Chapter 9

Broadband Antennas

Antennas that provide a good impedance match over a wide frequency range have been a topic of interest to hams for many years. The advantages of a broadband antenna are obvious—fewer adjustments during tune-up. For some of the new broadband transceivers and amplifiers, a broadband antenna means no tune-up at all; after setting the band and frequency, one is "in business."

Bandwidth Factor

The traditional measure of antenna bandwidth in terms of impedance is the standing wave ratio or SWR in the feed line. Most modern amateur equipment is designed to work into a 52-Ω load with an SWR of better than 2:1. Therefore, the frequency range within which the SWR in 52-Ω line is less than 2:1 is often used for antenna bandwidth comparisons. However, any SWR range and any line impedance may be used for comparison, as long as they are clearly specified and are used consistently for the antennas being compared.

In making bandwidth comparisons with SWR, the operating frequency must also be taken into account, for a specified frequency bandwidth range in one amateur band will not apply if the antenna is scaled to another band. For instance, if a dipole antenna has a 2:1-SWR bandwidth of 500 kHz when cut for 14 MHz, it will not have a 500-kHz bandwidth when scaled for 3.5 MHz.

Expressing the 2:1-SWR bandwidth as a percentage is convenient, using the following relationship.

$$\text{SWR bandwidth} = \frac{f2 - f1}{f_C} \times 100\% \qquad \text{(Eq 1)}$$

where

f1 is the lower frequency, above which the SWR is less than the specified limit

f2 is the upper frequency, below which the SWR is less than the specified limit

f_c is the center frequency, determined from

$$f_c = \sqrt{f1 \times f2} \qquad \text{(Eq 2)}$$

For example, the solid-line curve of Fig 1 shows the SWR versus frequency plot for a theoretical 3.75-MHz single-wire dipole in free space, fed with a 52-Ω line. The 2:1-SWR frequencies are 3.665 and 3.825 MHz. The 2:1-SWR bandwidth of this antenna is

$$\text{Bandwidth factor} = \frac{3.825 - 3.665}{\sqrt{3.825 \times 3.665}} \times 100 = 4.3\%$$

The bandwidth factor calculated in this way can be used if the antenna is scaled to another band and the same impedance feeder is used. If this 3.75-MHz dipole is scaled to operate at 14.2 MHz, the 2:1-SWR frequency range in that band should be 14.2 × 4.3% = 0.611 MHz or 611 kHz.

It is important to note that the bandwidth percentage factor will not be the same if a different type of feeder is used. The broken-line curve of Fig 1 shows the SWR response of the very same antenna, but with a 75-Ω feeder. The reason for the different SWR response is that, while the antenna impedance is unchanged for each individual frequency, the degree of mismatch does change with another feeder impedance. In this case, the 2:1-SWR bandwidth factor becomes 5.5%.

The curves of **Fig 1** and the information in the preceding paragraphs should not be interpreted to mean that 75-Ω line will necessarily provide a better match or broader SWR bandwidth with a dipole than 52-Ω line. A dipole near the earth will not have the same impedance as one in free space, and the curves indicate only that the free space impedance is nearer 75 Ω than 52 Ω. The only conclusion that should be drawn from this presentation is that the SWR bandwidth of an antenna is dependent upon the type of feeder employed. Thus, comparison of bandwidths with different feed lines can be misleading.

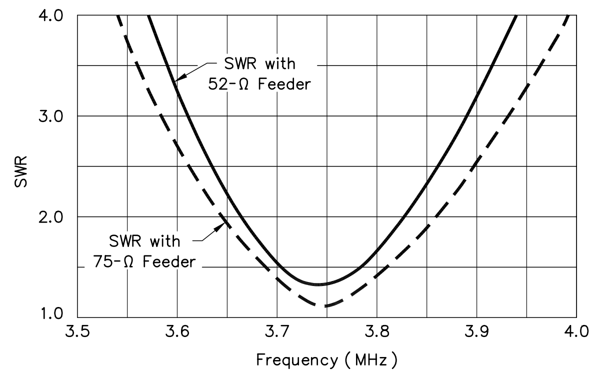


Fig 1—The SWR versus frequency plots for a hypothetical 3.75-MHz single-wire dipole in free space for 52 and 75-Ω feed lines. The 2:1-SWR bandwidth is 4.3% with a 52-Ω feeder and 5.5% with a 75-Ω feeder. These bandwidths will change as the antenna is brought near the earth.

Antenna Q

Another measure of antenna bandwidth is its Q. The method of determining antenna Q is discussed in Chapter 2. Briefly, however, the method requires knowing the values of antenna resistance and reactance at a known frequency percentage away from resonance. The Q of the dipole in the above example is approximately 13.

Antenna Q is independent of the feeder impedance and the band of operation. However, determining the Q of an antenna is somewhat nebulous, as the radiation resistance changes with frequency (but at a slower rate than the reactance changes). Calculating the Q from measurements at a frequency, say, 2% above resonance will generally not produce the same value as from a frequency 2% below resonance.

Another more serious difficulty arises in determining the Q of antenna systems which include some broadbanding schemes, such as those with resonating stubs or lumped LC constants at the antenna feed point. When such matching networks are used, the antenna may be resonant at more than one frequency within an amateur band. (Resonance is defined as the frequency or frequencies where the reactance at the feed point goes through zero.) With resonance ambiguities, departure from resonance by a specific frequency percentage becomes meaningless.

THE CAGE DIPOLE

The bandwidth of a single-wire dipole may be increased by using a thick radiator, one with a large diameter. The radiator does not necessarily have to be solid; open construction such as shown in **Fig 2** may be used.

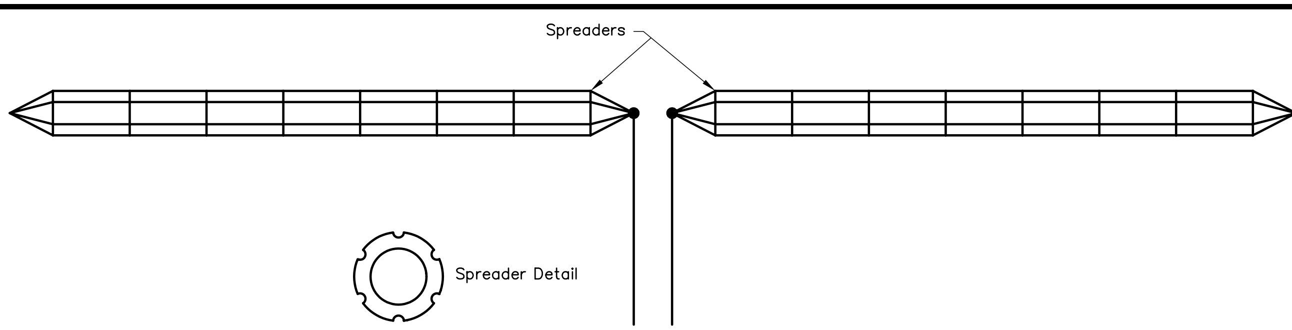


Fig 2—Construction of a cage dipole, which has some resemblance to a round birdcage. The spreaders need not be of conductive material, and should be lightweight. Between adjacent conductors, the spacing should be 0.02 λ or less. The number of spreaders and their spacing should be sufficient to maintain a relatively constant separation of the radiator wires.

The theoretical SWR response of a cage dipole having a 6-inch diameter is shown in **Fig 3**. The bandwidth factor of this antenna with 52-Ω line is 7.7%, and the Q is approximately 8. Its 2:1-SWR frequency range is 1.79 times broader than the antenna of Fig 1.

There are also other means of obtaining a thick radiator, thereby gaining greater bandwidth. The bow-tie and fan dipole make use of the same Q-lowering principle as the cage to obtain increased bandwidth.

Efficiency Factor

The bandwidth factor as calculated in the preceding section does not include any indication of radiation efficiency. The efficiency factor is another very important consideration when it comes to broadbanded antenna systems. Unfortunately, most broadbanding schemes involve some loss of radiation efficiency.

Typically with broadbanding schemes, the efficiency falls off at the band edges as the SWR increases. Losses occur not only in the matching-system components, but also the losses increase in the transmission line as the SWR rises. These losses can amount to several dB. So in addition to the SWR versus frequency response, attention should be given to the efficiency versus frequency characteristic of any broadbanded antenna. Trade-offs must generally be made between SWR bandwidth and efficiency at the band edges.

QST for October 1986 contains an article by Frank Witt, AI1H, disclosing the results of computerized calculations of dipole bandwidth versus efficiency for various broadbanding schemes. (See the bibliography at the end of this chapter.) Information in this section is based on that article.

When the SWR at the antenna end of the transmission line is less than 2:1, the transmission-line losses are virtually the same as those from the length of a matched line. Thus, for the part of the band over which the SWR is less than 2:1, one need consider only losses in the matching network when computing efficiency.

Efficiency is related to resistive or ohmic losses in the matching network. The lower the losses, the higher the efficiency. However, ohmic losses in the matching network will broaden the response of a dipole system beyond that possible with a lossless or ideal matching network. Users must decide whether they are willing to accept the lower efficiency in trade for the increased bandwidth.

An extreme degree of bandwidth broadening is illustrated in **Fig 4**. The broadening is accomplished by adding resistive losses. One may resort to network theory and derive the RLC (resistor, inductor, capacitor) matching network shown. The

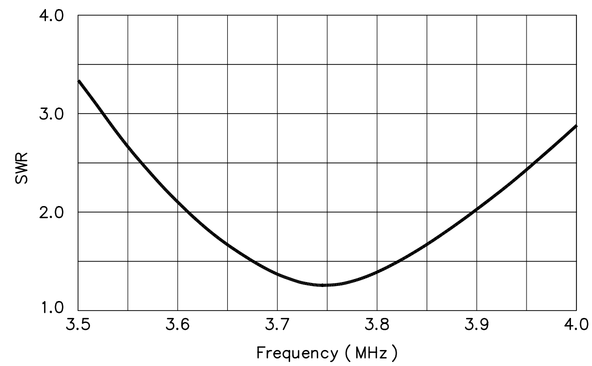


Fig 3—Theoretical SWR versus frequency response for a cage dipole of length 122 feet 6 inches and a spreader diameter of 6 inches, fed with 52-Ω line. The 2:1-SWR bandwidth frequencies are 3.610 and 3.897 MHz, with a resulting bandwidth factor of 7.7%.

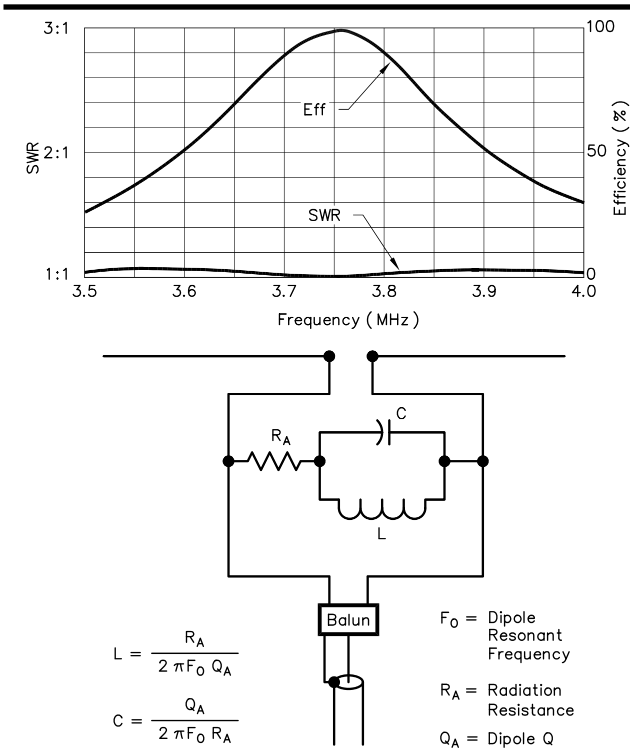


Fig 4—Matching the dipole with a complementary RLC network greatly improves the SWR characteristics, nearly 1:1 across the 3.5-MHz band. However, the relative loss at the band edges is greater than 5 dB.

network provides the complement of the antenna impedance. Note that the SWR is virtually 1:1 over the entire band, but the efficiency falls off dramatically away from resonance.

The efficiency loss may be converted to decibels from:

$$\text{dB (loss)} = -10 \log \frac{\text{Efficiency}}{100} \qquad \text{(Eq 3)}$$

From this, the band-edge efficiency of 25 or 30% shown in Fig 4 means that the antenna has about 5 dB of loss relative to an ideal dipole. Also note that at the band edges, 70 to 75% of the power delivered down the transmission line from the transmitter is heating up the matching-network resistor. For a 1-kW output level, the resistor must have a power rating of at least 750 W! Use of an RLC complementary network for broadbanding is not recommended, but it does illustrate how resistance (or losses) in the matching network can significantly increase the apparent antenna SWR bandwidth.

Resonators as Matching Networks

The most practical broadbanding network for a dipole is the parallel LC tuned circuit connected directly across the antenna terminals. This circuit may be constructed either with lumped constants, by placing a coil in parallel with a capacitor at the feed point, or by using one or more coaxial resonator stubs at the feed point.

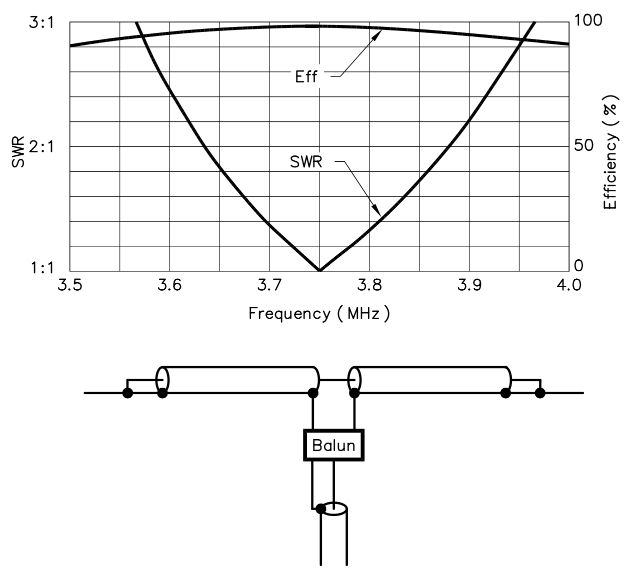


Fig 5—The double bazooka, sometimes called a coaxial dipole. The antenna is self-resonant at 3.75 MHz. The resonator stubs are 43.23-foot lengths of RG-58A coax.

THE DOUBLE BAZOOKA

The response of the somewhat controversial double bazooka antenna is shown in **Fig 5**. This antenna actually consists of a dipole with two quarter-wave coaxial resonator stubs connected in series.

Not much bandwidth enhancement is provided by this resonator connection because the impedance of the matching network is too high. With a 72-Ω feeder, this antenna offers a 2:1-SWR bandwidth frequency range that is only 1.14 times that of a simple dipole with the same feeder.

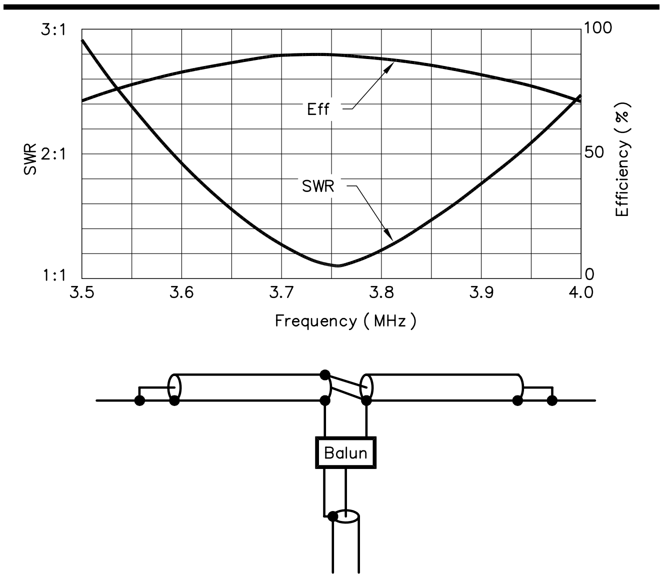


Fig 6—The crossed double bazooka yields bandwidth improvement by using two quarter-wave resonators, parallel connected, as a matching network.

THE CROSSED DOUBLE BAZOOKA

A modified version of the double-bazooka antenna is shown in **Fig 6**. In this case, the impedance of the matching network is reduced to one-fourth of the impedance of the standard double-bazooka network. The lower impedance provides more reactance correction, and hence increases the bandwidth frequency range noticeably, to 1.55 times that of a simple dipole. Notice, however, that the efficiency of the antenna drops to about 80% at the 2:1-SWR points. This amounts to a loss of approximately 1 dB. The broadbanding, in part, is caused by the resistive losses in the coaxial resonator stubs, which have a remarkably low Q (only 20).

The Q of Coaxial Resonators

The Q that can be acquired when resonators are made from coaxial cable is a parameter of interest. Table 1 summarizes the resonator Q that can be obtained from different types of coax at 1.9 and 3.75 MHz. If the cable loss is known, the Q of the resonator may be determined from

$$Q = \frac{278\ f_C}{A \times VF} \qquad \text{(Eq 4)}$$

where

f_c = dipole resonant frequency, MHz
A = line attenuation per 100 feet, dB
VF = velocity factor of line

For example, RG-8 foam coax has a velocity factor of 80% and an attenuation of 0.3 dB at 3.75 MHz. The Q is calculated as

$$Q = \frac{2.78 \times 3.75}{0.3 \times 80} = 43.4$$

Table 1
Resonator Q for Various Types of Coaxial Cable

Cable Type	Resonator Q	
	3.75 MHz	*1.9 MHz*
RG-174	6.5	4.5
RG-58A	20.0	15.1
RG-141	22.5	16.1
RG-8	41.0	30.6
1/2-in. Hardline	75.5	53.9
3/4-in. Hardline	109.1	77.1

CHEBYSHEV MATCHING

It is possible to widen the bandwidth further by again resorting to network theory. However, in contrast to matching with a complementary network (Fig 4), no resistors are used. The matching network parameters are chosen to yield a Chebyshev (often called equi-ripple) approximation. The simplest way to make use of this theory for broadbanding the dipole is to deliberately mismatch the dipole at the center of the band by adding a transformer to the matching network. This transformer must provide a voltage step-up between the transmission line and the antenna. The result is a W-shaped SWR characteristic. Low SWR is sacrificed at the band center to obtain greater bandwidth.

A broadband dipole using a Chebyshev matching network with a step-up transformer is shown in **Fig 7**. The transformer can also serve as a balun. The SWR is better than 1.8:1 over the entire 3.5-MHz band—not bad for about 43 feet of RG-58 coax and a slightly modified balun.

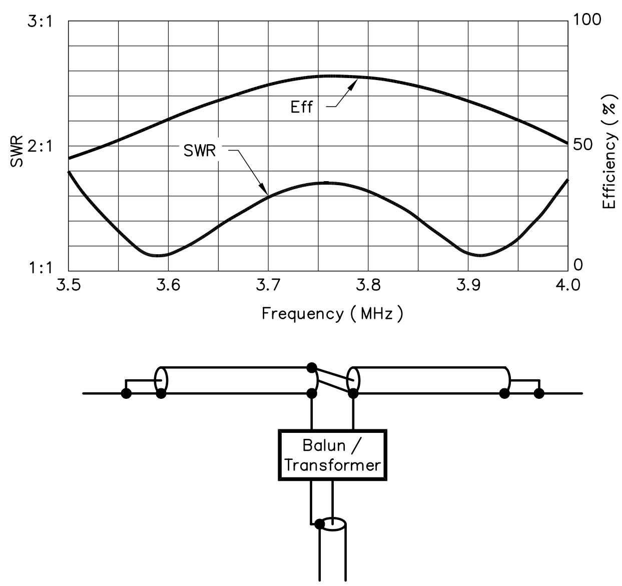


Fig 7—Chebyshev matching provides greater broadbanding by trading midband matching for increased bandwidth. The feed arrangement is 52-Ω line and a 1.91:1 step-up transformer balun. Different lengths of RG-58A resonator stubs are used, one of 30.75 feet and one of 12.49 feet. Note that the longer stub is left open at the outer end. (Design by Frank Witt, AI1H)

Can this be true? Are we getting something for nothing? Not really. Notice that the efficiency in Fig 7 falls to only 45% and 52% at the 3.5-MHz band edges. Only half of the available power is radiated. This low efficiency is directly attributable to the low Q of the coaxial resonator.

LC MATCHING NETWORK

Efficiency can be improved by using lower-loss coax or by using a matching network made up of a high-Q inductor-capacitor parallel-tuned circuit. The SWR response and efficiency offered by a network of lumped constants is shown in **Fig 8**. The 2:1-SWR bandwidth with 52-Ω line is 460 kHz, not quite great as that provided by the coaxial resonator in Fig 7. The LC network uses deliberate mismatching at band center, resulting in the W-shaped SWR characteristic. The network also functions as a balun. The capacitor is connected across the entire coil in order to obtain practical element values.

The efficiency at the band edges for the antenna system shown in Fig 8 is 90%, compared to 45% and 52% for that of Fig 7. However, the increase in efficiency is obtained at the expense of bandwidth, as noted above. Unfortunately, the very low impedance required cannot be easily realized with practical inductor-capacitor values. It is for this reason that a form of impedance transformation is used.

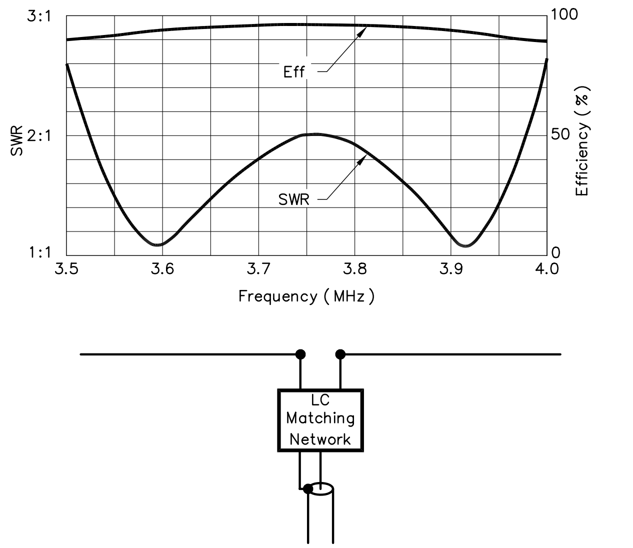


Fig 8—Efficient broadbanding with an LC matching network. The feeder is 52-Ω coax, and the matching network provides a step-up ratio of 2.8:1. See Fig 9 for details of the matching network. (Design by Frank Witt, AI1H)

A practical circuit for the LC matching network is shown in **Fig 9**, and **Fig 10** shows a method of construction. The taps on L1 serve to reduce the impedance of the matching network, while still permitting the use of practical element values. L1 is resonated at midband with C1.

The selection of a capacitor for this application must be made carefully, especially if high power is to be used. For the capacitor described in the caption of Fig 9, the allowable peak power (limited by the breakdown voltage) is 2450 W. However, the allowable average power (limited by the RF current rating) is only 88 W! These limits apply at the 1.75:1 SWR points.

Another Version

With slight alteration, the antenna system of Fig 8 can provide the performance indicated in **Fig 11**. Dubbed the 80-meter DXer's delight, this antenna has SWR minima near 3.5 and 3.8 MHz. A single antenna permits operation with a near-perfect match in the DX portions of the band, both CW and phone.

The modifications involve resonating the antenna and the LC network at a lower frequency,

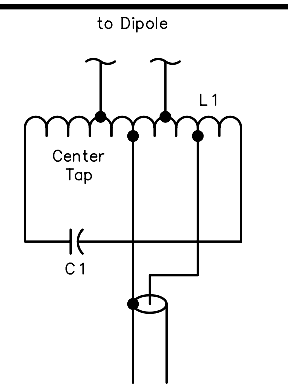


Fig 9—A practical LC matching network which provides reactance compensation, impedance transformation and balun action.

C1—400 pF transmitting mica rated at 3000 V, 4 A (RF).

L1—4.5 µH, $8\frac{1}{2}$ turns of B&W coil stock, type 3029 (6 turns per in, $2\frac{1}{2}$-inch dia, #12 wire). The primary and secondary portions of the coil have $1\frac{3}{4}$ and 3 turns, respectively.

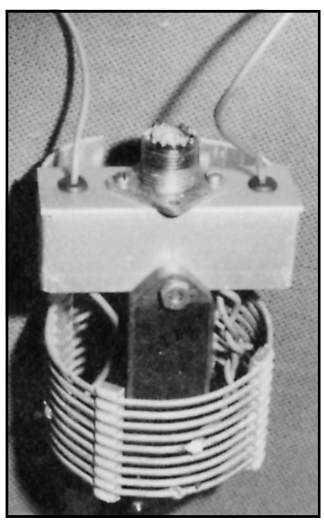


Fig 10—A method of constructing the AI1H LC matching network. See Figs 8 and 9. Components must be chosen for a high Q and must have adequate voltage and current ratings. The network is designed for use at the antenna feed point, and should be housed in a weatherproof package.

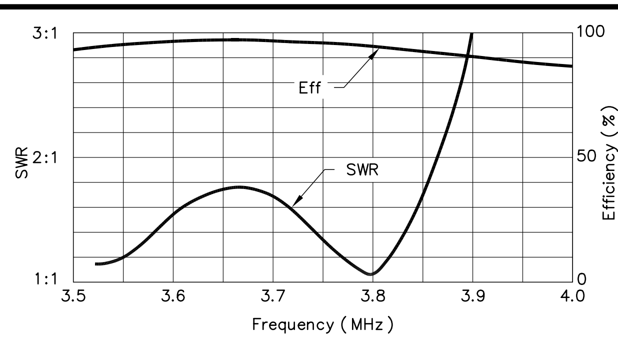


Fig 11—The 80-meter DXer's delight permits operation with a near-perfect match in the DX portions of the band, both CW and phone. See text for alterations required from the antenna system of Figs 8 and 9.

3.67 MHz instead of 3.75. This requires 4.7 µH of inductance, rather than 4.5. In addition, the impedance step-up ratio is altered from 2.8:1 to 2:1. This is accomplished by setting the dipole taps on L1 for 2½ turns, rather than 3.

Bandwidth Versus Efficiency Trade-Off

As is apparent in the preceding section, there is clearly a trade-off between bandwidth enhancement and efficiency. This is true because the broadbanding results from two causes: reactance compensation and resistive loading. Pure reactance compensation would be achieved with resonators having infinite Q. The resistive loading caused by nonideal resonators further increases the bandwidth, but the price paid is that some of the output power heats up the resonator, leading to a loss in efficiency.

The best one can do with 100% efficiency is to double the bandwidth. Larger improvements are accompanied by efficiency loss. For example, a tripling of the bandwidth would be obtained with an efficiency of only 38% at the 2:1 SWR points.

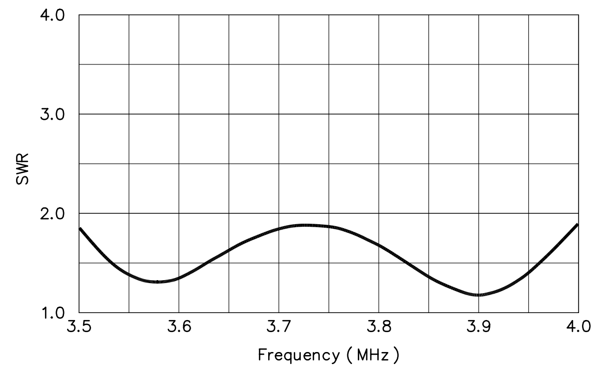


Fig 12—Theoretical SWR response of two stagger tuned dipoles. They are connected in parallel at the feed point and fed with 52-Ω line. The dipoles are of wire such as #12 or #14, with total lengths of 119 and 132 feet.

THE SNYDER ANTENNA

A commercially manufactured antenna utilizing the principles described in the preceding section is the Snyder dipole. Patented by Richard D. Snyder in late 1984 (see Bibliography), it immediately received much public attention through articles that Snyder published. Snyder's claimed performance for the antenna is a 2:1 SWR bandwidth of 20% with high efficiency.

The configuration of the Snyder antenna is like that of Fig 6, with 25-Ω line used for the resonators. The antenna is fed with 52-Ω line through a 2:1 balun, and exhibits a W-shaped SWR characteristic like that of Fig 7. The SWR at band center, based on information in the patent document, is 1.7 to 1. There is some controversy in professional circles regarding the claims for the Snyder antenna.

STAGGER TUNED DIPOLES

A single-wire dipole exhibits a relatively narrow bandwidth in terms of coverage for the 3.5-MHz band. A technique that has been used for years to cover the entire band is to have two dipoles, one cut for the CW portion and one for the phone portion. Of course separate antennas with separate feed lines may be used, but it is more convenient to connect the dipoles in parallel at the feed point and use a single feeder. This technique is known as stagger tuning.

Fig 12 shows the theoretical SWR response of a pair of stagger tuned dipoles fed with 52-Ω line. No mutual coupling between the wires is assumed, a condition that would exist if the two antennas were at right angles to one another. As Fig 12 shows, the SWR response is less than 1.9 to 1 across the entire band.

A difficulty with crossed dipoles is that four supports are required if the antennas are to be horizontal. A more common arrangement is to use inverted-V dipoles with just one support, at the apex of each element. The radiator wires can also act as guy lines for the supporting mast.

When the dipoles are crossed at something other than a right angle, mutual coupling between them comes into play. This causes interaction between the two elements—tuning of one by length adjustment will affect the tuning of the other. The interaction becomes most critical when the two dipoles are run parallel to each other, suspended by the same supports, and the wires are close together. Finding the optimum length for each dipole for total band coverage can become a tedious and frustrating process.

A Simple, Broadband 3.5-MHz Dipole Antenna

The following has been condensed from an article by Reed E. Fisher, W2CQH, that appeared in *The ARRL Antenna Compendium, Volume 2*. This antenna is shown in Fig 6, and **Fig 13** shows construction details. Note that the half-wave flat-top is constructed of sections of RG-58 or RG-59 coaxial cable. These sections of coaxial cable serve as quarter-wave shunt stubs which are essentially connected *in parallel* at the feed point. (Even though the center conductors and shields of the stubs connect to opposite feed-point terminals, the connection can be described as parallel.) At an electrical quarter wavelength (43 feet—inside the coax) from each side of the feed point X-Y, the center conductor is shorted to the braid of the coaxial cable.

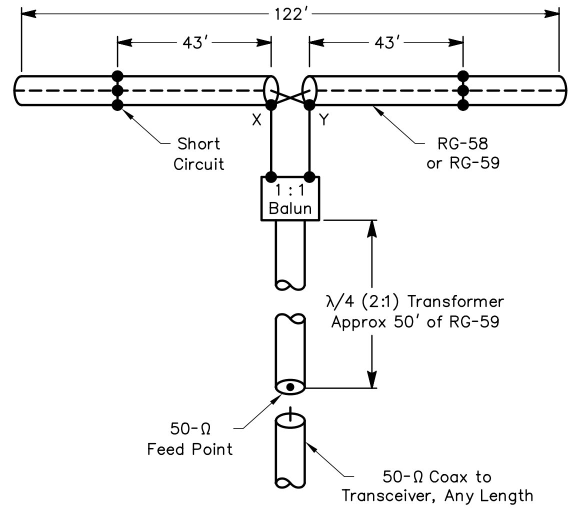


Fig 13—Details of the broadband 3.5-MHz dipole.

The parallel stubs provide reactance compensation. Stated briefly, this scheme provides a compensating reactance of opposite sign which tends to cancel the off-resonance antenna reactance. For example, at the band center of 3.75 MHz the antenna/stub combination of Fig 13 looks like a pure resistance of approximately 73 Ω. At the band edges of 3.5 and 4.0 MHz, the reactance provided by the parallel stubs will again make the combination look like a *pure resistance* which now has been transformed to approximately 190 Ω. Suppose the reference resistance (at feed point X-Y) is changed to the geometric mean value of the band center and band edge resistances which is $\sqrt{73 \times 190}$ = 118 Ω. Then the antenna will exhibit an SWR of 118/73 = 1.61 at 3.75 MHz, and 190/118 = 1.61 at both 3.5 and 4.0 MHz. In order to achieve this three-frequency compensation, the X-Y feed-point resistance must be near 118 Ω, not 50 Ω. In Fig 13, the quarter-wave transformer, constructed of the 50-foot section of 75-Ω coaxial cable (RG-59) which feeds the balun, provides the required resistance transformation. Such a broadband antenna is never perfectly matched, but the SWR is always less than 2. See **Fig 14**.

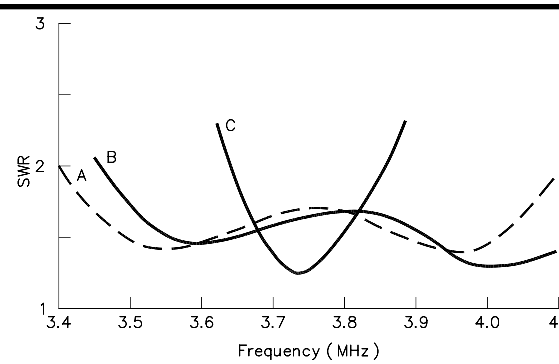


Fig 14—SWR curves for dipoles. Curve A, the theoretical curve with 50-Ω stubs and a λ/4, 75-Ω matching transformer. Curve B, measured response of the same antenna, built with RG-58 stubs and an RG-59 transformer. Curve C, measurements from a dipole without broadbanding. Measurements were made at W2CQH with the dipole horizontal at 30 feet.

The antenna at W2CQH is straight and nearly horizontal with an average height of about 30 feet. The antenna feed point rests over the center of a one-story ranch house.

Adjustment

First, the stubs must be a quarter wave long at the band center of 3.75 MHz. Good-quality RG-58 or RG-59, with a velocity factor of 0.66, should be cut a bit longer than the expected 43 feet. Remember, cheap coax or foam coax may have a different velocity factor. **Fig 15** illustrates

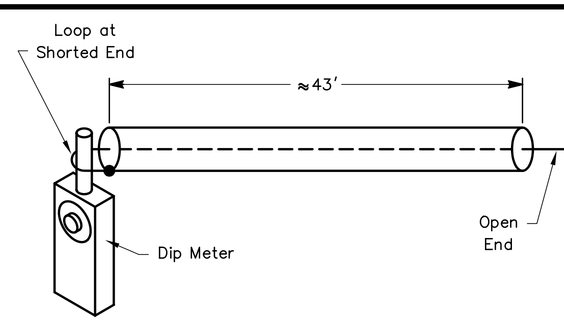


Fig 15—Adjust the stub length by coupling a dip meter to a loop at one end of the coax, and trim the other end until a sharp dip is observed at 3.75 MHz.

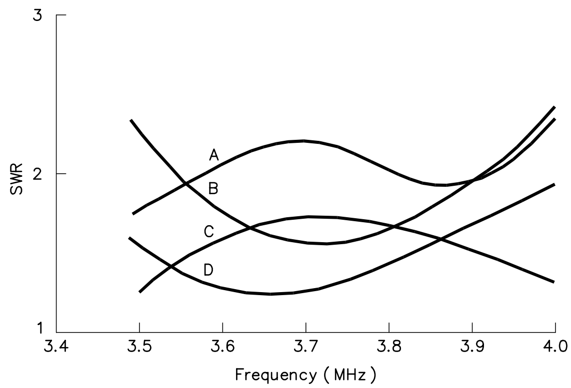


Fig 16—SWR curves for antennas at KE6HU. Curve A, the antenna shown in Fig 13; curve B, an antenna with two 50-Ω stubs and a 1.5:1 RG-59 transformer (see Fig 17). Curve C, an antenna with four 50-Ω stubs (see Fig 18) and a 1.5:1 RG-59 transformer. Curve D, an antenna with four 50-Ω stubs and a direct 50-Ω feed.

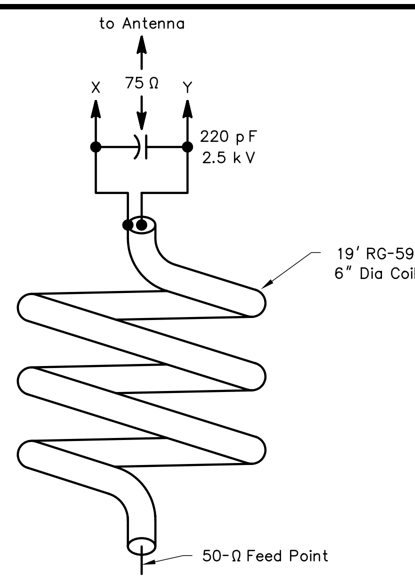


Fig 17—Details of a 1.5:1 transformer and balun for 3.5 MHz.

how the stubs may be resonated by inserting the coil of a dip meter into a small single-turn loop at the shorted end of the stub. Cut the stub until a sharp dip is obtained at 3.75 MHz.

Next, the balun/quarter-wave transformer combination should be checked. Connect a 120-Ω, 2-W carbon (noninductive) resistor to the 1:1 balun output terminals. Connect one end of a 55-foot section of RG-59 coax to the balun input. Connect the other end to a sensitive SWR indicator, then drive the indicator with less than 2 W of transmitter power at 3.75 MHz. Prune the cable length until the lowest SWR is obtained. The shunt (magnetizing) inductance of some commercial 1:1 baluns requires that the cable length be longer than a quarter wavelength (43 feet) for an input match to be obtained. The shunt inductance will also raise the transformed resistance to about 120 Ω instead of the $75^2/50 = 113$ Ω which would be obtained from the quarter-wave cable alone. This is a desirable condition. The W2AU balun is satisfactory and requires a cable length of about 50 feet.

Adjust the center frequency of the antenna flat-top to 3.75 MHz without stubs and quarter-wave transformer. To do this, first disconnect the center conductors of the stubs from feed points X-Y in Fig 13. Leave the coax braids attached. Then connect a length of 50-Ω coax from balun to transmitter and raise the antenna to its final height. Find the frequency where the SWR is lowest, then adjust the outer ends of the antenna (beyond the shorted stub section) until lowest SWR is obtained at 3.75 MHz. At W2CQH the total flat-top length is 122 feet—or 3 feet short of the textbook 468/f value of 125 feet.

Finally, connect the antenna system as shown in Fig 13. An SWR curve similar to curve A in Fig 14 should be observed.

LOWER Q VERSION

The antenna shown in Fig 13 was erected by Gil Gray, KE6HU, as an inverted-V dipole with the 110° apex at 60 feet and the center over a one-story ranch house. The results were disappointing. Curve A of **Fig 16** shows that although the flat frequency response remains, the SWR seldom falls below 2. Measurements made on the dipole alone, fed with 50-Ω coax and stubs disconnected, showed that the SWR reached 1 at 3.75 MHz. This indicated that 50 Ω (not 73 Ω) was the resonant resistance.

The simplest method of lowering the SWR to 1.5 at band center is to drive this 50-Ω antenna with a 75-Ω (not 118-Ω) source. This was done by building a 1.5:1 matching transformer consisting of a 19-foot section of RG-59 coax shunted by a 220-pF transmitting mica capacitor at the antenna. See **Fig 17**. A simple balun was built by coiling the coax into a 6-inch diameter, 12-turn roll. The antenna shown in Fig 13 was driven with the 1.5:1 transformer; curve B of Fig 16 shows the SWR results.

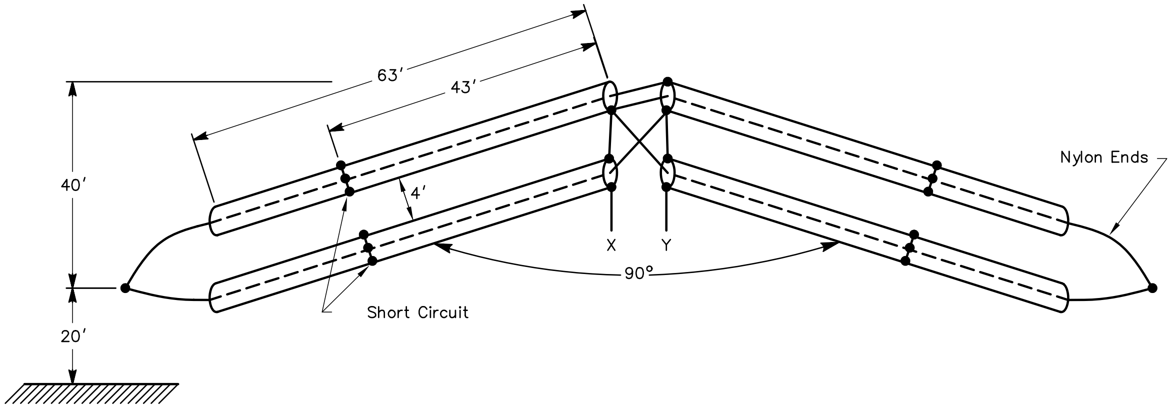


Fig 18—Details of the four-stub antenna.

Note that the band-center SWR is now 1.5 as expected, but the band-edge SWR exceeds 2. This high band-edge SWR results from the rise in antenna Q as the radiation resistance is lowered. This condition can be improved by constructing the antenna with four legs (stubs) as shown in **Fig 18**. Bill Mumford, W2CU, used such a four-stub antenna for several years, in the same inverted-V dipole configuration, with broadband performance. The antenna of Fig 18 was built of sections of RG-58 coax with four cross-connected stubs. The legs were hung as double catenaries with about a 4-foot spacing between the catenary centers.

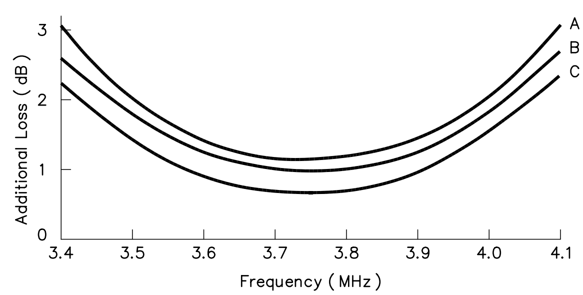
When this lower Q four-stub antenna was driven with the 1.5:1 transformer/balun, the response of curve C, Fig 16, was obtained. This antenna, though bulky, easily meets the SWR criterion. When the same four-stub antenna is driven directly with 50-Ω coax and a 1:1 balun (no transformer), the results are as shown in Fig 16, curve D. This is the configuration at W2CU, which also satisfies the SWR requirement. Thus, it appears that for inverted-V or other "bent" configurations, the four-stub antenna is required for acceptable SWR.

Additional Topics

The shunt stubs and quarter-wave matching section introduce some *additional* loss into this antenna system which is plotted in **Fig 19**. Note that a minimum loss of about 1 dB is achieved at 3750 kHz where the shunt stubs are in resonance. Curve C of Fig 19 shows that reduced loss results if the shunt stubs (flat-top) are constructed of RG-8 or RG-213 and the quarter-wave matching section is made of RG-11.

Both the W2CQH and KE6HU versions of this antenna seem to withstand 1 kW PEP in SSB operation with no ill effects. At 1 kW, approximately 300 V RMS exists across the antenna and shunt stubs, well within the voltage rating of solid polyethylene dielectric RG-58. At this power the current flowing in the center conductor of the quarter-wave transformer and the center conductor of the shunt stubs (near the short circuits) is nearly 6 A, so some heating occurs in these regions. If doubt exists about the power-handling capability, build the flat-top from RG-213 and the transformer from RG-11 coaxial cable.

Fig 19—Computed values of additional loss using two stubs and a λ/4 matching transformer. At A, RG-58 stubs and RG-59 transformer; at B, RG-59 stubs and RG-59 transformer; at C, RG-8 stubs and RG-11 transformer.



The Coaxial Resonator Match and the Broadband Dipole

This material has been condensed from an article by Frank Witt, AI1H, that appeared in April 1989 *QST*. A full technical description appears in *The ARRL Antenna Compendium, Volume 2.*

Fig 20 shows the detailed dimensions of the 3.5-MHz coaxial resonator match broadband dipole. Notice that the coax is an electrical quarter wavelength, has a short at one end, an open at the other end, a strategically placed crossover, and is fed at a T junction. (The crossover is made by connecting the shield of one coax segment to the center conductor of the adjacent segment and by connecting the remaining center conductor and shield in a similar way.) At AI1H, the antenna is constructed as an inverted-V dipole with a 110°included angle and an apex at 60 feet. The measured SWR versus frequency is shown in **Fig 21**. Also in Fig 21 is theSWR characteristic for an uncompensated inverted-V dipole made from the same materials and positioned exactly as was the broadband version.

The antenna is made from RG-8 coaxial cable and #14 AWG wire, and is fed with 50-Ω coax. The coax should be cut so that the stub lengths of Fig 20 are within 1/2 inch of the specified values. PVC plastic pipe couplings and SO-239 UHF chassis connectors can be used to make the T and crossover connections, as shown in **Fig 22** at A and B. Alternatively, a standard UHF T connector and coupler can be used for the T, and the crossover may be a soldered connection (Fig 22C). Witt used RG-8 because of its ready availability, physical strength, power handling capability, and moderate loss.

Cut the wire ends of the dipole about three feet longer than the lengths given in Fig 20. If there is a tilt in the SWR-frequency curve when the antenna is first built, it may be “flattened” to look like the shape given in Fig 21 by increasing or decreasing the wire length. Each end should be lengthened or shortened by the same amount.

A word of caution: If the coaxial cable chosen is not RG-8 or equivalent, the dimensions will have to be modified. The following cable types have about the same characteristic impedance, loss and velocity factor as RG-8 and could be substituted: RG-8A, RG-10, RG-10A, RG-213 and RG-215. If the Q of the dipole is particularly high or the radiation resistance is unusually low because of different ground characteristics, antenna height,

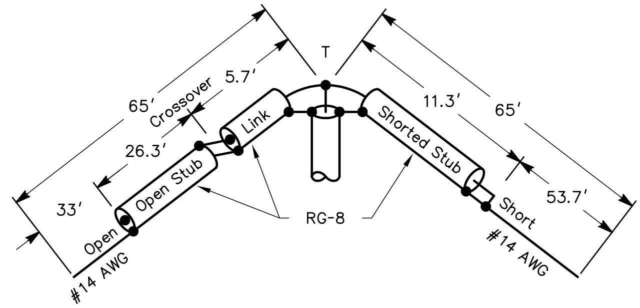


Fig 20—Coaxial resonator match broadband dipole for 3.5 MHz. The coax segment lengths total to one quarter-wavelength. The overall length is the same as that of a conventional inverted-V dipole.

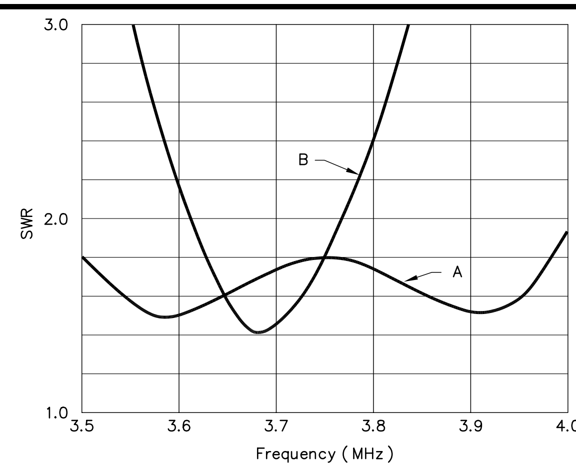


Fig 21—The measured performance of the antenna of Fig 20, curve A. Also shown for comparison is the SWR of the same dipole without compensation, curve B.

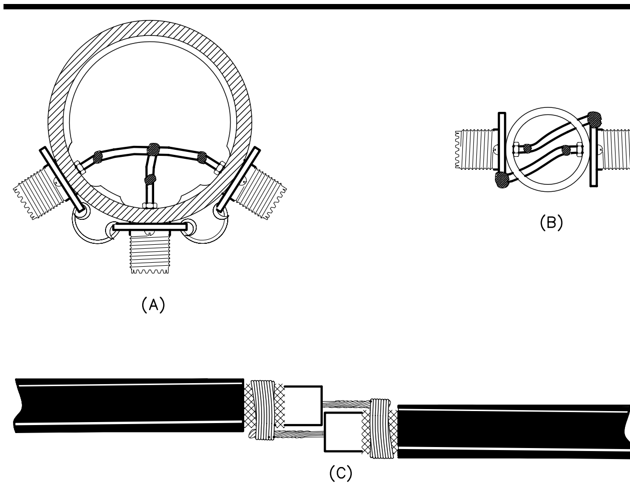


Fig 22—T and crossover construction. At A, a 2-inch PVC pipe coupling can be used for the T, and at B, a 1-inch coupling for the crossover. These sizes are the nominal inside diameters of the PVC pipe which is normally used with the couplings. The T could be made from standard UHF hardware (an M-358 T and a PL-258 coupler). An alternative construction for the crossover is shown at C, where a direct solder connection is made.

surrounding objects and so on, then different segment lengths will be required. In fact, if the dipole Q is too high, broadbanding is possible, but an SWR under 2:1 over the whole band cannot be achieved.

What is the performance of this broadband antenna relative to that of a conventional inverted-V dipole? Aside from the slight loss (about 1 dB at band edges, less elsewhere) because of the nonideal matching network, the broadband version will behave essentially the same as a dipole cut for the frequency of interest. That is, the radiation patterns for the two cases will be virtually the same. In reality, the dipole itself is not "broadband," but the coaxial resonator match provides a broadband match between the transmission line and the dipole antenna. This match is a remarkably simple way to broaden the SWR response of a dipole.

THE COAXIAL RESONATOR MATCH

The coaxial resonator match performs the same function as the T match and the gamma match, that is, matching a transmission line to a resonant dipole. These familiar matching devices as well as the coaxial resonator match are shown in **Fig 23**. The coaxial resonator match has some similarity to the gamma match in that it allows connection of the shield of the coaxial feed line to the center of the dipole, and it feeds the dipole off center. The coaxial resonator match has a further advantage: It can be used to broadband the antenna system while it is providing an impedance match.

The coaxial resonator match is a resonant transformer made from a quarter-wave long piece of coaxial cable. It is based on a technique used at VHF and UHF to realize a low-loss impedance transformation.

THE COAXIAL RESONATOR MATCH BROADBAND DIPOLE

Fig 24 shows the evolution of the broadband dipole. Now it becomes clear why coaxial cable is used for the quarter-wave resonator/transformer; interaction between the dipole and the matching network is minimized. The effective dipole feed point is located at the crossover. In effect, the match is physically located "inside" the dipole. Currents flowing on the inside of the shield of the coax are associated with the resonator; currents flowing on the outside of the shield of the coax

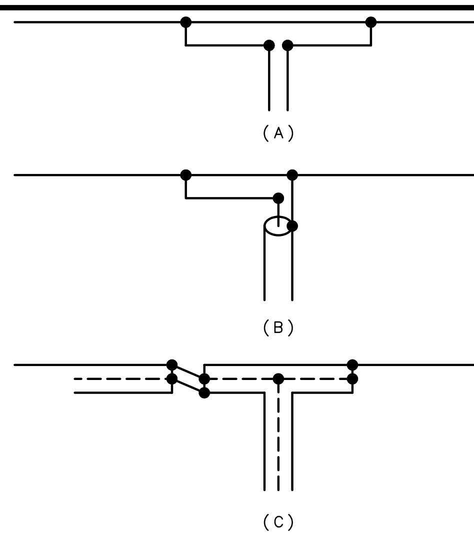


Fig 23—Dipole matching methods. At A, the T match; at B, the gamma match; at C, the coaxial resonator match.

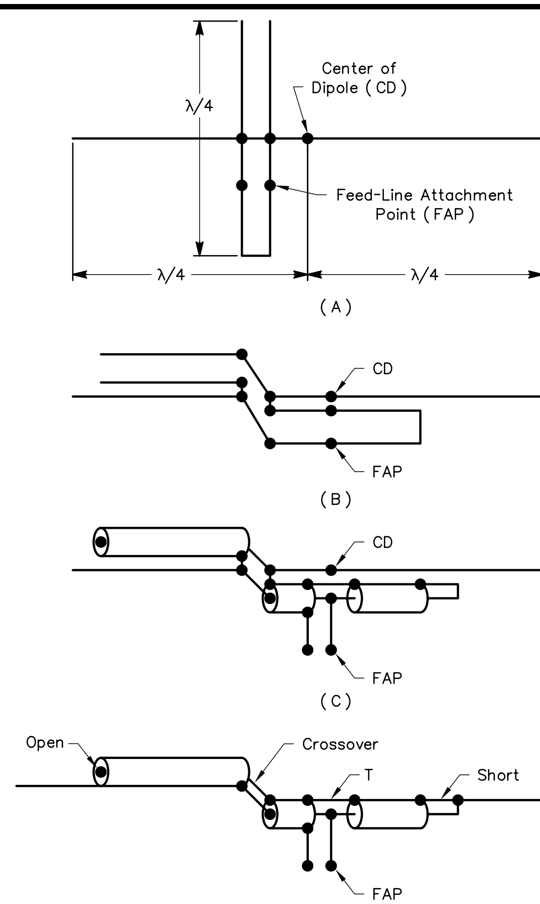


Fig 24—Evolution of the coaxial-resonator-match broadband dipole. At A, the resonant transformer is used to match the feed line to the off-center-fed dipole. The match and dipole are made collinear at B. At C, the balanced transmission-line resonator/transformer of A and B is replaced by a coaxial version. Because the shield of the coax can serve as a part of the dipole radiator, the wire adjacent to the coax match may be eliminated, D.

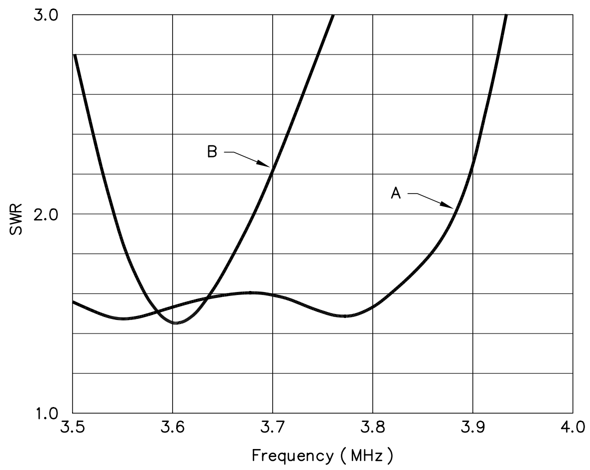


Fig 25—Measured SWR performance of the 3.5-MHz DX Special, curve A. Note the substantial broadbanding relative to a conventional uncompensated dipole, curve B.

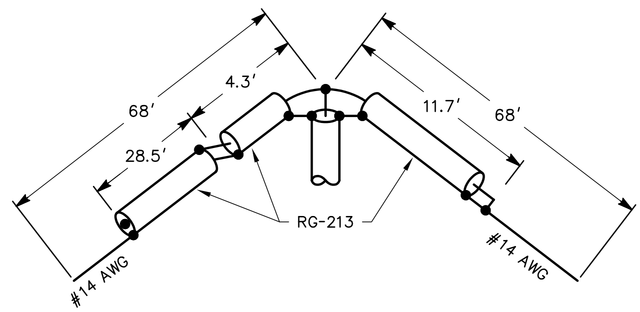


Fig 26—Dimensions for the 3.5-MHz DX Special, an antenna optimized for the phone and CW DX portions of the 3.5-MHz band.

are the usual dipole currents. Skin effect provides a degree of isolation and allows the coax to perform its dual function. The wire extensions at each end make up the remainder of the dipole, making the overall length equal to one half-wavelength.

A useful feature of an antenna using the coaxial resonator match is that the entire antenna is at the same dc potential as the feed-line potential, thereby avoiding charge buildup on the antenna. Hence, noise and the potential of lightning damage are reduced.

A Model for DXers

The design of Fig 20 may be modified to yield a "3.5-MHz DX Special." In this case the band extends from 3.5 MHz to 3.85 MHz. Over that band the SWR is better than 1.6:1 and the matching network loss is less than 0.75 dB. See **Fig 25** for measured performance of a 3.5-MHz DX Special built and used by Ed Parsons, K1TR. Design dimensions for the DX Special are given in **Fig 26**.

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