CHAPTER SEVENTEEN

U. H. F. Communication

An old and still valid definition of *ultra-high frequencies* is: *those frequencies which are not regularly returned to the earth at large distances.* Under this definition, the limit between *high* and *ultra-high* frequencies shifts with the sunspot cycle. From 1935 to 1940, the 30 megacycle band was regularly useful on winter days and on spring and fall afternoons, but from 1941 through 1945 it is due to become much more erratic. That is not to say, however, that higher frequencies are useless; for the very fact of limitation on distance covered is in itself a blessing for crowded bands, and brings back the old thrill of reaching out to difficult distances. There is good reason for the current trend—or landslide—to these very short wavelengths. In order to promote a better understanding of transmission methods, the several types will be classified and discussed.

Propagation

Direct Communication. *Horizon,* local, or direct point-to-point reception refers to two points between which there is no obstruction to the waves. This might be a mile or two hundred, depending on the altitude of the antennas and the nature of the intervening land.

The distance to the horizon is given by the approximate equation $d = 1.22\sqrt{H}$, where the distance d is in miles and the antenna height H is in feet. This must be applied both to the transmitting and receiving antennas. Actually, diffraction of the signal around the spherical earth makes the field strength decline as if the earth's diameter were 4/3 of the actual figure.

In the case of ground as smooth as a billiard ball, there is not actually a discontinuity of the signal at the horizon; that is, an airplane taking off beyond and below the horizon would begin to encounter some signal below an altitude actually in sight of the transmitting antenna.

Ground Wave. Because the signal is heard consistently beyond the horizon, the term *ground wave* is usually applied out to 30 or more miles—and much longer when one or both antennas are high. The waves are propagated, presumably, by *diffraction* or dispersion around the curve in the earth's surface in the same way as light is diffracted around a sharp corner. Out to this distance, the transmitting and receiving antennas give best results when both are either vertical or horizontal.

Low Atmosphere Bending. *Pre-skip,* extended ground wave, refracted-diffracted, or low atmosphere bending dx mean essentially the same thing. All refer to distances out to perhaps 200 or 300 miles, in the absence of unusual aurora or magnetic activity. Beams are pointed close to the direct line between the stations. The first two terms refer to the distance but not to the method by which the transmission is accomplished, and presumably differ from the local or ground wave type only because the greater distance is covered as a result of more power, better antennas, or more sensitive receivers.

Low atmosphere bending, on the other hand, in the narrow sense refers to pushing the signal over at the same distance with the aid of a temperature discontinuity or inversion in the lower atmosphere that bends the waves slightly downward, rather than just simple brute force methods implied by the other terms. It is frequent along the west coast of the U. S. A. and is prevalent in the summer in the east. It involves long slow fading, although close in where weak direct waves are also heard, fading can be violent. It is more apt to occur on days when there are stratus clouds than on cool, clear days with a deep blue sky. Often, evenings are better than days, due to the cooling of the earth. It is attributed to a discontinuity in the normal decrease of temperature with increasing height above the earth. The discontinuity or *temperature inversion* often occurs about one

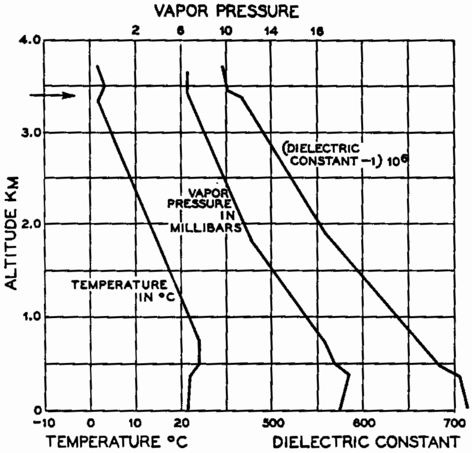

Figure 1.
ILLUSTRATING TYPICAL TEMPERATURE INVERSION AT 3.4 KM.
Air mass boundary heights shown by U.S. Weather Bureau free air data, compared to measured heights from frequency sweep patterns on ultra high frequencies.

mile up, and is generally predictable from weather information several days in advance. It produces no noticeable skip, the signal normally being diffracted around the curving earth and assisted by some bending above the surface. It does not appear to depend on the sunspot cycle. In general, it calls for similar antenna polarization or orientation at both ends for best results, whereas in ionosphere types of transmission it makes very little difference whether antennas are horizontal or vertical.

Aurora-type DX. The same and longer distances can be reached below 60 megacycles during periods of visible displays of the aurora borealis, and during magnetic disturbances. This has been termed *aurora-type dx.* These conditions reach a maximum somewhat after the sunspot cycle peak, possibly because the spots on the sun are nearer to its equator (and more directly in line with the earth) in the latter part of the cycle. Magnetic storms are often accompanied by ionosphere storms which churn up the regular layers and make reception on low frequency bands difficult. This condition, however, has often brought about "skipless" five and ten meter contacts, usually completed by pointing beam antennas in a northerly direction, regardless of the true direction of the other stations.

Short Skip. The lower of the two more important ionosphere layers is the *E* region. This accounts for 160-meter and broadcast dx at night. Sometimes a *sporadic* condition exists in this layer, the height of which is usually about 110 kilometers (68 miles) above sea level, which will reflect the highest frequency waves that return to the earth. One hop can be as long as 1200 miles, or slightly longer with antennas producing good low angle radiation and reception (below 3 degrees). Occasionally 1300 or 1350 miles can be covered, possibly with the help of low atmosphere bending at each end. *Sporadic-E* layer reception may occur at any time but is much more prevalent from late April to early September, and slightly more apt to occur in the late morning and early evening. Skip as short as 310 miles on 56 megacycles in one instance indicates that on an exceptionally good day, 2½ meter (112 megacycle band) signals might have been heard erratically at 1200 miles. The sporadic-E layer is spotty, accounting for contacts in definite areas, and permitting only a few days of double-hop reception. The number of favorable hours for ten and five meter short skip is expected to decrease for several years, but improved equipment is making possible five meter work, especially, under relatively poor conditions.

Horizontal antennas are every bit as good as verticals for this work, apparently, and the polarization of the transmitting antenna need not be the same as that used for receiving. Because u.h.f. antennas may be a number of wavelengths high, their vertical plane pattern may contain several angles at which transmission or reception is difficult or impossible; a null for a horizontal is at the same angle as a maximum for a vertical antenna, and the reverse, thus accounting for widely varying signal strengths should the waves come in at one of these critical angles. Beams show some directivity on sporadic-E reception but generally are not as sharp as in pre-skip dx, possibly due to better signal strength or to an angle of reception several degrees above the horizontal.

Long Skip. The higher of the two major reflecting layers of the ionosphere is the *F* region. This accounts for long-skip signals coming down as far away as 2200 miles in a single hop, with multiple hops common. The silent or skip zone may be around 1600 miles. On winter days, this layer accounted for ten meter (30 megacycle) transmission during the favorable part of the sunspot cycle. There was some evidence of five meter (56 megacycle) transmission by this method in

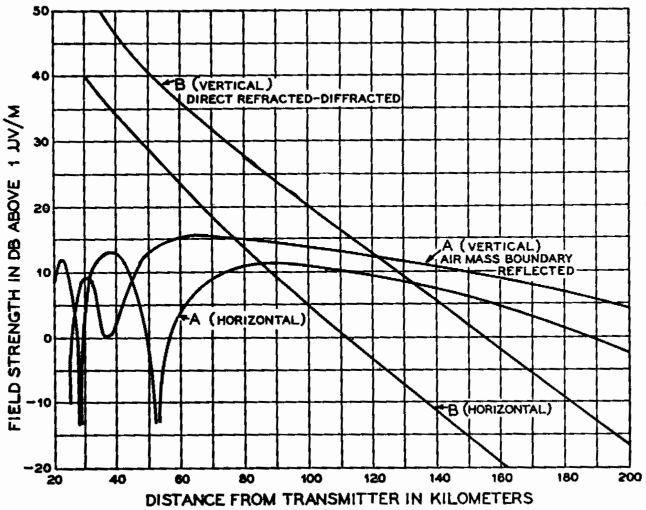

Figure 2.
TYPICAL U.H.F. PROPAGATION CHARACTERISTICS.
Calculated curves for air boundary reflected and earth refracted-diffracted radiation components, in both vertical and horizontal polarization. Short doublet antennas, 1 kw. power radiated, wavelength 4.7 meters, ground conductivity 5×10^{-11} E.M.U., and dielectric constant 80 for sea water. Height of transmitting antenna 42 meters, of receiving antenna 5 meters, air boundary height 1500 meters, effective radius of earth 8500 kilometers.

1937 and 1938 but ionosphere and sunspot records suggest that it may be 1947 or so before there is another favorable time for this kind of work. Ten meter signals are likely to suffer from less consistent *F*-layer reflections for several years following 1941.

Sometimes, this layer builds up in a way that if a beam antenna is aimed southeast in the morning or southwest in the afternoon, stations can be contacted within the normal skip band by bouncing the waves off of the edge of a layer located farther south.

Equipment Considerations

Years ago, tube bases were removed to get down to 100 meters, but experimentation is making 1¼ meters (224 megacycle band) as easy as 10 meters was a few years ago. Limits in the use of triode or pentode tubes are being approached, however, which may force further tube and circuit development. Beam tetrode tubes are now available to provide a kilowatt on 2½ meters, and good output on 1¼ meters. Triodes are now available to turn out considerable power on ¾ meters (400 megacycles). The tuned circuit—the basis of radio—is undergoing changes and may be replaced by *cavity resonance* at microwaves.

Even a perfect circuit must be coupled to something to be useful. A vacuum tube grid presents an apparent low resistance to the tuned circuit at short wavelengths. At 60 megacycles, this is about 2300 and 2500 ohms for the 6L7 and 1852, compared with 54,000 for the acorn 954 and 956. Normal receiving pentodes such as the type 57 have a relatively low input resistance even at 14 megacycles, reducing the effectiveness of the best circuit. With increasing frequency, there is a point for each tube where the output is no larger than the input, adding its shot-effect noise to the signal arriving in its plate circuit. This makes necessary the use of acorn tubes above a certain frequency.

In a properly designed receiver, thermal agitation in the first tuned circuit is amplified by subsequent tubes and predominates in the output. For good signal-to-set-noise ratio, therefore, one must strive for a high-gain r.f. stage exclusive of regeneration. Hiss can be held down by giving careful attention to this point. A mixer has one-third of the gain of an r.f. tube of the same type; so it is advisable to precede a mixer by an efficient r.f. stage.

The frequency limit of a transmitting tube is reached when the shortest possible external connections are used as the tuned circuit, except for abnormal types of oscillation. Generally, amplifiers will operate at higher frequencies than will oscillators. For satisfactory efficiency in an amplifier, it is important to place all tuning condensers so that leads and condenser frame have very little inductance. Otherwise, such leads should be increased to an electrical half wavelength. Wires or parts are often best considered as sections of transmission lines rather than as simple resistances, capacitances or inductances.

Transmission Line Circuits. At increasingly higher frequencies, it becomes progressively more difficult to obtain a satisfactory

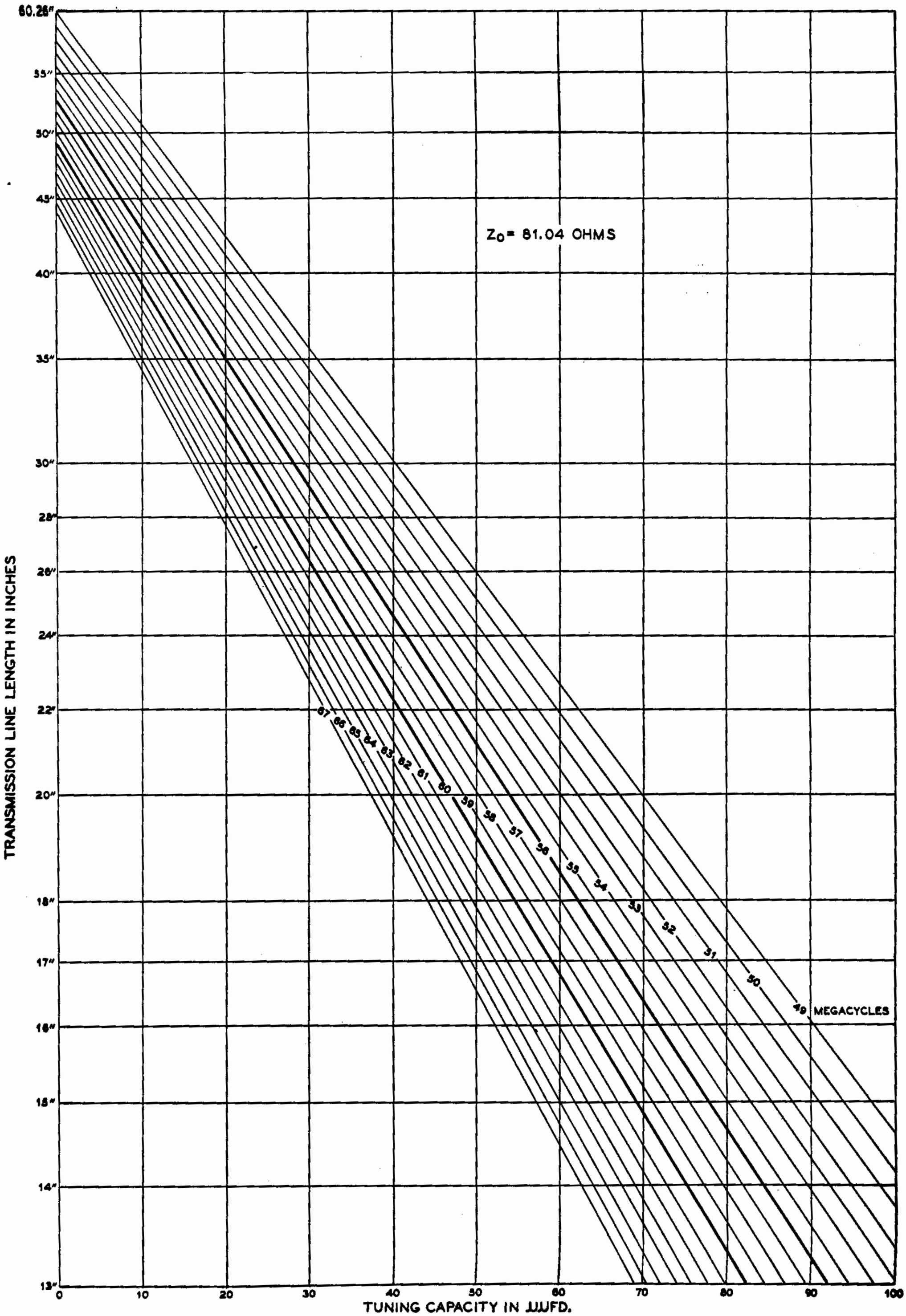
60.28"
55"
50"
45"
40"
35"
30"
28"
26"
24"
22"
20"
18"
17"
16"
15"
14"
13"
TRANSMISSION LINE LENGTH IN INCHES
Z₀ = 81.04 OHMS
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49 MEGACYCLES
0
10
20
30
40
50
60
70
80
90
100
TUNING CAPACITY IN μμFD.

Figure 3.

CHART SHOWING CAPACITY REQUIRED TO RESONATE SHORTENED LINES OF 81 OHMS SURGE IMPEDANCE.

See text for method of converting to other frequencies and surge impedances. Chart applies directly to coaxial lines and, through conversion (see text), to open-wire lines.

amount of selectivity and impedance from an ordinary coil and condenser used as a resonant circuit. On the other hand, quarter wavelength sections of parallel conductors or concentric transmission line are not only better but also become of practical dimensions.

Full quarter wavelength lines resonate regardless of the ratio of diameter to conductor spacing—with due allowance for the length of the shorting disc or bar. Substantial open-end impedance, Z_S, and selectivity, Q, can be built up with lines less than a quarter wavelength, loaded with capacity at the open end, provided that the condenser is an excellent one—preferably copper plates attached to the conductors with no dielectric losses. This is more important, of course, in lines used for frequency control that are lightly loaded. Lines also can be tuned (if not loaded with capacity) by substituting a variable condenser for the shorting bar or disc.

Any unintentional radiation from a coupling link, or resistance coupled into the line, will reduce its effectiveness. Lines that are much shorter than a quarter wave may require considerable capacity to restore resonance; the amount of required capacity can be reduced by using a line with a higher surge impedance—that is, wider spacing for two-wire lines, or a smaller inner conductor for a given outer conductor of a coaxial line. For greatest selectivity, or oscillator frequency control, the conductor *radius* should be about a quarter of the center-to-center line spacing or, in a coaxial, the inner conductor should be a quarter of the diameter of the outer pipe. For high impedance, ordinarily desired anywhere except for oscillator frequency control, the ratio can be eight-to-one or higher, thus reducing the necessary loading capacity on short lines.

Very large spacing is undesirable on open wire lines where the shorting bar may radiate so much that the tuned circuit has radiation resistance coupled into it and the impedance is reduced. Preferably, the active surfaces of lines should be copper or silver. A thin chrome plate over copper is also fairly satisfactory, as is an aluminum surface. The conductivity of the center conductor in a coaxial tank is much more important than that of the outer conductor, due to its smaller diameter.

Tuning Short Lines. Tubes hooked on to the open end of a transmission line provide a capacity that makes the resonant length less than a quarter wavelength. The same holds true for a loading condenser. How much the line is shortened depends on its surge impedance. It is given by the equation $1/2\pi fc = Z_0 \tan l$, in which $\pi = 3.1416$, f is the frequency, c the capacity, Z_0 the surge impedance of the line, and $\tan l$ is the tangent of the electrical length in degrees.

The surge or characteristic impedance of such lines can be calculated from the equations: $Z_0 = 276.3 \log_{10} (D/r)$ ohms for two-wire lines and $Z_0 = 138.15 \log_{10} (b/a)$ ohms for coaxial lines, where Z_0 is the surge impedance, $\log_{10}$ refers to the common logarithm, D and r refer to center-to-center spacing and conductor *radius* of two wire lines, b and a are outer conductor inner diameter and inner conductor outer diameter for coaxial lines. Charts showing characteristic surge impedance for parallel conductors and for coaxial lines may be found in chapter 20, figures 12 and 13.

The capacitive reactance of the capacity across the end is $1/2\pi fc$ ohms. For resonance, this must equal the surge impedance of the line times the tangent of its electrical length (in degrees, where 90° equals a quarter wave). It will be seen that twice the capacity will resonate a line if its surge impedance is halved; also that a given capacity has twice the loading effect when the frequency is doubled.

The accompanying chart (figure 3) can be used to determine the necessary line length or tuning capacity. For 112 megacycles, use the 56 megacycle curve but divide the capacity and line length scales by two. That is, if an 81.04 ohm line 30 inches long will tune to 56 megacycles with 28.20 $\mu\mu$fd. capacity, an 81.04 ohm line 15 inches long will tune to 112 megacycles with a 14.10 $\mu\mu$fd. condenser. Likewise, a 60 inch line of the same impedance will tune to 28 megacycles with 56.40 $\mu\mu$fd. This sounds like a lot of condenser, and can be reduced to 28.20 $\mu\mu$fd. by doubling the line impedance to 162.08 ohms. But in any event this circuit will outperform a coil both as to gain and selectivity. The capacities mentioned include circuit capacity; in the case of a mixer preceded by an r.f. stage, this will amount to about 10 $\mu\mu$fd. with acorn tubes, allowing 3 $\mu\mu$fd. for condenser minimum.

Coupling Into Lines. It is possible to couple into a parallel rod line by tapping directly on one or both rods, preferably through blocking condensers if any d.c. is

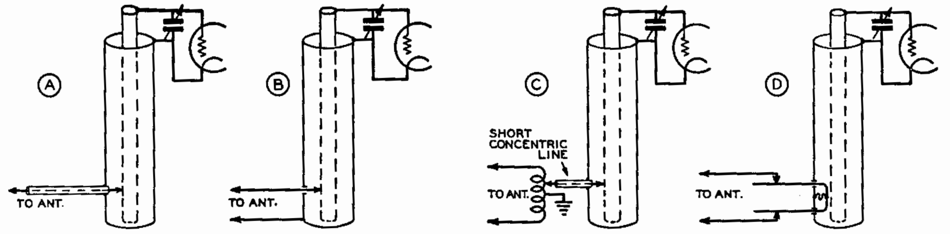

Figure 4.

METHODS OF COUPLING ANTENNA TO COAXIAL RESONANT CIRCUIT.

(A) Coupling a concentric line feeder to a concentric line resonant circuit. (B) Unbalanced method of coupling two wire line into a concentric line circuit. (C) Balanced-to-unbalanced method of coupling a two wire line to a concentric line resonant circuit. (D) Balanced loop method of obtaining good coupling from two wire line to a concentric line circuit.

present. More commonly, however, a "hairpin" is inductively coupled at the shorting bar end, either to the bar or to the two rods, or both. This usually results in a balanced load. Should a loop unbalanced to ground be coupled in, any resulting unbalance reflected into the rods can be reduced with a simple Faraday screen, made of a few parallel wires placed between the hairpin loop and the rods. These should be soldered at only one end and grounded.

An unbalanced tap on a coaxial resonant circuit can be made directly on the inner conductor at the point where it is properly matched. For low impedances such as a concentric line feeder, a small one-half turn loop can be inserted through a hole in the outer conductor of the coaxial circuit, being in effect a half of the hairpin type recommended for coupling balanced feeders to coaxial resonant lines. The size of the loop and closeness to the inner conductor determines the impedance matching and loading. Such loops coupled in near the shorting disc do not alter the tuning appreciably, if not overcoupled. Various coupling circuits are shown in figure 4.

Frequency Measurement

At ultra-high frequencies, Lecher wires or frames can be used to determine the approximate frequency of an oscillator; a crystal harmonic or receiver oscillator harmonic can then be used for closer measurement. A ten meter receiver with 1.6 Mc. i.f. will pick up an image 3.2 Mc. from a ten meter signal. If a five meter signal is picked up while the receiver is still tuned to ten meters, signal and image will be only 1.6 Mc. apart, and the dial setting will be incorrect by one-half of the i.f.

To explain, a 29-Mc. signal would be heard with the receiver oscillator higher in frequency by the amount of the i.f., or 30.6 Mc., with the dial reading 29 Mc. The image would come in when the oscillator is tuned to 27.4 Mc., at which time the dial will read 25.8 Mc. On the second harmonic, however, the dial set at 29 Mc. will place the 30.6 Mc. oscillator harmonic at 61.2 Mc., and bring in signals 1.6 Mc. lower, or on 59.6 Mc. The sub-harmonic of this is 29.8 Mc., or one-half of the i.f. higher than the dial setting of 29.0 Mc.

A 59.6 Mc. signal would also come in as an image when the receiver dial reads 27.4 Mc., or only one times the i.f. rather than twice as on the fundamental. At this setting, the oscillator is on 29 Mc., and its second harmonic is on 58 Mc., producing a 1.6 Mc. i.f. by beating against the 59.6 Mc. signal. The above is based on the assumption that the oscillator frequency is higher than the received signal, as is customary in commercial receivers. With a little care, this method can be used to spot bands as well as to place a transmitter in a band with fair accuracy.

Lecher Wire Systems. A Lecher wire measuring system consists of a pair of parallel wires one or more wavelengths long, short circuited at one end to provide a pick-up loop which can be coupled to the tuned circuit of a transmitter or receiver. The wires can be no. 12, approximately one inch apart. The shorter wavelength units can be stretched on a long wooden framework if no supports or insulators are used in the measuring range.

Energy induced in the parallel wires establishes standing waves of voltage and current along the wire when resonance is established with a shorting bar. The sliding bar (see figure 5) is moved along the wires until two successive points are located which

Frequency (Mc.)	¼ Wave (inches)	½ Wave (inches)
56	52.7	105.5
57	51.8	103.6
58	50.9	101.8
59	50.0	100.1
60	49.2	98.4
112	26.4	52.7
113	26.1	52.3
114	25.9	51.8
115	25.7	51.3
116	25.4	50.9
224	13.2	26.4
226	13.1	26.1
228	12.9	25.9
230	12.8	25.7
400	7.4	14.8
410	7.2	14.4

FREQUENCY VS. WAVELENGTH

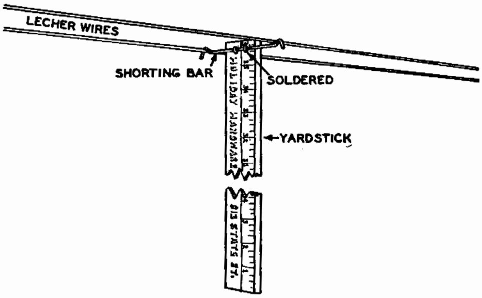

Figure 5.
LECHER WIRE MEASURING EQUIPMENT.
The wires are spaced about 1½ inch and pulled taut. "Bumps" will appear exactly ½ wavelength apart on the wires as the jumper is slid along. The wires may be coupled to the oscillator under measurement by means of twisted line.

cause the oscillator under test to draw more plate current or go out of oscillation. The distance between these two points is a half wavelength. This can be converted into meters by multiplying the length in feet by 0.61 (actually 0.6096) or the length in inches by 0.0508. For microwaves, the length in inches is usually converted to wavelength in centimeters by multiplying by 5.08. These factors convert to the metric system and take care of the fact that the points are one-half rather than one wavelength apart. An accuracy of only 1 per cent or so can be expected; receiver or oscillator harmonics should supplement these measurements for greater accuracy.

Lecher Frames. For a quick check of wavelength, any two parallel wires or rods can be used as a quarter wave Lecher *frame.* The open ends can be held near the oscillator while a screw driver or other shorting bar is run down the rods. The oscillator frequency will change and the output will dip when the Lecher frame crosses resonance. This point will give a close approximation of the frequency if half the shorting bar length plus one conductor from the shorting bar to the end near the oscillator is taken as 0.95 of a quarter wavelength. Accuracy to better than 3 per cent can be expected with this system.

Receiver Theory

So long as small triodes and pentodes will operate normally, they are generally preferred as u.h.f. tubes over other receiving methods that have been devised. However, the input capacity of these tubes limits the frequency to which they can be tuned. The input resistance, which drops to a low value at very short wavelengths, limits the stage gain and broadens the tuning. The effect of these factors can be reduced by tapping the grid down on the input circuit, if a reasonably good tuned circuit is used.

A mixer or detector can have a gain only of about one-third of that for the same tube used as an r.f. amplifier, so that for gain and principally for satisfactory signal-to-set-noise ratio, a good r.f. stage is advisable. The first tube in a u.h.f. receiver is most important in raising the signal above the thermal agitation noise of the input circuit, for which reason small u.h.f. types are definitely preferred. Regeneration increases over-all gain without improving the signal-to-noise ratio, provided that increased selectivity in the regenerative stage does not determine the receiver's over-all selectivity.

Superregenerative Receivers. A very effective simple receiver for use at ultra-high frequencies, if properly adjusted, is the superregenerative receiver. The theory of this type is covered in Chapter 4 and is illustrated in Chapter 18.*

Superheterodyne Receivers. Although they involve the use of more tubes, superheterodyne receivers are somewhat less critical to adjust properly than the superregenerative type. They have the advantages of not causing broad interference locally, and have

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* For a more extensive study of its basic theory and adjustment, see articles by Frederick W. Frink in Radio for March and April, 1938.

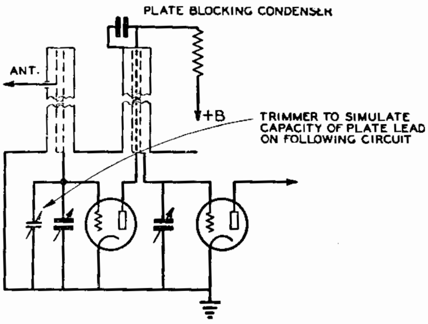

Figure 6.
CONCENTRIC TANK CIRCUITS AS USED IN ULTRA HIGH FREQUENCY RECEIVERS.
Concentric tanks are best at very high frequencies as they have a much higher impedance at these frequencies.

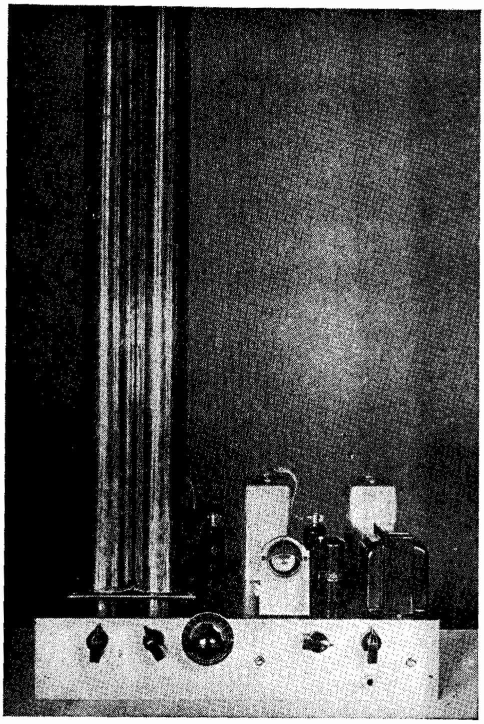

Figure 7.
SUPERHETERODYNE FOR 56 MC. USING CONCENTRIC TANK CIRCUITS.
The acorn tubes used in the high frequency stages are located under the chassis.

greater selectivity. The main problem in them is to obtain adequate oscillator voltage injection so that the conversion gain is satisfactory. Screen or suppressor injection requires a strong oscillator if the mixer tube's grid circuit is properly shielded; if it is not, leakage to the control grid will provide grid injection. The latter (often recommended by tube manufacturers for best gain on ultra-high frequencies) results in greatest "pulling" but this can be eliminated by use of a high intermediate frequency and proper construction.

Cathode injection is not recommended by manufacturers because a long cathode lead increases the *transit time effect* and decreases the apparent input resistance of the tube; however, at very high frequencies, several good receivers have used this variation of grid injection by having the mixer cathode clip tap directly on the oscillator tank with very little inductance from the tap to ground and to the grid and plate r.f. return leads.

A stable, hum-free oscillator is necessary in a u.h.f. superheterodyne. Small tubes like the acorn 955 or the HY615 are satisfactory for this purpose. Heater chokes may reduce hum in cathode-above-ground circuits. Doubler-oscillator circuits or a very high i.f. can be used to reduce the oscillator frequency. Crystal controlled oscillators can be used when the i.f. channel is a tunable receiver.

Here again, an r.f. stage is advantageous to prevent the oscillator from radiating, and to obtain the best signal-to-set-noise ratio, the gain of the r.f. stage being higher than for the mixer, with its output riding over subsequent noise in the receiver. The use of sections of transmission lines instead of coils can improve gain and simplify adjustment and ganging.

High signal input resulting from the use of a carefully designed antenna and feed line, and properly adjusted coupling to the input circuit of the receiver, are essential in obtaining maximum performance. Balanced or shielded feed lines, to reduce pick-up of undesired outside noise, are helpful. The best antenna systems are generally those that are most effective at angles close to the horizontal.

Transmitter Theory

At ultra-high frequencies, simple but well constructed stabilized oscillators coupled directly to the antenna are satisfactory for c.w. at 28 and 56 megacycles, and for modulated waves above 60 Mc. Master oscillators can be built to drive modulated amplifiers with adequate frequency stability. Where highly stable transmission is desired, however, the tendency among amateurs is to use a crystal

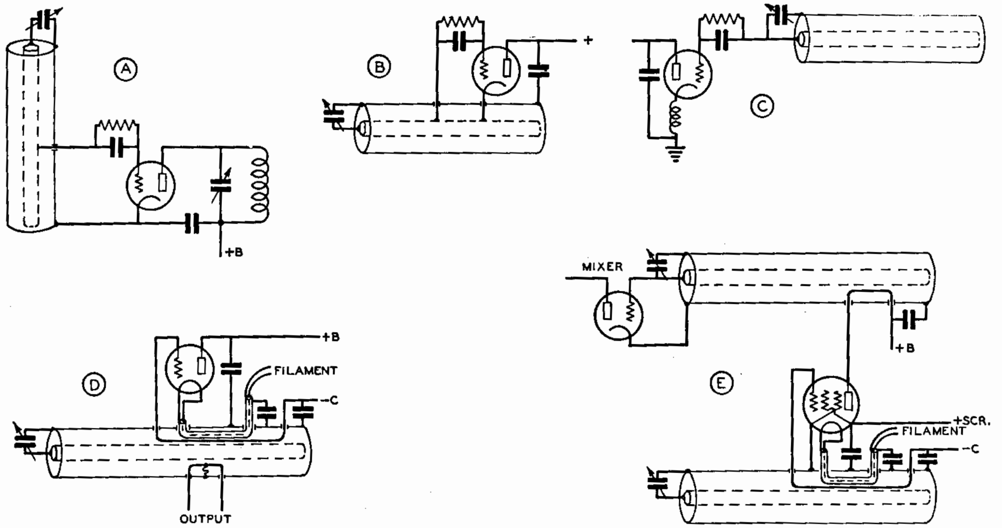

Figure 8.

TYPICAL COAXIAL LINE CONTROLLED OSCILLATOR CIRCUITS.

(A) Concentric line tuned grid, coil tuned plate oscillator. (B) Cathode-above-ground type oscillator circuit with concentric line. (C) Single control oscillator circuit without tap on line, although stability can be increased by tapping the grid down. (D) RCA's oscillator circuit used in a broad band transmitter having good stability, requiring only one tuned circuit. (E) Similar to (D) but showing pentode tube and balanced loop coupling to mixer stage. All coaxial tanks are shorted at the end opposite the tuning condenser.

or electron coupled oscillator at a lower frequency, followed by frequency multipliers. This arrangement provides good stability under modulation but may drift in frequency more with heating than will a well designed transmission-line-controlled u.h.f. oscillator.

Single-ended oscillator and amplifier stages are often used, but there is reason to prefer push-pull circuits in order to reduce tube capacity across resonant circuits, to obtain balanced arrangements, and to reduce the importance of the cathode leads.

In oscillators, it is highly important to have a lightly loaded, high Q circuit to control the frequency. Such circuits can substantially reduce hum, drift and frequency modulation. Partial neutralization is a help. A concentric line (when not used with a poor loading condenser) with loose coupling to the grid of the oscillator tube will turn out a good job in a single-ended or push-pull circuit. More commonly, parallel rods are used in push-pull circuits, particularly in plate circuits; if they have a large diameter, remarkably good stability can be obtained.

Due to the appreciable length of cathode leads in terms of wavelength at ultra-high frequencies, push-pull transmitters sometimes become inoperative or unusually inefficient as the frequency is raised. A section of small-size transmission line electrically a half wavelength long can be used to interconnect filaments and place them at ground potential, as indicated by figure 13. The shorting bar can be moved to the place where output is greatest or, in some cases, to the only place where oscillation will occur. This application of resonant lines should not be confused with the tuned-plate tuned-grid circuit in which the grid line is moved around to the filament and adjusted to provide the reactance common to grid and plate circuits necessary to maintain oscillation.

Neutralizing condensers are often used on

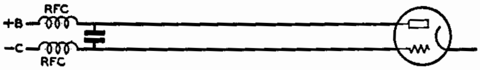

Figure 9.

SIMPLIFIED SCHEMATIC OF SINGLE TUBE OSCILLATOR USING RESONANT LINE WITH PARALLEL CONDUCTORS.

Tubes with an amplification factor of more than 10 are not well suited for use in this circuit. The blocking condenser serves as a shorting bar when frequency adjustment is required. The amount of feedback can be controlled over certain limits by varying the bias resistor or bias voltage.

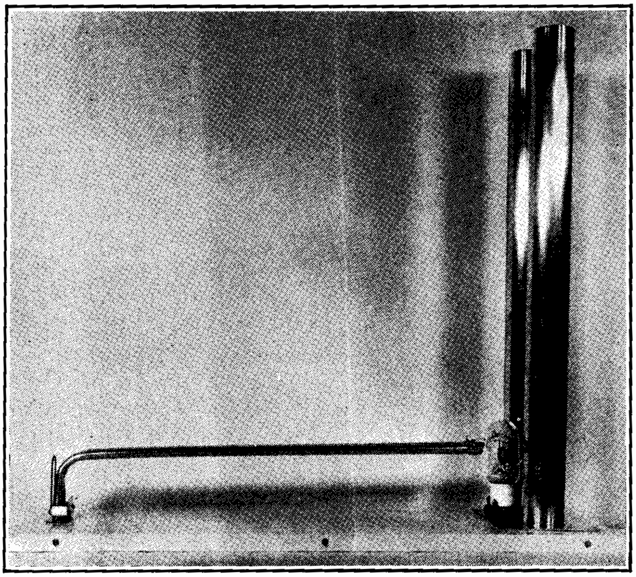

Figure 10.

TYPICAL U.H.F. PUSH-PULL OSCILLATOR USING CLOSE-SPACED RESONANT PIPES FOR FREQUENCY CONTROL.

A "Twin-30" special u.h.f. dual triode is used and permits high efficiency at 224 Mc.

u.h.f. oscillators, being adjusted on either side of true neutralization, in order to control the amount of feedback and to reduce the effect of tube and plate circuit variations upon the frequency-controlling grid circuit.

Two band operation in oscillators using parallel rods can be arranged conveniently by shorting the open end of the grid control line with a second shorting bar, and readjusting the plate circuit. The resulting half wavelength grid line is loaded by the tube input capacity, making it desirable to slide the grid taps down farther, and requiring a very much shortened line. For instance, a quarter wavelength grid line on 112 megacycles may be 19 or more inches long, whereas a loaded half wavelength line on 224 megacycles may turn out to be only 9½ inches, making it necessary to slide the upper or second shorting bar down from the former open end of the line.

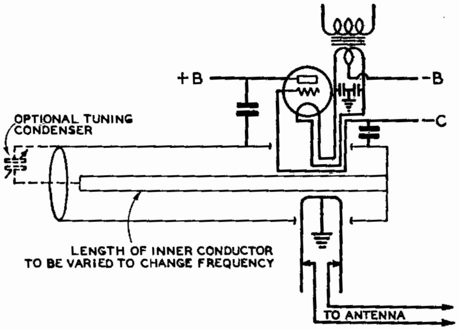

Figure 11.

COAXIAL PIPE OSCILLATOR USING SINGLE TANK CIRCUIT.

The frequency can be varied either by the optional tuning condenser shown or by varying the length of the inner conductor of the concentric line.

As in the case of receivers, good antennas are helpful, and low angle power is most useful. Less trouble is reported with the proper adjustment of antennas for transmitting than for receiving, however, probably because there is power available with which to work.

Amplifier Hints

The driving power required by an amplifier tube can be high if there are leads of any appreciable length from the grid or plate to any tuning condenser other than one used as a shorting bar on a pair of rods, or if the condenser has a long inductive path through its frame. The returns from these circuits to the cathode are important, especially in single-ended stages. Lead inductance can be reduced by using copper ribbon or tubing for connections, instead of smaller wire.

Frequency doublers have been used to 224 megacycles. Push-pull triplers, especially when some regeneration is permitted by using a dual frequency grid circuit or a tuned cathode circuit, are highly satisfactory even

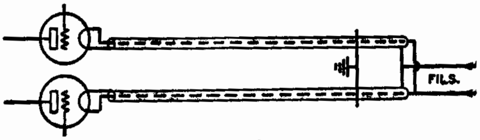

Figure 12.
Arrangement for using shortened ½-wave line in filament circuit to put both filaments at exact ground potential.

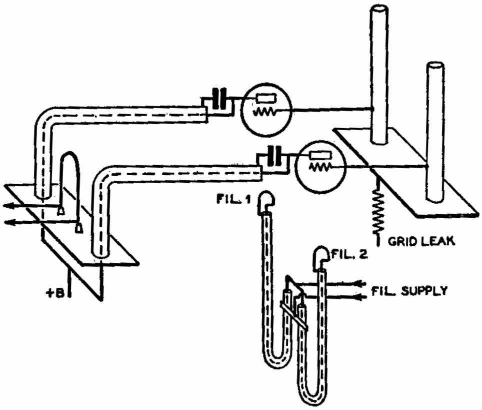

Figure 13.
Practical physical layout for push-pull oscillator using resonant lines in filament, grid, and plate circuits.

above 224 Mc. when suitable tubes are used.

Oscillation difficulties often arise in beam tetrodes due to the resonant frequency of the screen circuit. Where this occurs and cannot be corrected by changing the screen by-pass condenser or its position, a small choke can be inserted in the screen lead before the by-pass condenser.

Both in receivers and transmitters, regeneration or oscillation often results from the use of cathode bias, not adequately by-passed for u.h.f. Ordinary by-pass condensers have considerable inductance in them which combined with their capacity may place a sizable reactance in common with the grid and plate returns. Small silvered mica condensers have sometimes proved better than units of average size and higher capacity. Special u.h.f. sockets with built in by-pass condensers can be used to advantage above 200 Mc.

Centimeter Waves and Microwaves

With the advent of specially built tubes, it is no longer difficult to obtain appreciable power at ¾ meter (75 centimeters, 400 megacycles) and beyond. The W.E. 316-A will deliver five watts or more at 400 Mc., while the RCA 1628 as an amplifier is rated at 50 watts input at 500 Mc. and 43 watts at 675 Mc., the output depending on the circuit and efficiency.

A relatively new development is the velocity-modulated Klystron, with which an output of a hundred watts can be obtained at 750 Mc. in an oscillator-amplifier set-up. The tube is like a cathode ray tube, with the stream of electrons passing a hole in a surrounding copper can.

Due to the "cavity resonance" of the chamber, which is essentially a self-enclosed quarter-wave transmission line, power is developed within it which can be delivered to the load by means of a half-turn coupling loop. These tubes are available under the description "RCA-825 Inductive Output Amplifier." They are designed for use at frequencies of 300 Mc. and *above*, where they are capable of power outputs of 35 watts. A relatively high degree of efficiency is attainable with this type of amplifier stage, 60% efficiency being typical at 500 Mc. Power is placed on the "collector," or plate, which is rated at a maximum of 2000 v.d.c. and 50 ma. The higher voltages required on the other elements are attainable at low-cost, as in cathode-ray tube circuits, because of the insignificant current required. The rated collector dissipation of the tube is fifty watts.

Further U.H.F. Data. For information on transmitters, receivers and antennas for use on the ultra-high frequencies, turn to Chapters 18, 19 and 21.