I-3. Log-Periodic Octaline Hybrid Junctions

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The four-port circuits to be discussed are actually eight-port circuits with pairs of ports connected in a balanced manner. Thus, it may be necessary in some applications to use frequency-independent baluns, such as those described in the preceding paper, to feed the hybrid. Since the coupled outputs of the log-periodic octaline junctions are equal in magnitude and either in phase or out of phase, the circuit behaves as a magic *T*. Log-periodic quadraline hybrid junctions, for which the coupled outputs are 90° out of phase, will be the subject of a future paper. The log-periodic hybrids should find wide application in wideband search, ECM and monopulse tracking systems. As will be discussed, these circuits are best suited for the frequency ranges from 50 Mc to 10 Gc.

Figure 1 illustrates one type of log-periodic octaline junction. It consists of eight transmission lines emanating from a common origin. Opposite transmission lines are fed out of phase in a balanced manner, so that there are four terminal pairs associated with the structure. Adjacent transmission lines are coupled together at log-periodic intervals by coupled strip transmission lines, as shown in the upper left of Fig. 1. For simplicity, the coupling between the other transmission lines has been omitted. However, the complete network is symmetrical about all the transmission lines. By symmetry alone, it is seen that if a balanced voltage is applied to terminal

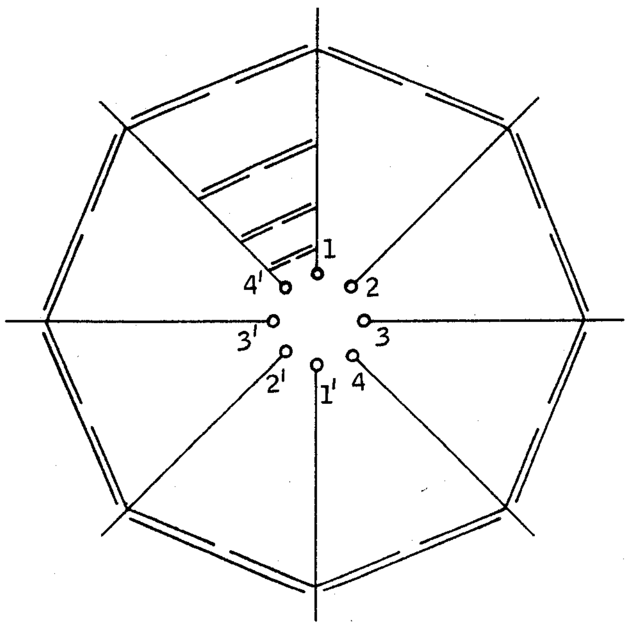

Fig. 1 Schematic representation of 8-port log-periodic hybrid circuit.

pair 1-1′, there will be no coupling to terminal pair 3-3′. Likewise, there is no coupling between pairs 2-2′ and 4-4′. In the remainder of this discussion, the four balanced ports will be referred to as 1, 2, 3, 4. The log-periodic coupling between the transmission lines is adjusted so that with an incident wave applied to port 1, there is no reflection at these terminals, and all of the power is coupled equally to ports 2 and 4. This is just the required performance of a hybrid.

The analysis of the octaline junction is quite similar to that for the two-port circuits described in the previous paper. In order to achieve hybrid performance, it is only necessary to specify that the circuit is unchanged by a rotation of 45 degrees about an axis perpendicular to the plane of the structure. With this assumed symmetry, a symmetry analysis leads to the following scattering matrix for the junction:

$$S = \begin{vmatrix} \alpha & \beta & 0 & -\beta \\ \beta & \alpha & \beta & 0 \\ 0 & \beta & \alpha & \beta \\ -\beta & 0 & \beta & \alpha \end{vmatrix} \tag{1}$$

where

$$\alpha = \frac{1}{2}(\Gamma_e + \Gamma_o), \quad \beta = \frac{1}{2\sqrt{2}}(\Gamma_e - \Gamma_o).$$

There are two doubly degenerate eigenvalues, Γ_e and Γ_o, for the circuit. A set of normal modes or eignevectors for the circuit is given by

$$a_1 = \frac{1}{\sqrt{2}}\begin{vmatrix} 1 \\ 1/\sqrt{2} \\ 0 \\ -1/\sqrt{2} \end{vmatrix} \qquad a_2 = \frac{1}{\sqrt{2}}\begin{vmatrix} 0 \\ 1/\sqrt{2} \\ 1 \\ 1/\sqrt{2} \end{vmatrix}$$

$$a_3 = \frac{1}{\sqrt{2}}\begin{vmatrix} 1 \\ -1/\sqrt{2} \\ 0 \\ 1/\sqrt{2} \end{vmatrix} \qquad a_4 = \frac{1}{\sqrt{2}}\begin{vmatrix} 0 \\ -1/\sqrt{2} \\ 1 \\ -1/\sqrt{2} \end{vmatrix} \tag{2}$$

Notice that a superposition of the first and third eigenvectors corresponds to the excitation of the circuit with an incident wave at port 1 only. The eigenvalues Γ_e and Γ_o are the input reflection coefficients for the first and third eigenvector excitations of the network. As in the preceding paper, it is necessary to design the circuit such that the phases of Γ_e and Γ_o are a linear function of the logarithm of the frequency and that Γ_e and Γ_o are 180° out of phase. Then, α and β become approximately

$$\alpha \approx 0$$

$$\beta \approx \frac{1}{2\sqrt{2}} \exp -j \left[\frac{2\pi \ln f}{|\ln \tau|} + \varphi + \frac{1}{2}\left(\ln \frac{Z_{oe}}{Z_{oo}}\right) \sin\left(\frac{2\pi \ln f}{|\ln \tau|} + \varphi\right)\right]. \tag{3}$$

When these conditions are achieved, the circuit performs as a magic *T*. The sinusoidal phase ripple does not degrade the performance of the hybrid as it does for the phase difference circuit, since the ripples for all of the coupled outputs are in phase. From the form of the scattering matrix and from the symmetry of the structure, it is readily seen that with an incident wave applied to port 1, the coupled outputs are out of phase, and with an incident wave applied to port 3, the coupled outputs are in phase.

The method of calculating Γ_e and Γ_o is quite similar to that used in the preceding paper. With incident waves applied to the junction, corresponding to either the first or third eigenvectors (refer to Eq. (2)), an electric wall may be placed along the radial transmission lines 3 and 3'. Since the voltage distribution on the radial lines is known, the impedance that the shunt-connected coupling lines present to the radial lines may be calculated in a straightforward manner. It turns out that the impedances presented to each of the radial lines for one ring of the coupling sections are identical. Thus, it is necessary to analyze only a single transmission line loaded at log-periodic intervals as in a preceding paper. The input reflection coefficient is then obtained by a straightforward matrix multiplication. The coupling coefficients for the coupled transmission lines, τ and other design parameters, may be varied to obtain the 180° phase difference between Γ_e and Γ_o.

Various types of coupling networks for the octaline junctions have been extensively studied. The optimum configurations will be discussed and explained in detail. Theoretically, VSWR's less than 1.1 may be achieved and, of course, the coupled outputs are ideally equal. Experimental results for a hybrid designed for the frequency range of 160 to 800 Mc will be presented.

With regard to size, the configuration illustrated in Fig. 1 is approximately one-half wavelength in diameter when printed on a board with a relative dielectric constant of 2.5. For higher frequency applications, it may be necessary to print the circuit on a conical surface, rather than a planar surface.