As the announcer on the late-night news asks, "Do you know where your signal is tonight?" we turn to VE3ERP, who provides the answer. Don't be frightened or turned off by the math. The machine does it all.

Do You Know Where Your Signal is Tonight?

BY GEORGE MURPHY*, VE3ERP

Most of your signal is probably getting out as it should. However, some of the signal may be getting frittered away on its journey from transmitter to antenna because your antenna impedance does not match your feed-line impedance.

Many antenna design descriptions will tell you the feed point impedance of a dipole can be *assumed* to be a pure radiation resistance load of "*about*" 70 ohms, or a vertical "*approximately*" 35 ohms, or a mobile whip "*as little as*" 5 ohms, or some other vague assumption. These values may apply in the Land of Oz, but in the Real World, the many on-site variables affecting an antenna installation rarely result in the antenna being a purely resistive load. Furthermore, the real load (which usually contains other AC current impediments besides radiation resistance) almost never has the same total impedance as the transmission line used to feed it. Therefore, an impedance transformation device to match the actual complex load impedance to the feed-line impedance is often necessary to provide the most efficient operation. There are many ways to do this, one of the *least* popular of these being the use of a series-section transformer[1] made entirely of coaxial cable (see fig. 1[A]).

A cursory glance at the equations in Table I[2] will immediately reveal two reasons why the average amateur radio experimenter has avoided these physically simple, easy-to-construct impedance transformers like The Plague. First, the mathematics involved are frightening (unless you are an algebra freak), and second, you have to know the antenna's complex impedance $R_L + jX_L$ (I can't even pronounce it, let alone understand it).

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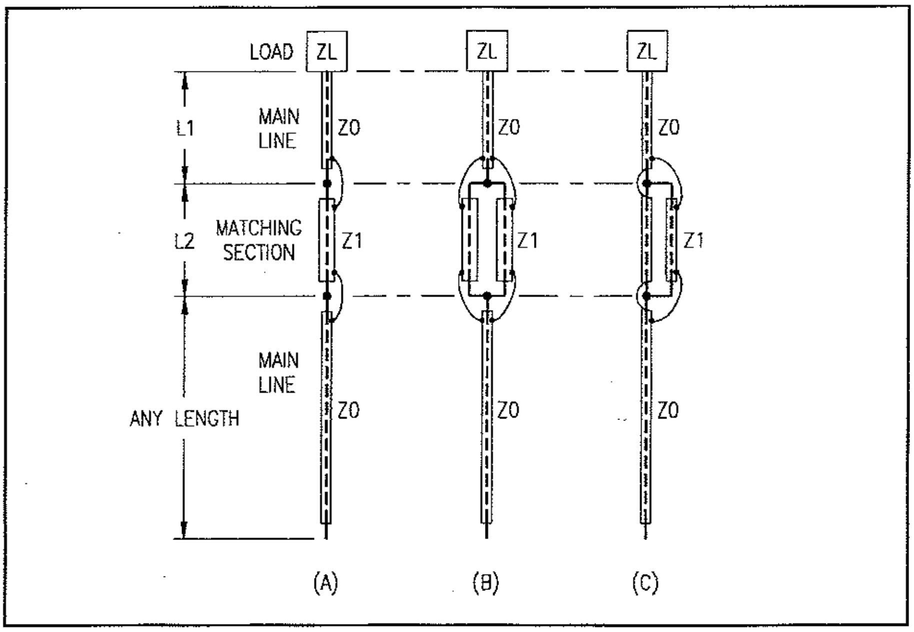

Fig. 1– Series-section impedance transformers made of coaxial cable. (See text for description.)

Don't let the equation scare you, though. Just ignore it for now while I tell you the good news.

Modern Technology To The Rescue

If you have a computer and *HAMCALC*[3] software (version 37 or later), forget the equation altogether. *HAMCALC* will do all the math for you. Fig. 2 is a hard-copy printout of a typical screen display produced by this program.

With the advent of small, affordable complex antenna analyzers such as the MFJ-259B and AEA SWR-121 HF, you can make direct readings of your antenna's resistive component *(R)* and reactive component *(X)*. If *(X)* is negative, it is a capacitive reactance *(–jX)*; if positive it is an inductive reactance *(+jX)*. In the jargon of antenna-speak, the antenna impedance therefore is $R \pm jX$ ohms[4].

The only other factors you need in order to design a series-section transformer are the operating frequency and the characteristic impedances (Z_0 for the main line and Z_1 for the matching section) of the coaxial cables you intend to use. The *HAMCALC* program "Series-Section Transformer" will take care of all this and design a transformer in a few seconds, or

Table I– Equations for determining values for series-section impedance transformers. You can leave this in a conspicuous spot to impress visitors while you simply ignore it and use your computer. →

Series-Section Transformer Equations

$$Z_L = R_L + jX_L$$

$$n = \frac{Z_1}{Z_0} \qquad r = \frac{R_L}{Z_0} \qquad x = \frac{X_L}{Z_0}$$

L2 = arctan B where:

$$B = \pm\sqrt{\frac{(r-1)^2 + x^2}{r(n-\frac{1}{n})^2 - (r-1)^2 - x^2}}$$

L1 = arctan A where:

$$A = \frac{(n-\frac{r}{n})\,B + x}{r + xnB - 1}$$

$$p = \sqrt{\frac{(R_L - Z_0)^2 + X_L^2}{(R_L + Z_0)^2 + X_L^2}}$$

$$SWR = \frac{1+p}{1-p}$$

$$L_M = \frac{299.9\, V_F\, L_d}{360\, f_{MHZ}}$$

Z_L = Load, in ohms
R_L = Resistive component of load ZL, in ohms
X_L = Reactive component of load Z_L, in ohms
Z_0 = Characteristic impedance of main line
Z_1 = Characteristic impedance of matching section
$L1$ = Electrical length of main line, matching section to load
$L2$ = Electrical length of matching section
p = Reflection coefficient
L_m = Line length in meters
L_d = Line in length in electrical degrees
V_f = Velocity factor of line
f_{MHZ} = Frequency in MHz

(Main line from transmitter to matching section can be any length) you can do it yourself using the equations in Table I[5].

Some Design Variations

Fig.1(A) shows the textbook configuration—a section of dissimilar coaxial cable spliced into the main feed line. But there is more to this than meets the eye. In the course of discussions with Roger Johnson, N1RJ, Roger pointed out other configurations are also possible:

Fig. 1(B) shows two lengths of a dissimilar cable in parallel spliced into the feed line. This provides a matching section with an effective characteristic impedance one-half the impedance of the cable used, thus providing a greater range of design options than available with the fig. 1(A) configuration.

Fig. 1(C) shows an L2 length of the same cable as the main line connected to the main line at two points L2 apart. This will be of particular interest to pecuniarily aware (–•–• •••• • •– •––•) amateurs who only have one type of coaxial cable on hand.

It is best to avoid using foam-type coaxial cable in this application. Due to practical limitations in maintaining a constant ratio of air to dielectric in the foam during manufacture, the properties of foam cable from different production runs may vary considerably from the textbook values.

A Design Example

Let's assume you are *not* living in the Land of Oz and you have a 7.15 MHz antenna with an impedance at the feed point of 35–j15 ohms (35 ohms radiation resistance and 15 ohms capacitive reactance). You don't have to know what these numbers mean. You just have to know that they exist, since they are needed for the equations or the computer program. You want to use RG-8 for the main line, and there happens to a bit of RG-11 on hand for the matching section.

Using *HAMCALC* if you have a computer, or the equations if you don't, you design a fig. 1(A) configuration to find that L1 = 36.64 ft. and L2 = 9.01 ft., for a total length of 45.65 feet. This is longer than the total length of feeder you need, so you try a fig. 1(B) configuration. This calculates L1 as 10.77 ft. and L2 as 9.98 ft., totalling 20.75 feet. Much better, but you only have 6 feet of RG-11 so you try fig. 1(C), using RG-8 for everything, and arrive at L1 as 14.93 feet and L2 as 4.93 feet. (see fig. 2).

That's it. Three possible solutions to an antenna problem you probably didn't even know you had until you started reading hi-tech articles such as this one.

Footnotes

1. Described in detail by Frank Regier, OD5CQ, in the July 1978 issue of *QST*.

2. From *The ARRL Antenna Book*, 17th edition, page 26-15.

3. *HAMCALC* is *free*—over 200 programs of interest to amateur and professional radio buffs. *HAMCALC* runs in either MS-DOS or Windows™. Written in GWBASIC, it requires a GWBASIC.EXE file installed in your hard drive. For a free HAMCALC 3½" diskette send US$5.00 (send US$6.00 if you want a copy of GWBASIC.EXE included) to cover costs of materials, packaging, and airmail delivery anywhere in the world to the author at the address shown at the beginning of this article.

4. For some other ways to measure antenna impedance, see the *HAMCALC* programs "Impedance—Antennas," "Impedance Bridge (3 meter)," and "Transmatch Design (ZL1LE)."

5. You will need a handbook to look up the impedances and velocity factors of the cable types you want to use, access to an expanse of smooth beach or desert, and a pointed stick for solving the equations in the sand. ■

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                       SERIES-SECTION TRANSFORMER

Frequency of operation................   7.150 MHz
Impedance of antenna..................   35-j15 Ω
Impedance of main feed line...........   52.00 Ω RG-8      Vel.Fac.=.657
Impedance of matching section.........   26.00 Ω RG-8      Vel.Fac.=.657
SWR...................................   1.69:1
Line from antenna to matching section..  57.351° length of RG-8
Matching section......................   19.651° length of RG-8

                 antenna ┬┬ feed point
                                                 ┌ 57.351° long =
          52.0 Ω Main ││Line RG-8          ←──┤  4.387 m.=
                                                 └ 14.394 ft.

                                                 ┌ 19.651° long =
    26.0 Ω Matching │[]│Section RG-8        ←──┤  1.503 m.=
                          2 in parallel          └  4.932 ft.

          52.0 Ω Main ││Line RG-8
                          (any length)
               from station
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Fig. 2 – A typical printout using HAMCALC to determine values for a series-section impedance transformer.