Say, you'd better read this one . . .

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Feeding That Antenna

I think that we will all agree that however good the transmitter or the operator—the station is no better than the antenna system. And, using the same logic, a good antenna is no better than the method used to feed it. We often tell a new ham that he may use any type of rig, but be sure to put plenty of time and effort into making sure that a good antenna is used. How many of us, however, heed our own advice? And, if we do, do we expend a little extra effort to see that the feed-line gets the r.f. to the antenna?

Twin-Lead

Many of us are using the popular receiving-type "Twin-Lead" to feed our transmitting antenna and this works well with low power under certain conditions, even though it was designed and intended for receiving use.

There is also available a transmitting type 72 ohm and 300 ohm "Twin-Lead". This cable will handle a kw., is easy to use and is quite efficient, providing it is kept clean. This is important if one hopes to prevent moisture from affecting the performance. The reason that moisture affects the performance of this type of cable is not that it penetrates the dielectric but that it changes the impedance due to the fact that the dielectric field between the two conductors takes in the air surrounding the insulating material as well as the material itself. Therefore, any moisture on the dielectric becomes part of the dielectric and changes the capacity between the conductors. The characteristic impedance of a transmission line is equal to the square-root of the inductance-to-capacity ratio ($Z=\sqrt{L/C}$). The capacity varies with wire size, spacing and dielectric. The dielectric of Twin-Lead includes the Polyethelyne insulation and the surrounding air and therefore any moisture on the line will change the dielectric constant, thereby changing the "C" factor and thus the impedance. This affect of moisture is smaller on the closer spaced lines and is at the minimum when the line is properly terminated. If your line has a very low standing wave ratio (SWR) in dry weather, then you will experience little change in loading in wet weather.

Cleaning Feed Lines

It is therefore recommended that anyone using this line lower his antenna occasionally and wipe the lead clean. The surface of the line is such that it will remain clean for quite some time. If this is too much trouble then it would be better, from the standpoint of efficiency under all conditions, to use coaxial cable or open-wire feed line even though the latter is a little harder to handle. Losses in the receiving type 72 ohm line per 100 ft. (at 28 Mc.) are 1.9 db while with the transmitting type they are 1.4 db and only .29 db at 3.5 Mc. Remember that every 3 db loss in the feed line (or anywhere else) is equivalent to cutting your power in half!

Coax

Coaxial cable, however, with its reduction of TVI problems is becoming more popular with hams day by day. When used properly these cables make excellent feed lines as proven by the fact that commercial companies use coaxial feed lines exclusively for TV, FM and Police radio—as its losses are very low below 300 Mc. However, as is the case with other solid dielectric feed lines, precaution must be taken to eliminate or minimize standing waves. This is especially important with coaxial cable as one cannot check the SWR with a neon bulb!

Pruning

One way to improve performance (at the higher frequencies) is to "prune" the feed line length so that it is non-reactive at the frequency of operation. While this may seem to be a "make-shift" proposition it is, nevertheless, a means of getting the utmost efficiency from solid dielectric cables as attested by the fact that directions for pruning are included with many types of h-f and v-h-f antennas furnished for police, mobile, marine and other commercial services by many well known companies.

For example, the ideal method of feeding that 1/4 wave whip antenna on your mobile job would be to use coax cable such as Belden or Amphenol #RG8/U. Although your transmitter may be only a few inches from the base of the antenna you should use about 8 to 10 ft. of cable to feed it. To find the correct length:

1st—With the feed line disconnected tune the transmitter final tank with circuit to resonance **at the desired frequency of operation** and note the setting of the dial.

2nd—Connect a piece of coaxial cable about 3/8 wavelength long to the transmitter antenna link coil (which will probably be about 1 or 2 turns and swung into place in the tank coil).

3rd—Lay this cable out straight and start pruning **very slowly**, keeping the transmitter tank tuned to resonance. When the proper length is reached you will note that the tank will again tune to resonance at **the same dial setting** as before the cable was connected. It is recommended that not more than 1/2" of cable be cut off at one time, otherwise it is possible that you will go by the resonant point without ever knowing it.

When this point is found you will have a non-reactive feed line (with a minimum of standing waves) which will transmit maximum power to the antenna. It is then a simple matter to attach the antenna and adjust its electrical length by the same method so that it too is non-reactive and the whole system "looks" like a purely resistive load to the final tank, which is the ideal condition.

Coupling Factors

The above method of feeding is recommended for any h-f or v-h-f antenna and any type of feed line and when properly used will eliminate the difficulties encountered when trying to adjust only the antenna to eliminate the reactance reflected by both the feed line and the antenna. This will probably account for the fact that many fellows have trouble getting their antenna to "load" and radiate efficiently, while others are using the same type of antenna with good results.

While on the subject of loading it might be well to mention here that it is not a good sign when an antenna (?) loads easily with very loose coupling between the link and the final tank coil. Loose coupling is possible only between two circuits that have high "Q" and a link circuit definitely does not meet this requisite. A "flat" feed line looks like a pure resistance to the transmitter which feeds power to it merely by the transformer action of the tank coil and link. It would be extremely difficult to put power into a low resistance line without tight coupling and anyone who would like to verify this should try to feed power into a nonreactive dummy antenna of the same resistance as the feed line impedance. It can only be done with a properly designed tightly coupled link. Yes, a link should be *designed* and not just happen. It is a part of the transformer that matches the plate impedance of the final tube, or tubes, to the impedance of the feed line enabling maximum transfer of energy to the antenna. Unless the radiation resistance of the antenna is the same as the impedance of the feed line another "transformer" will also be needed here. This is the delta match, "T" -match, "Q" bars or 1/4 wave matching section that happens to be your favorite or the most convenient to use for the type of antenna in question. More on this later.

Link Turns

The formula for figuring the correct number of link turns, assuming unity coupling, is:

$$N = \sqrt{\frac{T^2 \times Zl}{Zpl.}}$$

where: N number of link turns
T number of final tank coil turns
Zl feed line impedance
Zpl plate load impedance of final

If this formula does not seem to work for you look for trouble elsewhere. For one thing, a high "Q" final tank makes for easier antenna loading and increasing the final voltage-to-current ratio will have a tendency to raise the efficiency of the final. Commercial tank coils do not give a good tank Q when used with tubes operating on a low plate voltage-to-current ratio, and will make it difficult to load a non-reactive line. Also commercial fixed or swinging links should be tailored to suit the existing conditions.

Good loading with loose coupling is therefore a pretty good sign that the feed line is reactive and acting as a resonant circuit. Often with this condition the antenna can be disconnected from the feed line and the final will remain "loaded" and sometimes *increase*. Your final should remain at resonance with or without the feed line and/or antenna connected.

Check For Standing Waves

Should you care to check your line for reactance or standing waves it is very simple. Insert an additional 1/8 wavelength of line and check the loading. If it does not change, add another 1/8 wavelength (approximately). If either test has made it necessary to retune or has changed the loading then your line is *not* "flat".

A 2-wire feed line infinitely long would steadily transfer power from the transmitter and would cause no reaction on the output stage. This line may also be terminated in a non-reactive resistor equal to the characteristic impedance of the line and it will perform the same. In the first case the input, output and characteristic impedance are all equal. If, however, the line is short circuited or improperly terminated then a "reflection" will occur and the wave will "bounce" back. Because the reflected wave is out of phase with the transmitted wave there will be current and voltage additions and cancellations and as long as the frequency is constant these points of maximum and minimum voltage and current will not change position, hence the term "standing waves".

When the terminating resistance is incorrect the power formula $P=I^2R$ cannot be satisfied at the point of termination and little or no power will be absorbed. However we now find points of high current and high voltage along the line. The line has certain current and voltage handling capabilities and if we are to observe these we will not be able to operate at the full wattage rating of the line. The greater the SWR the less power we can put into the line. The SWR is the reason some fellows can run 1/2 kw. to Twin-Lead without trouble while others encounter difficulties with much less power.

Line Reactance: Capacitive or Inductive?

It is possible to determine whether the line is terminated in a capacitive or inductive reactance in the following manner. If the load is capacitive reactive the 1st voltage peak will be less than 1/2 wave from the load and the current peak less than 1/4 wave from the load. If inductive (similar to open-circuit condition) the peak nearest (within 1/4 wave) the load end of the line will be a voltage peak and the 1st current peak will be within 1/2 wave of the load end.

One thing to be recommended to give improved feed line performance is that steps be taken to cancel the coupling coil (link) inductance at the transmitter. This may be easily done by coupling the feed line through a series tuning condenser. One will suffice for coaxial cable but two (one in each leg) should be used with Twin-Lead.

S.W.R.

Standing Wave Ratio (S.W.R.) is the ratio between minimum and maximum line current (or voltage). If the minimum current at any point is 1 ampere and the maximum (1/4 wavelength away) is 2 amperes, the ratio would be 2 to 1. Standing waves not only waste power but also cause BCI and TVI interference (because of radiation from the feed line), reduce the receiving effectiveness of "beam" antenna (through feed line signal pickup), and make the antenna system very narrow in band-width. The band-width increases with proper matching. The main thing is that the *total* line loss be kept below approximately 1 db if possible, and on the lower frequencies a higher SWR can be tolerated. It must be remembered, however, that in order for a line to present a purely resistive load at the transmitter it must be properly matched to the antenna and this cannot be corrected at the transmitter. An antenna Q of at least 8 is required if one expects to be able to couple tight enough to "make 'er load up".

Folded Dipoles

In regard to the use of Twin-Lead cable for the entire construction of a "Folded Dipole" antenna, the following data may be useful. The usual formula may be used (492/f-Mc.) providing 5% is deducted from the final antenna length calculations. In other words the corrected formula now becomes 492/f-Mc. x .95 (95% of the physical length equals the electrical length) or 468/f-Mc. The reason for this is that radio waves travel more slowly in the antenna wire than in free space and consequently a wavelength on a wire will be shorter than in free space.

The velocity of propagation (VP) factor is not used here because in this type of antenna the current in each parallel leg is in phase, the radiation pattern being the same as for the regular single dipole. It is only when the conductors are carrying out-of-phase currents (a transmission line) that the lines of force are *through* the dielectric and it is necessary to consider the VP factor.

The input impedance at the center of the folded dipole is equal to about 4 times the radiation resistance of the regular 1/2 wave dipole (72 ohms) at the same height. This then is approximately 300 ohms when at multiples of 1/2 wavelength above ground.

Height of Antenna

Speaking of antenna height, it is found that the vertical pattern of a horizontal dipole is affected by height and best results will be obtained at about one wavelength high. The vertical half-wave antenna, however, should have its center at about 1/4 wave high for best results. The horizontal antenna will be the best for ground-wave work providing a height of at least 1/2 wave can be attained. On higher frequencies, however, the "ground-plane" type of antenna is extremely effective for local work. One disadvantage of putting up an antenna so high that it would have to be lowered every night to let the moon go by would be that the feed line losses would be terrific—Hi. The maximum usable vertical radiation angle for 20 meter DX will be about 15 degrees and for 10 meters, about 10 degrees.

Matching Devices

In order to match the feed line to the antenna it is often necessary to use some form of matching device. This may be 1/4 wavelength of Twin-Lead, coaxial cable, open wire line or "Q" bars and must be the *"mean"* impedance between the antenna and feed line impedance or $ZT=\sqrt{ZlZa}$. If it is desired to feed a 72 ohm antenna with 300 ohm Twin-Lead: Multiply the line impedance times the antenna impedance (72 x 300) and take the square root of this $\sqrt{21600} = 147$. The "mean" impedance is 147 ohms and therefore 150 ohm Twin-Lead could be used. This must be ¼ wavelength long at the desired frequency *LESS* the VP factor (for reasons mentioned previously). The formula would be 246VP/f-Mc. For example at 29 Mc. the matching transformer would be figured: 246 x .77 (VP factor for 150 ohm Twin-Lead) divided by 29 equals 6.53 ft. or 78.5 inches which will be the correct length. The VP factor for coax cable is .659 and should we desire to match a 72 ohm coax line to the bottom of a ground-plane antenna (approx. 28 ohms) we find that the "mean" impedance ($\sqrt{72 \times 28}$) required will be about 47 ohms. We therefore can use a piece of 50 ohm coax as the matching transformer. Using the above formula (246 VP/f-Mc.) we find the correct length at 29 Mc. will be 5.58 ft. or 67 inches.

Parallel Lines for Impedance Match

It is possible to parallel one or more sections of line to arrive at the desired transformer impedance, but it is recommended that each element be cut from the same spool, as the VP factor will vary slightly from lot to lot of cable. The cable may be cut slightly longer than called for and pruned ½ inch at a time until the desired performance is attained. When paralleling Twin-Lead, it is important that the sections be spaced by the amount of the spacing between conductors. In the case of coaxial cable, sections may merely be taped together. Coaxial cables have the advantage of being easy to install as they do not have to be spaced away from other objects. Being shielded they are of great help in reducing BCI and TVI trouble when transmitting and ignition noise when receiving. Also their operation is not affected by weather.

Stringing Twin-Lead

In regard spacing of Twin-Lead it might be well to mention that it should NOT be tacked to the wall, pinched in the window or taped to other cables or steel mast. In order to perform correctly it should be spaced AT LEAST the distance of the spacing between conductors. Antenna relays that cause a discontinuity in the line spacing also upset the impedance.

Twin-Lead Lightning Arrestor

On a single band antenna ¼ wavelength of Twin-Lead may be used conveniently as a lightning arrestor from the feed line to ground and will have absolutely no effect on antenna performance.

Summing it all up, if you want the most *from* your antenna, see to it that you get the most *into* it.

The data in this article is not necessarily new, but rather is an accumulation of information that often is difficult to locate when needed. (Knowledge is not *what* you know but *where* to find it.)

Using "Out-of-Band" Crystals for the Amateur Bands

Most amateurs use crystals in the lower amateur bands to multiply to frequencies in the harmonically related upper bands. Forty-meter crystals are the usual mainstay for 10, 15, and 20 meter operation in the average crystal-controlled mobile or fixed station.

A check of surplus crystals, lying idle in a drawer because they were not in any amateur band, disclosed quite a few that were usable on the third, fourth, or sixth harmonic. Nothing new or startling, but easily overlooked by many who could use a few extra operating frequencies.

For twenty meters, third harmonic operation of crystals from 4667 to 4783 is satisfactory. Crystals having fundamental frequencies of 4735 to 4766 will multiply into the phone portion of the band.

For fifteen meters, quadrupling from fundamental frequencies of 5250 to 5362 is practical, with the phone band covered by the range of about 5313 to 5362.

On ten meters the sixth harmonic* of 4750 to 4950 will multiply into the phone band and as low as 4667 kc is satisfactory for c-w operation. Also usable are crystals in the 9334 to 9900 kc range on their third harmonic. Phone from 9500 kc up to 9900. Don't overlook possible use of off-frequency crystals on the third, fourth, or sixth harmonic for 11 meters.

Though the fifth harmonics of some crystals would be usable in overtone oscillator circuits, it would require rewiring and tricky adjustment which would not be worth the effort.

So try a little arithmetic with those "useless" crystals. If you don't have some in the junkbox, a look in the current ads will show inexpensive crystals widely available.

*Tripling in the oscillator plate circuit and doubling in the doubler-buffer stage.

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