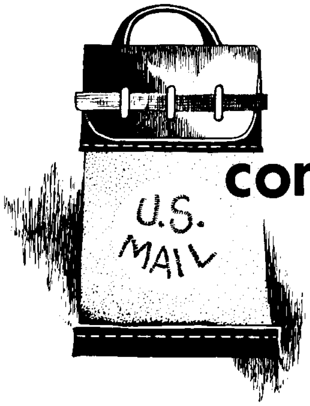

comments

microstripline preamplifiers

Dear HR:

WA6UAM's article on "Microstrip Preamplifiers for 1296 MHz,"[1] with a few exceptions explained below, is an excellent article. Having worked with stripline for several years, especially in development of the TIROS-ESSA antenna matching circuitry, I can attest to the value of such a practical construction article for the uhfer. It was also very timely, as more and more amateurs are starting to use stripline techniques to build uhf equipment.

However, in the design section of the article, several unfortunate errors and contradictions appear in the treatment of the S-parameter reflection coefficients and impedances, which are confusing and misleading, even to one who is familiar with S-parameter techniques. The confusion begins in the first paragraph on page 22, where the author states that complex impedances are generally shown in polar form, but can be converted to rectangular form through use of the Smith chart, as per instructions in the caption of **fig. 12**. The inference is quite clear that the conversion intended is between the polar and rectangular forms of an equivalent value of *impedance*. However, it is not *impedance* which is being converted, and furthermore, the Smith chart cannot perform this type of conversion. Therefore, the inference is incorrect.

The confusion is compounded in the next paragraph, where it is stated that **table 1** lists complex *impedances* in both polar and rectangular forms, while in the table itself both the polar and rectangular forms are stated to be *reflection coefficients*. This contradiction needs clarification, and the statements emphasize the previous, erroneous inference that the associated values appearing in polar and rectangular form in the table are numerically equivalent, while in fact they are not.

The confusion can be easily cleared up as follows: First, it is evident that the author is randomly interchanging reflection coefficient and impedance, confusing the polar-form reflection coefficient with the polar-form equivalent of the rectangular-form impedance. The two are not the same!

Impedance, $Z = E/I$, describes the relation between voltage and current in a circuit. Reflection coefficient, ρ, on the other hand, is the relationship between two voltages (the reflected and the incident) in a circuit containing *two* impedances at a junction, or two currents in the same circuit:

$$\overline{\rho} = \frac{E_{reflected}}{E_{incident}} = -\frac{I_{reflected}}{I_{incident}}$$

Accordingly, to clarify the first paragraph on page 22 of WA6UAM's article, the phrase "complex *impedances* in polar form . . . " is a mistatement which should be changed to read "complex *reflection coefficients* are generally shown in polar form, which can be converted to *impedance* in rectangular notation (R ± jX) on a Smith chart as indicated in **fig. 12**" (after the caption of **fig. 12** is also corrected).

Second, the complex numbers appearing in *polar* form in **table 1** are reflection coefficients, and the rows containing the polar-form values should be so labelled. Third, the complex numbers appearing in *rectangular* form in **table 1** are the *impedances* which will give rise to the accompanying value of reflection when terminating a line or source having an impedance of 50 ohms. In other words, taking an example from the second HP-25826E column, the 12.5 + j0.5 value is *not* the rectangular equivalent of the polar value 0.61 $\angle 178^\circ$, but is the complex impedance which will *yield* the complex reflection coefficient $\overline{\rho} = 0.61 \angle 178^\circ$ when the impedance 12.5 + j0.5 terminates a 50-ohm line or source. The rows containing complex numbers in the rectangular form should therefore be specifically labelled *impedance* S_{11} or S_{22}, as appropriate. Proof that the rectangular-form impedance is not equivalent to the listed polar value is further shown by the fact that the polar equivalent of the impedance 12.5 + j0.5 is actually 12.51 $\angle 2.29^\circ$, and *not* 0.61 $\angle 178^\circ$.

Fourth, as constructed in **figs. 9, 10, 11** and **13**, the graphs containing the S_{11} and S_{22} plots should be labelled *impedance*, not "reflection coefficient" because the only loci-identifying coordinates in the graphs are the resistance and reactance circles. The S-parameter graphs in the Hewlett-Packard design catalog[2] from which the figures in the article were taken contain *two* sets of coordinates by which the loci may be identified: resistance- and reactance-circle coordinates to identify the loci as impedances, *and* radial magnitude and angle coordinates to identify the loci as reflection coefficients. Thus the user could use whichever set of coordinates he desired to read the loci as impedances or reflection coefficients.

It is apparent in unravelling all this confusion that a misunderstanding also exists concerning the basic functions of the Smith chart. The function which the Smith chart is really performing in **fig. 12** is the conversion from the complex

1. H. Paul Shuch, WA6UAM, "Microstropline Preamplifiers for 1296 MHz," *ham radio*, April, 1975, page 12.

2. "Diode and Transistor Designers Catalog," Hewlett-Packard, May, 1974.

reflection coefficient in the polar form to the *normalized impedance* in the rectangular form. The magnitude (radius) and angle $0.8 \angle -50^\circ$ in **fig. 12** define a specific point in *reflection-coefficient* coordinates of the chart, while normalized impedance is found at this same point where the *r* and *x* impedance coordinates of 0.6 and 2.0 intersect, respectively. It cannot be emphasized too strongly that the chart is *not* converting impedance in the polar form to its equivalent impedance in the rectangular form.

Polar-to-rectangular conversion of equivalent impedances is relatively simple to calculate using the Pythagorean theorem. However, conversions between reflection coefficient and impedance are more difficult to calculate, hence the Smith chart is used to simplify reflection-to-impedance conversions. As a point of interest, polar-to-rectangular impedance conversions *can* be performed with an overlay combination of Smith and Carter charts having the same diameters (the Carter chart has impedance coordinates arranged to identify impedance in polar form). With the Smith-Carter overlay the user may enter the Smith chart in rectangular form and the corresponding point on the Carter chart is the polar-form equivalent. As a further point of interest, here is the expression for calculating the conversion from a complex reflection coefficient $\bar{\rho}$ to *normalized* impedance:

$$\frac{Z}{Z_c} = \frac{R + jX}{Z_c} = \frac{1 + \bar{\rho}}{1 - \bar{\rho}} = \frac{1 + \rho\angle\theta}{1 - \rho\angle\theta}$$

$$= \frac{1 + \rho \cos\theta + j\rho \sin\theta}{1 - \rho\cos\theta - j\rho\sin\theta}$$

Going in the opposite direction, to determine the reflection set up by a given complex impedance loading a line of impedance Z_c, we have

$$\bar{\rho} = \rho\angle\theta = \frac{R + jX - Z_c}{R + jX + Z_c}$$

Two additional errors of lesser importance are, first, on page 25 at the beginning of column 2, the shunt equivalent value of the series impedance 40 + j25 ohms should be changed from 34.8 +j55.6 ohms, to read *55.6 + j89* ohms. And second, the NEC VO21 column of **table 1**, the reactance −j38.5 in the parallel-circuit input impedance should be changed to indicate a *positive* reactance.

As a final point of interest, in 1953 the American Standards Association (ASA) adopted the Greek letter rho, ρ as the symbol to represent reflection coefficient, and many textbook and periodical publishers, as well as manufacturers of S-parameter measuring instrumentation, conformed. Prior to 1953, ρ was often used to indicate swr, while gamma, Γ and k were used interchangeably to represent reflection. It would be interesting to know why the people at Hewlett-Packard who produce solid-state components continue to use Γ, while those who produce the instruction manuals for their impedance and S-parameter measuring equipment are using ρ.

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W2DU has raised a valid point with regard to the rather loose terminology which I used in my recent article, and I concede that reflection coefficient and impedance are not synonomous, although they are related.

Several readers have questioned my failure to consider the transistor's transfer coefficient in calculating the matching networks. Actually, my simplistic design method, which ignores S_{12} in particular, results in a minute matching error which may be compensated by adjusting the trimmer capacitors at the input and output of the preamplifier.

For the benefit of those readers who have inquired about Rollett's stability factor, I should mention that K calculates to greater than unity for all transistor/bias combinations presented in the original article so the amplifiers are unconditionally stable. Nevertheless, I caution the builder to treat them as though they were not. That is, do not apply power until the amplifier is properly terminated in an antenna (or dummy load) and a converter

H. Paul Shuch, WA6UAM