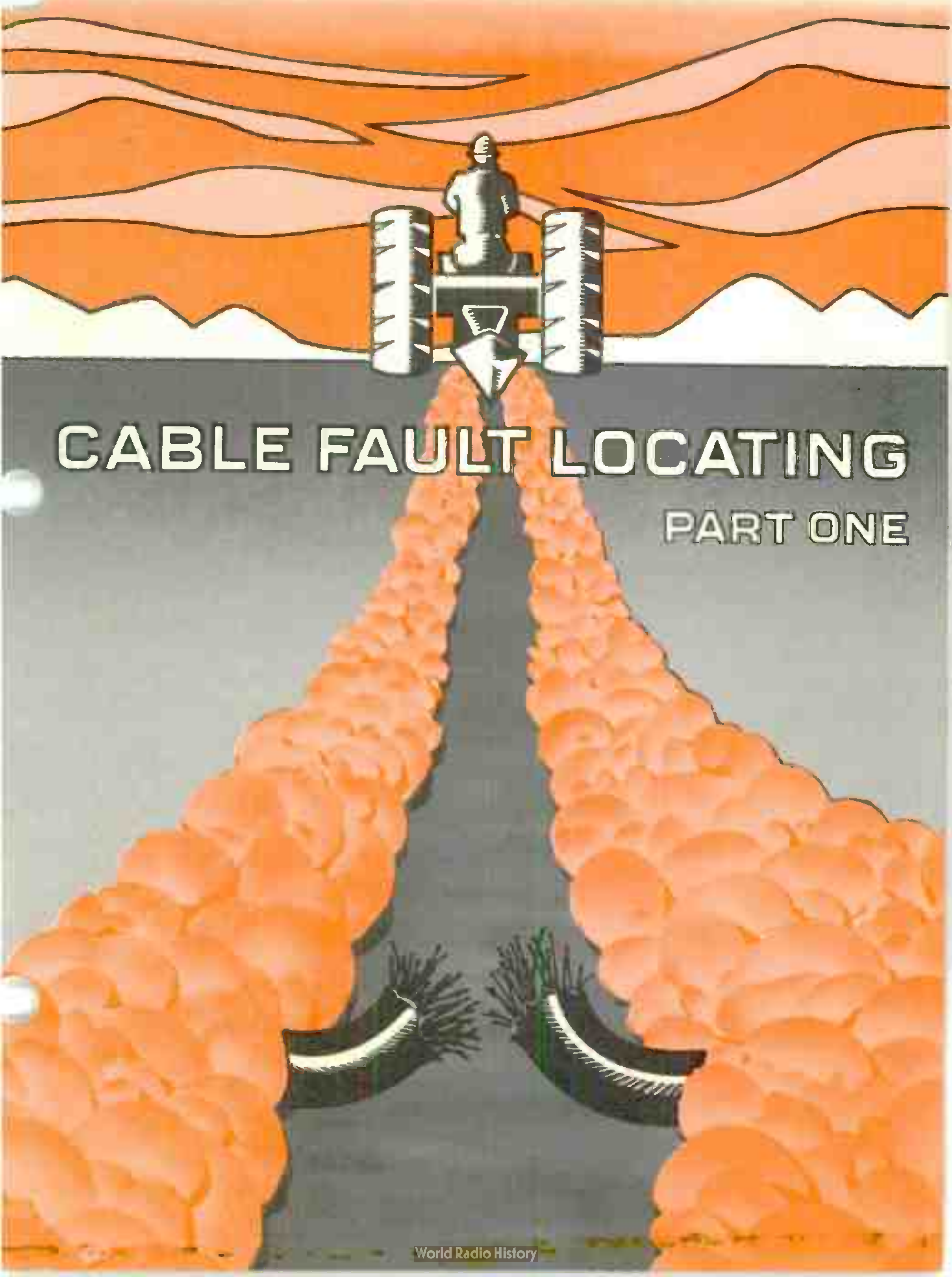
GTE LENKURT

# DEMODULATOR

NOVEMBER/DECEMBER 1979



## CABLE FAULT LOCATING

### PART ONE

**Locating and repairing cable faults requires technical skill and hard work. However, it is a vital task which must be performed to keep a telephone system working. This first of a two part series discusses faults commonly encountered in multipair cable and describes techniques for locating those faults.**

Thirty to forty years ago, variations of the Wheatstone Bridge, such as Murray and Varley loops, were about the only instruments available for cable fault location. Skilled operators of these devices were in great demand by telephone companies.

In those days, paper was the insulating material used for the conductors in a telephone cable. Paper is a satisfactory insulator as long as it remains dry. Moisture within the cable caused leakage between the conductors and eventual cable failure.

Since both conductors in a pair would generally be faulted at the same point, it was possible to "burn in" a fault by using a high-voltage to weld the conductors together and form a solid short. Locating the fault then became a matter of measuring the loop resistance and calculating the distance to the fault.

## Breakdown Test Sets

Breakdown test sets were fabricated to enable any craftsman to locate cable faults. The test set contained batteries connected in series to provide a high-voltage source. When this source was applied across a cable pair with a high-resistance fault, an arc would occur between the conductors and weld them together to form a solid short. A good approximation of the distance to the short could be calculated by measuring the loop resistance and dividing it by twice the known resistance per unit length of the wire.

Another technique, often used for aerial cable, was to place a tone on the faulty pair and trace it with an induction coil, to locate the short. In this case, the breakdown test set was not always used.

The breakdown method soon replaced the bridge reading method. This situation prevailed until the introduction of Polyethylene Insulated Conductor (PIC) cables.

This waterproof, plastic insulation has solved many of the problems caused by wet conductors, although occasionally defects in the insulation allow moisture to enter. Moisture which enters through the outer shield of a PIC cable presents a different set of problems than the same condition in a paper insulated cable.

Because about half the space inside a cable is filled with air, the sheath acts like a pipe. Any water that penetrates the sheath may flow for hundreds of feet, even uphill, if temperature variations create pressure differentials. This complicates fault location and repair since the problem may not be near the place where the water entered the cable (see Figure 1).

When water causes a fault in pulp or paper insulated cable, both conductors of a pair are commonly faulted. The conductors can be easily fused with a breakdown set. This is not the case with PIC cable.

Moisture in PIC cable commonly affects only one conductor in a pair. In this case it is not possible to burn in a fault, because one conductor is clear.

Moisture in PIC cable causes another common fault called battery cross. Water enters the cable through a damaged cable sheath. Microscopic pores in the polythelene insulation covering the individual conductors allow a current to flow through the water between the ring conductor and the cable shield. When office battery is removed from the conductor, battery may still be present. This battery can be traced to a second working ring which is also faulted.

This second fault may be located a considerable distance from the first fault. So, the trouble is actually caused by current flowing through the water in the sheath.

Other faults that can occur in PIC cable are sheath faults and open faults. A sheath fault is probably the most common fault in buried cable. It exists anytime the sheath has been damaged. Usually, it is a sheath to ground fault, although occasionally conductors are also grounded. Sheath faults are also known as "Earth" faults.

An open is usually the result of mechanical damage caused by digging implements or rodents. However, it can be caused by water corroding the wire conductor so badly it breaks. These are referred to as "dirty" opens.

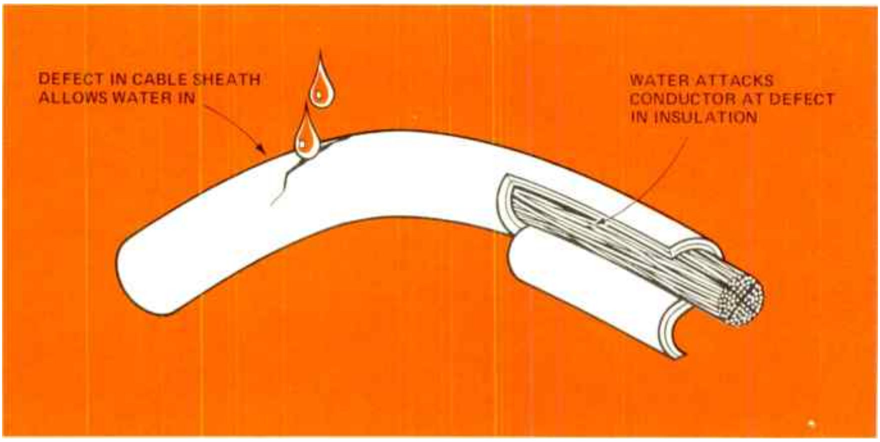


*Figure 1. Cable acts as a pipe permitting water to enter the sheath at one point, then travel hundreds of feet before attacking the conductors.*

A variety of test sets are available for locating faults in buried PIC cable. A few of the more common types are discussed in the following paragraphs.

## Sheath Fault and Cable Locator

The Sheath Fault and Cable Locator Test Set is used for tracing the path and depth of a buried cable. One type of test set consists of a transmitter, a receiver and an earth contact frame. The transmitter generates two tones, one at high-frequency for cable path and depth location. This tone is also used to obtain directional information for fault location. The second tone is subaudible and only used for sheath fault location.

The receiver is used to trace the tone along the cable length. The receiver detects the tone and provides visual indications on a meter and audible indications through a loud speaker. Reception of the tone is by a built-in-antenna. An earth contact frame is used to pick up the fault locating signal.

If sheath damage permits the shield to go to ground, the fault can be found with an earth contact frame. The sheath should be isolated at both ends of the faulted section. This is an important step since it is normal practice to ground the sheath at convenient points along the cable route, to minimize induced ac interference. Connect an ohmeter between sheath and ground to determine if a sheath to ground fault exists.

If the meter reading is higher than a megohm, the sheath is clear. Readings between 50,000 ohms and one megohm indicate a high-resistance fault. Reading below 50,000 ohms indicate a severe fault.

If a severe fault is indicated, be sure the sheath is not bonded to ground. Another problem which can give a false indication (generally a lower than true reading) is the presence of central office battery on the shield, due to shield to conductor leakage.

If a sheath to ground fault exists, the sheath fault locator is used to pinpoint the location. Figure 2 illustrates the use of a Dynatel® model 573 for sheath fault location. Not shown in the figure is the cable connecting the Earth Contact Frame to the Receiver (meter).

Courtesy of Dynatel/3M

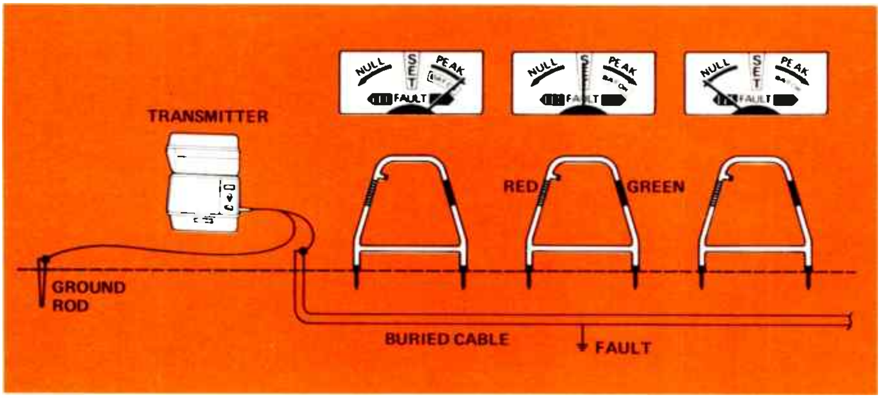


*Figure 2. Use of sheath fault locator and meter indication around the fault.*

*Figure 3. Sheath fault and cable locator test set.*

Courtesy of Dynatel 3M

The red marker on the frame is striped, the green marker is solid. The meter FAULT scale has the same color scheme and indicates the direction to the fault. Figure 3 is a photograph of the test set.

Loss of continuity is a common sheath problem. The problem frequently occurs at splice points as a result of corrosion resulting from improper connections.

## Conductor Fault Locator

A popular type of conductor fault locator is based on the Wheatstone Bridge principle. These modern sets use electronic circuits to increase sensitivity and eliminate the necessity for mathematical calculations. They do not require as much technical knowledge and skill to operate as did the older sets. Figure 4 is a photograph of a modern Conductor Fault Locator.

In contrast to the Sheath Fault and Cable Locator, which is essentially a signal tracing device, the Conductor Fault Locator is a terminal device. It is connected to the cable conductor at a termination and all tests and readings are made at that point.

The Conductor Fault Locator shows the distance to the fault by a direct readout. Better sets have long range capabilities which make them suitable for use at test desk locations.

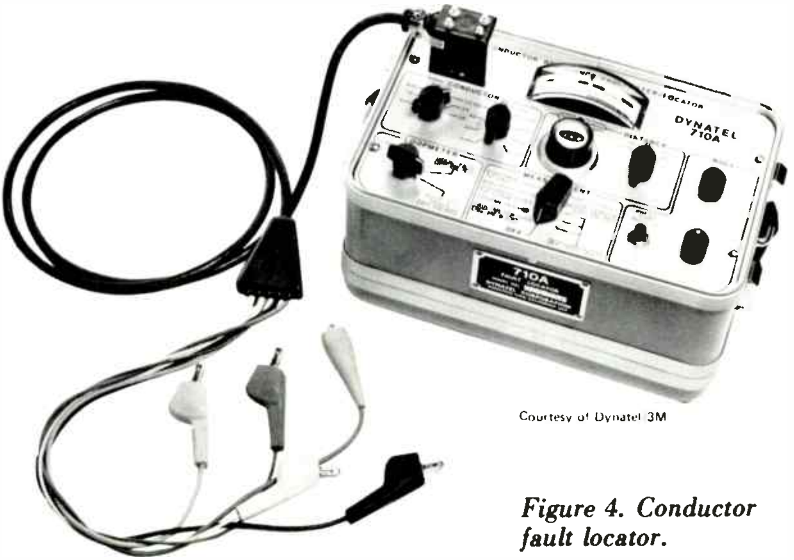
The use of this type of test set requires conductor continuity beyond the fault location. This means that a spare good pair is required to measure certain types of faults. Typical hookups are shown in Figure 5.

A detailed knowledge of the cable routing and characteristics is required for accurate fault location. Slack loops and loading coils must be accounted for to achieve accurate results. The shorting straps are included in all distance measurements so it is important that the straps have low resistance and be firmly connected.

## Cable Size and Temperature

Since the electrical characteristic actually being measured is resistance, the test set must be calibrated for the conductor gauge and temperature. Mistakes in these settings can cause substantial errors in the distance readings.

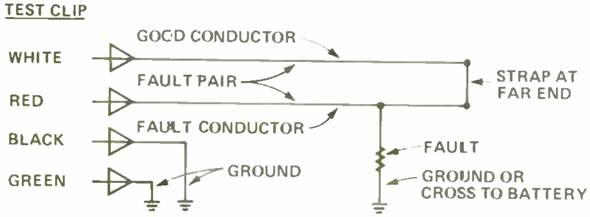
For example, 26 gauge copper conductor has approximately 62.3% more resistance than 24 gauge. If you are actually testing a 24 gauge cable, but have the test set selector set to 26 gauge, a fault at 1,000 feet will read as a fault at 623 feet on the distance dial. Of course, the absolute magnitude of the error increases with the distance to the fault.



Courtesy of Dynatel 3M

*Figure 4. Conductor fault locator.*

A. SINGLE PAIR HOOK-UP:
USING ONLY THE PAIR IN TROUBLE



B. SEPARATE GOOD PAIR HOOK-UP:
USING AN ADDITIONAL GOOD PAIR

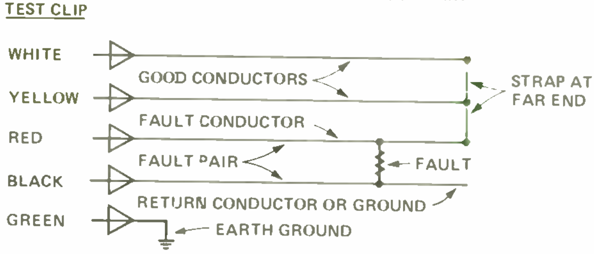


*Figure 5. Typical hookups for conductor fault location.*

The resistance of a copper conductor changes about 2% for every 10 degrees Fahrenheit change in temperature. Assume that the same cable fault exists at 1,000 feet as in the previous example. This time the gauge switch is set correctly to 24 gauge. The temperature control is set to 70 degrees but the actual cable temperature is 50 degrees.

The 20 degree error in temperature setting will cause a four percent error in the distance reading. The distance dial will show the fault location at 960 feet. Again the absolute error increases with the distance to the fault (i.e. if the fault were at 10,000 feet, the test set would indicate 9,600 feet.)

The size of a conductor can be determined by a simple measurement but determining the temperature of a cable is more difficult. Probably the most accurate way to determine the temperature of buried cable is to have a probe permanently buried in the earth to the same depth as the buried cable in the service area.

In most areas of the United States, the temperature of cold tap water is a satisfactory indication of buried cable temperature because telephone cable is buried at about the same depth as water pipes. In areas that have very cold weather, water pipes are buried considerably deeper than telephone cables. In these cases it is best to measure the temperature of the soil at the cable depth.

The temperature of underground cable can be determined by inserting a thermometer several feet into the duct. The cable conductors should be at the same temperature as the ambient temperature inside the duct.

## Aerial Cable Temperature

In general, aerial cable that is not in direct sunlight will have the same temperature as the air. An ordinary thermometer, placed in the shade will provide a temperature reading very close to the cable temperature.

An aerial cable in direct sunlight can have a much higher temperature than the surrounding air. Individual judgement is required to determine what temperature setting to use in these cases.

On a moderately warm day with air temperature between 75 and 80 degrees F and some breeze, a cable in direct sunlight will be about 20 degrees warmer than the air. On a hot day with the air temperature between 90 and 95 and with little or no breeze, a cable in direct sunlight will be about 40 degrees warmer than the air.

Actually, many long cable runs will be partially in shade and partially in sunlight. In this case the above correction factors should be halved. For a 75 degree day, with some breeze, the test set temperature control would be set to 85 degrees. On a 90 degree day, with no breeze, the temperature control would be set to 110 degrees.

When a cable is partially aerial and partially buried, an initial reading should be taken to determine the approximate location of the fault. At the same time, it should be determined whether the fault is closer to the test set or the strap. If the fault is in the buried section, set the temperature control to the buried cable temperature; if the fault is in the aerial section, set the temperature control to the aerial cable temperature. When the fault is closer to the strap, use the strap-to-fault distance measurement. When the fault is closer to the test set use the regular distance to fault measurement.

The cable, between the fault and the point to which it is measured, must be in a uniform environment for an accurate measurement. The conductor fault locator cannot accurately measure the distance to a fault, if substantial lengths of cable at different temperatures are between the fault and the point to which it is measured.

## Open and Split Locator

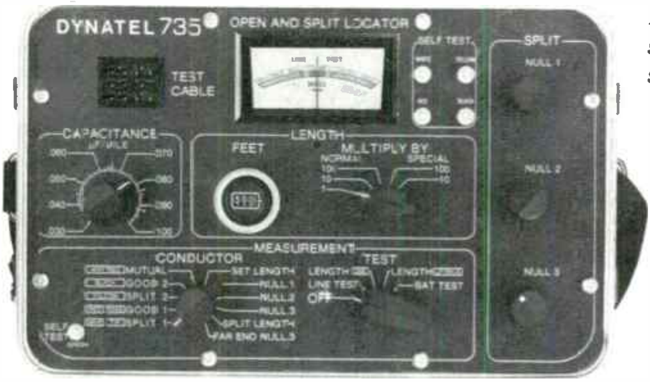
As previously stated, the use of a Conductor Fault Locator requires conductor continuity beyond the fault location. Continuity may be very difficult to establish in the case of open or split faults.

An Open and Split Locator test set is used to locate this type of fault. Figure 6 is a photograph of a Dynatel ® 735 test set.

The electrical property this test set measures is capacity. The capacity of a conductor is proportional to its length. The time required to charge a capacitor to a given voltage is proportional to the amount of capacity.

Therefore, if the time to charge a telephone pair to a given voltage is measured, the length can be calculated. This calculation is performed by the test set. Figure 7 illustrates the principle. Note that the third capacitor in the figure will not be charged and does not affect the distance measurement.

If line build-out capacitors are within the fault, their equivalent electrical length must be calculated and subtracted from the indicated distance to give the true fault location. The capacitance is not affected by temperature. Also, the construc-



Courtesy of Dynatel/3M

*Figure 6. Open and split locator test set.*

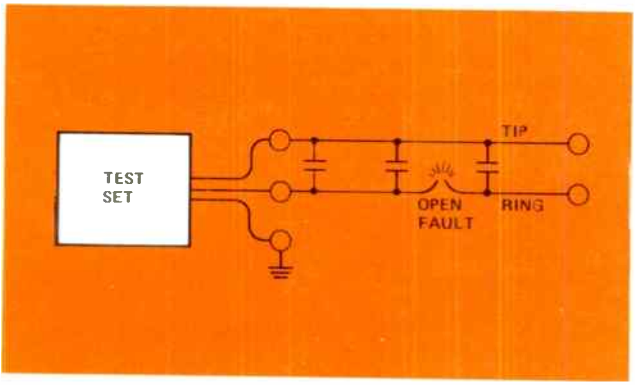


*Figure 7. Measuring conductor capacitance to find distance to open fault.*

tion of telephone cable makes capacitance substantially independent of conductor gauge.

The test sets we have described can be used to locate practically every type of cable fault. However, a telephone company's cable installations may be composed of various combinations of aerial; underground and buried cable. The conductors may be of different sizes and types of insulation. Space limitations do not permit a discussion of all the techniques used to locate cable faults in these types of installations. Many of these techniques are described in the references listed in the bibliography.

All of these techniques rely, to some degree, upon the operators skill and judgement. The more complex situations also require substantial knowledge and experience to interpret the test results. So, cable fault location has come full circle. Today, there is again a great demand for persons skilled in the art of cable fault location.

## Filled Cable

For simplicity, the previous discussion has considered only unfilled PIC and lead-covered, paper-insulated cables, where about half of the available space is occupied by air. Filled cable is discussed in the following paragraphs.

The development of filled cable began when it became apparent that water in buried PIC cable was a serious problem. The primary purpose for filling cable is to keep water out.

An early method was to fill the cable with kerosene. This did not work because kerosene is lighter than water. It simply floated away when water entered.

Petroleum jelly (petrolatum) is satisfactory for repelling water but has a low melting point. It is likely to melt and flow out of cable exposed to sunlight.

Numerous compounds have been tried but those that have proven most satisfactory to industry generally have a petroleum jelly base. Probably the most widely used filling material today is composed of petroleum jelly, low-density polyethylene and an antioxidizing agent. It has a sufficiently high melting point and retains its putty-like flexibility for many years.

This and other petrolatum based compounds have a tendency to deteriorate some of the materials used to insulate the cable conductors. For this reason, low molecular density polyethylene cannot be used for conductor insulation in a filled cable.

At first polypropelene was used to insulate the conductors because it was about the only insulation not seriously affected by petrolatum. Later, a high-density polyethylene was developed and proved satisfactory for use.

Because the filling compound has a higher dielectric constant than the air it replaces, the mutual capacitance between conductors increases. To compensate for this increase, and keep the cable compatible with air-core PIC cable, it is necessary to use thicker insulation on the conductors. The result is some increase in the cable size.

The Bell System began field testing filled cables in 1968. Based on the results of these and other tests, a properly filled cable is a satisfactory solution to the water problems in buried PIC cable.

## Conclusion

This first of our two part series discusses common faults found in multipair cable. Most of the faults described are "solid troubles" which affect vf as well as carrier transmission. The second part will discuss faults which may not impair vf but will adversely affect the transmission of high-frequency FDM and PCM carrier signals. Coaxial and optical-fiber cable testing will also be discussed.

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**EDITOR NOTE:**

**The use of Dynatel/3M equipment for illustrative purposes does not constitute an endorsement of that equipment. The Demodulator does not recommend any particular manufacturer's test equipment.**

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5. Horn, Frank W. — *Cable, Inside and Out*, Lee's ABC of the Telephone, Geneva, Illinois.

The following corrections apply to the applications programs presented in the March/April 1979 issue, "Path Profiling with a Programmable Calculator."

*PAGE 16:* BSTJ referenced should be "December 1969."

*PAGE 18:* Key entry 004 should be "LBL B."

KEY ENTRY 006 should be "RCL 1."

Under REGISTERS, 4 should be "$H_r$".

Under REGISTERS,
A should be "$H_a = H_x - H_r$".

B should be "$H_B = H_y - H_r$".

*PAGE 19:* KEY ENTRY 158 should be "X>Y?".

Under LABELS, e should be 016/022.

Under FLAGS, 1 should be blank.

Under COMMENTS, the formula given for the reflection point angle should have the value $K_{2a}$ changed to $K \cdot 2 \cdot a$, where a is equal to the earth radius at a value of $K=1$.

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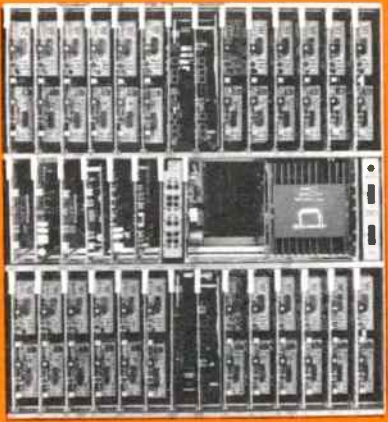

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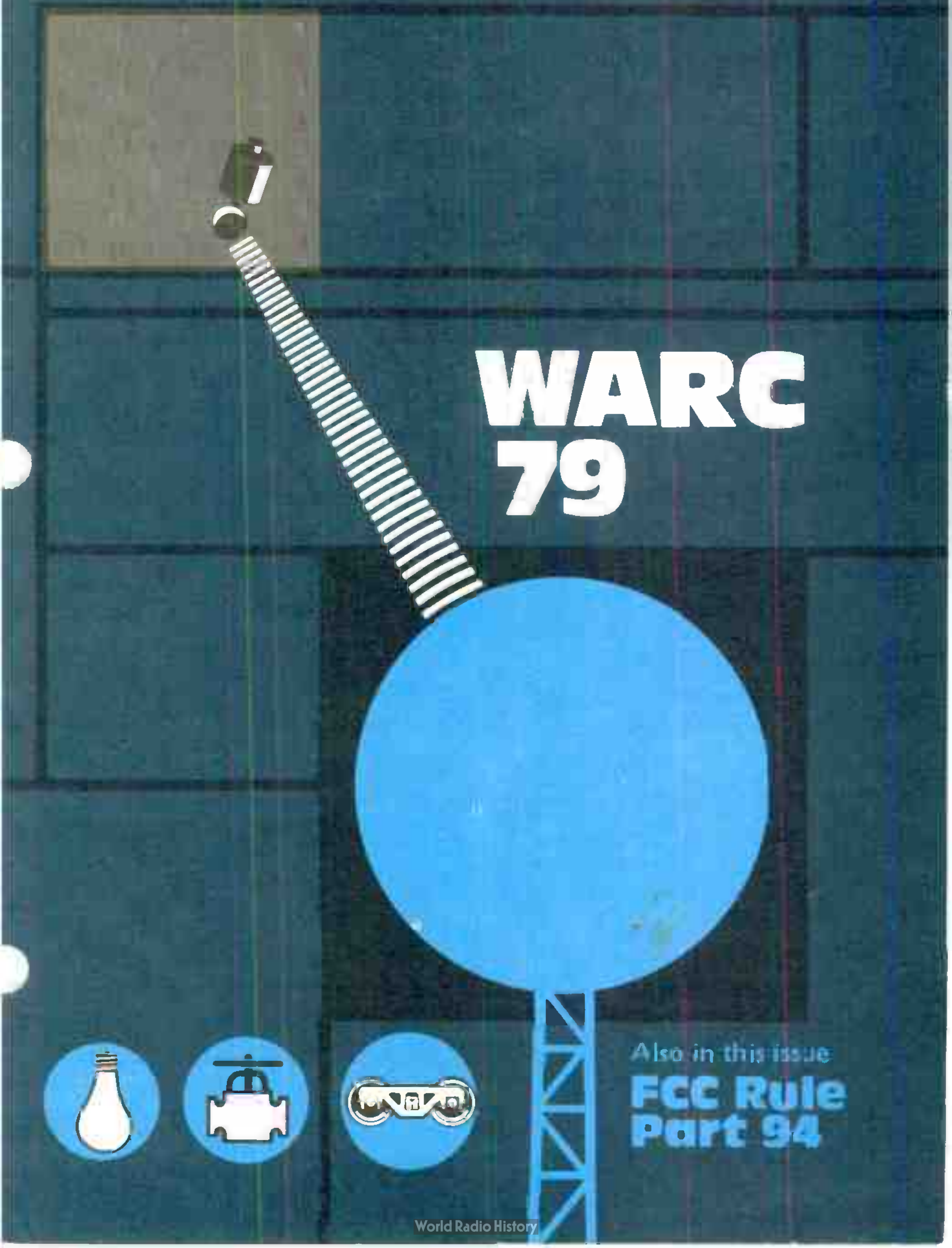
# DEMODULATOR

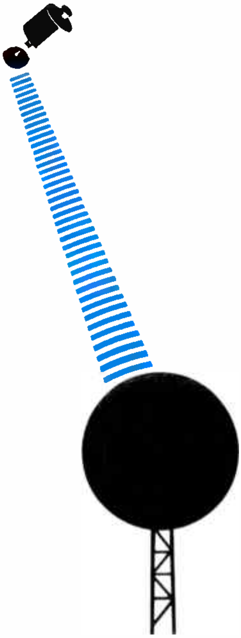
JANUARY/FEBRUARY 1980



# WARC 79

Also in this issue

## FCC Rule Part 94



**The January/February 1979 issues of the Demodulator discussed the then upcoming World Administrative Radio Conference. At that time, the industrialized nations were concerned that the lesser developed nations might try to reserve orbital slots and portions of the frequency spectrum for future satellite use. The conference has been held. The results are discussed in the following article.**

The 1979 World Administrative Conference (WARC) was held in Geneva, Switzerland. The conference began September 24, 1979 and ended, with the singing of the Final Acts, December 6, 1979. The conference was held under the auspices of the International Telecommunications Union (ITU). The ITU is the principal agency concerned with international civil communications. Founded in 1865, the Union is the oldest of the intergovernmental organizations which form the specialized agencies of the United Nations.

The purpose of the ITU is to provide standardized international communications procedures, including international radio regulations and frequency allocations. The Acts of the ITU have the force of treaties, so they must go through the treaty ratification procedure to be adopted by the United States.

Two semi-independent organs of the ITU are, the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR). The CCITT studies technical, operative and tariff questions about telegraphy and telephony. The CCIR studies technical and operating questions directly related to radio communications.

Both committees issue recommendations in their specific spheres of interest. The recommendations do not have the same force as the Acts of the ITU. Therefore, the recommendations do not require radification.

A third sub-organ of the ITU is the

International Frequency Registration Board (IFRB). The Board's responsibilities include recording all radio frequency assignments and preparing the International Frequency List.

Returning to our discussion of the WARC, the Final Acts will be published by the ITU in September, 1980 and will enter into force January 1, 1982. There are many individual effective dates for specific provisions. For example, the new frequency tolerances will take effect in two stages; one in 1984 and the other in January 1994.

## FCC Staff Report

After the conference, the FCC staff prepared a report to the Commission on the results of the conference and that report is available to the public. It is the basis for the following statements:

The anticipated politicalization did not occur. The conference generally concerned itself with technical matters.

The developing countries did support each other in areas where they had common interests. This is also true for the industrialized nations. All participating nations appeared to be guided by their perceptions of their best national interests. There was no evidence of bloc-voting along ideological lines, without reference to national interests.

The U.S. delegations submitted reservations on a few conference decisions because the delegates believe the decisions would adversely affect important national interests. A reservation is a formal protocol statement that the nation submitting the reservation will not necessarily be bound by a particular decision.

In any event, the Final Acts have the force of a treaty. Therefore, they must be ratified, which means approved by the Senate and signed by the President. It is not unusual for reservations to be included in the Final Acts ratified by the United States. After ratification, the FCC Rules and Regulations will have to be amended as required to implement the changes.

Even without the delays resulting from this U.S. domestic process, the Conference decisions will not cause any immediate changes in the structure or operation of the U.S. telecommunications systems, since most of the changes mandated by the Conference are intended to be phased-in over a long period of time.

The primary purpose of the WARC was to accomplish a general revision of international radio regulations. This purpose was achieved. Numerous changes were made in the areas of frequency allocation, frequency tolerances and spurious radiation limits.

A discussion of all these changes is beyond the space limitations of the Demodulator. However, some of the changes are discussed, because they are of particular interest to many of our readers.

As reflected by the following quotations, the FCC Staff believes the changes are beneficial.

"It is rather evident that allocation actions, as they affect or will affect the non-government community, were highly favorable and the Commission's expressed desire for flexibility was achieved."

Another part of the Staff Report:

"The Final Acts incorporated the various effective dates of results of other conferences, either adopting them, or abrogating them, as needed, to make the 1979 Final Acts a cohesive, non-contradictory set of International Radio Regulations."

In its summary, the Staff stated:

"The recently completed 1979 WARC should be viewed as substantially a success for the United States. While we did not achieve all our objectives, and many issues were deferred—either for further study by the sub-organs of the ITU or for consideration by subsequent Conferences—it is clear that the fears of impending disaster expressed by many, prior to the Conference, were not justified."

The forgoing excerpts, from the FCC Staff Report, were largely taken from the introductory matter and general discussion portions. The report also has four attachments:

I. Allocations
II. Regulatory
III. Resolutions and
Recommendations
IV. Future Conferences

Parts of each of these attachments are briefly discussed in the following paragraphs.

## Allocations Attachment

A number of new bands were identified to accomodate amateur satellite operations. All of the newly identified bands, below 40 GHz, were in bands already allocated to the terrestrial amateur service.

## 2.5 GHz Band

The 2.5 GHz band was substantially opened up to the Fixed Satellite Service. The FSS now shares this band coequally with the Broadcasting Satellite Service; at the same power flux density levels.

## 12 GHz Band

According to the FCC Staff Report, "The WARC decisions at 12 GHz met nearly all of the U.S. objectives." These objectives were:

a) The elimination of arc segmentation to enable the entire geostationary orbit to be used by both the fixed satellite and broadcasting satellite services.

b) The elimination of the possiblity of planning the fixed satellite service at the 1983 Region 2 Conference.

c) The maintaining of the viability of direct to home satellite broadcasting for the United States.

As a result of the conference decisions, the 10.7 to 11.7 GHz band is now available for world-wide use. The 11.7 to 12.1 GHz is available only to Region 2 (The Americas).

The countries of Region 2 agreed that the 11.7 to 12.1 GHz band will be used by the fixed satellite service and the band from the 12.3 to 12.7 GHz will be used by the broadcasting satellite service. The division of the 12.1 to 12.3 band, between these two services, will be decided at the Region 2 Broadcasting-Satellite Planning Conference in 1983. In other words the upper limit of the fixed satellite and the lower limit of the broadcast satellite services will be established at the Region 2 Conference. The United States is hopeful that the division will be established at 12.2 GHz.

The following information about the 12 GHz band comes from other sources that the FCC Staff Report. All sources are listed in the Bibliography.

The WARC Final Acts provide primary coequal status for the fixed (terrestrial) service in the 11.7 to 12.75 GHz band. In Region 2, this band is allocated in four segments.

The first, 11.7 - 12.1 GHz, band is allocated for fixed, fixed-satellite (space to earth) and mobile except aeronautical mobile services. The second, 12.1 - 12.3 GHz, band is for fixed, fixed-satellite (space to earth), mobile except aeronautical mobile, broadcasting and broadcasting satellite.

The third allocation, 12.3 - 12.7 GHz, is for fixed, mobile except aeronautical mobile, broadcasting and broadcasting satellite. The fourth, 12.7 - 12.75, band is for fixed, fixed-satellite (earth to space) and mobile except aeronautical mobile.

The following information is derived from the indicated footnotes to the international regulations adopted at the WARC:

— 2785A. The broadcasting-satellite service in the band 12.5 - 12.75 GHz is limited to community reception with a power flux-density of -111 db (referenced to one watt) per square meter, as defined in Annex B of Appendix 29A.

— 3787C. The bands 12.1 - 12.3 GHz in Brazil and Peru and 12.2 -12.3 GHz in the U.S. are also allocated to the fixed service on a primary basis.

— 3787F. For Region 2 stations in the broadcasting satellite service, assignments in the 12.3 to 12.7 GHz band will be made available in a plan to be established by the 1983 Region 2 Administrative Radio Conference. Assignments in the plan may also be used for transmissions in the space-to-earth fixed satellite service providing such transmissions do not cause more interference, or require more protection from interference than do the broadcasting satellites operating under the same plan. With respect to the space services, this band shall be principally used by the broadcasting satellite service. The lower limit of this band shall be modified in accordance with the decisions of the 1983 Region 2 Conference.

## BSS Uplinks

For Region 2, the WARC allocated the 14.5 - 14.8 GHz and the

17.3 - 18.1 GHz to the FSS exculsively for uplinks to broadcasting satellites. The 17.3 - 18.1 GHz band is preferred for Region 2 and will be the subject for detailed planning at the Regional Conference. Of course, other fixed satellite (earth-to-space) bands can be used for the same purpose.

## 3 and 4 GHz Downlinks

The conference identified the bands 3400-3700 MHz and 4500 -4800 MHz for downlink use by international systems, particularly INTELSAT. Although the United States had recommended the expansion of the 2 GHz spectrum, for this purpose, it accepted the conference decision.

However, two caveats were expressed. The first is in a footnote to the allocation table for the 3400-3600 MHz band. The sense of this footnote is that the Radiolocation Service and the Fixed-Satellite Service are on a co-equal basis in Regions 2 and 3 until the Radiolocation Service can be reaccommodated.

The second is in the form of a declaration by the USA, Canada, UK, Netherlands, Australia and Belgium. The declaration says that these nations will not withhold support for INTELSAT implementation of the FSS in these bands in any country other than those listed in the footnote 3748B. Furthermore, these nations will make reasonable efforts to accommodate FSS, consistent with footnotes 3736, 3736A and 3748B.

## 14 GHz Mobile-Satellite Service.

The WARC provided an allocation in the 14.0 - 14.5 GHz band for mobile-satellite service on a secondary basis. This service could accommodate mobile earth stations. Such stations could be used for on-the-spot, real-time coverage of current events.

## Regulatory Attachment

Only minor changes were made to the provisions dealing with the advance publication, coordination, notification and registration of space telecommunications services. Similar changes were made in the provisions for terrestrial stations operating in bands shared with the space services.

Many of the provisions regarding terrestrial services were revised for clarification and increased emphasis. Several resolutions and recommendations were adopted to provide technical assistance to developing countries.

As a result, the IFRB will select frequency assignments for countries in need of special assistance and will assist in the identification of sources of interference to stations of countries in need for special assistance. Numerous other resolutions and recommendations were passed to provide methods for transferring telecommunications technology and urging the developing nations to participate in the CCIR and CCITT.

The WARC adopted the CCIR studies and recommended new methods of classifying and designating emissions. The new procedure will allow more efficient use of the spectrum by improving international frequency registration techniques. This will enable protential interference to be more accurately identified while planning new systems in shared frequency bands.

The WARC also adopted the CCIR recommendations regarding station keeping of space stations. Under this regulation, future satellites in the BSS and FSS services must limit their unintentional arc displancement to ± 0.1 degrees in the East-West direction. This action is designed to reduce interference problems resulting from the large number of satellites in geostationary orbit around the earth's equator.

Space stations which have made application before January 1, 1987 do not have to comply with the ± 0.1 degree requirement. They will be governed by the old requirement which is ± 0.5 degress in most cases.

The questions of equitable access to the Geostationary Orbit was extensively debated at WARC. As a result, the conference decided to convene a World Administrative Conference on the Geostationary Orbit and the planning of space services.

This conference will be held in two sessions. The first will take place about 1984 and the second, 18 months later. Quoting from the FCC Staff Report; "Although the terms of reference are indefinite, the intent is to develop plans to insure equitable access by all countries to the geostationary orbit and appropriate frequency bands."

## Resolutions and Recommendations

A total of 87 Resolutions and 90 Recommendations was adopted by the WARC. Twenty Resolutions and 46 Recommendations were referred to the CCIR for study.

## Future Conferences

The WARC recommended that three future world conferences and seven regional conferences be held. Specific dates or agendas were not established. This is a function of the ITU Administrative Council.

In addition to the above Conferences, the ITU schedules an Administrative Council meeting annually (in the May/June time frame) and Plenipotentiary Conferences periodically to revise the Convention. The next Plenipotentiary is scheduled for Nairobi in the fall of 1982. Furthermore, CCIR Plenary sessions are held every four years, with interim and final meetings held in the intervening period. The relevant Resolutions and Recommendations of WARC 79 will be among the matters considered at these CCIR meetings.

## Conclusions

WARC 79 was a definite success, considering that it was the first conference in twenty years to address an overall revision of international radio regulations. Also, given the time limitations of the conference, it is not surprising that the delegates confined themselves to establishing broad general policies and left the detailed planning, required to implement these policies, to future conferences and to the specialized suborgans of the ITU.

The January/February and March/April 1979 issues of the Demodulator discussed satellite communications problems resulting from limitations of the frequency spectrum and geostationary orbit. The WARC allocated more of the frequency spectrum to the fixed satellite service to partially alleviate the frequency crowding and consequent interfence problems. The actions to make the entire geostationary orbit available to segments of the 12 GHz band and the new station keeping tolerance will reduce interference problems and, to a lesser extent, orbital congestion.

Meanwhile, applied research and development projects are underway to provide solutions to these problems. One such program to reduce spectrum crowding was described in the May/June 1979 Demodulator. It is the 19/29 GHz propagation experiment conducted by GTE and the University of South Florida.

The Demodulator also described NASA's ongoing experiments, involving space stations and orbital antenna farms. These are designed to provide solutions to the problem of orbital congestion. When these devices become operational, the ITU will probably be heavily involved in establishing regulations to govern their use.

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# FCC Rule Part 94

**The following discussion is in response to numerous inquiries about how Part 94 FCC Rules and Regulations impacts existing and new "Industrial" microwave stations. At the time of this writing, Part 94 requires that all, "Private Operational Fixed Microwave", systems be totally compliant to the provisions of Part 94 by August 1, 1985.**

**The discussion presents information of a general nature, which should not be used as a basis for engineering or legal decisions involving an actual system. Questions regarding specific systems should be referred to the FCC or a competent engineering/legal authority.**

In November 1975, the FCC released a memorandum and order establishing a "Private Operational Fixed Microwave Service." A private operational fixed microwave link provides communications between specific fixed points. Stations are authorized to transmit the licensee's own communications, those of its parent corporation or of other subsidiaries of the same parent. This is in contrast to "Domestic-Public Radio Services" which offer common-carrier telephone services to the general public.

## FCC Rules, Part 94

The objectives of the FCC's 1975 memorandum were to improve spectrum utilization and provide a more uniform quality of service in the affected frequency bands. To realize these objectives, a new Rule Part, designated Part 94, was formulated and became effective July 1, 1976.

Part 94 contains the following provisions:

1.Stringent technical standards for microwave systems authorized after July 1, 1976.

2. Less stringent standards for microwave systems authorized between July 20, 1961 and July 1, 1976. However, these systems must meet the stringent standard after July 31, 1985.

3. No technical standards for non-interfering systems authorized before

July 20, 1961. However, these systems must also meet the stringent standards after July 31, 1985. The following paragraphs discuss each of these provisions in turn.

## Stringent Standards

Systems authorized after July 1, 1976 preferably operate on prior coordinated frequency pairs chosen from specific lists provided in Part 94. The frequency of each transmitter must be maintained, within the tolerances shown in Table 1, over a −20°C to +50°C ambient temperature range.

Antennas must comply with certain minimum standards for directivity, to minimize interference to and from other systems. The requirements are stated in terms of maximum beamwidth and minimum off-axis radiation suppression. Category A and Category B antenna requirements are specified for each frequency band. For example, in the 6525-6875 MHz band, the maximum Category A antenna, half-power beamwidth is 1.5 degrees; for Category B the maximum beamwidth is 2.0 degrees.

Category A is mandatory in frequency congested areas which are identified in FCC Public Notice 64123. Category B is for uncongested areas. However, a current licensee in an uncongested area cannot deny area access to a new applicant, if an upgrade of an existing Category B antenna to Category A will reduce interference to an acceptable level. These levels are established in Section 94.63 of Part 94.

For a given frequency range, the beamwidth decreases with increasing diameter of the antenna dish. So, Part 94 effectively prescribes certain minimum antenna sizes. In the 6525-6875 MHz and 1850-1990 MHz bands, this equates to an 8 foot dish for Category A and a 6 foot dish for Category B.

*Table 1. Frequency Tolerances.*

| FREQUENCY BAND (MHz) | FREQUENCY TOLERANCE (%) |
|---|---|
| 952 – 960 | 0.0005 |
| 1,850 – 1,990 | 0.002 |
| 2,130 – 2,150 | 0.001 |
| 2,180 – 2,200 | 0.001 |
| 6,525 – 6,875 | 0.005 |
| 12,200 – 12,700 | 0.005 |
| 12,700 – 40,000 | 0.03 |
| ABOVE 40,000 TO BE SPECIFIED IN AUTHORIZATION | |

In the 2130-2150/2180-2200 MHz (for most antenna manufacturers) and in the 12,200 to 12,700 MHz bands, the minimum diameter is 6 feet for Category A and 4 feet for Category B. Two-foot diameter dishes are permitted for some paired 12 GHz frequencies, with restrictions on bandwidth, transmitter power and system length.

The off-axis radiation criteria are expressed in terms of minimum radiation suppression required at angles from 5 to 180 degrees from the centerline of the main beam. Separate criteria are listed for various frequency bands. Passive reflectors are exempt from these beamwidth and off-axis radiation requirements and continue to be allowed.

Part 94 does not specifically prohibit periscope antenna systems. However, their uncertain, and often unpredictable, off-axis radiation characteristics make it very difficult for new periscope systems to meet the radiation envelope standards required for certification. An exception is occasionally made for periscopes used at electric power facilities. On a case-by-case basis, these antennas may be excluded from the directivity requirements, if it can be shown that technical considerations preclude the use of other antenna types.

Passive reflector and periscope antenna systems often use the same type antenna and reflectors. Perhaps some latitudinal and/or longitudinal displacement from the antenna may qualify a reflector as a passive. However, the FCC may disallow such a definition, on a case-by-case basis.

## Less Stringent Standards

FCC Part 94 permits the continued use, through July 31, 1985, of microwave systems authorized between July 20, 1961 and July 1, 1976, providing they were in compliance with the technical standards of the then appropriate Rule Part 87, 89, 91 or 93. Until Part 94 became effective, these other rule Parts governed operational-fixed microwave stations in the avaiation, public-safety, industrial and land transportation services respectively. The older Rule Parts continue to provide the basis for VHF systems licensing and the eligibility requirements for prospective Part 94 licensees.

In the 6525-6875 MHz band, these older parts specified a frequency stability of ± 0.02% over an ambient temperature range of −30°C to +50°C. A 5° antenna beamwidth limitation made it practical to use a 4 foot diamter dish alone or coupled into a 4 foot by 6 reflector (Periscope antennas were allowed in any area).

## Least Stringent (No) Standards

Part 94 also authorizes continued non-interfering use, through July 31, 1985, of radios and antennas which were authorized before July 20, 1961. These stations were originally licensed under old FCC Parts 7, 9, 10, 11 and 16. A transmitter frequency stability of ± 0.05% is typical of the technical standards in these parts. Continuing operation of these older systems under Part 94 is also continguent on their not interfering with systems which conform to closer tolerances. The provisions for older systems are generally referred to as "grandfathering" rules.

Section 94.61 in Part 94 specifically states that all systems in the covered services must comply with the stringent standards after July 31, 1985. The pertinent part of this paragraph is reproduced below:

*SUBPART C — TECHNICAL STANDARDS*

*Section 94.61 Applicability*

*(a) The technical standards of this subpart shall govern, effective July 1, 1976, the issuance of authorizations for new stations and changes in authorized stations as specified in Section 94.45. Stations authorized prior to this date not meeting the provisions of this subpart may contined to be authorized for operation under previous technical standards as show in Section 94.92 through July 31, 1985. Except as provided in Section 94.65, effective August 1, 1985 all stations will be required to operate in accordance with the provisions of this subpart.*

Section 94.45 defines what changes in authorized stations will require FCC approval by license modification or special temporary authority. Section 94.65 contains tables of frequencies which are normally available for licensing under Part 94. These sections are discussed later.

The last sentence in Section 94.61 states that "effective August 1, 1985, all stations will be required to operate in accordance with the provisions of this subpart." "This subpart" is Subpart C-Technical Standards. Nevertheless, there is confusion among some users of microwave licensed before July 20, 1961.

The confusion apparently results from Section 94.92, paragraph (b). Taken out of context, this paragraph seems to authorize the operation of these older systems beyond August 1, 1985. However, it can be seen that this is not so when paragraph (b) is considered as a part of Section 94.92 and the whole Section is considered within the context of Part 94.

Section 94.92 follows:

*Section 94.92 Technical Standards for Stations Authorized prior to July 1, 1976.*

*(a) The technical standards indicated in the table in this section (Table 2 in this article) apply to private microwave systems using the frequency bands above 952 MHz listed in the table and which were authorized prior to July 1, 1976, but after July 20, 1961.*

*(b) These standards shall not be applicable to transmitting equipment (including antennas) which where authorized to be operated on these frequencies prior to July 20, 1961, or for which an authorization is issued based on an application filed with the Commission prior to July 20, 1961. Such licensees of equipment and systems not subject to these technical standards, including their successors or assigns in business, will be permitted to utilize such equipment provided such operation does not result in harmful interference to another station or system which is conforming to these*

*Table 2. Part of Section 94.92**

| FREQUENCY BAND (MEGAHERTZ) | POWER (WATTS) | TOLERANCE (PERCENT) | BANDWIDTH | BEAMWIDTH (DEGREES) |
|---|---|---|---|---|
| 952–960 | 30 | 0.0005 | 100 kHz | 20 |
| 1850–1990 | 18 | .02 | 8 MHz | 10 |
| 2130–2150 | 15 | .001 | 800 kHz | 10 |
| 2150–2160 | 15 | .001 | 10 MHz | 360 |
| 2180–2200 | 15 | .001 | 800 kHz | 10 |
| 2450–2500 | 12 | – | – | – |
| 6525–6575 | 7 | .02 | 25 MHz | 7 |
| 6575–6875 | 7 | .02 | 10 MHz | 5 |
| 10550–10680 | 5 | – | 25 MHz | 4 |
| 12200–12700 | 5 | .05 | 20 MHz | 4 |
| ABOVE 16000 | 5 | – | 50 MHz | – |

*FOOTNOTES AND EXPLANATORY MATTER DELETED FROM THIS ABRIDGED TABLE, BECAUSE THEY ARE NOT PERTINENT TO OUR DISCUSSION.

*technical standards. In case of such harmful interference, such nonconforming licensee will be required to take whatever measures are necessary to alleviate the interference.*

When Section 94.92 is taken as a whole, it is apparent that the standards referred to in the first line of paragraph (b) are the relaxed standard in the Table which is a part of the Section. If paragraph (b) is taken out of context "These standards" may be interpreted as meaning the Technical Standards in Subpart C, thereby leading to the mistaken conclusion that pre-1961 radios are "grandfathered" beyond August 1, 1985.

Paragraph (a) states that the standards in the Section 94.92 Table apply to systems " which were authorized prior to July 1, 1976 but after July 20, 1961." From our previous discussion and from Section 94.61 in the rule, it is clear that the standards in the Table will be completely superseded by the Subpart C-Technical Standards, effective August 1, 1985. At that time Section 94.92 will have no reason to exist and will become null and void because it is subservient to Section 94.61.

In administering Part 94, the FCC has routinely granted approval for moving a non-compliant, pre-7/1/76 or pre-7/20/61 transmitter from one location to another providing the move is justified by the user as expediting a Part 94 upgrade of other parts of his system. Such changes in any part of his system will probably not jeopardize the "grandfathering" of any other part of his system through July 31, 1985.

## Sections 94.45 and 94.65

As previously stated, Section 94.45 defines what changes in authorized stations require FCC authorization by license modification or special temporary authority. The following changes in antenna characteristics are listed as requiring license modification or special temporary authority:

— Any change in antenna azimuth.

— Any change in antenna beamwidth. (even if beamwidth is made narrower by using a larger parabola etc..).

— Any change in antenna or passive repeater location greater than 1 second or which involves a requirement for special aeronautical study.

— Any change in antenna height (up or down.)

— Any changes in antenna polarization.

— Any change in size of passive reflectors or repeaters associated with the facilities of an authorized station.

The following changes in radio parameters are also listed as requiring license modification or special temporary authority:

— Any change in frequencies used.

— Any increase in emission bandwidth beyond that authorized.

— Any change in type of emission.

— Any change in authorized effecive radiated power (ERP) in excess of 3dB.

— Substitution of equipment having a different frequency tolerance.

An equipment change involving only a reduction in emission bandwidth or a change, within 3dB, of effective radiated power may be made by notifying the FCC. Formal license modification is not required in these cases.

All license modifications must be preceded by an interference protection analysis except:

— Any improvement in transmitter frequency stability.

— Any decrease in transmit power.

— Any decrease in antenna beamwidth while still maintaining the median ERP within 3dB of the licensed value (up or down).

The provisions of Section 94.45 are not only applicable to transmitter change outs. They also apply to any new transmitter installation. For example, if an "as-built" waveguide or coax run is longer than originally estimated and results in a decrease of more than 3dB in the median ERP, a major license modification must be initiated. The modification must be preceded by another interference protection analysis.

Section 94.65 of Part 94 contains tables of paired frequencies which are normally available for assignments in the Private Operational Fixed Microwave Service. New systems should make every effort to use these pairings.

This may not always be practical since systems licensed prior to July 1, 1976 may continue to use non-standard transmitter-receiver spacings. New systems may find it necessary to deviate from the standard frequency pairings to avoid interference into and from these older systems.

However, non standard pairings should be considered a last resort, rather than an easy expedient, in solving frequency coordinating problems. Otherwise, the newer system may someday stand alone as an impediement to orderly growth in an area.

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## *ANNOUNCEMENT*

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