comments
Drake TR7/DR7	−41	−32	3.8	5.6	6.3	6.6	20 fair	good filters, AGC pumps
Collins 75S3B	−44	−20	4.5	5.1	5.8	6.3	250 good	good filters
ICOM IC701	−46	−26	5.2	9.4	15.0	—	20 poor	HAS-65 dB hump ±10 kHz out
Ten Tec Omni D	−48	−20	4.4	6.3	10.0	—	36 good	
Ten Tec Triton IV/544	−48	−30	6.0				20 poor	
Atlas 350XL	−51	−28		4.0		7.0	150 poor	good filters
Astro 200	−52	−35						
Yaesu FT901DM	−56	−29	3.6	7.6	17.0	—	8 poor	
Ten Tec Argonaut	−58	−35	4.0	6.0	14.0	18.0	10 poor	modified KVG filter
Kenwood TS820S	−60	−34					110 good	
Yaesu FT301S	−64	−36					30 poor	
Heathkit SB303	−64	−41	4.4	6.0	9.0	10.0	70 good	modified mixers
Collins KWM2	−65	−26	4.5	5.1	6.0	6.3	60 good	good filters, AGC pumps
Yaesu FT101E	−65	−36					10 good	
Yaesu FT301D	−68	−32					65 poor	
Kenwood TS520	−72	−36	4.0				70 fair	

strong rf and a weak LO signal (noise sidebands); it will generate an output in either case.

Tune the receiver to 14.04 MHz and slowly key the 14.02-MHz oscillator on and off (leave the 14.04-MHz tone off), while decreasing the step attenuator until the noise output has a just-perceptible change. An increase in noise level is an indication of reciprocal mixing with the LO noise sidebands, provided that the test oscillator output is clean. If the noise decreases, gain compression is indicated. Note the input power to the receiver; this power is listed in **table 1** as the **gain compression input**.

Some receivers will exhibit reciprocal mixing up to 10-20 kHz from the strong signal. Then a gradual change to gain compression with a higher power input signal will occur further away from this input. In either case, the ultimate performance of the receiver will be limited if either of these phenomena occurs at too low a level. Only one strong input signal is required to cause these problems, so an input 20 dB higher than the two-tone input is probably a reasonable minimum number.

selectivity test

Another test may be run to check receiver selectivity by using one test signal and tuning the receiver to measure bandwidth. This test explores the ability of the complete receiver to reject unwanted signals, which is normally not as good as that of the filter itself because of signal leakage around the filter.[3]

Tune the receiver to 14.02 MHz and adjust the attenuator for a convenient, low S-meter reading, such as S2. About 90 dB of attenuation will be needed. Note the attenuator reading, then increase the signal by 60 dB. Tune away from the signal until it's no longer heard and the S-meter reads zero. Then tune back toward 14.02 MHz until the S-meter again reads S2 and note the receiver frequency. Now tune to the opposite side of the signal and repeat the slow approach to the signal for an S2 reading. Note this second frequency.

The bandwidth at −60 dB is the difference between the first and second frequency readings. The procedure can be repeated for readings of −70 dB, −80 dB, or until the receiver runs out of signal rejection or the test oscillator runs out of power. The latter isn't a problem unless the receiver has more than 90 dB rejection.

One characteristic to watch for is a rig that may be 80 dB down ±5 kHz away from the signal but deteriorates to perhaps 65 dB down at 10-15 kHz away and may never recover to the −80 dB level further out. It seems clear that present-day specifications of only −6 dB and −60 dB are *not* adequate to determine whether a receiver has a good filter and minimizes signal leakage around it.

checking the S-meter

The next item to check is the S-meter. For example, a reading of S9 with an input of −70 dBm (71 μV across 50 ohms) would be reasonable in view of the traditional value of 50-100 μV for S9. Linearity can be checked by increasing the input signal to 10, 20, and 30 dB over S9 and observing meter readings. Below S9, increments of 5-6 dB per S-unit may be verified.

Results to date have been dismal. Various S-meters not only read between 8 and 250 μV for S9, but the linearity was so poor that using the meter for evaluating a) gain differences between two transmitting antennas, or b) front-to-back ratios of receiving antennas is strictly a guessing game — unless the meter response has been verified. Manufacturers could do much better in this area with little additional expense and make the S-meter a useful adjunct to operating convenience.

conclusions

The various rigs tested are listed in **table 1** in order of decreasing third-order intermodulation performance. By making a few comparisons of the data, at least three conclusions may be reached:

1. Modern solid-state equipment has finally caught up with the best of 15-year-old vacuum-tube technology.

2. Manufacturers are gradually improving their products, as evidenced by newer models generally testing better than older ones.

3. Some of the newer equipment using double balanced mixers doesn't seem to extract the maximum benefits that such devices can deliver.

Other conclusions could also be reached but the point is that, without this information, only part of the material needed to evaluate the performance of any given radio is available. As this article has indicated, it's not necessary to own a completely equipped lab to gather useful information. All you need is the simple test setup described in this article.

Manufacturers should provide this data. Indeed, American manufacturers' data sheets are getting better (Atlas, Drake). Japanese data sheets either make no mention of the subject or else have enough slack built into their specifications to make meaningful comparisons impossible. So, until considerable improvement occurs in the data provided, you may want to build a couple of test oscillators before you visit your local radio store.

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TS-180S FEATURES:

- Digital Frequency Control (DFC), including four memories and digital up/down paddle-switch tuning. Memories are usable in transceiver or split modes, and can be tuned in 20-Hz steps up or down, slow or fast, with recall of the original stored frequency. (Also available without DFC.)
- All solid-state; 200 W PEP/160 W DC input on 160-15 meters, and 160 W PEP/140 W DC on 10 meters.
- Improved dynamic range, with improved circuit design and RF AGC ("RGC"), which activates as an automatic RF attenuator to prevent receiver overload.
- Adaptable to three new bands, and VFO covers more than 50 kHz and DFC 100 kHz above and below each band.
- Built-in microprocessor-controlled digital display. Shows actual frequency and switches to show the difference between the VFO and "M1" memory frequencies. Blinking decimal points indicate "out of band." (An analog monoscale dial is also included.)
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- Dual SSB filter system (second filter is optional) to provide very sharp receiver selectivity, improved S/N, and 30 dB compression with RF speech processor on transmit.
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- Selectable wide and narrow CW bandwidth on receive (500-Hz CW filter is optional).
- SSB normal/reverse switch (proper sideband is automatically selected with band switch).
- Dual RIT (VFO and memory/fix).
- Available without DFC. Digital frequency display still included, with differential function showing difference between VFO and "digital hold" frequencies.

OPTIONAL ACCESSORIES:

- DF-180 digital frequency control (for TS-180S without DFC).
- YK-88CW 500-Hz CW filter.
- YK-88SSB second filter for dual-filter system.

PS-30 SP-180 TS-180S VFO-180 AT-180

MC-50

simple, low cost 440-MHz bandpass filter

Straightforward design and construction of a half-wavelength stripline resonator

Bandpass filters which use half-wavelength transmission-line resonators are attractive in many applications because of their simple construction and ease of adjustment. Such filters have been described previously in the Amateur literature.[1] Generalized design information, however, was not provided for frequencies other than those discussed in reference 1. Also, the construction techniques and materials are somewhat cumbersome. In this article I will present some simple equations which can be used to design a quarter- or half-wavelength resonator at any frequency. A simplified construction technique using copper-clad printed-circuit material is also discussed; *this technique can result in considerably smaller filters*. The design example is a tunable bandpass filter for receiver and low-powered transmitter applications in the 250 to 500 MHz range.

half-wave resonators

A section of transmission line one-half wavelength long and shorted at both ends will behave as a resonator because it supports the formation of a standing wave at its resonant frequency. This is illustrated in **fig. 1**. If means are provided for coupling rf energy into and out of the line section, the half-wave resonator can serve as a bandpass filter with a fairly high Q and low insertion loss. The Q of the resonator is primarily a function of the dielectric loss in the transmission line; for this reason air dielectric lines are normally used as resonators — microstripline on fiberglass epoxy substrates should be avoided. To make the resonator tunable the line length is reduced to somewhat less than one-half wavelength, and capacitive loading is applied at the center as shown in **fig. 2A**. Although a quarter-wavelength line can also be used as a resonator, the half-wavelength version is preferred because it provides better isolation between the input and output ports.

To analyze such a line, it is convenient to visualize it as two loaded quarter-wavelength lines connected in parallel as shown in **fig. 2B**. A transmission line less than one-quarter wavelength long and shorted at one end will present an inductive reactance at the open end given by

$$X_L = Z_o \tan \phi \tag{1}$$

where Z_o is the characteristic impedance of the transmission line and ϕ is its electrical length in degrees.[2] A capacitive reactance equal in magnitude to X_L, which is placed across the open end of the transmission line will tune the line to resonance (similar to a capacitor in a parallel-resonant L-C tank circuit). The required capacitance is given by

$$C = \frac{10^6}{2\pi f_{MHz} X_L} \ pF \tag{2}$$

where f_{MHz} is the frequency in megahertz and X_L is the inductive reactance in ohms. In the case of the loaded half-wavelength line, the total capacitance required is twice that of the loaded quarter-wave case, because the half-wave line consists of two parallel quarter-wavelength lines (see **fig. 2**).

examples

Let's design a bandpass filter centered at 440 MHz. Assume that the filter is to resonate with a center loading capacitance of 4 pF, and calculate the resonator length required to meet this condition. For the

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moment the characteristic line impedance can be chosen arbitrarily; I'll use 180 ohms in this example since that is the approximate impedance used later in the construction example (line impedance will be discussed in greater detail later). Since the entire line requires 4 pF of center loading at resonance, each half of the line should resonate with 2 pF loading capacitance. Rewriting **eq. 2**, the required inductive reactance X_L of the quarter-wavelength line is given by

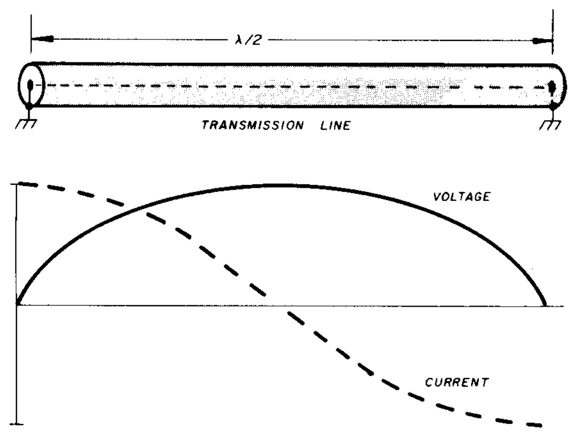

fig. 1. Voltage and current distribution along a half-wavelength section of transmission line with both ends shorted.

$$X_L = \frac{10^6}{2\pi f_{MHz}\, C_{pF}} \tag{3}$$

$$= \frac{10^6}{(6.28)\,(440)\,(2.0)} = 180.95\ ohms$$

The electrical length of the line is

$$\phi = \frac{4\,\ell}{\lambda} \bullet (90°) \tag{4}$$

where ℓ is the physical length and λ is the wavelength in the line. Substituting the ϕ from **eq. 4** into **eq. 1** and solving for ℓ provides an expression for the line length in terms of wavelengths in the line.

$$\ell = \frac{\lambda}{4} \bullet \frac{\arctan\,(X_L/Z_o)}{90°} \tag{5}$$

The wavelength in the line is

$$\lambda = \frac{300}{f_{MHz}\sqrt{E_r}}\ meters \tag{6}$$

where E_r is the dielectric constant of the line; if the dielectric is air, $E_r = 1$ (if the dielectric is air, the wavelength in the line will be the same as that in free space). Substituting this expression for λ, and assuming an air-dielectric line, provides the final expression for the length of the quarter-wave resonator.

$$\ell = \frac{300}{4f_{MHz}} \left[\frac{\arctan\,(X_L/Z_o)}{90°}\right]\ meters \tag{7}$$

For an $X_L = 180.95\ ohms$, a line impedance (Z_o) of 180 ohms, and a frequency of 440 MHz, the length of the air-dielectric quarter-wavelength line which will resonate with a 2.0 pF capacitor is 0.0855 meters or 8.55 cm (3.37 inches) long. A half-wavelength resonator will be twice this length (17.10 cm or 6.731 inches) and will require twice as much loading capacitance (4 pF) to tune it to resonance.

The above example assumes that the required capacitance has been chosen, then proceeds to determine the length of the resonator. Suppose, however, that the resonator length is specified and you wish to determine the capacitance required to tune it to a given frequency. Using approximately the same numbers as in the previous example, the resonator length will be 17 cm (6.7 inches); the required tuning capacitance at 440 MHz is to be calculated. This is equivalent to finding twice the capacitance required to tune a quarter-wavelength (8.5 cm or 3.4 inch) resonator to 440 MHz. Using **eqs. 6** and **4**, the electrical length of the shorted 8.5 cm (3.4 inch) air-dielectric line is 44.88 degrees. Therefore, if the line's characteristic impedance Z_o is 180 ohms, **eq. 1** gives the inductive reactance of the line as 177.4 ohms. **Eq. 2** provides the value of a capacitor with this reactance, 2.04 pF. Doubling this value, the capacitance required to tune the 17 cm (6.7 inch) half-wavelength resonator to 440 MHz is 4.08 pF.

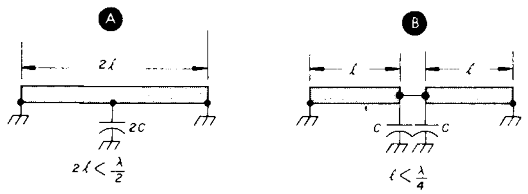

fig. 2. Capacitively loaded half-wavelength stripline resonator (A), and equivalent circuit using two quarter-wavelength lines (B). A groundplane is assumed to be present in both cases.

You may wonder why the inductive reactance in both these examples is nearly equal to the line's characteristic impedance; it's purely coincidental. This condition occurs when the physical length of the line is close to one-eighth wavelength. The length of a so-called "quarter-wave" resonator can theoretically be anything between zero and $\lambda/4$ if the proper loading capacitance is used.

impedance calculations

One significant problem encountered in the above calculations is determining the characteristic impedance of a practical air-dielectric stripline. Normally, the stripline resonator used in a filter will be enclosed in a metal box for shielding purposes. However, enclosing the stripline in a box introduces errors into the formulas which are used to calculate line impedance because of the electric field distortion as shown in **fig. 3**. Calculating the impedance of the enclosed stripline in **fig. 3C** is rather difficult but you can get a rough idea of its magnitude by examining **figs. 3A** and **3B**. It will be assumed that the width of the line and the spacing between the line and the ground plane is the same in all three cases.

The approximate characteristic impedance of a microstripline, neglecting fringing effects and leakage flux, is given by

$$Z_0 \approx 377 \left(\frac{h}{w}\right) \frac{1}{\sqrt{E_r}} \tag{8}$$

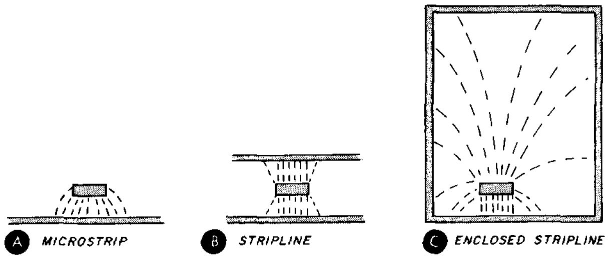

fig. 3. Electric field lines in microstrip (A), true stripline (B), and enclosed stripline (C). Enclosed stripline is used in the bandpass filter described in this article.

where w is the line width and h is its height above the ground plane.[3] Since an air-dielectric line is used, E_r can be replaced by 1. The impedance of the true stripline in **fig. 3B** is not as easily calculated, but is available in graphical form,[3,4] and is considerably lower than that of the microstripline with similar dimensions in **fig. 3A**. It can generally be assumed that the characteristic impedance of the enclosed stripline (**fig. 3C**) will be between that of the microstripline (**fig. 3A**) and the true stripline (**fig. 3B**).

construction techniques

A filter similar to the preceding design example was built using pieces of single-clad printed-circuit material. Even though this is a uhf application, virtually any type of PC material may be used because in this case the dielectric properties of the material have no effect on circuit performance. The use of copper-clad material allows greater flexibility in the design and construction of bandpass filters than do the construction techniques described in reference 1. Fewer tools are needed, and the filters can easily be built by apartment dwellers (such as myself) without access to a machine shop.

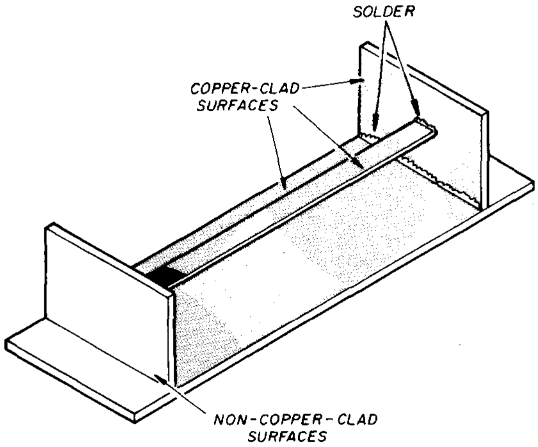

fig. 4. Construction of a half-wavelength resonator using four pieces of single-clad PC material. Dielectric of the circuit board is not important in this application.

As shown in **fig. 4**, four pieces of PC material are used — the stripline itself, the ground plane, and two end pieces to support the stripline. These can be cut out using a small pruning saw or sheet-metal shears. All pieces are soldered together at their edges. The stripline should be installed last, is nominally 18.0 cm long (7 inches) and 1.0 cm (3/8 inch) wide, and is mounted with the copper-clad side up for ease of attaching the center loading capacitor. Spacing between the stripline's upper surface and the ground plane is about 8 mm (5/16 inch). The line impedance was estimated *a posteriori* to be approximately 180 ohms.

The tuning capacitor was originally a 3-30 pF variable (Calectro A1-225), but half of its rotor and stator plates were carefully removed to bring its capacitance down to approximately 2 to 15 pF. The tuning capacitor is connected to the exact center of the stripline with a single *very short* wire.

Input and output coupling is accomplished by means of inductive coupling lines which run between

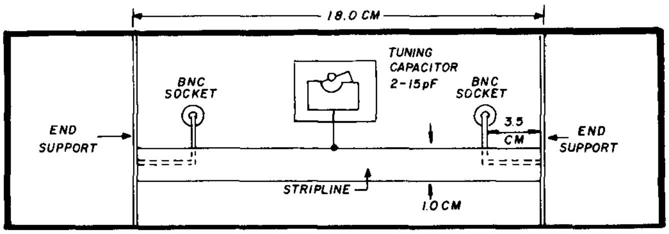

fig. 5. Rear view of the half-wavelength filter, showing the loading capacitor connections and the input/output coupling inductances.

the stripline and the ground plane in the region of the highest field intensity. As originally designed, each coupling wire starts at a BNC connector, runs under the stripline for about 3.5 cm (1 3/8 inch) and terminates in a soldered connection to the end support; this is illustrated in **fig. 5**. The entire filter assembly was mounted in a 25 x 5 x 4 cm (10 x 2 x 1 9/16 inch) Minibox for shielding purposes, with the BNC connectors and the capacitor mounting screws providing the mechanical connections between the ground plane PC board and the enclosure.

performance

The tuning range cannot be found analytically, since both the line's electrical length and the required tuning capacitance are functions of frequency. Using an iterative method, however, it is possible to determine the approximate tuning range. A frequency is arbitrarily picked (let's say 350 MHz). **Eqs. 6**, **4**, **1**, and **2** are then solved in succession, keeping in mind that ℓ is one-half the length of the half-wavelength line. The resulting capacitance, 3.26 pF, is then doubled and this value, 6.52 pF, is observed to lie within the tuning capacitor's range, of 2 to 15 pF. By trying various frequencies, the approximate limits of the tuning range can be found. For this specific filter, the required tuning capacitance vs frequency is listed in **table 1**. Since individual construction techniques, and hence, characteristic line impedance, may vary, the tabular values should be considered only as nominal.

table 1. Center loading capacitance required to tune an 18-cm (7.1-inch) long, 180-ohm air-dielectric half-wavelength resonator to various frequencies.

frequency (MHz)	tuning capacitance (pF)
200	22.3
225	17.4
250	13.9
300	9.3
350	6.5
400	4.7
450	3.5
500	2.6
550	1.9

The filter described here had a measured insertion loss of about 1 dB and a VSWR of approximately 1.6:1 at 440 MHz. By observing the extent of mesh of the tuning capacitor plates, the capacitance required for resonance at this frequency was about 4 pF, which is in agreement with the value obtained analytically.

The VSWR was attributed mainly to mismatch at the BNC connectors between the coupling lines and the external transmission lines. The characteristic impedance of the coupling lines was estimated to be around 115 ohms, by modeling them as circular conductors between two ground planes.[3] Their electrical length of 18.5 degrees at 440 MHz gives them a reactive component of +j38.5 ohms. To cancel this reactance a 10-pF silver-mica capacitor was placed in series with each input/output coupling line at the BNC socket. A schematic of the modified filter is shown in **fig. 6**.

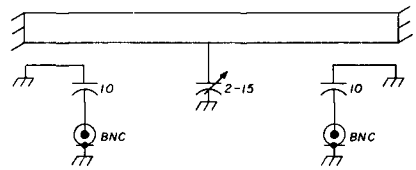

fig. 6. Schematic of the modified 440-MHz bandpass filter with improved input/output matching (see text).

Measurements on the improved filter indicated the VSWR was reduced to approximately 1.2:1 at 440 MHz, while the overall insertion loss remains around 1 dB. Unfortunately, it wasn't possible to measure the VSWR at any other frequencies, so it isn't known whether the 10-pF capacitors improve or degrade performance at frequencies far removed from 440 MHz. However, there should be very little variation over the 420 to 450 MHz range.

This filter was designed for use ahead of a wideband (10 MHz bandwidth) receiver operating near 440 MHz to attenuate local fm signals in the 450-470 MHz range. It should also provide significant attenuation of television signals over most of the 470-806 MHz broadcast band. Although bandwidth measurements were not performed, operating experience indicates the 3-dB bandwidth is roughly 3 or 4 MHz, or slightly less than one per cent. This bandwidth should find application among users of wideband modes, such as ATV and packet radio, who want to reduce desensitization caused by out-of-band interference. The filter should also be effective in suppressing unwanted multiplier products in low power (1-watt class) exciters.

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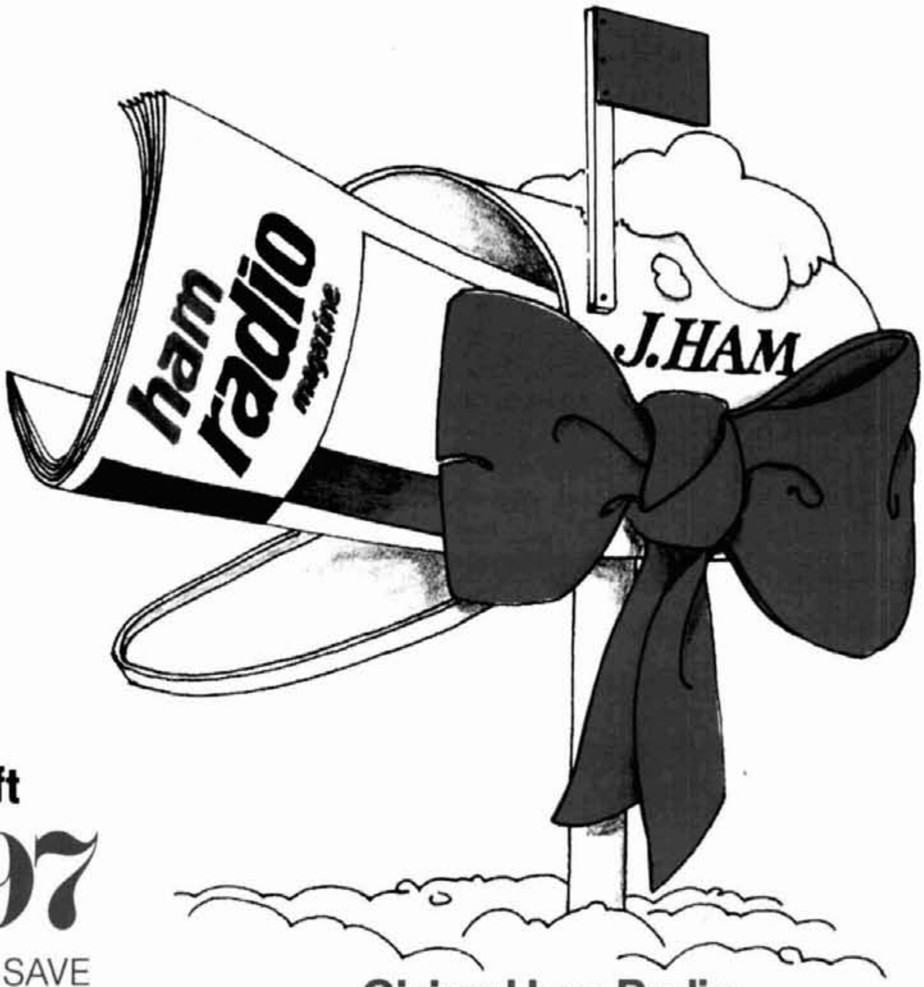

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what is your real standing wave ratio?

Some quantitative answers to a question as old as ham radio

A number of magazine articles have appeared over the years discussing the relative merits of having a low standing wave ratio (SWR). Although it's been demonstrated that excellent results can be obtained with an unmatched transmission system, it's a generally accepted fact that the most straightforward method of guaranteeing acceptable performance under all conditions is by adjusting the various matching devices for minimum SWR. This is particularly true for those not completely familiar with the subtleties of transmission-line theory, as many complex effects occur in unmatched, or tuned, transmission line systems. Regardless of the reasons, most Radio Amateurs are concerned, to some degree, about their voltage standing wave ratio VSWR, or just plain SWR.

One of the reasons for the popularity of SWR as a measure of transmission-system performance is the relative ease with which it can be measured. An SWR bridge can be purchased at the nearest discount store. Even some supermarkets carry SWR bridges. Sealed in plastic packages, and intended primarily for our 11-meter friends, these inexpensive instruments provide an excellent method for an Amateur Radio operator to evaluate the degree of "match" of his antenna system and transmission line. A typical setup for measuring SWR is shown in **fig. 1**.

As shown in the figure, the normal arrangement for measuring SWR in an Amateur station consists of connecting an SWR bridge in series with the transmission line as it leaves the transmitter or transceiver. The bridge is then used to measure the standing wave ratio *at the input to the transmission line*. If the transmission line were perfectly efficient, *i.e.*, if it had no loss, then the SWR measured at this point would equal exactly the SWR at the antenna. Unfortunately, however, all real transmission lines have some loss. This transmission line loss not only prevents all the transmitter output power from reaching the antenna but also introduces a significant error in the SWR measurement. As we will see, the standing

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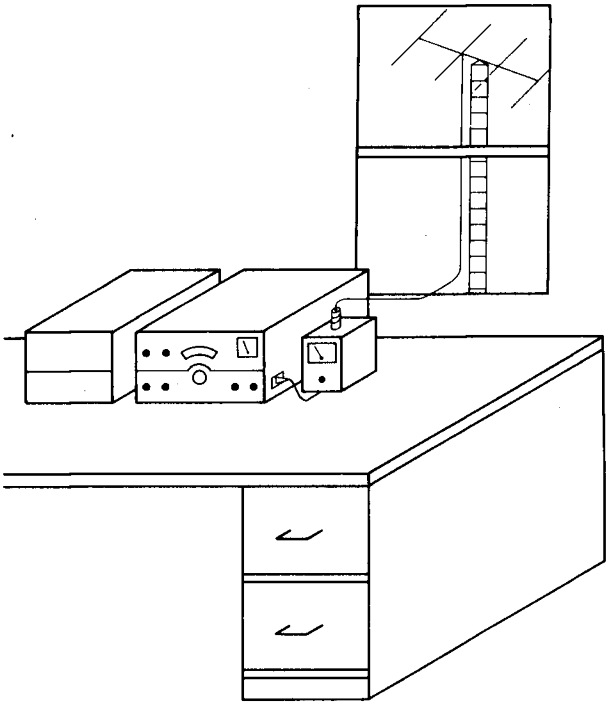

fig. 1. Typical ham setup for measuring SWR. An SWR bridge is connected in series with the transmission line as it leaves the transmitter or transceiver.

wave ratio at the antenna (**fig. 2**) isn't necessarily equal to the standing wave ratio at the transmitter when a lossy transmission line is used.

transmission-line losses

Fig. 3 illustrates the effect of both a lossless transmission line and one with loss on dc pulses. Both lines are terminated in a matched load:

$$Z_l = Z_0$$

$$Z_l = \text{load impedance}$$

$$Z_0 = \text{line characteristic impedance}$$

Note that in both cases the incident pulse is completely absorbed in the load, resulting in no reflected pulse. We may calculate the standing wave ratio at the transmitter in both cases as:

$$SWR = \frac{V_i + V_r}{V_i - V_r} \tag{1}$$

where V_i = incident pulse voltage
V_r = reflected pulse voltage

Thus:

$$SWR = \frac{1+0}{1-0} = 1 \text{ or } 1{:}1$$

For the lossless transmission line the situation is unchanged at the load end. For the lossy line, however, the incident voltage is only 0.707 at the terminal end, thus:

$$SWR = \frac{0.707+0}{0.707-0} = 1 \tag{2}$$

In other words the standing wave ratio for a matched line is 1:1 regardless of *where it's measured or how much loss it has*.

unmatched loads

Now consider the case of an unmatched load. Referring to **fig. 4**, we see that the standing wave ratio measured at the load end for the lossless and lossy transmission lines is respectively given by:

$$SWR = \frac{1+0.5}{1-0.5} = 3{:}1 \text{ (lossless)} \tag{3}$$

$$SWR = \frac{0.7+0.35}{0.7-0.35} = 3{:}1 \text{ (lossy)}$$

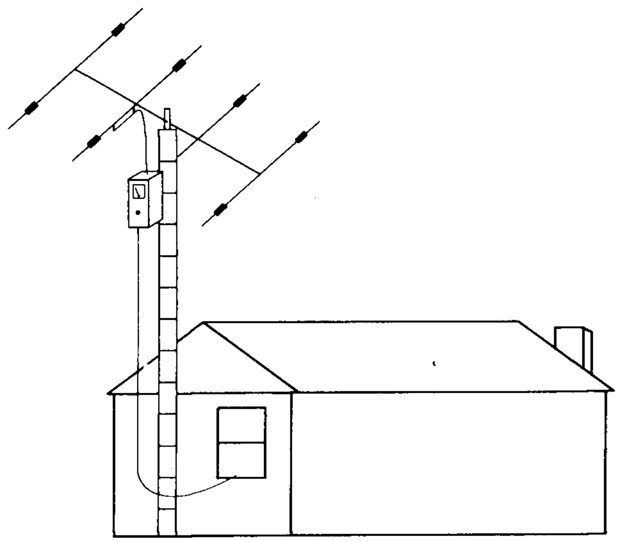

fig. 2. An SWR bridge connected at the antenna will show an entirely different set of conditions if a lossy transmission line is used.

The SWR measured at the source (transmitter) end of the line, however, is quite another situation:

$$SWR = \frac{1+0.5}{1-0.5} = 3{:}1 \text{ (lossless)} \tag{4}$$

$$SWR = \frac{1+0.25}{1-0.25} = 1.67{:}1 \text{ (lossy)}$$

Thus for the lossless line the SWR is the same no matter *where* it's measured. For the lossy line, however, the SWR appears to be lower when measured

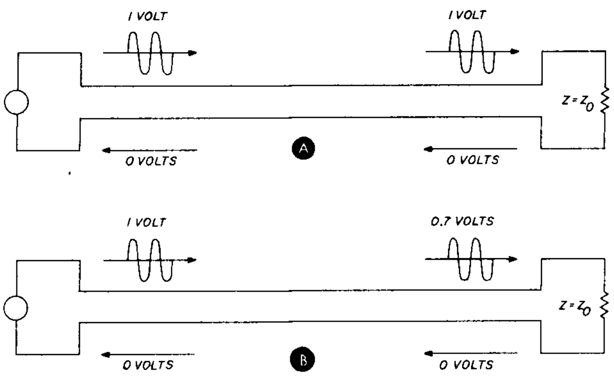

fig. 3. Effect of wave propagation on a matched transmission line. *A* shows a "lossless" transmission line; *B* shows a lossy line. Note that in both cases the incident pulse is completely absorbed in the load, resulting in no reflected voltage.

at the transmitter end. This effect is caused by the additional attenuation suffered by the reflected wave as it travels down the transmission line and back, whereas the incident wave is measured *directly at the source*.

Fig. 5 is a plot of measured *versus* actual SWR for various amounts of transmission line loss. The error is quite significant. **Fig. 6** is a plot of typical transmission line losses versus frequency. Using these two graphs, we can estimate the actual SWR at the antenna for your installation, based on the measured SWR at the transmitter.

example

Consider a typical installation consisting of a beam antenna connected to a transmitter by 61 meters (200 feet) of RG-8/U coaxial cable. Suppose the SWR is measured as 2.5 at 28 MHz. From **fig. 6**, the loss of RG-8/U, when matched, at this frequency is about 1 dB per 30.5 meters (100 feet). Thus the cable loss in the example is

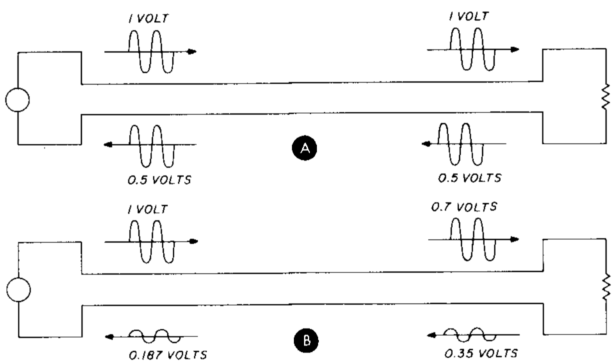

fig. 4. Wave propagation on lines terminated in unmatched load; *B* shows the same conditions for a lossy transmission line. For the "lossless" line the SWR is the same no matter where it's measured; for the lossy line the SWR appears to be lower when measured at the generator (transmitter) end.

$$\begin{aligned} L &= (\text{loss per 30.5 meters})\\ &\quad (\text{cable length}/30.5)\\ &= (1)(61/30.5)\\ &= 2\,dB \end{aligned}$$

In terms of English units:

$$\begin{aligned} L &= (1)(200/100)\\ &= 2\,dB \end{aligned}$$

Referring to **fig. 5**, the actual antenna SWR is about 5.5.

consequences

What are the consequences of the error of SWR

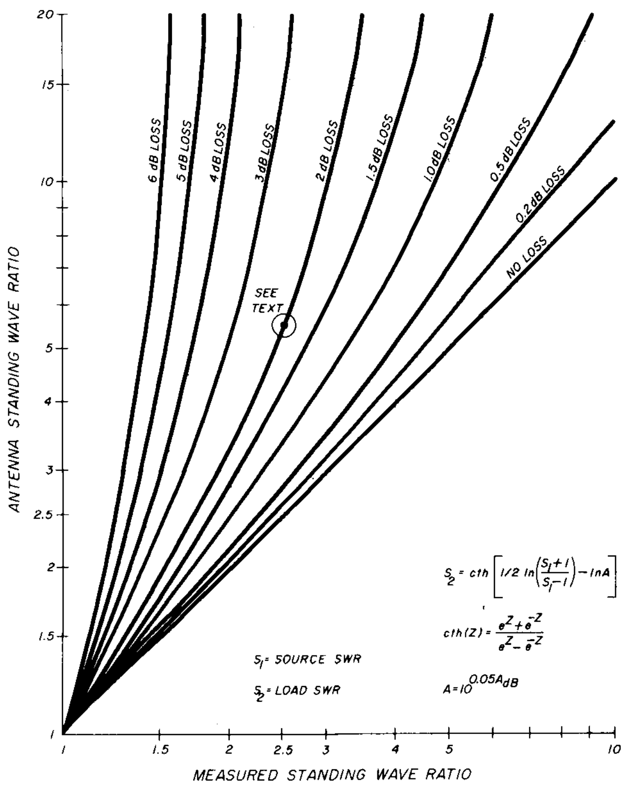

fig. 5. Antenna standing wave ratio as a function of measured standing wave ratio with transmission-line losses as a parameter.

measurement? The first consequence that comes to mind is the effect on the power-handling capability of the transmission line (see **fig. 7**). In the previous example, for instance, the power rating of RG-8/U coaxial cable is about 1600 watts at 28 MHz when operated at unity SWR (**fig. 7**). Derating for the computed standing wave ratios, we find the maximum recommended power-handling capacity of the cable would be:

$$P_{max} = \frac{1600\ watts}{4.2} = 381\ watts \qquad (6)$$

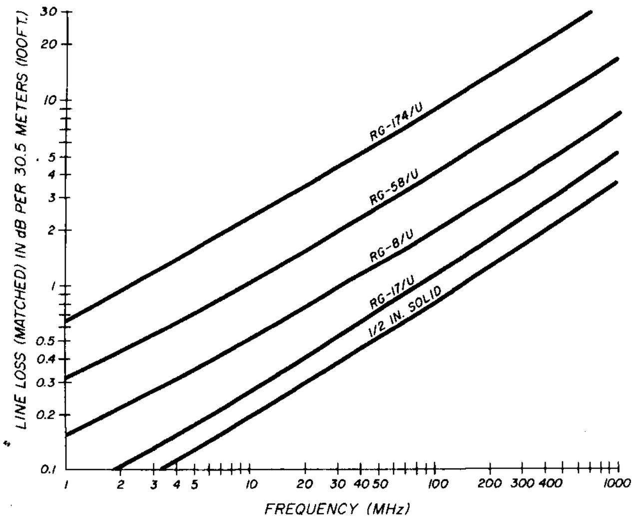

fig. 6. Transmission-line loss (matched) as a function of frequency for several types of coaxial cable.

What if we'd calculated the maximum power based on the measured SWR? The maximum power capability of the cable would have been:

$$P_{max} = \frac{1600\ watts}{2.5} = 640\ watts \qquad (7)$$

As you can see, the coax power-handling capability would have been exceeded by about 60 per cent.

testing

Another problem arises in testing antennas. Many Amateurs test their antennas by measuring the SWR at the transmitter rather than at the antenna. The

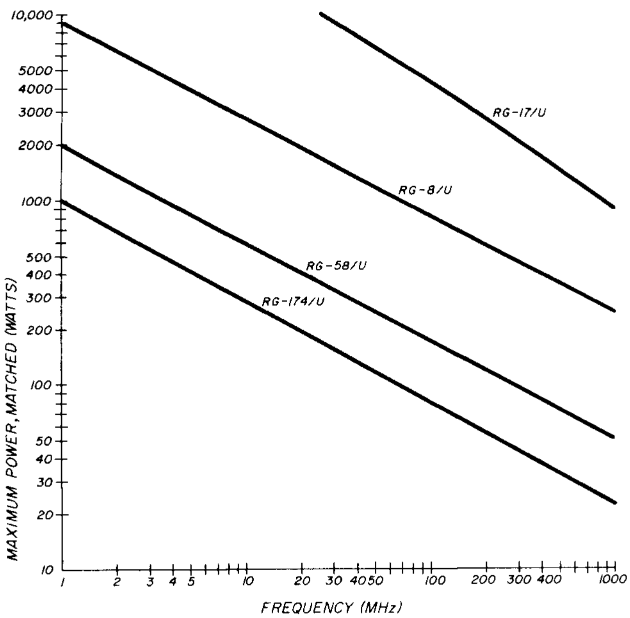

fig. 7. Power-handling capability of popular coaxial cables as a function of frequency.

result is that the antenna *appears* to perform better than it really does. It would be much better either to measure the SWR at the antenna, or at least make an attempt to correct for the feedline loss.

Feedline loss depends on standing wave ratio. Consider the case of a transmitter with tune and load controls adjusted for maximum voltage across the input to the transmission line (**fig. 8**). (This implies a transmitter output impedance equal to the complex

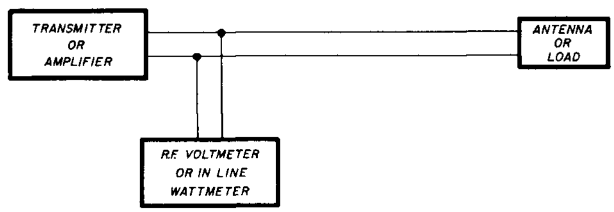

fig. 8. Adjusting the transmitter for maximum output voltage results in a conjugate match, or a condition in which the transmitter output impedance equals the complex conjugate of the impedance seen at the input to the coaxial line. This condition is assumed in figures 9 through 12.

conjugate of the effective transmission line input impedance — a condition referred to as conjugate match.)

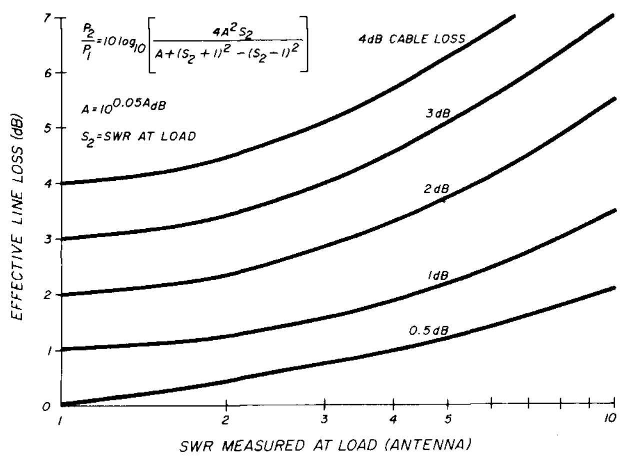

fig. 9. Effective line loss as a function of SWR measured at the load, with cable loss as a parameter.

lossless lines

For the case of the lossless line, the reflected wave is completely reflected at the source and ultimately arrives again at the antenna. Each time the wave arrives at the antenna part of it is absorbed, and part of it is reflected. The reflected portion is again reflected by the source, and so on until the entire wave is *completely absorbed* by the antenna.

Since the line has no loss, and since we're assum-

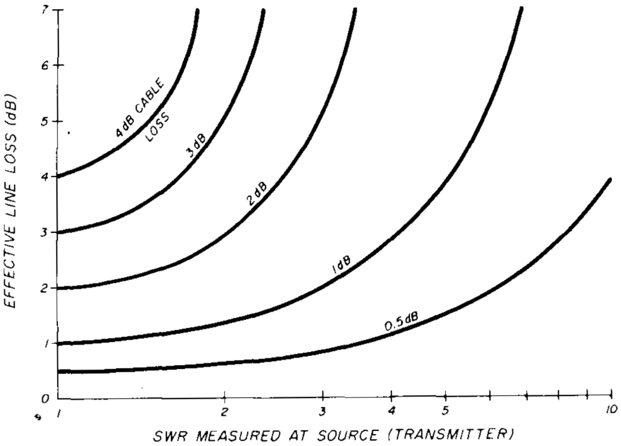

fig. 10. Effective line loss as a function of SWR measured at the source, with cable loss as a parameter.

ing complete lossless reflection at the source (transmitter), the energy is transferred to the antenna with 100 per cent efficiency regardless of whether the antenna is matched to the transmission line.

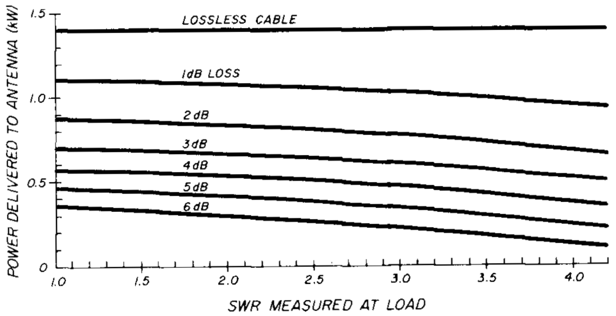

fig. 11. Power delivered to the antenna as a function of SWR measured at the load, with cable loss as a parameter.

lossy lines

Now consider the case of a lossy transmission line. For the matched load the resulting loss is simply the loss of the transmission line. The mismatched load,

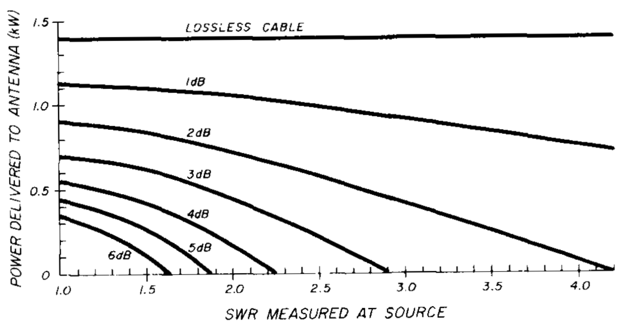

fig. 12. Power delivered to antenna as a function of SWR measured at the source, with cable loss as a parameter.

however, results in quite a different situation. Each time the wave is reflected and travels down the transmission line, it becomes smaller in amplitude by an amount equal to the transmission-line loss. Thus, even if the transmitter is perfectly tuned for "conjugate match," only part of the "re-reflected" energy

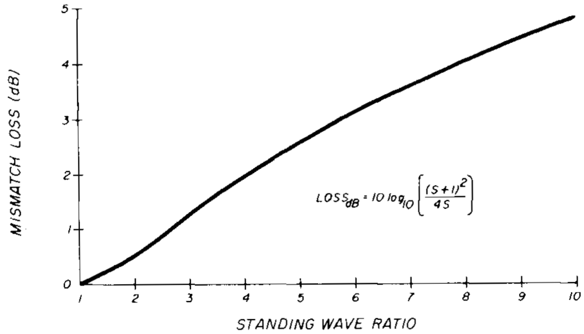

fig. 13. Mismatch loss as a function of SWR.

reaches the antenna, with the portion growing progressively smaller each time around. In other words, in addition to the portion of energy lost in the transmission line the first time, an additional amount is lost due to reflections.

Fig. 9 is a plot of effective feedline loss for various values of standing wave ratio as measured at the antenna. **Fig. 10** is the same plot versus SWR at the source (transmitter). **Figs. 11** and **12** are plots of power delivered to the antenna by a 2-kilowatt amplifier tuned for maximum voltage across the transmission line at the source. **Fig. 11** is plotted versus load

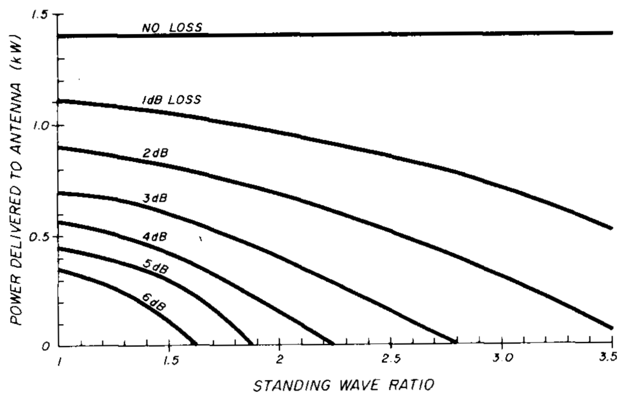

fig. 14. Power delivered to antenna, including mismatch loss for a 2-kW broadband transmitter, as a function of SWR. Output impedance is equal to cable characteristic impedance.

SWR for various line losses; **fig. 12** is plotted versus source SWR. A line loss of 2 dB, for example, would result in only 450 watts being delivered to the load if an SWR of 3:1 is measured at the amplifier output.

mismatch loss

One final comment on line loss. Many hams are now using solid-state transmitters with broadband final amplifier stages. Since there are no adjustments on this type of transmitter, it's not possible, in general, to achieve a conjugate match at the source, as discussed earlier. As a result, there is another loss to be considered when computing the power delivered to the antenna. Mismatch loss is simply the loss resulting from reflected power being absorbed by the source (transmitter) rather than re-reflected power, as discussed previously. **Fig. 13** is a plot of the additional mismatch loss versus source SWR. **Fig. 14** is a plot of power delivered to the load, including mismatch loss for a 2-kilowatt broadband transmitter, with output impedance equal to the transmission line characteristic impedance.

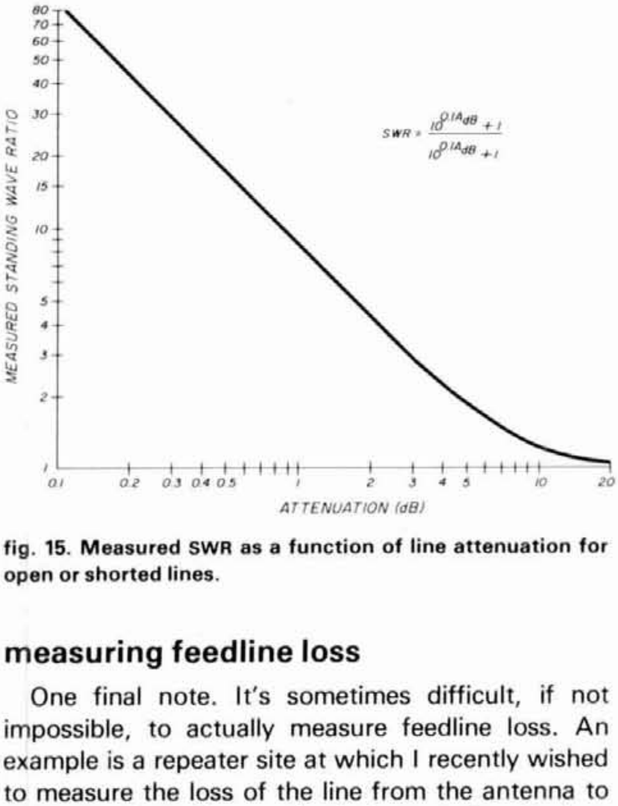

fig. 15. Measured SWR as a function of line attenuation for open or shorted lines.

measuring feedline loss

One final note. It's sometimes difficult, if not impossible, to actually measure feedline loss. An example is a repeater site at which I recently wished to measure the loss of the line from the antenna to the transmitter. One method of measuring the loss would be to carry either a power meter or a signal generator up the tower for connection to the coax at the antenna. An alternative method would be to simply short or open the transmission line at the antenna and measure the resulting standing wave ratio at the transmitter. **Fig. 15** could then be used to compute the transmission line loss. For example, a shorted SWR of 4:1 would correspond to a feedline loss of approximately 2.3 dB.

ham radio

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the ham notebook

Collins 32S cooling

One of the major enemies of final amplifiers, tube or transistor, is heat. My Collins 32S-1 is no exception, and a cooling fan over the amplifier cage is attempting to lengthen the life of my 20-year-old rig.

I got tired of unplugging the fan after operating and dreaded the thought of forgetting to shut if off.

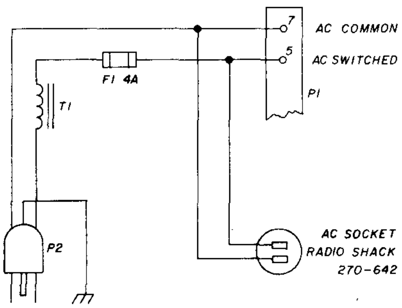


fig. 1. Partial schematic of the Collins 516-F2 supply showing a socket addition for an amplifier cooling fan.

An outboard switch was contemplated — and the thought quickly discarded. I preferred to have the fan turn on and off with the transmitter power. This is how I did it.

I mounted an ac chassis-mount receptacle (Radio Shack part 270-642) on the 516-F2 chassis in the space occupied by the stick-on, serial-number label. (I transferred the label information with an engraving pencil to the chassis.) This location almost perfectly centers the receptacle between XV1 and XV2. The socket was wired as shown in **fig. 1**, using heat-shrink tubing on the receptacle terminals.

A fan such as the Rotron *Whisper* may be spray painted and secured to the cabinet lid directly through the holes with M3 (4-40) hardware. A cover on this fan isn't recommended, as it will create a back pressure and hamper the cooling-system efficiency.

When the fan is plugged into the 516F-2 receptacle, the fan will turn on and off with the 32S FREQUENCY CONTROL switch to provide extra cooling.

Paul K. Pagel, N1FB

shunt-fed tower

A problem that commonly occurs when one tries to shunt feed a tower for 160, 80, and 40 meters is not having a large effective diameter for the shunt section. A small-gauge wire makes things a bit touchy and wire

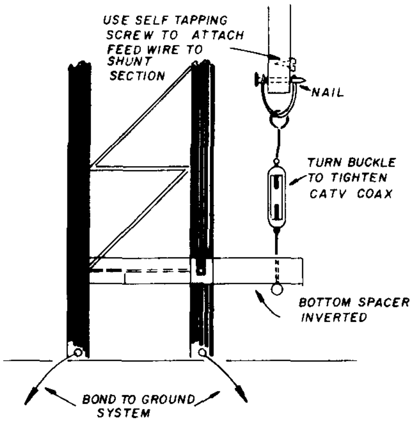


fig. 2. Bottom spacer and connection for the shunt-fed tower. Looping the spacer over the tower rung allows you to maintain tension in the gamma section, holding it rigid. Either the material for the bottom spacer or the connection between the turnbuckle and hardline must be insulated.

cages always seem to get twisted up during mounting.

These problems are eliminated if the relatively large diameter CATV coax is used. This material can usually be obtained free (or, at most, for a few dollars) from the CATV company warehouse scrap yard as "reel ends."

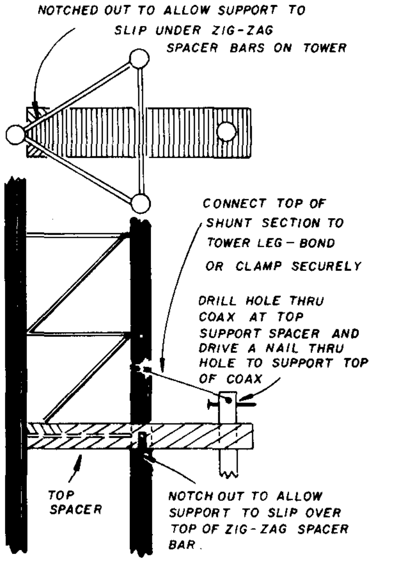


fig. 3. Diagram of the top spacer and connection to the tower.

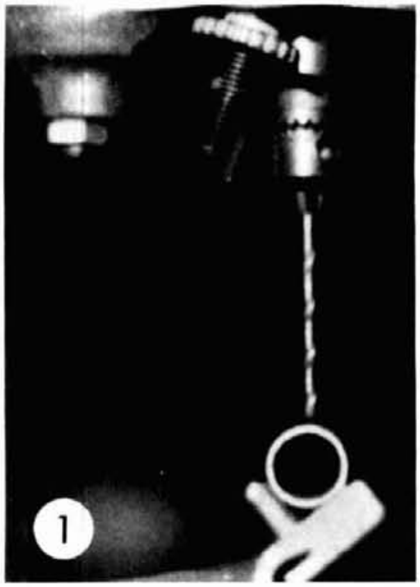
My system requires no clamps for attaching the shunt feed element to a 36-meter (118-foot) ROHN 25 tower (see **figs. 2** and **3** for construction of spacer/clamp assembly). Some experimentation with the spacing between the tower and shunt section will be required to achieve a VSWR of 1.0:1.

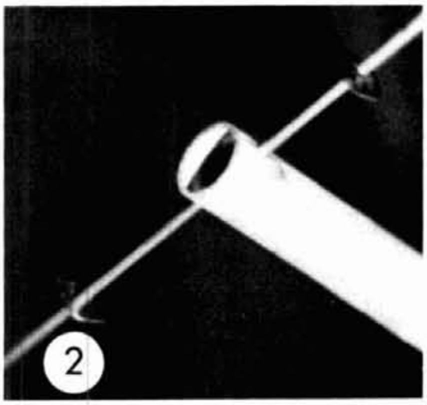
Dick Bingham, N6HZ

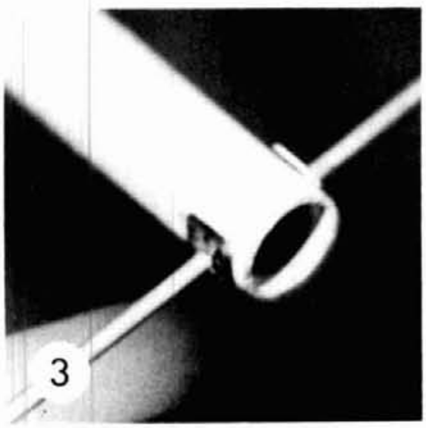
Yagi antenna for uhf — simplified construction

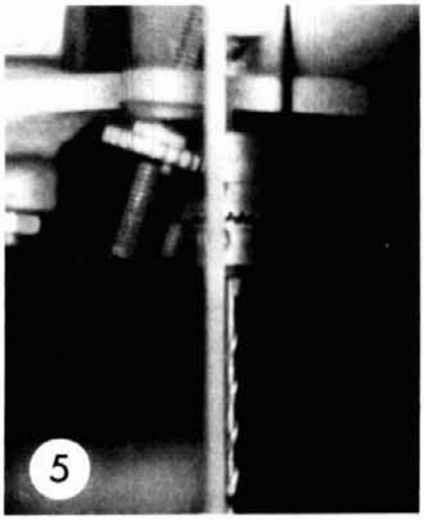
Homebrewing antennas has never been one of my strong points. Most of my beams had more of an omnidirectional characteristic than a main lobe. The problem was making all the elements point in the same direction. If your main construction tools are the same as mine — a blow torch and a sledge hammer — then the techniques I managed to acquire may be helpful in making your next beam look more like an antenna than a corkscrew.

Drilling holes is probably the most critical part of construction. I used a drill stand to hold the drill in place. I made a guide from a piece of V-channel aluminum bolted to a piece of wood (see **photo 1**). The V block keeps the tubing from wandering during drilling. Be sure the drill is centered in both directions in the stand. Use a scrap piece of tubing to drill a test hole, then insert an antenna element to check for alignment. It took me three tries to get the drill oriented just right.









The next problem was how to hold the elements in the boom without using a lot of clamps or brackets. After many tries, I used speed nuts. They worked well and held the elements firmly in place. I pressed a speed nut onto each element end (**photo 2**). Caution: When pushing the speed nuts up to the boom, be certain that the element is centered (**photo 3**), because backing up the speed nuts is nearly impossible. Speed nuts are available in many sizes at most hardware stores. I applied a liberal coat of silicone rubber to protect the speed nuts from rust (**photo 4**).

it's used to align the other holes as you look down the boom. The drill bit acts as a gunsight for alignment (**photo 5**). If minor alignment exists, correction can be made by forming the elements.

The antenna shown in **photo 6** was my first attempt to built a 432-MHz Yagi using the method described. The cost was just over $5.00, using an aluminum boom and welding rods for elements. I've also built some 2-meter Yagis. Tests have shown that these homebrew antennas are within ½ dB of their commercial counterparts. Pattern checks have shown a clean main lobe.

Thomas Varmecky, WA3CPH

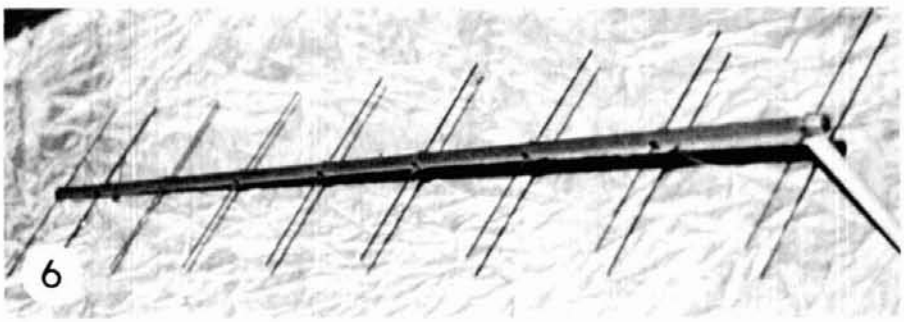
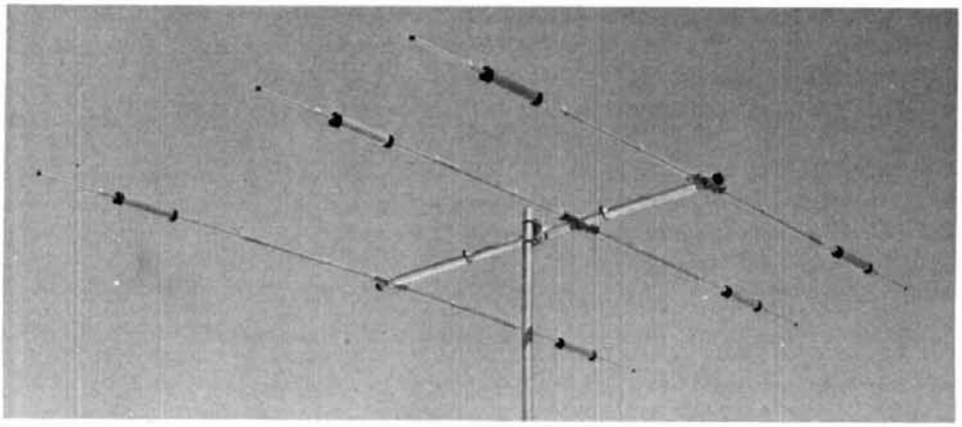


Photo 1: Drill stand for working aluminum tubing is made from a piece of V-shaped aluminum bolted to a piece of wood. Photo 2: Speed nuts hold the element to the boom. Photo 3: Detail showing element-to-boom mating using speed nuts. Photo 4: Final assembly of element to boom. A coat of silicone rubber protects the joints from rust. Photo 5: Use the drill bit as a gunsight for alignment when drilling holes for the other elements. Photo 6: Complete 432-MHz homebrew Yagi antenna. Antenna elements are welding rods; entire antenna cost just over $5.00.

WILSON SYSTEMS INC. MULTI-BAND ANTENNAS



$139.95

SYSTEM 33

(FORMERLY SYSTEM THREE)

FACTORY DIRECT ONLY

Capable of handling the Legal Limit, the "SYSTEM 33" is the finest compact tri-bander available to the amateur.

Designed and produced by one of the world's largest antenna manufacturers, the traditional quality of workmanship and materials excells with the "SYSTEM 33".

New boom-to-element mount consists of two 1/8" thick formed aluminum plates that will provide more clamping and holding strength to prevent element misalignment.

Superior clamping power is obtained with the use of a rugged 1/4" thick aluminum plate for boom to mast mounting.

The use of large diameter High-Q traps in the "SYSTEM 33" makes it a high performing tri-bander and at a very economical price.

A complete step-by-step illustrated instruction manual guides you to easy assembly and the lighweight antenna makes installation of the "SYSTEM 33" quick and simple.

The same quality traps are used in the SY33 that are used in the SY36.

SPECIFICATIONS

Band MHz	14-21-28	**Turning radius**	15'9"
Maximum power input	Legal limit	**Maximum mast diameter**	2" O.D.
Gain (dbd)	Up to 8 dB	**Surface area**	5.7 sq. ft.
VSWR at resonance	1.3:1	**Wind loading at 80 mph**	114 lbs.
Impedance	50 ohms	**Assembled weight (approx.)**	37 lbs.
F/B ratio	20 dB or better	**Shipping weight (approx.)**	42 lbs.
Boom (O.D. x length)	2" x 14'4"	**Direct 52 ohm feed—no balun required**	
No. elements	3	**maximum wind survival**	100 mph
Longest element	27'4"		

CALL
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1-800-634-6898

WSI WILSON SYSTEMS, INC.

4286 S. Polaris Ave., Las Vegas, Nevada 89103

Prices and specifications subject to change without notice.

$44.95

WV-1A

4 BAND TRAP VERTICAL (10 - 40 METERS)

No bandswitching necessary with this vertical. An excellent low cost DX antenna with an electrical quarter wavelength on each band and low angle radiation. Advanced design provides low SWR and exceptionally flat response across the full width of each band.

Featured is the Wilson large diameter High-Q traps which will maintain resonant points with varying temperatures and humidity.

Easily assembled, the WV-1A is supplied with a hot dipped galvanized base mount bracket to attach to vent pipe or to a mast driven in the ground.

Note:
Radials are required for peak operation.
(See GR-1 below).

SPECIFICATIONS:

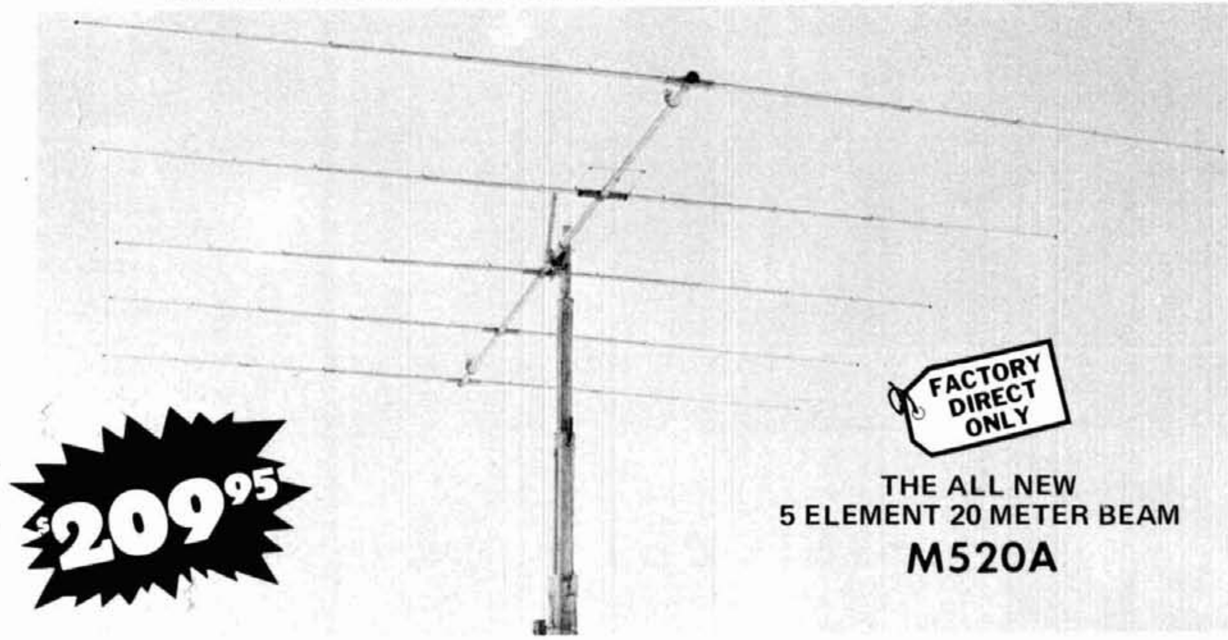
- Self supporting—no guys required.
- Input Impedance: 50 Ω
- Powerhandling capability: Legal Limit
- Two High-Q Traps with large diamater coils
- Low Angle Radiation
- Omnidirectional performance
- Taper Swaged Aluminum Tubing
- Automatic Bandswitching
- Mast Bracket furnished
- SWR: 1.1:1 or less on all Bands

GR-1

$9.95

The GR-1 is the complete ground radial kit for the WV-1A. It consists of: 150' of 7/14 stranded copper wire and heavy duty egg insulators, instructions. The GR-1 will increase the efficiency of the GR-1 by providing the correct counterpoise.

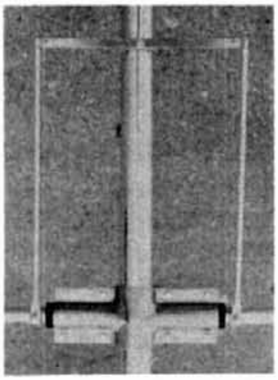
WILSON MONO-BAND BEAMS



At last, the antennas that you have been waiting for are here! The top quality, optimum spaced, and newest designed monobanders. The Wilson Systems' new Monoband beams are the latest in modern design and incorporate the latest in design principles utilizing some of the strongest materials available. Through the select use of the current production of aluminum and the new boom to element plates, the Wilson Systems' antennas will stay up when others are falling down due to heavy ice loading or strong winds. Note the following features:

1. Taper Swaged Elements – The taper swaged elements provide strength where it counts and lowers the wind loading more efficiently than the conventional method of telescoping elements of different sizes.
2. Mounting Plates – Element to Boom – The new formed aluminum plates provide the strongest method of mounting the elements to the boom that is available in the entire market today. No longer will the elements tilt out of line if a bird should land on one end of the element.
3. Mounting Plates – Boom to Mast – Rugged 1/4" thick aluminum plates are used in combination with sturdy U-bolts and saddles for superior clamping power.
4. Holes– There are no holes drilled in the elements of the Wilson HF Monobanders. The careful attention given to the design has made it possible to eliminate this requirement as the use of holes adds an unneccessary weak point to the antenna boom.

With the Wilson Beta-match method, it is a "set it and forget it" process. You can now assemble the antenna on the ground, and using the guidelines from the detailed instruction manual, adjust the tuning of the Beta-match so that it will remain set when raised to the top of the tower.



Wilson's Beta match offers maximum power transfer.

The Wilson Beta-match offers the ability to adjust the terminating impedance that is far superior to the other matching methods including the Gamma match and other Beta-matches. As this method of matching requires a balanced line it will be necessary to use a 1:1 balun, or RF choke, for the most efficient use of the HF Monobanders.

The Wilson Monobanders are the perfect answer to the Ham who wants to stack antennas for maximum utilization of space and gain. They offer the most economical method to have more antenna for less money with better gain and maximum strength. Order yours today and see why the serious DXers are running up that impressive score in contests and number of countries worked.

SPECIFICATIONS

Model	Band Mtrs	Gain dBd	F/B Ratio	Bandwidth @ Resonance 2:1 VSWR Limits	VSWR @ Resonance	Impedance	Matching	Elements	Longest Element	Boom O.D.	Boom Length	Turning Radius	Surface Area (Sq.Ft.)	Windload @ 80 mph (Lbs.)	Maximum Mast	Assembled Weight (Lbs.)
M520A	20	11.5	25 dB	500 KHz	1.1:1	50 Ω	Beta	5	36'6"	2"	34'2½"	25'1"	8.9	227	2"	68
M420A	20	10.0	25 dB	500 KHz	1.1:1	50 Ω	Beta	4	36'6"	2"	26'0"	22'6"	7.6	189	2"	50
M515A	15	12.0	25 dB	400 KHz	1.1:1	50 Ω	Beta	5	25'3"	2"	26'0"	17'6"	4.2	107	2"	41
M415A	15	10.0	25 dB	400 KHz	1.1:1	50 Ω	Beta	4	24'2½"	2"	17'0"	14'11"	3.1	54	2"	25
M510A	10	12.0	25 dB	1.5 MHz	1.1:1	50 Ω	Beta	5	18'6"	2"	26'0"	16'0"	2.8	72	2"	36
M410A	10	10.0	25 dB	1.5 MHz	1.1:1	50 Ω	Beta	4	18'3"	2"	12'11"	11'3"	1.4	36	2"	20

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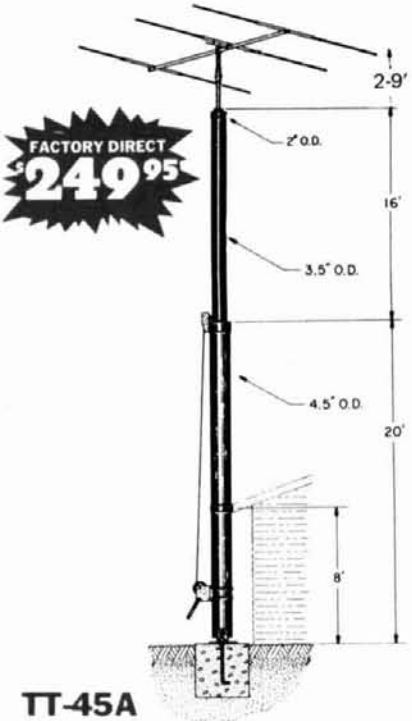
New, Improved Wilson Towers

Hinged Base Plate - Concrete Pad, Heavy Duty Winch

Mounting the House Bracket

The Hinged Base Plate allows tower to be tilted over for access to antenna and rotor from the ground.

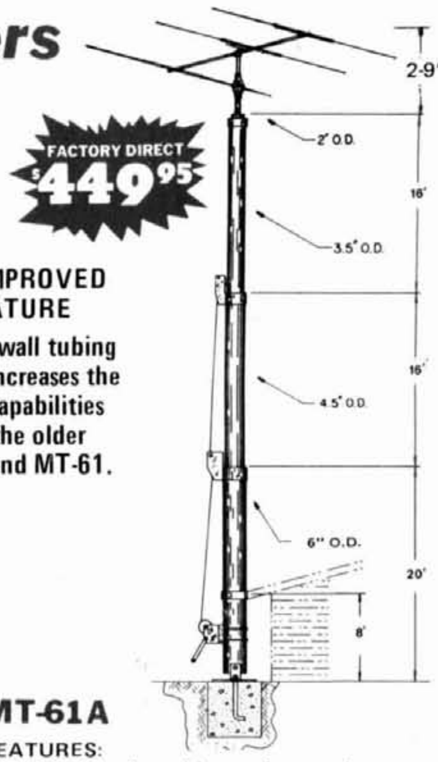


TT-45A

FEATURES:

- Maximum Height 45' (will handle 12 sq. ft. at 38') @ 50 mph
- 1200 lb. winch
- Totally freestanding with proper base
- Total Weight, 243 lbs.

The TT-45A is a freestanding tower, ideal for installations where guys cannot be used. If the tower is not being supported against the house, the proper base fixture accessory must be selected. (Requires 12"x12"x36" of concrete.)



NEW IMPROVED FEATURE

Heavier wall tubing greatly increases the stress capabilities over the older TT-45 and MT-61.

MT-61A

FEATURES:

- Is freestanding with use of proper base
- Maximum Height is 61' (will handle 12 sq. ft. at 53') @ 50 mph
- 1200 lb. brake winch
- 4200 lb. raising cable
- Total Weight, 400 lbs.

Recommended base accessory: RB-61A, FB-61A.

The MT-61A is our largest and tallest freestanding tower. By using the RB-61A rotating base fixture the MT-61A is ideally suited for the SY33 or SY-36. If you plan to mount the tower to your house, caution should be taken to make certain the eave is properly reinforced to handle the tower. If not, one of the base accessory fixtures should be used. (Requires 18"x18"x48" concrete.)

GENERAL FEATURES

All towers use high strength heavy galvanized steel tubing that conforms to ASTM specifications for years of maintenance-free service. The large diameters provide unexcelled strength. All welding is performed with state-of-the-art equipment. Top sections are 2" O.D. for proper antenna/rotor mounting. A 10' push-up mast is included in the top section of each tower. Hinge-over base plates are standard with each tower. The high loads of today's antennas make Wilson crank-ups a logical choice.

TILT-OVER BASES FOR TOWERS

FIXED BASE

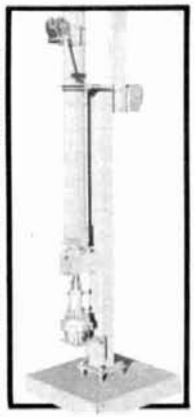
The FB Series was designed to provide an economical method of moving the tower away from the house. It will support the tower in a completely free-standing vertical position, while also having the capabilities of tilting the tower over to provide an easy access to the antenna. The rotor mounts at the top of the tower in the conventional manner, and will not rotate the complete tower. (Requires 3'x3'x5½' of concrete.)

FB-45A . . . $ 99.95
FB-61A . . . 129.95

ROTATING BASE

The RB Series was designed for the Amateur who wants the added convenience of being able to work on the rotor from the ground position. This series of bases will give that ease plus rotate the complete tower and antenna system by the use of a heavy duty thrust bearing at the base of the tower mounting position, while still being able to tilt the tower over when desiring to make changes on the antenna system. (Requires 3'x3'x6' of concrete.)

RB-45A . . . $139.95
RB-61A . . . 199.95



Tilting the tower over is a one-man task with the Wilson bases.

(Shown above is the RB-61A.)

(Rotor not included)

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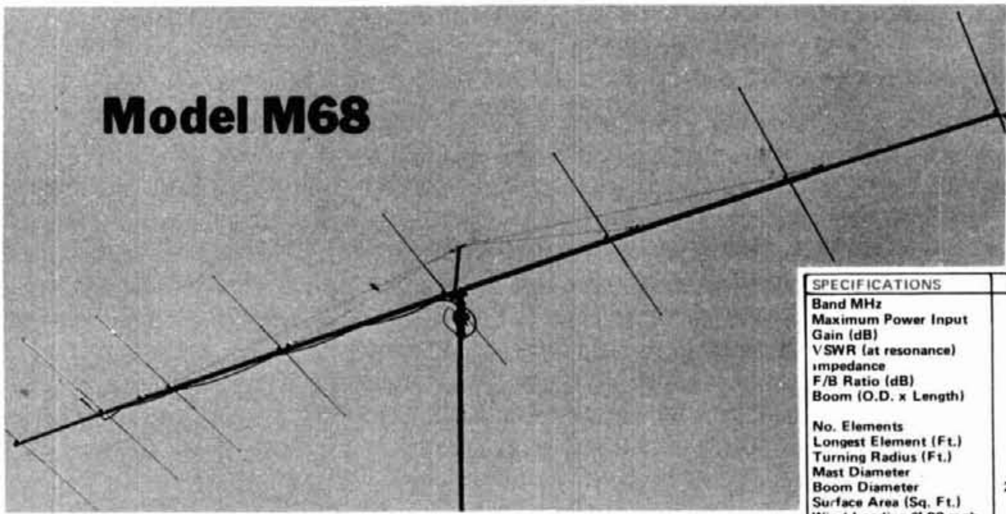
6 METER BEAMS



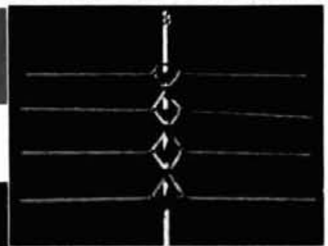
As low as $27.95

SPECIFICATIONS	MODEL M68	MODEL M66	MODEL M64
Band MHz	50	50	50
Maximum Power Input	4 Kw	4 Kw	4 Kw
Gain (dB)	13.5	13.0	10.0
VSWR (at resonance)	1.1:1	1.1:1	1.1:1
Impedance	50 ohms	50 ohms	50 ohms
F/B Ratio (dB)	26	26	25
Boom (O.D. x Length)	2" to 1½" x 36'10"	2" x 25'8"	1½" x 11'6"
No. Elements	8	6	4
Longest Element (Ft.)	9'8"	9'8"	9'8"
Turning Radius (Ft.)	19'0"	13'10"	7'6"
Mast Diameter	2" O.D.	2" O.D.	1½" O.D.
Boom Diameter	2" to 1½" O.D.	2" O.D.	1½" O.D.
Surface Area (Sq. Ft.)	5.8	4.5	1.5
Wind Loading @ 80 mph	145	112	37
Assembled wght. Approx.	34 lbs.	26 lbs.	11 lbs.
Shipping wght. Approx.	39 lbs.	31 lbs.	13 lbs.
Matching Method	Gamma	Gamma	Gamma
PRICE	$84.95	$54.95	$27.95

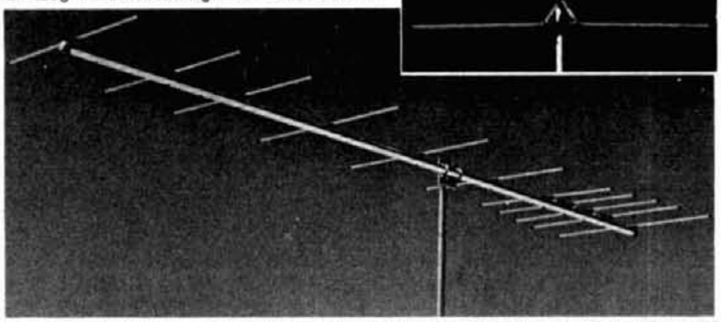
8 elements W - I - D - E spaced on a L - O - N - G 37' boom . . . for those long hauls to JA and VK land! Choose 4, 6 or 8 elements to put you in the action on six meters.

Starting at $19.95

2 METER BEAMS



Wilson's new 2 meter series combines the ultimate in design and quality materials. These top performing beams feature 7, 9 or 11 aluminum elements held to the heavy walled boom with the exclusive molded Lexan® boom to element mounting. The four driven elements use Log Periodic design for broad band characteristics providing full 144-148 MHz coverage with less than 1.2 to 1 VSWR across the band. Universal mounting is provided for vertical or horizontal polarization.



SPECIFICATIONS	M27	M29	M211
Band MHz	144-148 MHz	144-148 MHz	144-148 MHz
Gain (dB)	11 dB	13.7 dB	14.5 dB
VSWR	Less than 1.2:1 across band	Less than 1.2:1 across band	Less than 1.2:1 across band
Impedance	50 ohms balanced	50 ohms balanced	50 ohms balanced
Number of Elements	7	9	11
Boom (O.D. x Length)	1" O.D. x 5'4"L.	1" O.D. x 10'0"L.	1½" O.D. x 12'6"
Longest Element	40"	40"	40"
Surface Area (Sq. Ft.)	.8	1.5	2.8
Assembled wght Approx.	3.5 lbs.	5 lbs.	6 lbs.
Shipping wght. Approx.	6.5 lbs.	8 lbs.	9 lbs.
Turning Radius	38"	64"	78"
PRICE	$19.95	$24.95	$29.95

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Las Vegas, NV 89103 — (702) 739-7401

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Toll-Free Order Number
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WILSON SYSTEMS ANTENNAS

Qty	Model	Description	Shipping	Price
	SY33	3 Ele. Tribander for 10, 15, 20 Mtrs.	UPS	$139.95
	SY36	6 Ele. Tribander for 10, 15, 20 Mtrs.	UPS	189.95
	WV-1A	Trap Vertical for 10, 15, 20, 40 Mtrs.	UPS	44.95
	GR-1	Ground Radials for WV-1A	UPS	9.95
	M-520A	5 Elements on 20 Mtrs.	TRUCK	209.95
	M-420A	4 Elements on 20 Mtrs.	UPS	139.95
	M-515A	5 Elements on 15 Mtrs.	UPS	119.95
	M-415A	4 Elements on 15 Mtrs.	UPS	79.95
	M-510A	5 Elements on 10 Mtrs.	UPS	84.95
	M-410A	4 Elements on 10 Mtrs.	UPS	64.95
	WM-62A	Mobile Antenna: 5/8 λ on 2, 1/4 λ on 6	UPS	19.95
	M-86	8 Elements on 6 Mtrs.	UPS	84.95
	M-66A	6 Elements on 6 Mtrs.	UPS	54.95
	M-46	4 Elements on 6 Mtrs.	UPS	27.95
	M-112	11 Elements on 2 Mtrs.	UPS	29.95
	M-92	9 Elements on 2 Mtrs.	UPS	24.95
	M-72	7 Elements on 2 Mtrs.	UPS	19.95
		ACCESSORIES		
	HD-73	Alliance Heavy Duty Rotor	UPS	109.95
	RC-8C	8/C Rotor Cable	UPS	.12/ft.
	RG-8U	RG-8U Foam-Ultra Flexible Coaxial Cable. 38 strand center conductor, 11 guage	UPS	.21/ft.

WILSON SYSTEMS TOWERS

Qty.	Model	Description	Shipping	Price
	TT-45A	Freestanding 45' Tubular Tower	TRUCK	$249.95
	RB-45A	Rotating Base for TT-45A w/tilt over feature	TRUCK	139.95
	FB-45A	Fixed Base for TT-45A w/tilt over feature	TRUCK	99.95
	MT-61A	Freestanding 61' Tubular Tower	TRUCK	449.95
	RB-61A	Rotating Base for MT-61A w/tilt over feature	TRUCK	199.95
	FB-61A	Fixed Base for MT-61A w/tilt over feature	TRUCK	129.95

NOTE:
On Coaxial and Rotor Cable, minimum order is 100 ft. and in 50' multiples.
Prices and specifications subject to change without notice.
Ninety Day Limited Warranty, All Products FOB Las Vegas, Nevada
PRICES EFFECTIVE NOV. 1, 1979

Nevada Residents Add Sales Tax

Ship C.O.D. ☐ Check enclosed ☐ Charge to Visa ☐ M/C ☐

Card # ______________ Expires ______________

Bank # ______________ Signature ______________

Please Print

Name ______________ Phone ______________

Street ______________

City ______________ State ______ Zip ______

Prices and specifications subject to change without notice.

comments

(Continued from page 6)

wherein *L*, *W*, and *t* represent length, width, and thickness.

To maintain 12 amperes/square foot, you must measure the resistance of the bath with the piece to be processed in place and apply Ohm's law or use a variable voltage supply with an ammeter in the circuit. Maintaining this current will require a power supply capable of supplying 15-20 volts at a current equal to 125-150 per cent of the calculated amount. Voltage will vary with bath temperature and alloy.

Best anodizing results are obtained by maintaining a constant current throughout the cycle. By maintaining the bath temperature between 68 and 72F (use a long glass dairy thermometer) and the current at 12 amperes/square foot, the time required to produce a given coating thickness will be 80 ampere minutes per 0.01 mil or 0.0001 inch. In other words, 6.7 minutes' time will produce 0.0001 inch of coating (80 divided by 12) if the other parameters are observed.

In substantiation of this, note that automobile trim is generally required to have a 0.3-mil coating, and most anodizers achieve this with a 20-minute treatment.

Most dyes work well on coatings of 0.3 mil and up. Note, too, that for any alloy worthy of consideration by the Amateur fraternity, the coating weight or thickness will vary no more than three per cent in either direction when coated according to these suggestions.

Proper operating practice should be observed if you expect usable results. The material must be *clean* as a prerequisite to anodizing. Scrubbing the piece with a good soap or detergent should suffice, provided the piece is then thoroughly rinsed. A good test for cleanness is that the rinse water falls off the surface in an unbroken fashion; that is to say, it should not form beads as does the rain on the waxed hood of a car.

Pretreatments such as buffing, wire brushing, or etching should be given some thought by the experimenter. Once the piece has been properly racked (fastened to the aluminum rod or strip for suspension in the bath), it should be carefully lowered into the electrolyte with the power off.

The power should then be applied at a low level and quickly increased to the calculated current. The bath should have some mild agitation during the whole anodizing cycle. Whatever method is used to agitate the bath must take into consideration the hazards of dealing with an *acid* bath. The power should be turned off before the piece is removed.

Aluminum racks are anodized along with the piece of work. Hence, before they're used again they should be sanded, wire brushed, or etched in the contact areas to ensure a good electrical contact. Alloy 2024-T3 or -T351 will work best as rack material for Amateur use. Good electrical contacts are very important to the success of any anodizing experiment.

Anodizing may be done by various methods (including ac anodizing) and for many reasons. By and large, the greater portion of such treatments represented by the H_2SO_4 processes are meant to enhance the appearance of the item treated. The use of the process by the Radio Amateur should be regarded as a means of improving his handiwork.

Any experimenter in need of further corrosion protection of an aluminum item would be well advised to take his problem to a professional anodizer. These sources are listed in the yellow pages of your local phone book.

The work cited in the reference is a three-volume set and is highly recommended to anyone interested in more information on aluminum or the processes employed to fabricate it.

Robert A. Ridout, WA9UXK
McHenry, Illinois

autotune circuit

Dear HR:

Shown in **fig. 1** is a circuit, road tested on a Heath HW-7, that can be used for "touch tuning" a vfo. S1 and S2 are momentary pushbutton switches. S1 provides down-frequency tuning and S2 allows up frequency tuning. The tuning rate is controlled by the time constants R1-C1, for down, and R2-C1, for up; the values given are for about 5 seconds per kHz. Nothing is critical, the jfet is a 4/$1.00 special, and the rf choke and capacitors were chosen by "reach." R3 provides current limiting at about 2.5 mA, and R4 is for insurance.

The idea is presented as an effort to eliminate the mechanical mish-mash that is often associated with dial drives. Using this circuit with a frequency counter for readout will provide a rather neat receiver. Such niceties as variable or selectable R1C1/R2C2 time constants could be added.

Roy Propst, K4JFZ
Carrboro, North Carolina

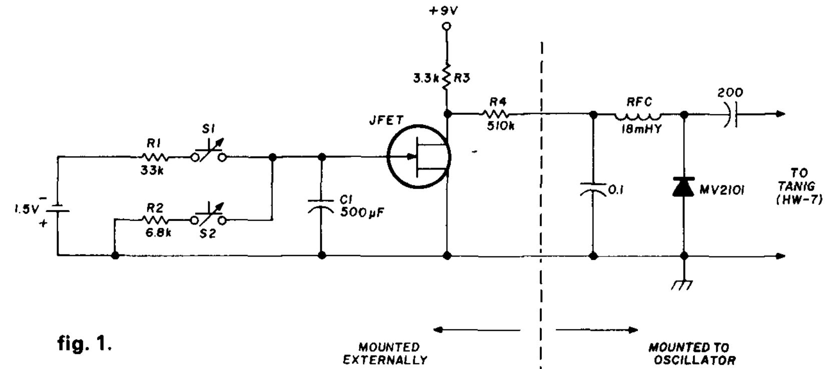

fig. 1.

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For those who wish to mount the encoder in a hand-held unit, the PC board measures only 9/16" x 1-3/4". This partial kit with PC board, crystal, chip and components.
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ACCUKEYER (KIT) THIS ACCUKEYER IS A REVISED VERSION OF THE VERY POPULAR WB4VVF ACCUKEYER ORIGINALLY DESCRIBED BY JAMES GARRETT, IN QST MAGAZINE AND THE 1975 RADIO AMATEUR'S HANDBOOK. **$16.95**

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1106	AC Battery Charger	$ 9.95
1107	Cigarette Lighter Adaptor Cord	$ 9.95
1108	Antenna Adaptor Cord	$ 9.95
1110	Carrying Case (Leather)	$17.85
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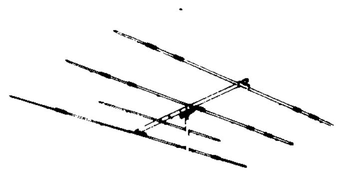

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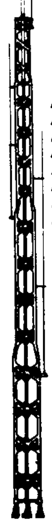

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TH3JR	3 el. 10-15-20M beam	169.95	139.95	14AVQ/WB	40-10M Trap vertical	69.95	57.00
Hy-Quad	2 el. 10-15-20M Quad	274.95	219.95	12AVQ	20-10M Trap Vertical	42.95	34.95
205BA	5 el. "Long John" 20M beam	329.95	259.95	14RMQ	Roof Mounting kit (verticals)	33.95	29.95
155BA	5 el. "Long John" 15M beam	199.95	159.95	5BDQ	80-10M Trap doublet	109.95	89.95
105BA	5 el;"'Long John" 10M beam	129.95	109.95	2BDQ	80-40M Trap doublet	59.95	49.95
204BA	4 el. 20M beam	249.95	199.95	66B	6 el. 6M beam	119.95	99.95
204MK5	5 el. conversion kit	99.95	79.95	203	3 el. 2M beam	15.95	
153BA	3 el. 15M beam	89.95	79.95	205	5 el. 2M beam	21.95	
103BA	3 el. 10M beam	74.95	59.95	208	8 el. 2M beam	29.95	
402BA	2 el. 40M beam	239.95	189.95	214	14 el. 2M beam	34.95	
BN-86	Balun for beam antennas	15.95	15.95	LA-1	Deluxe lightning arrestor	59.95	49.95
TH2MK3	2 el. 10-15-20M beam	149.95	119.95	TH5DX		269.95	209.95

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		Regular	Special
Classic 33	3 el. 10, 15, 20 Mtr. beam	304.75	209.95
Classic 36	6 el. 10, 15, 20 Mtr. beam	392.75	249.95
TA-33	3 el. 10, 15, 20 Mtr. beam	264.00	189.95
TA-36	6 el. 10, 15, 20 Mtr. beam	392.75	249.95
TA-33 Jr.	3 el. 10, 15, 20 Mtr. beam	197.00	149.95
TA-40KR	40 Mtr. Add On	119.95	89.95

CUSHCRAFT

ATB-34	4 ele. 10, 15, 20 Mtr. beam	289.95	219.95	A147-11	11 ele. 146-148 Mhz. beam	36.95	30.95
ATV-4	10, 15, 20, 40 Mtr. Vertical	89.95	69.95	A147-22	22 ele. Power Pack	109.95	89.95
ATV-5	10, 15, 20, 40, 80 Mtr. Vertical	109.95	89.95	A144-10T	2 Mtr. "Twist" 10 ele.	42.95	34.95
ARX-2	2 Mtr. Ringo Ranger	39.95	32.95	A144-20T	2 Mtr. "Twist" 20 ele.	62.95	52.95
AR-6	6 Mtr. Ringo	36.95	32.95	A147-20T	2 Mtr. beam	62.95	52.95
ARX-220	220 Mhz. Ringo Ranger	39.95	32.95	A430-11	432 Mhz. 11 ele. beam	34.95	29.95
ARX-450	435 Mhz. Ringo Ranger	39.95	32.95	A432-20T	430-436 Mhz. Beam	59.95	49.95
A144-11	11 ele. 144-146 Mhz. beam	36.95	30.95				

HUSTLER

3-TBA	3 ele; 10, 15, 20 Mtr. beam	259.95	189.95
4-BTV	10-40 Mtr. Vertical	99.95	79.95
5-BTV	10-80 Mtr. Vertical	134.95	99.95
RM-75	75 Meter Resonator	16.95	14.50
RM-75S	75 Meter Super Resonator	31.95	27.50
G6-144B	2 Mtr. Base Colinear	79.95	59.95
G7-144	2 Mtr. Base Colinear	119.95	89.95

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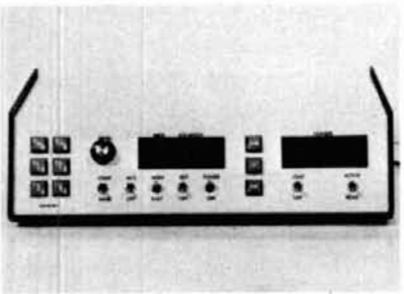
NEW products

For literature on any of the new products, use our *Check-Off* service on page 118.

memory keyer

Announcing Con-puter 1, the totally new type of memory keyer for Amateur Radio CW contests or casual operation. Con-puter 1 permits



the operator to store contest exchange messages which contain serial numbers. Such exchanges are required in the Sweepstakes, WAE, VK/ZL, and many other CW contests.

After initial storing of desired contest messages by the operator, Con-puter 1 automatically inserts the correct serial number. This number is also displayed. Each time the message is initiated, the serial number automatically increases by one, and the complete message, with number, is sent without further attention from the operator. Numbers up to 9999 can be accommodated.

Con-puter 1 also contains a leading-zero option which, when activated, automatically places zeros in front of numbers less than 100. The memory and address locations are digitally displayed for loading convenience. Con-puter 1's front panel has been kept simple for operating ease. It operates like a regular memory keyer when the serial number feature is not needed. Approximately two hundred characters may be stored in the four primary and four secondary message locations. The keyer has built-in sidetone and speaker. Either a regular or iambic key paddle may be used. Continuously adjustable keying speed is 5-60 WPM. Power requirements are 120-volt ac, 60 Hz, or 12-volt dc. Memory contents may be protected against power loss by connecting an external battery to terminals provided for that purpose on the rear panel.

The heavy duty aluminum cabinet measures 30 × 9 × 25 cm (12 × 3½ × 10 inches). Price is $379 fully assembled, shipped prepaid and guaranteed. The operator's manual may be purchased separately. For information, contact Con-puter 1, 3006 Lockheed, Midland, Texas 79701.

low-cost portable dmm

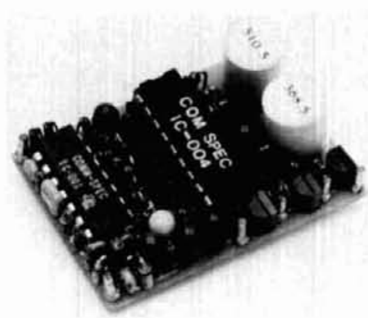
The Model ME-521DX multimeter is a 3½-digit battery-powered unit. It features a high-low ohm switch for all ranges, five function modes, automatic zero adjustment, automatic polarity, and overload protection.

Low current drain ensures long battery life and thousands of measurements without the need for battery replacement. This accurate and completely portable device has voltage measurement capability to 1000 Vdc and 600 Vac, a current measurement range to 1000 mA (ac or dc), and a resistance measurement range to 20 megohms. Accuracy is typically 0.5 per cent.

For more information, contact Soar Electronics Corporation, 813 Second Street, Ronkonkama, New York 11779.

SD-1 sequential decoder

A new product announced by Communications Specialists is the SD-1 Two-Tone Sequential Decoder.



This microminiature product measuring just 3 × 4 × 2 cm (1.2 × 1.67 × 0.65 inches) will fit all mobile units and most portables.

It uses plug-in, field-replaceable, K-2 frequency determining elements available in all EIA tone frequencies from 268.5 Hz to 2109.0 Hz.

Power requirements are 6 to 16 Vdc unregulated at 10 mA. Reverse polarity and over-voltage protection are built-in. All connections to the board are made with push-on connectors, and color-coded wires are furnished.

The SD-1 may be driven by the discriminator, audio stages, or from the speaker circuit. Switched outputs include high-current closure to ground for a horn relay, a latched high-current closure for a call light, and a latched low-current, high voltage circuit to unmute the receiver.

The unit is completely immune to rf, and comes complete with universal mounting hardware. A full one-year warranty applies when the unit is returned to the factory for repair.

Wired, tested, and complete with two K-2 elements, the SD-1 sells for \$59.95. For additional information contact Communications Specialists, 426 West Taft Avenue, Orange, California 92667.

Bird 300-watt dry rf load resistor

Bird Electronics has a new 300-watt high-power coaxial load resistor, which supplements their Bird Dry Loads group ranging from 2 to 600 watts. The new model is designated no. 8173. It handles 300 watts continuous duty. Voltage standing-wave ratio is 1.1 maximum from dc to 1000 MHz; 1.25 maximum from 1000 to 2000 MHz.

A data sheet on all Bird Termaline® dry rf coax load resistors, including the new model 8173, is available from Bird Electronic Corporation, 30303 Aurora Road, Cleveland, Ohio 44139.

TH5DX for 10-15-20 meters

Hy-Gain Electronics, division of Telex Communications, Inc., has introduced the newest member of its famous Thunderbird line of tri-band antennas. The TH5DX offers outstanding performance on 20, 15, and 10 meters. It features five elements on a 6-meter (18-foot) boom, with three active elements on 15 and 20 meters and four active elements on 10 meters. The TH5DX also features separate air-dielectric Hy-Q traps for each band. This allows the TH5DX to be set for the maximum F/B ratio and the minimum beam width possible for a tri-band antenna of this size. Also standard on this antenna are Hy-boom-to-mast bracket and taper-swaged elements. Write Hy-Gain, 8601 N.E. Highway 6, Lincoln, NB 68505.

450-MHz power amplifiers

Telco Products Corporation announces a complete new ULTRA series of 450-MHz rf power amplifiers specifically designed for Amateur, police-, emergency-, business-band, and Class-A CB radio applications up to 50 watts. The new ULTRA line uses the most advanced state-of-the-art technology: strip line construction.

Four new ULTRA uhf power-amplifier models are American manufactured in full compliance with latest FCC specifications:

ULTRA I 1-2W input, 15W output. Ideal for use with low-power, hand-held transceivers.

ULTRA II 3-5W input, 25W output. Puts you a cut above the rest.

ULTRA III 3-5W input, 50W output. The legal limit for Class-A CB radio.

ULTRA IV 3-5W input, 100W output. The ULTRA-powered amplifier for maximum output.

Suggested retail prices for the ULTRA amplifiers are: ULTRA I \$259.00; ULTRA II \$289.00; ULTRA III \$379.00; and ULTRA IV \$499.00. The frequency range of these amplifiers is 400-512 MHz. Please specify your transmit frequency with your order. For additional information contact Telco Products Corporation, 44 Sea Cliff Avenue, Glen Cove, New York 11542 or call (516) 759-0300.

CDE antenna rotors

Two new high-performance antenna rotor systems, the Ham IV™ and the CD-45, have been introduced by Cornell-Dubilier Electric Corporation of Newark, New Jersey.

HAM IV

The new Ham IV is designed for large communication antenna arrays of up to 15.0 square feet wind load area, tower mounted. Highlights of the Ham IV include power braking, machined steel drive gears, dual transformer circuitry, and other design features to make it the choice of serious communicators.

The new CD-45 accommodates antenna arrays of up to 8.5 square feet wind load area tower mounted, and features a professionally styled control unit, illuminated metered readout, all-steel drive components and automatic disc braking.

Both the Ham IV and the CD-45 operate at safe, low-voltage control levels, with reliable snap-action rotational controls for accurate, trouble-free operation. For more information, write Leonard Sabal, Cornell-Dubilier Electric Corporation, subsidiary of Federal Pacific Electric Company, 150 Avenue L, Newark, New Jersey 07101.

new tower from Tri-Ex

Tri-Ex Tower Corporation introduces the Super Z-25. Flush joints, a new concept in tower engineering design, enables this tower to be a full 3 meters (10 feet) high. Flush joints tend not to freeze into the next section, making it easy to disassemble and reuse the tower. This flush joint is backed up by an inner joining sleeve, which adds strength and makes it easier and safer to add on tower sections.

For further information contact Frank Cavallaro, Tri-Ex Tower Corporation, 7182 Rasmussen Avenue, Visalia, California 93277. Telephone: (209) 732-8383.

test clip and IC puller

AP Products has a new test clip designated Super Grip II. It features a narrower noise clearance, which easily attaches to high-density boards. ICs with as little as 1 mm (0.04 inch) between opposing legs can be tested.

A new "duck bill" contour has been added to the contact tips for more secure contact with DIP ICs. Combined with AP's "contact comb" construction, the Super Grip II test clips provide positive, reliable, no-shorting connections every time. Offset pin rows make it easier to attach test probes. "Button heads" on the pin ends prevent probes from sliding off once they're in place.

Heavy-duty springs apply firm contact pressure for testing — hefty grip when pulling ICs. Industrial-grade nylon forms the test-clip body, which is integrally molded around contact pins and the steel pivot pin in the hinge.

AP Super Grip II test clips are available in 8-, 14-, 16-, 18-, 20-, 22-, 24-, 28-, 36-, and 40-pin configurations. For more information on Super Grip II test clips, contact your nearest AP distributor or sales representative. His name, address, and phone number can be obtained quickly through AP's toll-free number: 800-321-9668.

fm adapter for FT101

Holdings of Blackburn (England), is offering a new fm adapter for the Yaesu FT101E and FT101F transceivers. The unit is contained in a small box that fits nicely on top of the FT transceiver, similar to their "G3LLL RF Clipper," which has been popular for some time.

The transmitter portion of the adapter has built-in clipping, filtering, and variable pre-emphasis, which provides good audio quality and effective communications through the clarifier circuit of the transceiver.

Modified FT101 transceivers can be used on the 10-meter fm channels, or they can be fitted with a transverter for use on the various vhf and uhf bands. Installation is simple, and complete instructions are included with the unit.

The FT101 fm adapter can be obtained through the Fox-Tango Corporation, Box 15944, West Palm Beach, Florida 33406; or directly from Holdings of Blackburn Ltd., 39/41 Mincing Lane, Blackburn, BB2 2AF England.

modular towers for fixed-station or portable use

A new line of towers is offered by Lunar Electronics of San Diego, California. Modular design makes these towers a natural for site surveys, field operation, and portable communications of all types including Amateur Radio EME work.

The towers are made of aluminum angle pieces, which bolt together to form a sturdy structure that can support considerable antenna arrays. The basic tower package (model LT-1) consists of a quadrilateral base, rotor and thrust-bearing mounting plates, and one modular tower section. The LT-1 yields a 3.4-meter-high (11-foot-high) structure when erected. Add-on modular sections (model LT-2) are 1.8 meters (6 feet) long. These add-on modular sections

More Details? CHECK — OFF Page 118

can increase tower height to nearly 9 meters (30 feet).

The tower can be readily mounted on flat or peaked roof tops. A length of 2 × 4 lumber placed under each leg pair provides a simple and effective mount. The 2 × 4s help to distribute tower weight over several roof joists. The modular tower sections must be guyed. Optional stainless-steel hardware is available (S suffix).

The tower is built from aluminum angle, so it forms its own ladder when properly erected and guyed. The base span is 109 cm square (43 inches square); tower sections are 24 cm square (9.5 inches square). Weight of base and lower tower section is about 25 kg (55 pounds). Each additional tower section weighs about 10 kg (22 pounds). Installation is an easy two-man job.

Further information is available from Lunar Electronics, 2785 Kurtz St., Suite 10, San Diego, California 92110, (714) 299-9470.

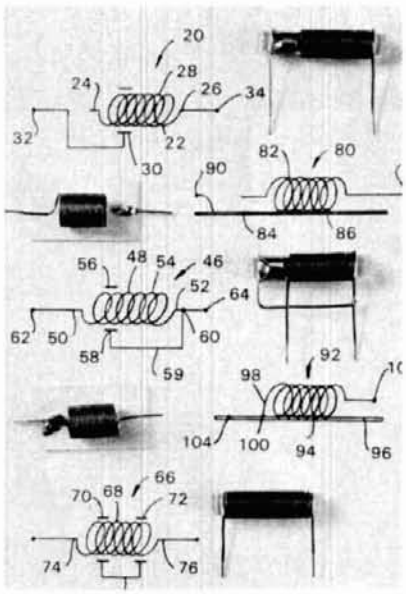
automatic microprocessor encoder

A new, sophisticated, microprocessor-controlled encoder has been introduced by U.S. Communications Corporation of Kent, Washington, a major supplier of mobile telephone automation equipment. These MICRO-CODER units are completely keyboard programmable and offer lighted keypad, ANI, positive disconnect, last-number recall, ten 15-digit number memory storage, call routing, and many other features and functions.

The user can program and recall memory dial numbers at will, and a special electronic lock prevents unauthorized changing ANI or other functions once they are programmed. Model MT-141 is designed for DTMF dial encoding, with DTMF ANI. The MT-141 is self-contained and will interface with a standard dash-mount transceiver through the microphone jack. For applications, information, brochures, and pricing, contact U.S. Communications Corporation, 1819 South Central, #46, Kent, Washington 98031.

incaps

A family of unique electronic parts that can reduce the cost and complexity of television sets, radios, and other electronics equipment was announced recently by the DEE Company of Michigan. *Incaps** (*In*ductor-*Cap*acitor) are single, low-cost components that replace the separate inductors and capacitors traditionally used to build series- or par-



allel-tuned resonant circuits that are the heart of many circuits. The use of *Incaps* can reduce the parts count in these basic circuits by up to 50 per cent. An article in the February, 1979, issue of *QST* discussed the development of *Incons* and how they may be used for various filtering requirements.

A brochure which describes the various styles of *Incaps*, and shows experimental RFI and TVI filters is available upon request from A. C. Doty, Jr., The DEE Company of Michigan, 8360 Rushton Road, South Lyon, Michigan 48178.

**Incap* is a trademark of The DEE Company of Michigan, with registration pending.

fet probe application note

What does the oscilloscope user gain in return for the added expense of an fet probe; what are its advantages and limitations?

A new application note, "FET Probes: The Next Step in Quality Signal Measurements (AX-3580)" by Ron Lang, recently issued by Tektronix, Inc., answers these and many other often-asked questions from oscilloscope users. Also presented are graphs, schematic diagrams, and simple equations dealing with probe response to various types of signals and signal sources. It's a valuable teaching aid for vocational schools and industrial training courses, as well as being an informative guide.

This free application note may be obtained by writing Julie Schmit, Delivery Station 76-260, Tektronix, Inc., Post Office Box 500, Beaverton, Oregon 97077.

cavity filter

Wacom Products, Inc., a manufacturer of duplexers and coaxial cavity filters for the two-way radio industry, has announced that a patent has been issued by the U.S. Patent Office on an rf filter network, which the company calls the BpBr Circuit™. Inventor of the filter network is Lloyd C. Alcorn, Jr., the company's manager of engineering. Application for the patent has been pending for over two years and was granted on March 21, 1978, under U.S. Patent 4,080,601.

The BpBr Circuit™ consists of a passive reactance network connected in series with single coupling loop on the coaxial cavity filter. The filter provides frequency-response curves with bandpass cavity characteristics at the pass frequency and a notch above and below the resonant frequency. The notch is considerably deeper and wider than that of the conventional notch filter. Notch frequency is adjusted by varying the length of the adjustable stub on the filter.

The BpBr Circuit™ filters and duplexers provide impressive performance characteristics and are largely responsible for Wacom's fast growth over the past few years. The products are being used extensively by the commercial land mobile industry, federal and state governmental agencies, Amateur Radio groups, and the foreign market.

In addition to a complete line of bandpass and band-reject filters and duplexers, Wacom offers a wide variety of filters and duplexers with the BpBr Circuit™. Models are available for operation in the various frequency bands between 40-900 MHz. Information on these products can be obtained by contacting Wacom Products, Inc., P.O. Box 7307, Waco, Texas 76710. Telephone (817) 776-4444.

Multicore emergency solder melts with a match

Multicore Solders, of Westbury, New York, has introduced a new, handy, tape-like solder-strip for quick on-the-spot soldering repairs. Called Emergency Solder, it can be easily carried in a shirt pocket or stored flat. It requires only the heat of an ordinary match or candle flame to melt the solder.

Multiple cores of rosin flux are incorporated into the flat strips during the manufacturing process, eliminating any requirement for a separate fluxing application. The flux is noncorrosive and nonconductive, and need not be removed after soldering.

To solder two wires, simply twist the wires together, wrap the solder strip lightly around them, and apply the flame from a match. Move the flame slowly back and forth until the solder flows into the splice. For larger wires, wrap two layers around the splice and use a candle to apply the flame for sustained heat. Insulating tape or sleeving should be used after soldering electrical wires.

To solder sheet metal, the solder should be placed either between or on the metal parts to be connected. Hold the parts together while applying heat from a candle flame or soldering iron, and then let the joint cool. Multicore Emergency Solder is suitable for any easily solderable metal. It is not suitable for aluminum.

Emergency solder is furnished in an attractive two-color display package with 90 cm (36 inches) of the solder strip. Complete illustrated directions for use are included on the inside of each package. See your local Multicore Solders dealer, or write them at Westbury, New York 11590.

SST dummy load

The SST DL-1 is a unique non-corrosive chemical dummy load which has been developed and tested by K4RLJ for twelve years. There is no other dummy load like it. Unlike messy oil-filled dummy loads, the DL-1 will not leak. It is sealed and ready to use.

The SST DL-1 is rated at 1000 watts PEP for 15 seconds. High-input to small-size ratio makes it ideal for base station, portable, mobile, and work-bench operation by hams and commercial users. Accurate readings will result when used with SWR and power meters. Its SWR is less than 1.5:1 from 1 to 225 MHz. The DL-1 is priced at $17.95, and is available from your SST dealer or direct from SST Electronics, P.O. Box 1, Lawndale, California 90260.

Hamtronics R75 vhf fm receiver kits

The model R75 receiver kit is the fourth-generation receiver by Hamtronics. It incorporates all the previous design features plus some new ones. Chief feature of the R75 is a wide range of selectivity options. Four models, with different crystal filters, provide optimum selectivity for each type of service, ranging from ±30 kHz at −60 dB for weather-satellite reception to ±15 kHz at −100 dB for split-channel repeater service.

The 102 × 109 mm (4 × 4¼ inch) receiver consists of two PC boards. Kits are available for the 10-, 6-, 2-, and 1.25-meter ham bands. The kits can also be used on adjacent commercial and weather satellite frequencies. Prices of the R75 receiver kit range from $69.95 to $99.95 depending on crystal-filter option.

For more information, including a catalog on the complete line of Hamtronics kits, call 716-392-9430 or write Hamtronics, Inc., 65F Moul Road, Hilton, New York 14468. (For overseas air mail delivery or catalog, please send four IRCs.)

CDE antenna rotor brochure

Cornell-Dubilier Electric Corporation has released a new eight-page color brochure presenting their complete line of antenna rotor systems. Each of the six rotor systems is illustrated and described. They include the Tailtwister,™ designed for king-sized antenna arrays of up to 30 square feet wind load area; the new Ham IV,™ the latest version of the world-famous Ham Series; the new CD-45, incorporating professional features at a popular price; the Big Talk,™ with IC control that lets you preprogram locations most commonly used; the AR-40, a deluxe unit with solid-state accuracy and silent operation; and the AR22XL, a popular-priced system with automatic control.

Included in the CDE Antenna Rotor Systems brochure is a breakaway photograph of the time-tested Bell Rotor, which illustrates the ruggedness and quality construction that has made CDE world famous. A complete specification chart is also included covering all six models.

For additional information, contact Leonard Sabal, Cornell-Dubilier Electric Corporation, subsidiary of Federal Pacific Electric Company, 150 Avenue L, Newark, New Jersey 07101, telephone (201) 589-7500.

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ANTECK, Inc.

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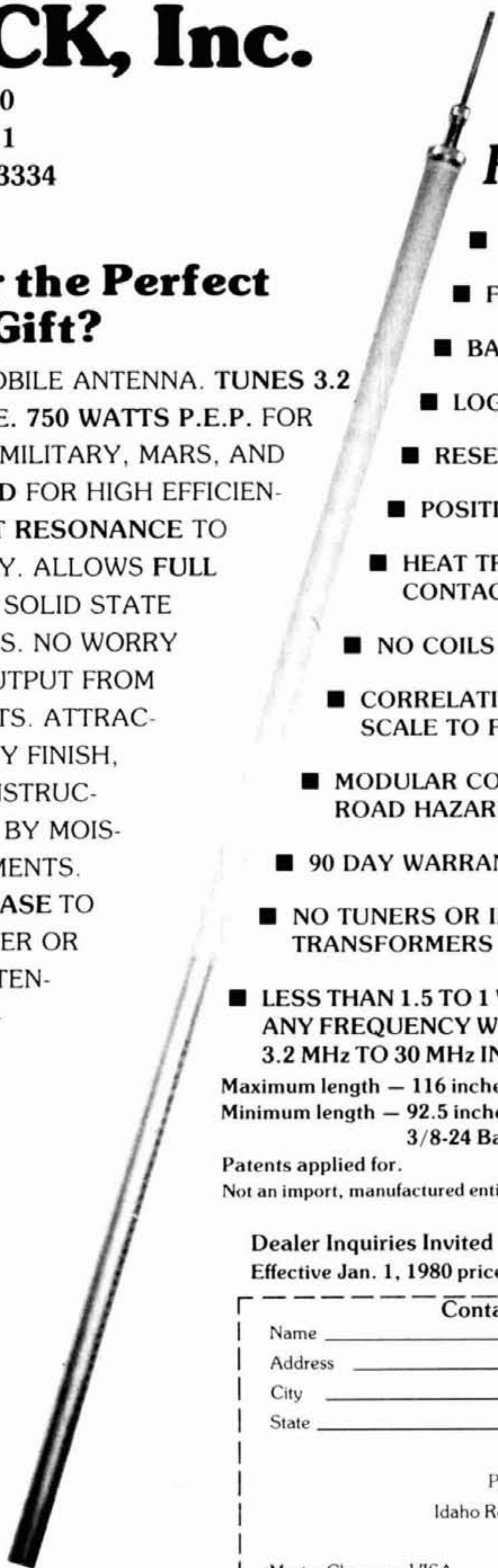

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Not because we say so, but because they say so. . .

"The *'New Yorker'* of audio magazines" —ESS, Input, Sacramento, CA

Audio Amateur is a magazine that continues a great American tradition—a tradition that loves tinkering and experimentation and embraces rather than eschews technology. Readers of this magazine, I suspect, don't simply discuss the latest heavily advertised "quantum leap" forward. **TAA** subscribers are impressed more by an interesting project they can build from scratch. They love to extract, by modification, the greatest possible perfection from classic and recently introduced audio products.

Like the **New Yorker**, the **Audio Amateur** publishes articles that are measured and thoughtful, articles that are beyond superlatives by the bushel basket found in most of the mass circulated audio magazines. The reasoned tone results in part from the considerable contributions made by English writers, including the late B.J. Webb. Edward T. Dell, Jr., the editor, almost always includes a thoughtful editorial that, alone, is worth the cost of admission. Unlike some of the little audiophile magazines, **TAA** is generally beyond clannish allegiance to a few manufacturers. Articles on projects to construct and modify appeal to the fondness of its readers for a wide range of projects.

Audio Amateur has served up a smorgasbord of projects over its ten year existence. How to properly adapt a Grace arm to an AR turntable, build a record cabinet, modify a Formula-4 tonearm to improve low frequency reproduction, or build a 10 dollar three-element Yagi antenna have all been offered as appetizers, projects that require some familiarity with tools and a few nights of your time. The main course offerings demand various degrees of more sophisticated electronic skill. If you've only assembled a one tube radio (twenty years ago), many of the electronic projects are going to be more than you can chew. Numerous past articles have shown how to improve classic Dynaco products. Recently, Nelson Pass of the Threshold Corp. discussed how to build a 40 watt per channel class A amplifier. Electronic articles typically assume an ability to find the parts necessary to build the projects. Chances are you'll spend some time searching through parts catalogs and local surplus houses before you can begin to wade into the actual construction.

Sophisticated articles that examine specific audio problems but do not involve building projects also abound. Walt Jung, contributing editor, has discussed slewing induced distortion in amplifiers in a series of articles. How we actually perceive sound and how many speakers may be necessary to recreate the closest possible approximation of the live event has also been discussed.

If speaker building is your forte, past articles have dealt with horn loaded and transmission line designs. Instructions on how to build electrostatic transducers from scratch, and box fabrication for sub-woofers with an accompanying active crossover have also been features. It's a measure of **TAA** contributor ingenuity that a complex driver like the Heil air-motion transformer has been built by an amateur — complete instructions on how to build a home version of the large Heil appeared in the magazine in 1977.

An excellent analysis of recently introduced audio kits is a regular feature. Kit reviews are technically very thorough and are often more objective than you find elsewhere. A regular feature, "Audio Aids," offers all kinds of informative hints from readers. A letter section from readers comments on past articles and present concerns and lends a thoughtful and inquiring tone to the magazine. Advertisements, themselves, are often helpful to the reader since many of the ads list parts that are vital for project construction. Most of the better kit manufacturers also advertise in **Audio Amateur.**

If you are already an audio craftsman, or would like to become one, **Audio Amateur** is an excellent touchstone. For less than the price of a good meal and a movie ticket, you can receive four issues a year.

—George Hortin, Staff Writer
INPUT, published by **ESS, Inc.**
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Send coupon to: **The AUDIO AMATEUR Magazine,** PO Box 176, Dept. H[29], Peterborough NH 03458

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THE AUDIO AMATEUR is the only U.S. publication I know of devoted exclusively to the home builder and experimenter in audio. The major distinction of this magazine is that it is written by doers. Thus its pages contain useful information, not just another collection of mystic reviews. Its information content on construction projects, sources of parts, and basic audio and electroacoustic theory make it one of the outstanding values for the amateur.

W. MARSHALL LEACH, Jr.,
Dept of Electrical Engineering,
Georgia Institute of Technology, Atlanta

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Yesterday you could admire all-band digital tuning in a short wave receiver.* Today you can afford it.

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And what you see on the outside is just a small part of what Panasonic gives you inside. There's a double superheterodyne system for sharp reception stability and selectivity as well as image rejection. An input-tuned RF amplifier with a 3-ganged variable tuning capacitor for excellent sensitivity and frequency linearity. Ladder-type ceramic filters to reduce frequency interference. And even an antenna trimmer that changes the front-end capacitance for reception of weak broadcast signals.

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The Command Series from Panasonic. If you had short wave receivers as good. You wouldn't still be reading. You'd be listening.

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WANTED: Conar 452 Transceiver. William Murks, Route 2, Box 176-A, Loretto, TN 38469.

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RECONDITIONED TEST EQUIPMENT for sale. Catalog $.50. Walter, 2697 Nickel, San Pablo, CA 94806.

AFC — STOP VFO DRIFT. See June '79 HR. Complete unit $49.95 + shipping. Read Easton, K6EHV, 3691 Gay Way, Riverside, CA 92504.

QSL CARDS 500/$10. 400 illustrations, sample. Bowman Printing, Dept. HR, 743 Harvard, St. Louis, MO 63130.

WWV FREQUENCY COMPARATOR Receiver Model 550, very clean, nice cabinet, manual $85. K6KZT, 2255 Alexander, Los Osos, CA 93402.

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FERRITE BEADS: w/specification and application sheet - 12/$1.00. Assorted PC pots - 10/$1.00. Miniature mica trimmers, 3-40 pF. - 5/$1.00. Postpaid. Includes latest catalog. Stamp for catalog alone. CPO Surplus, Box 189, Braintree, MA 02184.

WANTED: HeathKit Aircraft band receiver of about 10 yrs. ago. K2EDX, RD#1, Rome, NY 13440.

RTTY AFSK Modulator PC board. See Feb. 79 Ham Radio. Drilled $5.00 F. E. Hinkle, 12412 Mossy Bark, Austin, TX 78750.

WANTED: Manual or schematic for Lavoie Labs Spectrum Analyzer Model LA 17. Tony Sheppard, VE3DIR, 2 Brooklawn Ave., Scarborough, Ont. Canada. M1M 2P4.

CLUB CALL PINS 3 lines 1¼ × 3¼ $1.55 each. Call first, Name and Club. Colors Blue, Black, or Red with White letters. (Catalog) Arnold Linzner, 2041 Linden Street, Ridgewood, N.Y. 11227.

WANTED: AFSAV-39C keyers, AN/FRA-86 & AFSAV-133 demods., and type "N" coaxial bulkhead lightning arresters. C.T. Huth, 146 Schonhardt St., Tiffin, OH 44883.

FREQUENCY ALLOCATION CHART. See how the entire radio spectrum is used. 2 kHz to 200 GHz. Send $3.00. Collins Chart Co., Box 935, Coronado, CA 92118.

CES MODEL 235A Automatic Microdialer $69.95. The only automatic dialing touch tone microphone. Also a variety of new and surplus parts. Free Catalog. Key Electronics, Box 3506H, Schenectady, NY 12303.

More Details? CHECK—OFF Page 118

STOP LOOKING for a good deal on amateur radio equipment — you've found it here — at your amateur radio headquarters in the heart of the Midwest. Now more than ever where you buy is as important as what you buy. We are factory-authorized dealers for Kenwood, Drake, Yaesu, Collins, Wilson, Ten-Tec, Atlas, ICOM, DenTron, MFJ, Tempo, Regency, Hy-Gain, Mosley, Alpha, CushCraft, Swan and many more. Write or call us today for our low quote and try our personal and friendly Hoosier Service. HOOSIER ELECTRONICS, P.O. Box 2001, Terre Haute, Indiana 47802. (812) 238-1456.

COMPLETE HAM STATION $225. Heathkit DX-100, Drake 2-C, used, excellent. KA1BEB, Kangas Rd., New Ipswich, NH 03071. Tel. (603) 878-1554.

IN NEED of September 1968 Ham Radio. Last issue for complete set. J. D. Young, WA8KNE, 2076B Langley, Great Lakes, IL 60088.

WANTED — Ham Radio Magazine — 1968 issues, May, September and October. Will pay any reasonable price. Rick Nabor, K9GYO, 8640 S. 86th Avenue, Justice, IL 60458.

ICOM 701 USER'S CLUB is now operational. Send SASE to N8RT, Rob Pohorence, Dept. HR, 9600 Kickapoo Pass, Streetsboro, OH 44240.

SHACK CLEANING — Sweep generator (4-220) $55. Signal generators TS-510A (equiv. HP608D) $265; URM26B (4-410 MHz) $215. Dow-Key Coax relay (BNC) $6 ea. all 5 - $25. For complete list send SASE: Norm Cohen, 7808 Sheryl, Norfolk, VA 23505. (804) 489-1793.

WANTED: ST-6; several used 220 MHz rigs. Michaelson, N7SM, (801) 467-6785.

THE MEASUREMENT SHOP has used/reconditioned test equipment at sensible prices; catalog. 2 West 22nd St., Baltimore, MD 21218.

INFO-TECH M200E(72)TU, M300KBD Tx & Rx 60, 66, 75, 100 wpm — 170n, 425n, 850n Shift & ASCII 110, 300 Baud & CW 4-125 wpm. Bob Smith, WB6ODR, 9129 Pueblo Rd., Lakeside, CA 92040. (714) 443-3400.

MANUALS for most ham gear 1937/1970. Send 25¢ for "Manual Catalog." HI, Inc., Box H864, Council Bluffs, Iowa 51502.

WANTED — Hilltop Property near Pollock Pines, California. WA6COA, 4 Ajax Place, Berkeley, CA 94708.

PORTA PAK — Make your FM mobile a self-contained portable. Models in stock for most popular makes. 4.5 amp hr model $80.00. 9 amp hr $103.00. Charger included, shipping extra. P.O. Box 67, Somers, WI 53171.

WANTED — Motorola KXN1024 and KXN1052 channel elements. WA6COA, 4 Ajax Place, Berkeley, CA 94708.

ROHN TOWER — Buy wholesale from Worldwide distributor. 20G $27.06 section; 25G $37.62 section; 45G $67.76 section; 48 ft. foldover tower, $605.00; 48ft. BX free-standing $213.40. Hill Radio, 2503 GE Road, Box 1405, Bloomington, IL 61701. (309) 663-2141.

NORTH AMERICAN DX REPORT — free sample — SASE to Suites R2-R3, 615 S. Frederick Ave., Gaithersburg, MD 20760 — Phone (301) 840-1987.

ESTATE SALE: Radio Antiques Send SASE for 8-page list. Ward Becht, 625 Tufts, Burbank, CA 91504.

RTTY — ST-5, NS-1A owners get increased selectivity with our bandpass active filter 2125/2295 Hz. HR 4/79. Kit $11.95, wired/tested $16.95 postpaid. SASE for info. Nat Stinnette Electronics, Tavares, FL 32778.

COSMAC ASSEMBLER runs in 1KB, text editor in one page. Cassette and manual $19.95, specs for SASE. The Elfry, Box 802H, Clarksville, MD 21029.

WANTED: TD-687/URR demux., AFSAV-39C keyer, & AN/FRA-86 demod. C. T. Huth, 146 Schonhardt, Tiffin, OH 44883.

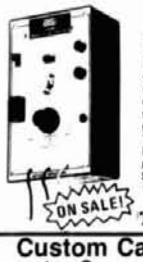
Coming Events

MASSACHUSETTS: 1200 Radio Club, W1DC, Annual Auction, November 17, 1979, 10:00 AM - 4:00 PM, at Honeywell Facility, 300 Concord Road, Billerica, MA 01821, Route 3 at Exit 27, between Routes 495 and 128. Talk-in 147.72-12. Proceeds support Billerica and Waltham repeaters.

FLORIDA: The Fort Myers Amateur Radio Club & ARRL will host Hamarama '79, Nov. 3 and 4, at the Ramada Inn in Fort Myers. Dealer displays, educational forums, outdoor flea market. Registration $3.00 per person. Contact K4VGN, 334-6190 or WD4ERA, 332-1825. Contact Ramada Inn direct for special rates.

More Details? CHECK — OFF Page 118

Transistor Checker



– Completely Assembled –
– Battery Operated –

The ASI Transistor Checker is capable of checking a wide range of transistor types, either "in circuit" or out of circuit. To operate, simply plug the transistor to be checked into the front panel socket, or connect it with the alligator clip test leads provided. The unit safely and automatically identifies low, medium and high-power PNP and NPN transistors. Size: 3¼" x 6¼" x 2"
"C" cell battery not included.

ON SALE!

Trans-Check $19.95 ea.

Custom Cables & Jumpers

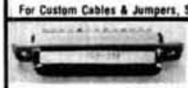
NEW! NEW!

DB 25 Series Cables

Part No.	Cable Length	Connectors	Price
DB25P-4-P	4 Ft.	2-DP25P	$15.95 ea.
DB25P-4-S	4 Ft.	1-DP25P/1-25S	$16.95 ea.
DB25S-4-S	4 ft.	2-DP25S	$17.95 ea.
Dip Jumpers			
DJ14-1	1 ft.	1-14 Pin	$1.59 ea.
DJ16-1	1 ft.	1-16 Pin	1.79 ea.
DJ24-½	1 ft.	1-24 Pin	2.79 ea.
DJ14-1-14	1 ft.	2-14 Pin	2.79 ea.
DJ16-1-16	1 ft.	2-16 Pin	3.19 ea.
DJ24-1-24	1 ft.	2-24 Pin	4.95 ea.

For Custom Cables & Jumpers, See JAMECO 1979 Catalog for Pricing

CONNECTORS
25 Pin-D Subminiature



DB25P (as pictured)	PLUG (Meets RS232)	$2.95
DB25S	SOCKET (Meets RS232)	$3.50
DB51226-1	Cable Cover for DB25P or DB25S	$1.75

PRINTED CIRCUIT EDGE-CARD
.156 Spacing–Tin–Double Read-Out – Bifurcated Contacts – Fits .054 to .070 P.C. Cards

15/30 SE	PINS (Solder Eyelet)		$1.95
18/36 SE	PINS (Solder Eyelet)		$2.49
22/44 SE	PINS (Solder Eyelet)		$2.95
22/44 WW	PINS (Wire Wrap)		$3.95
50/100 WW (.125 Spacing)	PINS (Wire Wrap)	R681-1	$6.95

4-Digit Clock Kit

- Bright .357" ht. red display
- Sequential flashing colon
- 12 or 24 hour operation
- Extruded aluminum case (black)
- Pressure switches for hours, minutes & hold functions
- Includes all components, case and wall transformer
- Size: 3¾ x 1¾ x 1¾

JE730 .... $14.95

Jumbo 6-Digit Clock Kit

- Four .630"ht. and two .300"ht. common anode displays
- Uses MM5314 clock chip
- Switches for hours, minutes and hold functions
- Hours easily viewable to 30 feet
- Simulated walnut case
- 115VAC operation
- 12 or 24 hour operation
- Includes all components, case and wall transformer
- Size: 6¾ x 3¼ x 1¾

JE747 .... $29.95

- Bright .300 ht. comm. cathode display
- Uses MM5314 clock chip
- Switches for hours, minutes and hold modes
- Hrs. easily viewable to 20 ft.
- Simulated walnut case
- 115 VAC operation
- 12 or 24 hr. operation
- Incl. all components, case & wall transformer
- Size: 6¾" x 3-1/8" x 1¾"

JE701

6-Digit Clock Kit $19.95

REMOTE CONTROL TRANSMITTER & RECEIVER

- CAN BE USED AS REMOTE CONTROL FOR TV
- USE IT FOR YOUR OWN GARAGE DOOR OPENER
- TRANSMITS BETWEEN [illegible]
- THOUSANDS OF USES FOR REMOTE CONTROL APPLICATIONS
- TRANSMITTER USES A 9V BATTERY
- SCHEMATIC INCLUDED

$19.95

Digital Stopwatch Kit

- Use Intersil 7205 Chip
- Plated thru double-sided P.C. Board
- LED display (red)
- Times to 59 min. 59.59 sec. with auto reset
- Quartz crystal controlled
- Three stopwatches in one: single event, split (cummulative) & taylor (sequential timing)
- Uses 3 penlite batteries
- Size: 4.5" x 2.15" x .90"

JE900 $39.95

MICROPROCESSOR COMPONENTS

8080A/8080A SUPPORT DEVICES		
8080A	CPU	$7.95
8212	8-Bit Input/Output	3.25
8214	Priority Interrupt Control	5.95
8216	Bi-Directional Bus Driver	3.49
8224	Clock Generator/Driver	3.95
8226	Bus Driver	3.49
8228	System Controller/Bus Driver	4.95
8238	System Controller	5.95
8251	Prog. Comm. I/O (USART)	7.95
8253	Prog. Interval Timer	14.95
8255	Prog. Periph. I/O (PPI)	9.95
8257	Prog. DMA Control	19.95
8259	Prog. Interrupt Control	19.95
6800/6800 SUPPORT DEVICES		
MC6800	MPU	$14.95
MC6802CP	MPU with Clock and Ram	24.95
MC6810API	128X8 Static Ram	5.95
MC6821	Periph. Inter. Adapt (MC6820)	7.49
MC6828	Priority Interrupt Controller	12.95
MC6830L8	1024X8 Bit ROM (MC68A30-8)	14.95
MC6850	Asynchronous Comm. Adapter	7.95
MC6852	Synchronous Serial Data Adapt.	9.95
MC6860	0-600 bps Digital MODEM	12.95
MC6862	2400 bps Modulator	14.95
MC6880A	Quad 3-State Bus. Trans. (MC8T26)	2.25
MICROPROCESSOR CHIPS—MISCELLANEOUS		
Z80(780C)	CPU	$14.95
Z80A(780-1)	CPU	16.95
CDP1802	CPU	19.95
2650	MPU	19.95
6502	CPU	11.95
8035	8-Bit MPU w/clock, RAM, I/O lines	19.95
P8085	CPU	19.95
TMS9900JL	16-Bit MPU w/hardware, multiply & divide	49.95
SHIFT REGISTERS		
MM500H	Dual 25 Bit Dynamic	$.50
MM503H	Dual 50 Bit Dynamic	.50
MM504H	Dual 16 Bit Static	.50
MM506H	Dual 100 Bit Static	.50
MM510H	Dual 64 Bit Accumulator	.50
MM5016H	500/512 Bit Dynamic	.89
2504T	1024 Dynamic	3.95
2518	Hex 32 Bit Static	4.95
2522	Dual 132 Bit Static	2.95
2524	512 Static	.99
2525	1024 Dynamic	2.95
2527	Dual 256 Bit Static	2.95
2528	Dual 250 Static	4.00
2529	Dual 240 Bit Static	4.00
2532	Quad 80 Bit Static	2.95
3341	Fifo	6.95
74LS670	4X4 Register File (TriState)	2.49
UART'S		
A-Y-5-1013	30K BAUD	5.95

MICROPROCESSOR MANUALS			
M-Z80	User Manual		$7.50
M-CDP1802	User Manual		7.50
M-2650	User Manual		5.00
ROM'S			
2513(2140)	Character Generator(upper case)		$9.95
2513(3021)	Character Generator(lower case)		9.95
2516	Character Generator		10.95
MM5230N	2048-Bit Read Only Memory		1.95
RAM'S			
1101	256X1	Static	$1.49
1103	1024X1	Dynamic	.99
2101(8101)	256X4	Static	3.95
2102	1024X1	Static	1.75
21L02	1024X1	Static	1.95
2111(8111)	256X4	Static	3.95
2112	256X4	Static MOS	4.95
2114	1024X4	Static 450ns	7.95
2114L	1024X4	Static 450ns low power	10.95
2114-3	1024X4	Static 300ns	10.95
2114L-3	1024X4	Static 300ns low power	11.95
5101	256X4	Static	7.95
5280/2107	4096X1	Dynamic	4.95
7489	16X4	Static	1.75
74S200	256X1	Static Tristate	4.95
93421	256X1	Static	2.95
UPD414 (MK4027)	4K	Dynamic 16 pin	4.95
UPD416 (MK4116)	16K	Dynamic 16 pin 250ns	9.95
TMS4044-45NL	4K	Static	14.95
TMS4045	1024X4	Static	14.95
2117	16,384X1	Dynamic 350ns (house marked)	9.95
MM5262	2KX1	Dynamic	4/1.00
PROM'S			
1702A	2048	FAMOS	$5.95
2716INTEL	16K*	EPROM	59.95
TMS2516 (2716)	16K*	EPROM	49.95
	*Requires single +5V power supply		
TMS2532	4KX8	EPROM	89.95
2708	8K	EPROM	10.95
2716 T.I.	16K**	EPROM	29.95
	**Requires 3 voltages, –5V, +5V, +12V		
5203	2048	FAMOS	14.95
6301-1(7611)	1024	Tristate Bipolar	3.49
6330-1(7602)	256	Open C Bipolar	2.95
82S23	32X8	Open Collector	3.95
82S115	4096	Bipolar	19.95
82S123	32X8	Tristate	3.95
74186	512	TTL Open Collector	9.95
74188	256	TTL Open Collector	3.95
74S287	1024	Static	2.95

JE600 HEXADECIMAL ENCODER KIT

FEATURES:
- Full 8 bit latched output for microprocessor use
- 3 User Define keys with one being bi-stable operation
- Debounce circuit provided for all 19 keys
- LED readout to verify entries
- Easy interfacing with standard 16 pin IC connector
- Only +5VDC required for operations

FULL 8 BIT LATCHED OUTPUT—19 KEYBOARD

The JE600 Encoder Keyboard provides two separate hexadecimal digits produced from sequential key entries to allow direct programming for 8 bit microprocessor or 8 bit memory circuits. Three (3) additional keys are provided for user operations with one having a bistable output available. The outputs are latched and monitored with LED readouts. Also included is a key entry strobe.

JE600 .... $59.95
Hexadecimal Keypad only $14.95

DIGITAL THERMOMETER KIT

- Dual sensors—switching control for indoor/outdoor or dual monitoring
- Continuous LED .8" ht. display
- Range: -40°F to 199°F / -40°C to 100°C
- Accuracy: ±1° nominal
- Set for Fahrenheit or Celsius reading
- Sim. walnut case - AC wall adapter incl.
- Size: 3-1/4"H x 6-5/8"W x 1-3/8"D

JE300 .... $39.95

62-Key ASCII Encoder Keyboard Kit

The JE610 62-Key ASCII Encoder Keyboard Kit can be interfaced into most any computer system. The JE610 Kit comes complete with an industrial grade keyboard switch assembly (62 keys), IC's, sockets, connector, electronic components and a double-sided printed wiring board. The keyboard assembly requires +5V @ 150mA and –12V @ 10mA for operation.

FEATURES:
- **60 Keys generate the full 128 characters, upper and lower case ASCII set**
- **Fully buffered**
- **2 user-define keys provided for custom applications**
- **Caps lock for upper case only alpha characters**
- **Utilizes a 2376 (40 pin) encoder read only memory chip**
- **Outputs directly compatible with TTL/DTL or MOS logic arrays**
- **Easy interfacing with a 16-pin dip or 18-pin edge connector**

JE610 ..... $79.95
62-Key Keyboard only . . $34.95

REGULATED POWER SUPPLY

NEW

JE200
5V-1 AMP POWER SUPPLY

- **Uses LM309K**
- **Heat sink provided**
- **PC Board construction**
- **Provides a solid 1 amp @ 5 volts**
- **Can supply up to ±5V, ±9V and ±12V with JE205 Adapter**
- **Includes components, hardware & instructions**
- **Size: 3½"x5"x2"H**

JE200 $14.95

JE205
ADAPTER BOARD – Adapts to JE200 – ±5V, ±9V and ±12V

- DC/DC converter w/ +5V input
- Toriodal hi-speed switching XMFR
- Short circ. protection
- PC Brd. construction
- Piggy-back to JE200 board
- Size: 3½"x2"x9/16"h

JE205 $12.95

$10.00 Min. Order – U.S. Funds Only
Calif. Residents Add 6% Sales Tax
Postage – Add 5% plus $1 Insurance (if desired)

Spec Sheets – 25¢
1980 Catalog Available – Send 41¢ stamp

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The Incredible "Pennywhistle 103"

$139.95 Kit Only

The Pennywhistle 103 is capable of recording data to and from audio tape without critical speed requirements for the recorder and it is able to communicate directly with another modem and terminal for **telephone** "hamming" and communications. In addition, it is free of critical adjustments and is built with non-precision, readily available parts.

Data Transmission Method	Frequency-Shift Keying, full-duplex (half-duplex selectable)
Maximum Data Rate	300 Baud
Data Format	Asynchronous Serial (return to mark level required between each character)
Receive Channel Frequencies	2025 Hz for space; 2225 Hz for mark
Transmit Channel Frequencies	Switch selectable: Low (normal) – 1070 space, 1270 mark; High – 025 space, 2225 mark
Receive Sensitivity	–46 dbm accoustically coupled
Transmit Level	–15 dbm nominal. Adjustable from –6 dbm to –20 dbm
Receive Frequency Tolerance	Frequency reference automatically adjusts to allow for operation between 1800 Hz and 2400 Hz
Digital Data Interface	EIA RS-232C or 20 mA current loop (receiver is optoisolated and non-polar)
Power Requirements	120 VAC, single phase, 10 Watts
Physical	All components mount on a single 5" by 9" printed circuit board. All components included.

Requires a VOM, Audio Oscillator, Frequency Counter and/or Oscilloscope to align

TRS-80 16K Conversion Kit

Expand your 4K TRS-80 System to 16K. Kit comes complete with:
- 8 each UPD416-1 (16K Dynamic Rams) 250NS
- Documentation for conversion

TRS-16K $75.00

COMPUTER CASSETTES

- 6 EACH 15 MINUTE HIGH QUALITY C-15 CASSETTES
- PLASTIC CASE INCLUDED 12 CASSETTE CAPACITY
- ADDITIONAL CASSETTES AVAILABLE #C-15-$2.95 ea

CAS-6 $14.95
(Case and 6 Cassettes)

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UHF Channel 33 TV Interface Unit Kit

Wide Band B/W or Color System
★ Converts TV to Video Display for home computers, CCTV camera, Apple II, works with Cromeco Dazzler, SOL-20, IRS-80, Challenger, etc.
MOD II is pretuned to Channel 33 (UHF).
* Includes coaxial cable and antenna transformer.

MOD II $29.95 Kit

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EPROM Erasing Lamp

- **Erases 2708, 2716, 1702A, 5203Q, 5204Q, etc.**
- **Erases up to 4 chips within 20 minutes.**
- **Maintains constant exposure distance of one inch**
- **Special conductive foam liner eliminates static build-up**
- **Built-in safety lock to prevent UV exposure**
- **Compact – only 7-5/8" x 2-7/8" x 2"**
- **Complete with holding tray for 4 chips**

UVS-11E...................... $69.95

IDEAL FOR TRS 80 — CASSETTE CONTROLLER

"Plug/Jack interface to any computer system requiring remote control of cassette functions"

The CC100 controls cassette motor functions, monitors tape location with its internal speaker and requires no power. Eliminates the plugging and unplugging of cables during computer loading operation from cassette.

#CC-100 $29.50

new

Micro-Miniature Joystick

- 2 each 100K pots (Linear Taper)
- Printed Circuit Board Mount
- Size: 1" x 1-3/16" x 1-3/16"

Micro-Miniature Joystick $4.95

More Details? CHECK—OFF Page 118

Now — the industry's first truly super keyboard

INFO-TECH M-300C TRI-MODE KEYBOARD

A microprocessor controlled keyboard that generates: Morse, RTTY, & ASCII.

Morse Features:
- 4 to 125 W.P.M. in 1 W.P.M. increments.
- 9 adjustable weight levels
- relay keying
- sidetone with tone and level adjustments
- special keys: AS, BK, BT, AR, SK, CQ, DE

RTTY Features:
- 4 speeds
- 2 shifts (170 & 850 hz)
- built in AFSK
- built in CWID
- built in RY generation

ASCII Features:
- 110 & 300 Baud
- 2 shifts (170 & 850 hz)

Best of all, still only 450^{00} F.O.B. Factory

Other Features:
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- Automatic CR/LF
- 700 Character Running Buffer
- 10 recallable, user programmable message memories of 120 characters each
- CQ & DE special keys on all modes
- Keyboard control of all functions
- 4 row keyboard eliminates figures/letters shifting on RTTY
- Many more features.

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605-343-6127

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3202 Summer Avenue
Memphis, Tennessee 38112
800-238-6168

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8342 Olive Blvd.
St. Louis, Missouri 63132
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Gadsden, Alabama 35904
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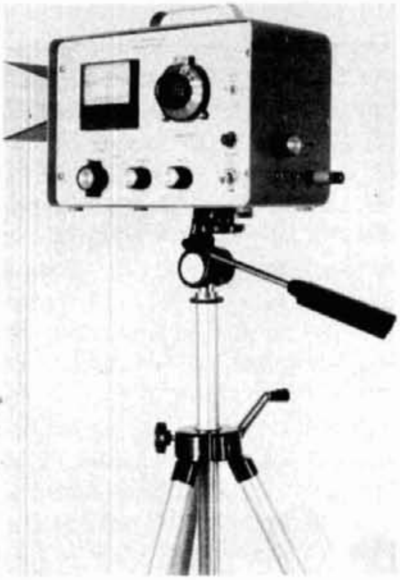
TELEMETRY COMMUNICATIONS & INSTRUMENTATION, CORP.

10 GHz GUNNPLEXER® MICROWAVE TRANSCEIVER

FRONT END BY MICROWAVE ASSOCIATES



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- TONE OSCILLATOR
- ELECTRONICALLY TUNEABLE
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- MULTIPLE IF FREQ'S
- MODULAR CONSTRUCTION
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THREE MODELS AVAILABLE

TELEMETRY MODEL TMX10

- 10 GHz, 10 MW Gunn Transceiver
- 17 dB Horn Antenna
- 30 MHz Low Noise Pre-Amp
- 10.7 MHz Post IF Amp/Demod
- Crystal IF Filters
- Integrated Circuit Modulator
- Internal Voltage Regulators
- AFC
- Tone Oscillator

VIDEO MODEL TVX10

- 10 GHz, 10 MW Gunn Transceiver
- 17 dB Horn Antenna
- 45 MHz Low Noise Pre-Amp
- 45 MHz Post IF Amp/Demod
- Audio Subcarrier Mod/Demod
- Room for III Video Channels
- Internal Voltage Regulators
- Volume Control

TM/VIDEO MODEL TM/VX10

- 10 GHz, 10 MW Gunn Transceiver
- 17 dB Horn Antenna
- 45 MHz Low Noise Pre-Amp
- 45 MHz Post IF Amp/Demod
- Wideband/Narrowband Operation
- Audio Subcarrier Mod/Demod
- AFC
- AC-DC Power Supply

OPTIONS

- 45, 60, 100, 111 MHz IF Freq Available
- Narrow Band Crystal Filters
- 50 Hz, 220 VAC Power Supply
- Higher Gunn OSC Power Output
- Higher Gain Antennas

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MODEL TMX10 . . . . $379.95
MODEL TVX10 . . . . . $379.95
MODEL TM/VX10. . . $529.95
(Combines TM/Video Models)

TCI CORP.
411 N. BUCHANAN CIRCLE #3
PACHECO, CA 94553

PHYSICAL SPECIFICATIONS
Size: 6" h. × 9" l. × 5" d.
Color: Blue Enclosure, Gray Front Panel
Weight: 3 Pounds
Speaker Included
Tripod or Mast Mounting
Microphone Optional

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SAROC™

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A Knob with a new twist "VRS™"
Swan Astro 150 Exclusive Microprocessor Control w/memory gives you over 100,000 fully synthesized frequencies, and more!
▪ VRS — Variable Rate Scanning, a dramatic new technique for unprecedented tuning ease and accuracy
▪ POWER — 235 watts PEP and CW on all bands for that DX punch
▪ Advanced microcomputer technology developed and manufactured in the U.S.A.
▪ Price? See your authorized SWAN dealer for a pleasant surprise!
RIT FINE
FULL
NB
VOX
ON
STBY
SEMI BREAK IN
OFF
PTT
OFF
SWAN
ASTRO 150 SSB TRANSCEIVER
KEY/MIC
AF GAIN IF GAIN
MIC GAIN
MODE
LSB USB CW CWN
3.5 7.0 14.0 21.0 28.0
BAND
UP
DOWN
Dual Meter
Reads PEP output in watts and receive "S" units.
Full Break-in CW
(or semi, switch selected)
Wide Frequency Coverage
10M — 28.0-30.0 MHz
15M — 20.8-23.0 MHz
20M — 13.8-16.0 MHz
40M — 6.0-8.3 MHz
80M — 3.0-4.5 MHz
160M — 1.8-2.4 MHz*
*in lieu of 10M band on Model Astro 151
Mike Tuning
For accurate 100 Hz steps or fixed rate scan.
PSU-5 Power Supply with Speaker
ASTRO 150 Transceiver
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HE MOST ADVANCED HF SSB TRANSCEIVER AVAILABLE.
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SOMETHING DIFFERENT
The FT-107 Series with "DMS"*

"It's A Cut Above The Rest"

* OPTIONAL DIGITAL MEMORY SHIFT ("DMS")
12 discrete memories. Stores individual frequencies or use as 12 full coverage VFOs (500 kHz each)

- Solid State
- 240 watts DC SSB/CW
- 160-10 meters, WWV
  (2 auxiliary band positions are available for future expansion)
- RF Speech Processor
- SSB, CW, AM, FSK
- Built-in SWR Meter
- Excellent Dynamic Range
- Audio Peak/Notch Filter
- Variable Bandwidth
- Full Line of Accessories

The FT-107 has been created as a result of a blending of technologies — computer, solid state and RF design. By careful utilization of these disciplines and the experience gained from our FT-301 series, YAESU has achieved an HF transceiver which offers unique features (e. g. "Digital Memory Shift"), efficient operation and a level of performance that has been previously unattainable.

RECEIVER:

Sensitivity: 0.25 uV for 10dB S/N, CW/SSB, FSK
1.0 uV for 10dB S/N, AM
Image Rejection: 60dB except 10 meters (50dB)
IF Rejection: 70dB
Selectivity: SSB 2.4 kHz at −6dB, 4.0 kHz at −60dB.
CW 0.6 kHz at −6dB, 1.2 kHz at −60dB.
AM 6 kHz at −6dB, 12 kHz at −60dB
Variable IF Bandwidth
20dB RF Attenuator
Peak/Notch Audio Filter
Audio Output: 3 watts (4-16 ohms)
Accessories: FV-107 VFO (standard not synethized)
FTV-107 VHF (UHF Transverter)
FC-107 Antenna Tuner
SP-107 Matching Speaker
FP-107 AC Power Supply

TRANSMITTER

Power Input: 240 watts DC SSB/CW
80 watts DC AM/FSK
Opposite Sideband Suppression: Better than 50dB
Spurious Radiation: −50dB.
Transmitter Bandwidth 350-2700 hz (−6dB)
Transmitter: 3rd IMD −31dB neg feedback 6dB
Transmitter Stability: 30 hz after 10 min. warmup
less than 100 hz after 30 min.
Antenna Input Impedance: 50 ohms
Microphone Impedance: 500 ohms
Power Required: 13.5V DC at 20 amps
100/110/117/200/220/234V AC at 650 VA

YAESU
The radio.

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