A NEW DIPLEXER - REALIZED IN STRIPLINE

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ABSTRACT

Diplexers usually have a three-way common junction whose rather complex discontinuity imposes severe restrictions on attempts to control the different impedances presented by channels of different frequency. A new type of stripline diplexer has been developed that employs series-connected distributed elements emerging from its common junction to yield a compact structure free of these discontinuity problems. The concept was implemented in a printed-circuit diplexer built as part of a C-band varactor-tripler circuit, and was verified by test.

Introduction

Coaxial and printed distributed elements readily lend themselves to parallel and cascade connection in microwave circuits (Figures 1A and 1B), but connecting the same elements in series (Figure 1C) is much more complicated. The problem is often avoided by using coupled-line structures whose electrical equivalents contain circuit elements connected in series. Indeed, many of the commonly used microwave filters (side-coupled, interdigital) employ this concept, as do other microwave components such as couplers[1] and multiplexers[2]. In addition, the use of circuit elements connected in series has proved to be crucial for expanding the bandwidth of various components[1,3,4] and, as shown below, can provide a compact structure for diplexers.

Structural Description

Figure 2 illustrates the usual type of three-way junction, and Figure 3 the newly developed stripline version and its electrical equivalent. Both are printed circuits. As shown in Figure 3A, two broadside-coupled lines are centered between ground planes, which are separated by a distance B_o. The width of the coupled lines is identified as W_4, and the distance between them as B. Being excited symmetrically, the coupled lines form a shunt stub with an input impedance of Z_{i4} (Figure 3B). The Z_{i1}, Z_{i2}, and Z_{i3} terms represent the input impedances of the series stubs; the series configuration results from the termination of their electric fields on the upper and lower printed lines, forming Z_{i4}. In this case, the Z_{i1}, Z_{i2}, and Z_{i3} impedances should be regarded as electrically floating in reference to the ground planes, yielding a "Y" connection. To ensure that they are not side-coupled between themselves, the following relations should be fulfilled:

$$W_4 > W_1 + W_2 + W_3 + S_{12} + S_{13} \qquad (1)$$

$$S_{12} > B \quad \text{and} \quad S_{13} > B \qquad (2)$$

The W and S terms, which are omitted in Figure 3A, respectively represent the widths of the corresponding stubs and the distances separating them. Relations 1 and 2 set a practical limit on the number of different channels emerging from a junction.

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In order to control Z_{i1}, Z_{i2}, Z_{i3}, and Z_{i4}, their corresponding characteristic impedances Z_{01}, Z_{02}, Z_{03}, and Z_{04} should be realized precisely. For this purpose, the Z_{01}, Z_{02}, and Z_{03} transmission lines are considered as regular printed lines between ground planes separated by a distance B (Figure 3A). For this case, the relationship between Z_0 and W/B can be found in Matthaei, et al.[1] Because these broadside-coupled lines, which form the shunt stub with the input impedance Z_{i4}, are excited symmetrically, their characteristic impedance, Z_{04}, can be calculated as follows:

$$Z_{04} = \frac{1}{2} Z_{0E}$$

where Z_{0E} is the even-mode characteristic impedance of the broadside-coupled lines. Cohn[5] provides the relation between Z_{0E} and the corresponding geometrical parameters W_4, B_o, and B.

Implementation

The stripline-diplexer concept was implemented with the construction of an all-printed version of a C-band varactor tripler. Essentially, every varactor multiplier is a combination of a diplexer and a matching network. For this implementation, the input impedance (Port 2 in Figure 3) is required to be 50 ohms at both the input and output frequencies (f_i and f_o). Port 1 is driven by a source whose impedance is 50 ohms at frequency f_i, and Port 3 is terminated by a load of 50 ohms at frequency f_o (for the tripler case, $f_o = 3f_i$). To meet this requirement, the input channel (Z_{i1}) and output channel (Z_{i3}) should behave as illustrated in Figure 4 and as outlined below. Using

$$Z_i = Z_{02} \frac{Z_L + jZ_{02} \tan \theta_2}{Z_{02} + jZ_L \tan \theta_2}$$

where Z_i is the input impedance, Z_{02} the characteristic impedance of the transmission line, θ_2 the electrical length, and Z_L the terminating load, it is clear that the circuits depicted in Figures 4A and 4B respectively meet the requirements for the input and output channels. This can be verified by noting for the input-channel circuit that, at the output frequency ($3f_i$), the shorted load is transferred to a short along one wavelength ($\theta_2 = 360^o$) of a line with Z_0 = 30 ohms and

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then through a single quarter wavelength ($\theta_1 = 90^o$) of line with Z_0 = 90 ohms, to yield $Z_i(3f_i) = \infty$. In order to yield $Z_i(f_i) = 0$, the same channel should maintain

$$\frac{Z_{02}}{Z_{01}} = - \frac{\tan \theta_1}{\tan \theta_2}$$

With $\theta_1 = 120^o$ and $\theta_2 = 30^o$, the characteristic-impedance ratio becomes $Z_{02}/Z_{01} = 3$. The circuit shown in Figure 4B can be verified similarly.

The input and output circuits having been established, it remains to determine the circuit at the common port (Port 2, Figure 3B). If Z_{i2} and Z_{i4} together constitute a bandpass-filter circuit passing f_i and $3f_i$ simultaneously, the diplexer design for a varactor tripler is completed. For this purpose, Z_{i2} should consist of an open stub one-quarter wavelength long at f_i, and Z_{i4} should consist of a shorted stub one-quarter wavelength long at the same frequency. Because impedance changes periodically as a function of frequency in transmission lines, this circuit will yield a passband at f_i as well as at $3f_i$. The Z_{02} and Z_{04} values were chosen on the basis of geometrical constraints, with W_2 as narrow as possible and W_4 as wide as possible.

Tested apart from the varactor tripler, the diplexer yielded the results plotted in Figure 5, which also shows the calculated theoretical values.

References

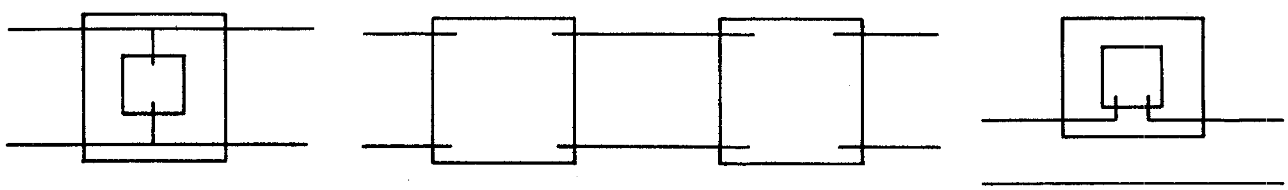
1. G. L. Matthaei, L. Young, and E. M. T. Jones, Microwave Filters, Impedance Matching Networks, and Coupling Structures, New York, McGraw-Hill, 1964.

2. R. Kihlen, "Stripline Triplexer for Use in Narrow Bandwidth Multichannel Filters," IEEE Trans. MTT, July 1972.

3. R. J. Wenzel, "Exact Theory of Interdigital Band-Pass Filters and Related Coupled Structures," IEEE Trans. MTT, September 1965.

4. I. Galin and A. I. Grayzel, "A New Type of a Compact Wideband Stripline Filter," Proc. 3rd European Microwave Conference, Brussels, 1973.

5. S. B. Cohn, "Characteristic Impedance of Broad-Side Coupled Strip Transmission Lines," IRE Trans. MTT, November 1960.



A. Parallel B. Cascade C. Series

FIGURE 1: ELECTRICAL CIRCUIT CONNECTIONS.

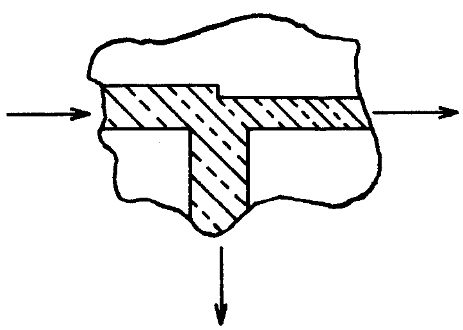
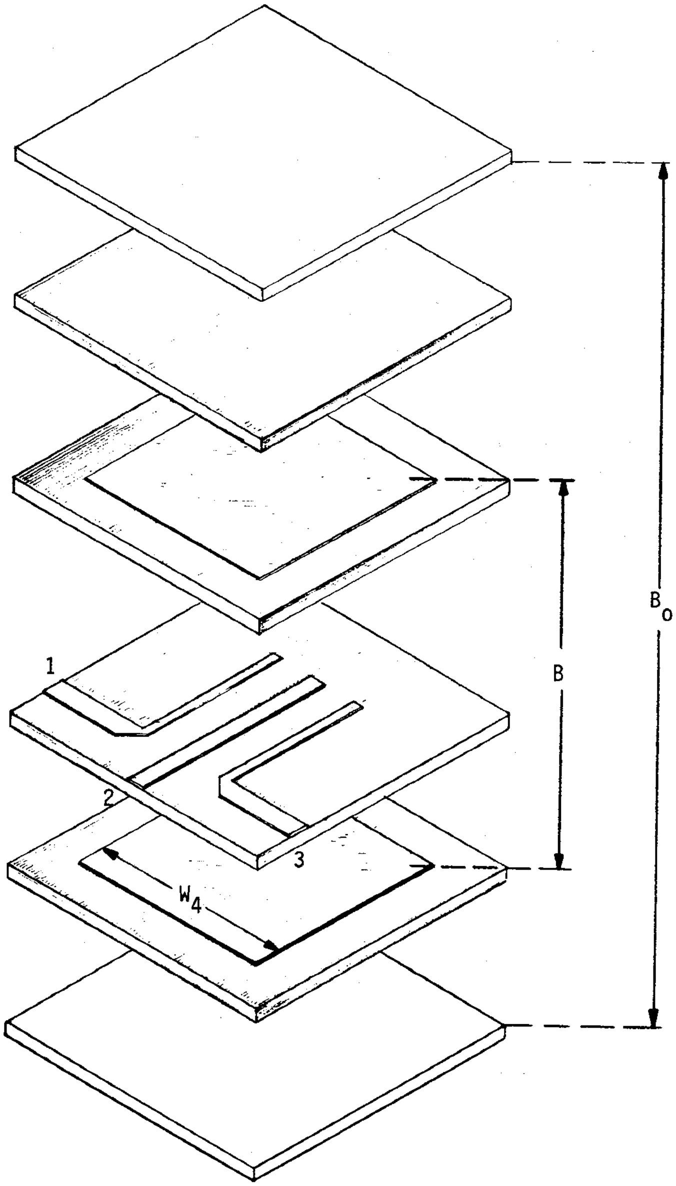
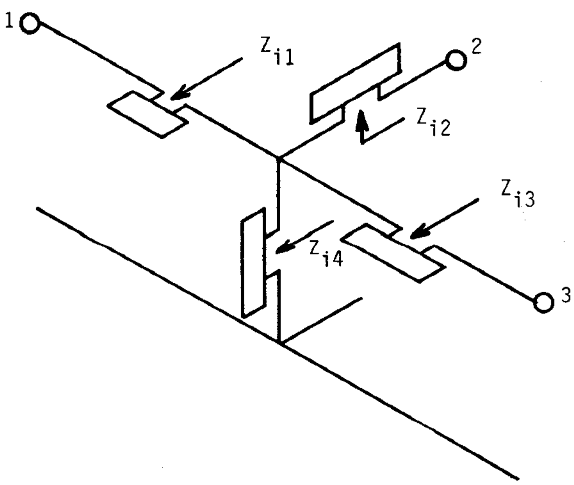


FIGURE 2: 3-WAY JUNCTION, PRINTED-CIRCUIT VERSION.

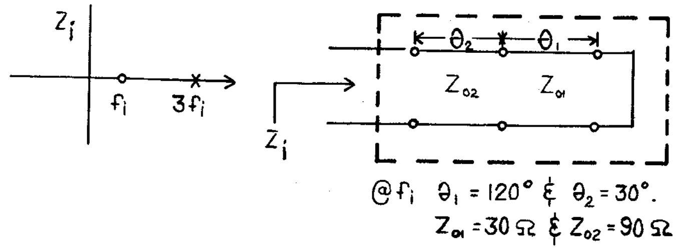


A. Structure

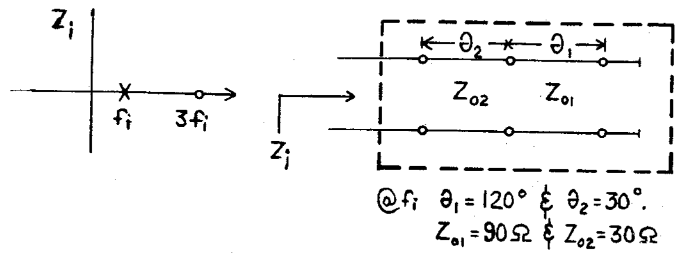


B. Equivalent Electrical Circuit

FIGURE 3: NEW THREE-WAY JUNCTION IN STRIPLINE.



A. Input Circuit: $Z_i(f_i) = 0$ and $Z_i(f_o) = \infty$



B. Output Circuit: $Z_i(f_i) = \infty$ and $Z_i(f_o) = 0$

FIGURE 4: IMPEDANCE VS FREQUENCY, DIPLEXER CIRCUITS FOR VARACTOR TRIPLER.

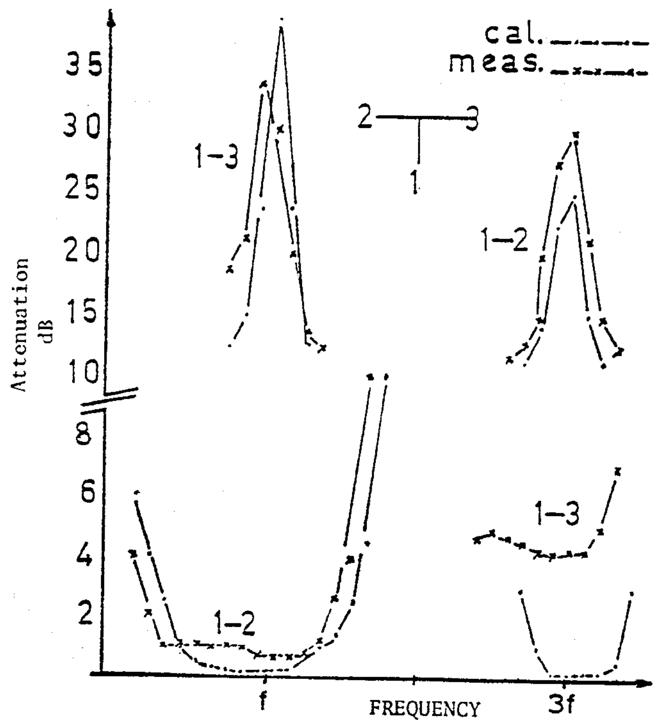


FIGURE 5: MEASURED AND CALCULATED RESULTS.