Sept 5, 2011

G5RV ANTENNA HISTORY

This information from the 1936 Antenna Handbook by the staff of “Radio Magazine” pre-dates Louis Garvey’s first published works by a decade.

This information is similar to the G5RV and is valuable information for those designing Multi-band antennas.

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The RADIO ANTENNA HANDBOOK

THE

RADIO
ANTENNA HANDBOOK

BY

THE ENGINEERING STAFF OF "RADIO"

Under the direction of

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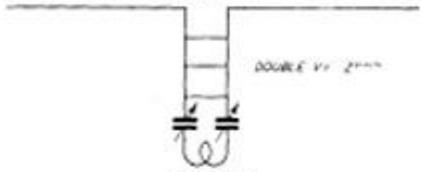


Figure 8
The "Double Zepp." See Figure 7.

Zepp. Feeder Table

Feeder Length	Voltage Fed	Current Fed
$\frac{\lambda}{8}$	Parallel	Series
$\frac{3\lambda}{8}$	Series	Parallel
$\frac{5\lambda}{8}$	Parallel	Series
$\frac{7\lambda}{8}$	Series	Parallel
$\frac{9\lambda}{8}$	Parallel	Series
$\frac{11\lambda}{8}$	Series	Parallel

The feeders can be shortened from the lengths shown up to about 10% of a half wave at the operating frequency without changing the tuning system. Feeder spacing is not critical, 6" being about average. Spacing may be decreased at the higher frequencies, and vice versa.

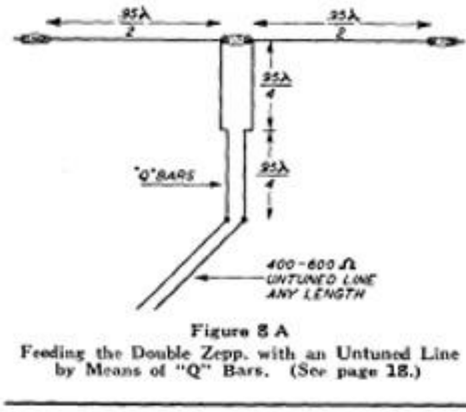


Figure 8 A
Feeding the Double Zepp. with an Untuned Line by Means of "Q" Bars. (See page 18.)

The Collins Multiband Antenna System

The Collins Multiband Antenna System is a special type of center-fed Zepp. using copper tubing as the resonant feeders in order to minimize the losses inherent in this type of feeder. The simplest type of multiband antenna, known as the Type A, consists of a half-wave radiator at the lowest desired frequency, plus two copper tubing feeders which are each exactly a quarter wave long. See figure 9. As the feeders are exactly the right length to make them resonant at the operating frequency and all its even harmonics, the station end of the feeders acts like a pure resistance (without any reactive components) and thus no loading coils or condensers are needed at

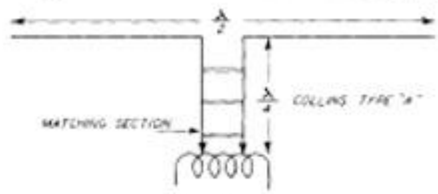


Figure 9
The Type A "Multiband" Antenna System (Center-fed Zepp. with Special Feeders).

the station end to tune this system. The nominal input impedance is twelve hundred ohms on all bands. Thus there is high voltage at the station end which, though generally undesirable, is satisfactory in the Collins version of the center-fed Zepp. due to the special construction of the feeders. The main advantage of the Collins feeder system over the conventional center-fed Zepp. lies in the fact that the characteristic impedance of the feeders instead of being 600 ohms, as in the usual Zepp. antenna with 6 inch feeder spacing, is 300 ohms in the Collins version. This has a very marked advantage in that the input resistance of the feeders never goes above approximately 1200 ohms instead of the 5000 ohms it would become under certain conditions when using the conventional feeders with six inch spacing. The radiation resistance at the center of a half-wave Hertz antenna is 75 ohms on its fundamental frequency and approximately 1200 on all of its even harmonics. The geometric mean between 75 and 1200 ohms is 300 ohms, which is the ideal characteristic impedance of the feeders for a minimum of standing waves. The standing waves are not eliminated from the line due to the fact that there is always an impedance mismatch between the feeders and the antenna, but as the feeders are particularly designed for low losses, the actual measured efficiency of the feeders runs about 97% for moderate lengths. The design formulas for the type A Collins multiband antenna are as follows:

$$\text{Antenna length in feet} = \frac{(K-.05)\ 492{,}000}{f_{kc}}$$

$$\text{Feeder length in feet} = \frac{234{,}000\ M}{f_{kc}}$$

Where

K = number of half wave lengths desired.
f_{kc} = frequency in kilocycles.
M = number quarter wave lengths desired.

Several different models of such an antenna system are possible and Table I shows representative combinations designed for use on amateur bands. In each of the arrangements shown in Table I the length of the multiband transmission line is so chosen that the reactance at the transmitter end is negligible and the line can be coupled to the output tank circuit of the transmitter by a simple pickup coil. An impedance matching network need not be used provided the number of turns in the pickup coil is continuously adjustable. The feeders can be tapped on each side of a split plate tank through .002 μμfd. blocking condensers. Figures B, E, J, K, O, and Q on pages 35 and 36 show different methods of coupling the Collins feeders to various types of plate tanks.

In cases when it is not convenient to use a transmission line as long as is shown in Table I it is, of course, entirely practicable to reduce the length of the line to a convenient value and build out the equivalent electrical length by inserting an impedance matching network between the transmitter and the line. When such a network is used the line can be made any length, and then

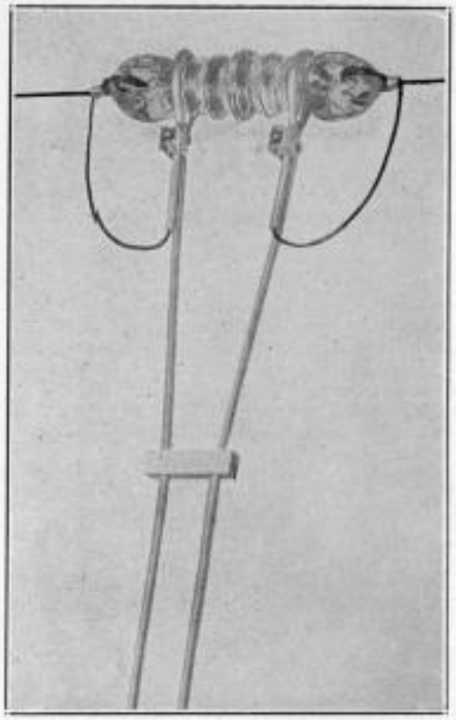


Figure 10
Showing how the "Multiband" line is connected to the antenna.

the only important dimension is the antenna itself. The only precaution which must be observed is that the transmission line should not be ⅛, ⅜, ⅝, etc. wave length long at any of the operating frequencies. If the line happens to be cut to a length equivalent to an odd number of ⅛ wave lengths, trouble may be encountered due to the network transmitting not only the fundamental fre-

TABLE I
MULTIBAND ANTENNA SYSTEM DATA

Model	A	B	C	D	E	F	G
Antenna Length—Feet	136	136	275.5	250	67	67	103
Feeder Length—Feet	66	115	99	122	65	98	82.5
Frequency Range Mc.	3.5- 4.0 7.0- 7.3 14.0-14.4	3.7- 4.0 14.0-14.4	1.7- 2.0 3.5- 4.0 7.0- 7.3 14.0-14.4	1.7-2.0 3.7-4.0	7.0- 7.3 14.0-14.4 28.0-29.0	7.0- 7.3 14.0-14.4 28.0-29.0	3.7- 4.0 7.0- 7.3 14.0-14.4
Nominal Input Impedance	1200 ohms All Bands	75 ohms All Bands	1200 ohms 1.7, 3.5, 14 Mc. 75 ohms 7 Mc.	1200 ohms All Bands	75 ohms 7 Mc. 1200 ohms 14 Mc. 28 Mc.	1200 ohms All Bands	1200 ohms All Bands

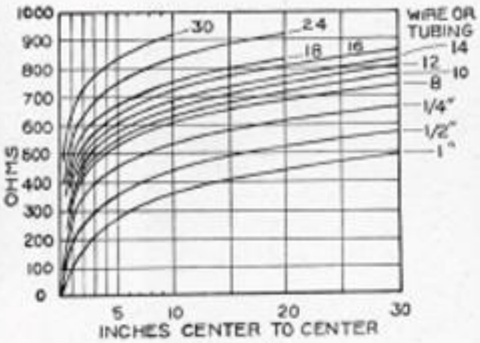


Figure 11
Conductor and Spacing Versus Line Impedance.

quency but also harmonic frequencies. This difficulty can be overcome by proper adjustment of the impedance matching network, but in general it is better to avoid these specific lengths.

Table I can be used directly for designing multiband antennas for amateur use. It will be noticed that the antenna lengths shown are an even number of one-quarter wave lengths long at the lowest and highest frequencies. In the case of antennas for 14,000 kc. and 4,000 kc. operation the frequencies are not harmonically related, but the lengths are chosen for the highest frequency, and they are also approximately right for the lower frequency where small variations in length do not represent very large percentages of a wave length.

In designing similar systems for other groups of frequencies, the antenna length should be (k—.05) 492,000/f ft. where f is the frequency in kilocycles and k is the number of half-wave lengths. Thus, for two or more frequencies integral values of k should be chosen to give approximately the same length and the exact length should be that for the highest frequency.

For example, consider a model A antenna. At 14,300 kc. and k = 4 (a two wave length antenna) the length is 136 feet. This length is also correct for f = 7,050 and k = 2 or f = 3440 and k = 1. The frequency range of the amateur bands may be tolerated by this length even though the transmission line be terminated in an antenna impedance not a pure resistance.

The feeder length should be determined by the relation 234,000 m/f feet where f is the frequency in kilocycles and m is the number of quarter wave lengths. That is, the 66 ft. feeder of model A antenna is one wave length at 14,200 kc., a half-wave length at 7,100 kc., and one-quarter at 3,550 kc.

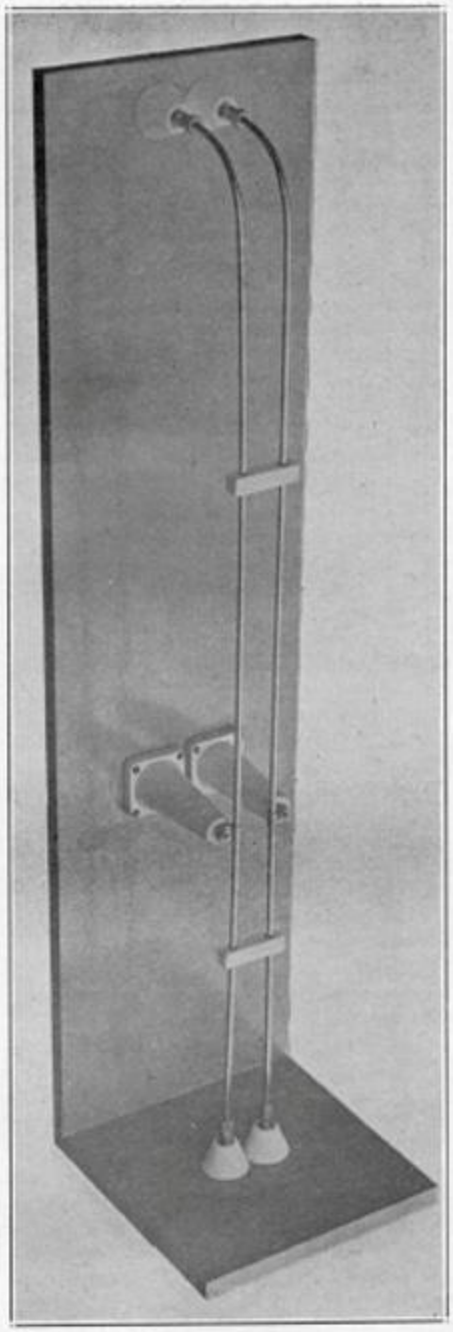
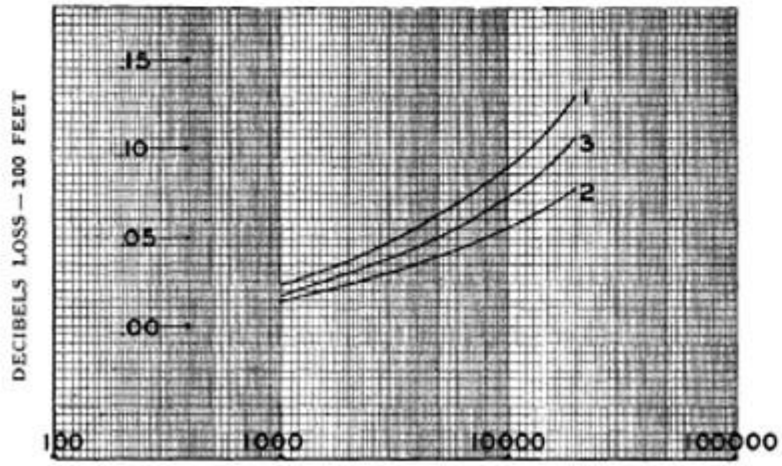


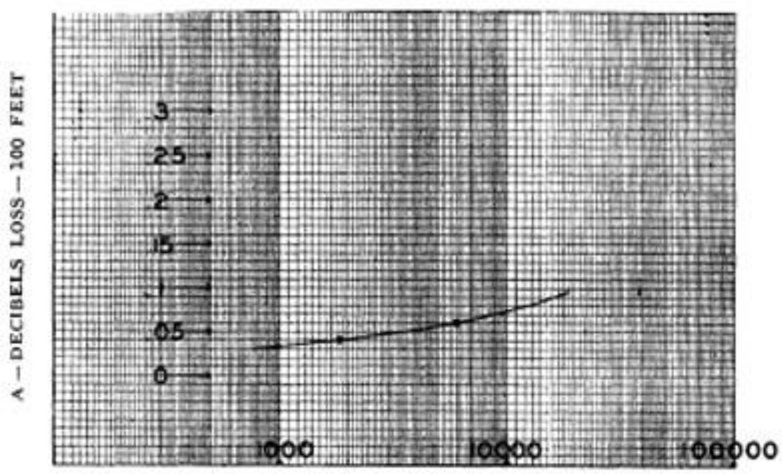
Figure 12
The constructional model illustrated above shows the manner of assembly. The spacers hold the ¼ seamless copper tubing rigidly at 1½ inch spacing. The stand-off insulators and feed-through insulators facilitate installation. Oil-impregnated wood spacers may be used in amateur multiband installations.



FREQUENCY — KILOCYCLES PER SECOND

LOSS VERSUS FREQUENCY (COMPUTED LOSS PLUS 50%)

1—No. 12 hard drawn copper spaced 6" (Z equals 600)
2—¼" copper tubing spaced 1½" (Z equals 300)
3—¾" aluminum tubing spaced 1½" (Z equals 300)



FREQUENCY — KILOCYCLES PER SECOND

LOSS VERSUS FREQUENCY

(Measured Loss)

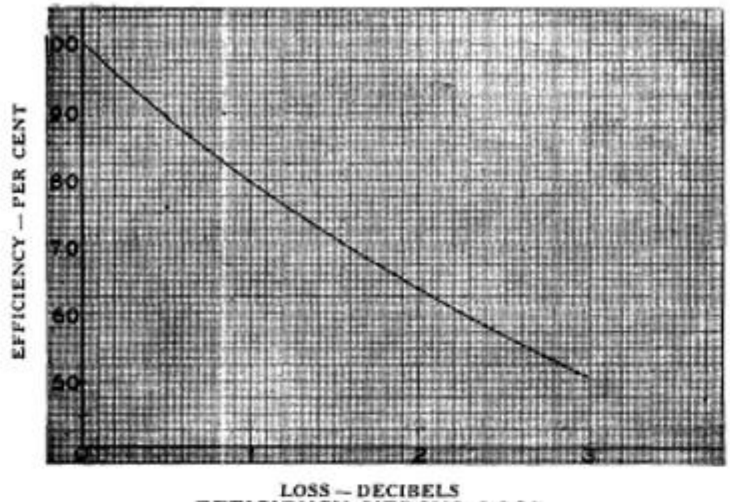
¼" COPPER TUBING SPACED 1½". (Z EQUALS 300 OHMS)

Velocity of Propagation Equals 95% of Free Space

(Z = Surge Impedance of Line)

A slight variation from the above procedure is indicated in Model G. In this antenna the length of 103 feet is 1½ wave lengths at 14,100 kc. and approximately ¾ and ⅜ wave lengths on the 40 and 80 meter bands. The feeder length of 82.5 feet is 1¼ wave lengths at 14,200 kc. and approximately ⅝ and 5/16 wave lengths at the 40 and 80 meter bands. That is, on 40 and 80 meters the transmission line is terminated in an impedance largely reactive but is of such length that the impedance at the input to the transmission line is approximately a pure resistance. The loss in the transmission line is slightly larger under this condition, but this antenna may be used successfully where space is a factor.

Many amateurs are using so-called "Zeppelin" antennas rather than antennas fed at the center because their transmitters happen to be located nearer the end than the center of the antenna and the transmission line is shorter if it is connected to the end of the radiator. The Zeppelin antenna is an



EFFICIENCY VERSUS LOSS

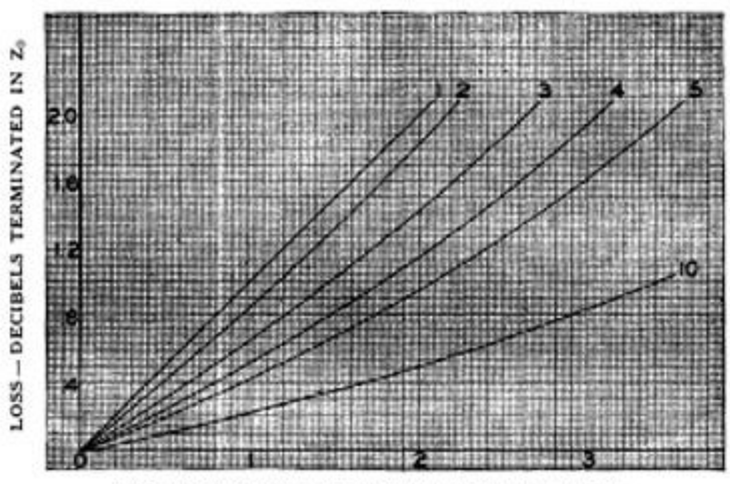


CHART FOR DETERMINING LOSS IN GIVEN TRANSMISSION LINE DUE TO AN IMPEDANCE MISMATCH
(Number on Each Curve Indicates Impedance Ratio)

inherently unbalanced system (Zeppelin feeders balanced for equal currents are not balanced for equal phase and vice-versa) and a considerable portion of the energy is unavoidably radiated from the feeders, which radiation may or may not be useful for transmission. The multiband system just described should receive preference over the Zeppelin arrangement even if the transmitter is close to one end of the antenna, because the additional loss introduced by running the transmission line horizontally to a point under the center of the antenna, then vertically to the antenna itself will be entirely negligible, and probably will be considerably less than the loss in Zeppelin feeders. The multiband feeders are readily supported from suitable stand-off insulators and can be carried around corners by making bends having a minimum radius of about 10 inches. It is entirely feasible to double back the line in trombone fashion, if desired, to obtain a length which will obviate the use of an impedance matching network.

The type B Collins two-band antenna (see table on page 12) is particularly interesting to the phone man due to the fact that the nominal input impedance of the feeders is

Frequency in kilocycles	Quarter wave feeder section	Half-wave radiator
3500	66' 10"	133' 7"
3600	64' 11"	129' 10"
3700	63' 2"	126' 4"
3800	61' 6"	123'
3900	59' 11"	119' 10"
3950	59' 2"	118' 4"
4000	58' 5"	116' 10"
7000	33' 5"	66' 9"
7050	33' 2"	66' 4"
7100	32' 11"	65' 10"
7150	32' 9"	65' 4"
7200	32' 6"	64' 11"
7250	32' 3"	64' 6"
7300	32'	64'
14,000	16' 9"	33' 5"
14,100	16' 7"	33' 2"
14,200	16' 5"	32' 11"
14,300	16' 4"	32' 9"
14,400	16' 3"	32' 6"
28,000	100'	16' 8.5"
28,500	98.4"	16' 5"
29,000	96.5"	16' 1.5"
29,500	94.8"	15' 10.5"
30,000	93"	15' 7.5"
56,000	50"	100"
57,000	49.2"	98.4"
58,000	48.3"	96.5"
59,000	47.4"	94.8"
60,000	46.5"	93"

Length Versus Frequency Table for Johnson Q and Collins Multiband Antenna Systems.

75 ohms on both bands. Thus, if it is not convenient to bring the lower end of the feeders directly in the operating room, a twisted pair transmission line can be attached to the lower end of the feeders and then run any reasonable distance back to the operating room. This particular application of the "Multiband" antenna brings out very strongly its resemblance to the "Johnson Q" antenna, except for the fact the "Q" antenna is useful only on one band.

The Linear Transformer

Every quarter wave Zepp. feeder acts as an impedance matching transformer, and an understanding of this method of impedance transformation serves to explain the theory of operation of the Collins Multiband antenna and the Johnson Q antenna. It is possible to construct a wide variety of quarter-

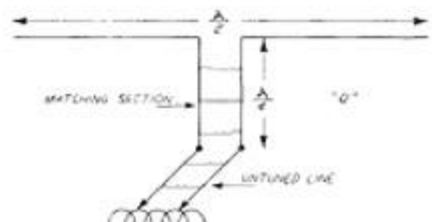


Figure 13
The Johnson Q Antenna.

wave Zepp. feeders all of which may be resonant to the same frequency but which differ in the wire size and the wire spacing used. Upon the wire size and the wire spacing depends what is known as the average, characteristic surge impedance of the particular resonant, quarter-wave matching section (matching transformer or Zepp. feeder; call it what you will). Let us take for example a quarter-wave Zepp. feeder consisting of no. 12 wire spaced six inches, which happens to have a surge impedance of 600 ohms. Let the far end be terminated with a pure resistance and let the near end be fed with radio frequency energy at the frequency for which each feeder is a quarter wavelength long. If an impedance measuring set is used to measure the impedance at the near end while the impedance at the far end is varied, an interesting relationship between the 600 ohm characteristic surge impedance of this particular quarter wave matching line and the impedance at the two ends will be discovered. When the impedance at the far end of the line is the same as the characteristic surge impedance in the line itself (600 ohms) the impedance measured at the near end of the quarter wave line will also be found to be 600 ohms.

Incidentally, the line, under these conditions, would not have any standing waves on it, due to the fact that it is terminated in its characteristic impedance. Now let the resistance at the far end of the line be doubled or changed to 1200 ohms. The impedance measured at the near end of the line will be found to have been cut in half and

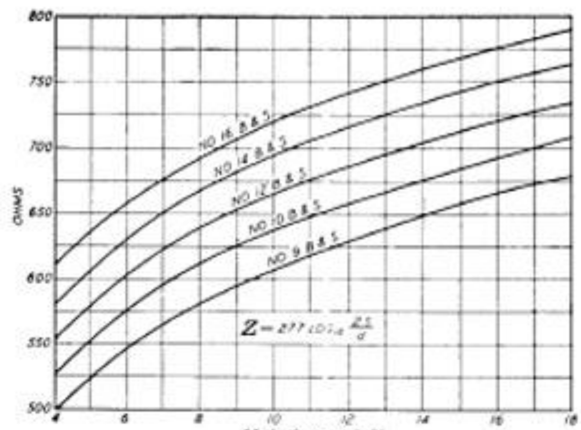


Figure 14
Characteristic Surge Impedance for Open Wire Lines of Various Spacings and Conductors. For Q Bars see Figure 11.

is now 300 ohms. If the resistance at the far end is made half the original value of 600 ohms, or 300 ohms, the impedance at the near end doubles the original value of 600 ohms and becomes 1200 ohms. Therefore as one resistance goes up the other goes down proportionately. It will always be found that the characteristic surge impedance of the quarter-wave matching line is the geometric mean between the impedances at both ends. This relationship is shown by the following formula:

$$Z_{MS} = \sqrt{Z_A Z_L}$$

where

Z_{MS} = Impedance of matching section.
Z_A = Antenna resistance.
Z_L = Line impedance.

The Johnson Q Antenna

The above formula is used in determining the proper spacing for the quarter-wave tubes used in the Johnson Q antenna. When the Q is used as a half-wave Hertz antenna, the spacing of the aluminum tubes which comprise the quarter wave matching transformer should be such that the **characteristic surge impedance equals the geometric mean between the radiation resistance of the antenna and the characteristic surge impedance of the non-resonant line** which conveys r.f. energy from the transmitter to the station end of the quarter wave matching transformer.

The standard form of the Johnson "Q" is shown in figure 13.

Figures 11 and 14 show in graphical form the characteristic impedance of several common transmission lines or matching transformers. From these curves can be determined the characteristic impedance of the particular type of non-resonant line that is to be used between the station and the Johnson Q matching section. Then by putting this value of surge impedance and the radiation resistance in the formula shown above the geometric mean of these two values can be determined. This geometric mean is the required value of characteristic surge impedance for the quarter wave matching section and again, from the graph of figure 11 the proper spacing for the tubing used in the

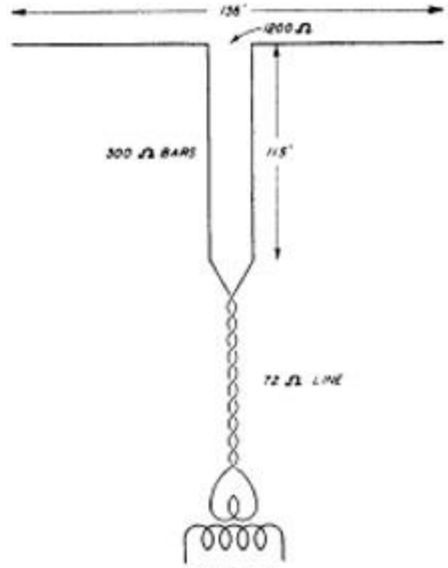


Figure 15
Collins Type B Multiband Antenna Fed with Twisted Pair (Any Length). Useful on Both 20 and 80 Meters. See Table I, Page 12.

matching section can be determined. While it is generally assumed that the radiation resistance of a half wave antenna measured at its center is 72 ohms, this value assumes the presence of no nearby objects and that the antenna is either exactly a half wave high or is remote from the earth. As a practical matter the radiation resistance of an antenna can depart quite widely from its assumed value of 72 ohms for a half-wave Hertz, and there is no simple and accurate means of measuring the actual

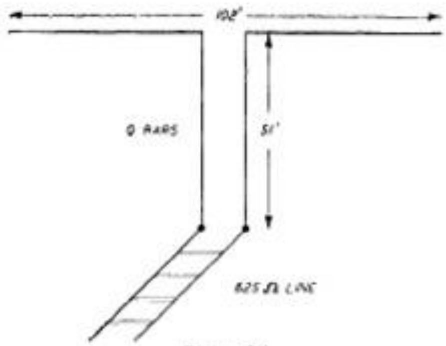


Figure 16
Spec'al Two-Band Q Antenna, 3.8 to 4.0 Mc. and 14.0 to 14.4 Mc.

radiation resistance. Thus, from a theoretical standpoint, the Johnson Q and the Collins Multiband antennas are highly efficient, but as a matter of practice considerable cut and try variations from theory are necessary to obtain maximum performance from these antennas. However, 15% variation in spacing of the matching section causes little loss.

Another useful type of Q antenna is shown in figure 16. It operates on two bands, 3.8 to 4.0 Mc. and 14.0 to 14.4 Mc.

Non-Resonant or Untuned Transmission Lines

The tuned transmission lines used in Zepp. antenna systems do not have an even distribution of voltage and current on them, due to the presence of standing waves. Thus in order to operate properly, the electrical length of a resonant transmission line is quite critical. In the non-resonant transmission line there is a smooth and even distribution of voltage and current along the line and the line length can be anything up to several thousand feet without material loss of energy. The only critical characteristic about the untuned line is its termination at the antenna end. It is the reflection from the antenna end which starts waves moving back toward the transmitter end. When waves moving in both directions along a conductor meet, standing waves are set up.

All transmission lines have distributed inductance, capacity and resistance. Neglecting the resistance, as it is of minor importance in short lines, it is found that the inductance and capacity per unit length determine the characteristic, or surge impedance of the line. When any transmission line is terminated in an impedance equal to its surge impedance, reflection of energy does not occur and no standing waves are present. When the load termination is exactly the same as the line impedance it simply means that the load takes energy from the line just as fast as the line delivers it, no slower and no faster. Thus for proper operation (with standing waves and associated losses eliminated) some form of impedance-matching arrangement must be used between the transmission line and the antenna, so that the radiation resistance of the antenna is reflected back into the line as an impedance equal to the line impedance.

The use of a linear transformer in the Johnson Q and the Collins Multiband antennas, and the quarter-wave stub section in the J and T types of matched-impedance antennas act as the means of transforming the antenna resistance into the equivalent of the line impedance. Remember that the radiation resistance of a half-wave antenna varies from 73 to 2400 ohms, measuring out from the center to each end. As most commonly-used lines have a characteristic impedance of between 400 and 600 ohms (excepting the twisted pair and the concentric lines, which will be discussed later), matching a line to an antenna is not a simple matter. If the line is to be directly attached to the antenna, it must be attached at a point where the antenna impedance is the same as the line impedance.

The Two-Wire Open Line

As the impedance of a line depends on its distributed inductance and capacity,

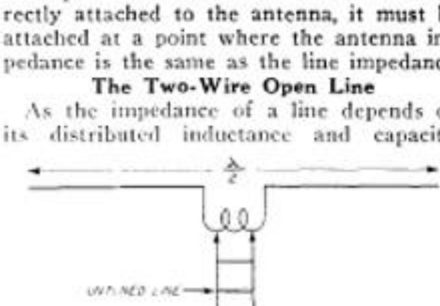


Figure 17
One of Many Possible Methods of Coupling an Untuned, Open-Wire Line.

which are functions of the wire size and spacing, the impedance may be obtained directly from the following formula.

$$Z_s = 277 \log_{10} \frac{S}{R}$$

Where: Z_s is the characteristic impedance of the line, S is the wire spacing, and R is the **radius** of the wire (one half of the diameter of the wire). Note that R and S can be in any units as long as the same units of measurement are used in both cases. What is required is the **ratio** between the two, not their actual absolute measurements.

The chart shown in figure 14 on page 21 shows line impedance against conductor spacing for several commonly used wire sizes. Figure 17 shows one way of using an untuned two-wire line to couple the transmitter to the antenna.

The Coaxial (Concentric) Line

The characteristic impedance of a coaxial (concentric) line may be determined from the formula

$$Z_s = 138.5 \log \frac{R_o}{R_i}$$

Where: Z_s is the line impedance, R_o is the inside radius of the outer tube, and R_i is the outside radius of the inside tube.

Short lengths of concentric line may be constructed by stringing glass beads on no. 12 wire, crimping them into position, and threading through quarter-inch copper tubing.

The Twisted Pair Untuned Line

The recent development of low-loss, low-impedance transmission cable for use at the high frequencies (such as EO1) allows a very flexible transmission line system to be used to convey energy to the antenna from the transmitter. The low-loss construction is largely due to the use of low-loss insulation plus a good grade of weatherproof covering. The older twisted flex cables used by amateurs had quite high losses and should be avoided. Generally avoid stranded cable at the high frequencies, as solid conductors usually have less r.f. resistance.

A twisted-pair line should always be used as an untuned line, as standing waves on the line will produce excessive losses and can easily break down the line insulation.

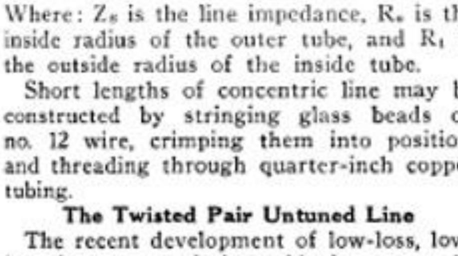


Figure 18
Half-Wave Doublet Fed with 72 Ohm Twisted Cable.

The radiation from twisted-pair lines, for a given slight amount of reflection loss, is much less than for a two-wire 600 ohm line with the same amount of reflection. However, the resistance and dielectric losses in the twisted-pair line run considerably higher

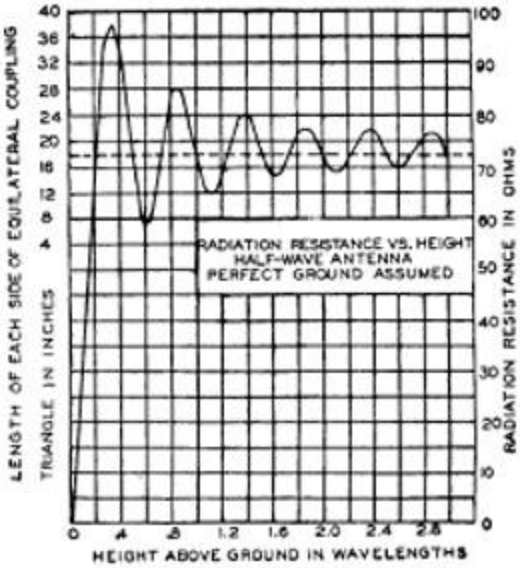


Figure 19
Height of Radiator (Half Wave) Versus Radiation Resistance. Triangle Size Correct for 80 Meter (3.7 Mc.) Band. Divide by 2 for 40 Meters, 4 for 20 Meters, Etc.

than for the 600 ohm line. If the line is to turn many sharp corners, the twisted pair is far superior to the 600 ohm line.

The twisted pair line is particularly satisfactory in mobile applications where a transceiver might be mounted on the dashboard of a car and the antenna mounted on the rear or front bumper. See figure 27. For turning sharp corners and running close to large bodies of metal the twisted pair is almost as good as the coaxial (concentric) tubing line, whose cost unfortunately places it out of reach of the average amateur at the present time.

Coupling to the Antenna

Coupling at the antenna deserves careful attention. In the following discussion the antennas are shown horizontally, though manifestly the half-wave types at least can be operated vertically if purely non-directional, low-angle transmission is desired.

The line should leave the antenna for some distance at right angles to the antenna wire, or at least at an angle of 45 degrees or more, to avoid standing waves along the line.

It has been said that a 72 ohm line matches the **average** impedance of a half-wave antenna, still assuming the antenna to be horizontal. However, as figure 19 shows only too clearly, we cannot simply let it go at 72 ohms, for the various heights of antennas may present us with the need of matching

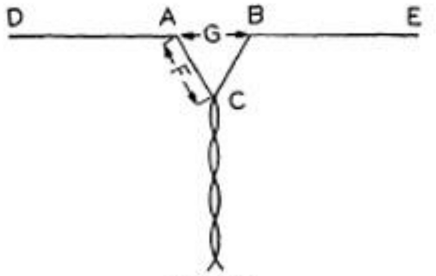


Figure 20
Reference Schematic of the Doublet of Figure 18.

antennas with impedances all the way from 60 to 100 ohms. Figure 19, by the way, refers to "effective" height, but this is reasonably close to actual height over most soils. In some extreme locations tin roofs, trees, and houses reduce the effective height to a small fraction of the height above earth, but in a doubtful place one may first try ¾ of the actual height, applying that to the curve of the figure 19 to get the impedance at the center of the antenna.

The "Y Match"

The "Y match" method of figure 20 is a common and simple means of adjusting the line impedance to the antenna impedance. A length "G" of the antenna-wire is removed and the line is "forked" for some distance back, shown as "F" in figure 20. It is convenient to make F and G the same length. These lengths are shown on the left edge of figure 19, and these figures are the important ones—those at the right being of academic, rather than practical, interest.

Because the impedance of the line changes at the point C, and at the points A and B, there are small voltage "bumps" at these points. Those at A and B are relatively unimportant, and add nothing to the job of the insulators used to tie A and B together. The story is different at C, and it is accordingly important that moisture be kept out of the crotch, especially as it might work in along the paper-wrap of the wire. Plenty of rubber tape and the electrical repairman's old reliable friend "P & B insulating paint" will do the trick. If "P & B" is strange to you, ordinary automobile top dressing will do nicely—not the thin stuff like "Duco", but the more "gooey" kind.

Delta Match

It is mechanically simpler to leave the antenna wire uncut, and to bridge the split line across a portion of the uncut antenna. This "delta" method of matching is not as flexible as to frequency, and for that reason, perhaps, is in little use among amateurs for low impedance lines. It is quite practical, though the triangle dimensions are not those given by figure 19.

Harmonic Operation

If a horizontal antenna is made 3/2, 5/2 or 7/2 wave long instead of ½ wave, we increase the horizontal directive effect. The total radiation is not changed materially, but more of it goes in particular directions. This is shown by figure 21. In the top di-

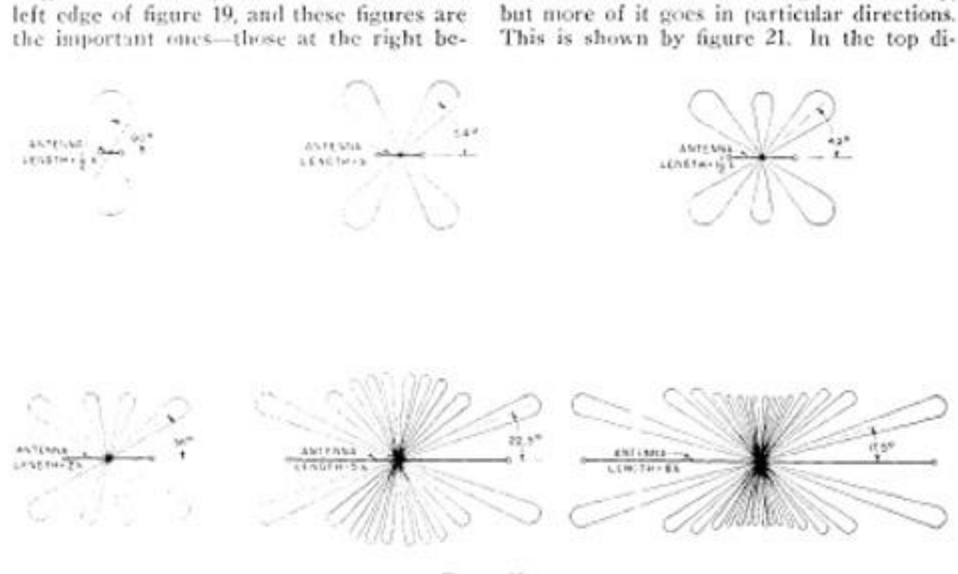


Figure 21
Approximate Field Pattern of Harmonically Operated Antennas, Showing Angles of Radiation Lobes (Looking Down on Antenna from Above).

agram of that figure we are supposed to be looking down on a ½ wave horizontal antenna. The solid "figure 8" shows the directional effect.

In the 2d diagram we look down on a 3/2 wave antenna, showing the pattern of transmission: four broad loops at 42 degrees to the antenna.

The 5/2 wave antenna gives sharper loops at 33 degrees, while 7/2 gives some nice beams at 28 degrees.

Several things are to be noted. As the antenna is made longer the major directional lobes become narrower and consequently longer—meaning stronger—but also there are growing up at the same time smaller lobes, intentionally shown in somewhat exaggerated size, which do produce signals in additional directions and may puzzle the operator of the antenna who does not expect transmission in those directions.

Table II

Length of 72 ohm twisted-pair line (Type EO-1, with no. 12 wire, spaced 0.17" on centers) which produces 15% power loss.

Frequency	Wavelength (approx.)	Greatest permissible line length
1750 kc.	172 m.	650 feet
3500 "	85.5 "	325 "
7000 "	43 "	173 "
14,000 "	21.4 "	100 "
28,000 "	10.7 "	60 "
56,000 "	5.35 "	35 "

The impedance of these longer antennas, when "looked into" at their centers, is greater than that of a half-wave antenna, as shown by table III. With this in mind, a larger coupling triangle has been used to operate successfully odd-half-wave antennas up to and including 7/2 wavelengths.

Table III

Impedance at the center of various horizontal antennas at great height. Practical antennas will vary 25% both ways from these figures.

Length of antenna	Impedance
1/2 wave	72 ohms
3/2 "	100 "
5/2 "	118 "
7/2 "	125 "

The 7/2 Wave Antenna

The 7/2 wave system is very useful, in that 2-band operation is most practical. If the 7/2 wave antenna is made for 14,000 kc., we find that it is a ½ wave antenna for 2000 kc. Similarly a 7/2 wave 10.7 meter (28,000 kc.) radiator is a ½ wave antenna for 75 meter (4000 kc.) phone.

A 3/2 wave section for 20 meters (99 feet), operating as shown in the third diagram of figure 21, is also a good actor. The four main lobes (alone) cover much territory, the two smaller ones filling in between.

While the losses in a long, twisted-pair line are higher than for a high, straight, 600 ohm two-wire line, they are lower than those of the average single wire feeder.

Table II shows the losses to be expected with 72 ohm line-wire such as was first referred to. Such a table would be very complicated if all possible sorts of wire were to be included. Shorter feeders give a correspondingly lower loss.

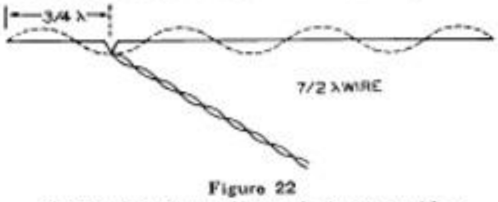


Figure 22
Method of Feeding a Harmonic Antenna with a Twisted Pair When It Is Physically Impossible to Center Feed It.

Off-Center Feeding

Where it is not physically possible to feed the center of the antenna, an arrangement such as that of figure 22 may be used. Since the (radiation) load is no longer the same for the two line wires their currents will not be quite equal, but the radiation pattern remains substantially unchanged. The line attaches at a current maximum point; that is, at an odd number of quarter-waves from the end.

Unequal line currents may also be found where one "half" of the antenna is not of the same length as the other "half". They may also be met where one end of the antenna is materially higher than the other, but in no case does much harm seem to result.

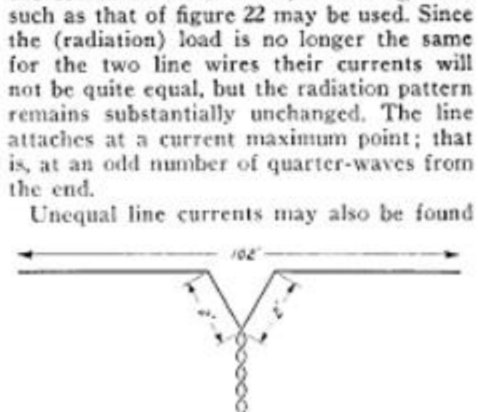


Figure 23
This 20-75 Meter "Compromise" Antenna Gives Excellent Results.