THE SERIES SECTION **TRANSFORMER**

By Charles J. Michaels, W7XC, 13431 N. 24th Avenue, Phoenix, Arizona 85029

Here's the problem. You've just put a half-wave dipole for 40 meters at 52 feet, connected 70 feet of RG-213 (50 ohm) coax, and trimmed the antenna to resonance at 7.15 MHz — but the best VSWR you can get is 1.6:1. Although the calculated extra 0.05-dB loss (above the 0.38-dB calculated matched loss — see **Appendix A**) is negligible, you don't like the VSWR and your transceiver doesn't either.

Check the input impedance curve of a half-wave dipole versus height (0.375 wavelength in this case) in almost any antenna text and you'll find that you should have about 85 ohms for a VSWR of 1.7:1 at the antenna, and 1.62:1 through 70 feet of RG-213 line (see **Appendix B**). What to do?

How about a balanced L net at the antenna? Hmm, two coils and a capacitor in a weather protective box. Weight, wind load?

How about a stub matching system? Gosh, that RG-213 is heavy enough now!

Or how about a quarter-wave matching section? Let's see,

$$Z_o = \sqrt{Z_L\ Zi} = \sqrt{50 \times 85} = 65.2 \text{ ohms}$$

Sixty-five ohm coax? Not exactly a standard item!

Is a transmatch the only answer? No!

A solution

This, and many other matching problems, can often be solved by using a series section transformer. The technique uses a calculated length of feedline, ℓ_2, removed at a calculated distance, ℓ_1, from the load, and replaced by a piece of feedline with an impedance different from that of the main line (see **Figure 1**). This technique can also provide a match to loads that include reactance. Furthermore, it becomes *part* of the feedline rather than an addition.

Calculation

Use the aforementioned problem as an example. Your first task is to determine feasibility. The ℓ_2 section of line must have a characteristic impedance either less than

$$Z_1 / \sqrt{VSWR}$$

or greater than

$$Z_1 \sqrt{VSWR}$$

In this case the antenna VSWR is 1.7:1 and, because

$$50 / \sqrt{1.7} = 38.3 \text{ ohms}$$

and

$$50 \sqrt{1.7} = 65.2 \text{ ohms}$$

the ℓ_2 section must have an impedance of either less than 38.3 ohms or greater than 65.2 ohms. RG-11 at 75 ohms is standard, so the system is feasible.

To simplify the calculations, normalize the load impedance R_L and X_L, and the Z_2 impedance to the main line impedance Z_1 as follows:

$$n = Z_2/Z_1 \quad (1)$$

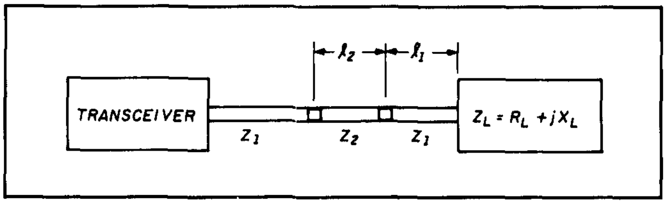
$$r = R_L/Z_1 \quad (2)$$

$$x = X_L/Z_1 \quad (3)$$

Because Z_2 is 75 ohms, R_L is 85 ohms, X_L is zero ohms (a dipole is a pure resistance at resonance), and Z_1 is 50 ohms using **Equations 1, 2,** and **3**, n = 75/50 = 1.5, r = 85/50 = 1.7 and x = 0/50 = 0.

The *angular* length of section ℓ_2, or $\ell_2°$, is calculated as follows:

FIGURE 1



Series section transformer. Z_1 is the main-line characteristic impedance. Z_2 is the matching-section characteristic impedance. See text for calculation of Z_2, ℓ_1, and ℓ_2.

$$\ell_2^\circ = \arctan B \quad \textbf{(4)}$$

where:

$$B = \left[\frac{(r - 1)^2 + x^2}{r\,(n - \frac{1}{n})^2 - (r - 1)^2 - x^2}\right]^{1/2}$$

For the example:

$$B = \left[\frac{(1.7 - 1)^2 + 0^2}{1.7\,(1.5 - \frac{1}{1.5})^2 - (1.7 - 1)^2 - 0^2}\right]^{1/2}$$

$$= 0.842$$

A trigonometry table of tangents or a scientific calculator indicates that a tangent of 0.842 corresponds to an angle of 40.11°. This angle is converted to feet of transmission line by **Equation 5**.

$$\ell' = (2.733 \times \ell^\circ \times V_f)/F \quad \textbf{(5)}$$

where:

ℓ' = length in feet
ℓ° = length in degrees
V_f = velocity factor of line
F = frequency in MHz

In the example, velocity factor V_f is assumed to be 0.66 for both the RG-213 and RG-11. Quality coax is usually very close to specification. Using **Equation 5**:

$$\ell'_2 = (2.733 \times 40.11 \times 0.66)/7.15 = 10.12', \text{ or } 10'\ 1.4''$$

The angular length of section ℓ_1 is calculated as follows:

$$\ell_1^\circ = \arctan A \quad \textbf{(6)}$$

where:

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

For the example,

$$A = \frac{(1.7 - \frac{1.7}{1.5})\,0.842 + 0}{1.5 + 0 - 1} = 0.441$$

0.441 is the tangent of 23.8°.

Again using **Equation 5**,

$$\ell'_1 = (2.733 \times 23.8 \times 0.66)/7.15 = 6', \text{ or } 6'0''$$

The design is now complete.

If you find the quotient is negative when calculating B of **Equation 4**, then Z_2 is too close to Z_1. This may happen when reactance is present in the load, despite initial indications of feasibility.

When calculating A of **Equation 6**, the result can be a negative number implying a negative angular length. In this case, add 180° to the negative angle to obtain the correct length.

Implementation

Cut the RG-213 coax line 6′ from the antenna and insert a 10′ 1.4″ length of RG-11 line. You can do this neatly with PL-259 connectors and barrels weatherproofed by wrapping the connectors and barrels with RTV compound. If you use connectors and barrels, include their lengths in the ℓ_1 and ℓ_2 lengths.

You may shorten the remaining RG-213 line to the station if you wish, as 10′ 1.4″ has been added. Because the addition is small, it's probably not worthwhile to shorten this line. In VHF applications, take extra care to include the connector and barrel lengths in the calculations.

Other applications

This system is applicable to both coaxial and balanced lines. In fact, because a wide range of balanced line impedance is available through your choice of conductor diameter and spacing, balanced lines offer a wide range of matching section parameters.

You can also use this system at the sending end, when it may be necessary to match a line of other than the 50 ohms for which your transceiver, VSWR meter, and low pass filter are designed.

Appendix A—Loss total

RG-213 at 7.15 MHz has 0.55-dB loss per 100 feet. Therefore, 70 feet of matched line has 0.7 × 0.55 = 0.38-dB loss.

$$\text{Loss total} = 10 \log_{10}\left[\frac{B^2 - C^2}{B\,(1 - C^2)}\right]$$

where

$B = 10^{Lm/10}$
Lm = loss matched in dB

and

$$C = \frac{S_\ell - 1}{S_\ell + 1}$$

where

S_ℓ = VSWR at load

$$C = \frac{1.7 - 1}{1.7 + 1} = 0.25926$$

$$B = 10^{0.38/10} = 1.09144$$

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$$\text{Loss/Total} = 10 \log_{10}\left[\frac{1.09144^2 - 0.25926^2}{1.09144\,(1 - 0.25926^2)}\right] = 0.43$$

0.43 − 0.38 = 0.05 additional loss due to 1.7:1 VSWR

Appendix B—VSWR

S_i = VSWR at generator end of line
S_ℓ = VSWR at load end of line

$$C = \frac{S_\ell - 1}{S_\ell + 1}$$

$B = 10^{Lm/10}$
Lm = loss matched in dB

$$S_i = \frac{B + C}{B - C}$$

$$C = \frac{1.7 - 1}{1.7 + 1} = 0.25926$$

$$B = 10^{0.38/10} = 1.09144$$

$$S_i = \frac{1.09144 + 0.25926}{1.09144 - 0.25926} = 1.62$$

VSWR at input to line is 1.62:1