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A BANDSTOP FILTER CONSTRUCTED IN NON-RADIATIVE DIELECTRIC WAVEGUIDE

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Abstract: The exact design of a bandstop filter in Non-Radiative Dielectric Waveguide is described. The filter makes use of side-coupled guides to realize an equivalent of a shunt capacitor and transmission line section. Theoretical and practical results of the coupled lines as well as the filter performance is presented.

I INTRODUCTION

Up to the present no bandstop filters for integrated use in Non-Radiative Dielectric Waveguide (NRD-Guide) have been described, and only two bandpass filters [1]. This paper describes the theoretical frequency response as well as measured values of a pair of coupled NRDguides with shorted ports, and its incorporation in the design of a bandstop filter. A third order filter is designed as an example.

II COUPLED GUIDES WITH ARBITRARY PORT CONDITIONS

Present analysis of coupled NRD-guides treats only the case of the four guide ports terminated in matched impedances [2]. Making use of signal flow graphs, an equivalent circuit for a pair of coupled NRD-guides with arbitrary port conditions was derived. Practical figures for coupling were measured; in the case of guides terminated as shown in Fig. 1(a), it was found that a poor correlation exists between the calculated and measured coupling properties. This is due to the coupling between the unterminated ends of the guides and the adjacent guide. The frequency response obtained was also not suitable for application to practical filters [3].

In order to reduce the end coupling, the ends of the guides were terminated in short circuits extending partly across the gap between the guides, as shown in Fig. 1(b). This structure is very well suited to application as a filter element. The forward transmission coefficient for a pair of guides with coupling factor C thus terminated is given by [3],

$$S_{21}=\cos(C\ell)\exp(-jk\ell)\left[1-\frac{\Gamma^2\sin^2(C\ell)\exp(j2k\ell)}{1-\Gamma^2\cos^2(C\ell)\exp(-j2k\ell)}\right]$$

Fig. 2 shows typical theoretical and practical transmission responses obtained by means of this section. The differences between the two curves can be ascribed to the effects of the short circuits which interfere with the adjacent guide, and are not taken into consideration in the theoretical calculation. The coupled lengths correspond quite well to the calculated values, but the gap widths can differ from the theoretical by as much as 30%.

III EQUIVALENT CIRCUIT

The average of the odd and even mode wave numbers that is, $(k_e+k_o)/2$, is equal to the wave number for the uncoupled guide. This means that the phase length of a pair of coupled guides is not affected by the properties of the coupled sections, and consequently an empirical equivalent circuit for the coupled section can readily be obtained, as shown in Fig. 3.

Under Richards' Transform [4] the section has the equivalent of a shunt capacitor cascaded with a unit element, the length of which is well in excess of $\lambda/4$; the way in which this is accommodated in the design is discussed below. Fig. 4 shows the agreement between the measured response and that of a shunt capacitor model.

IV FILTER DESIGN AND MEASUREMENTS

The filter design follows the conventional procedure [5] for a bandstop structure. In this case a third order Chebyshev prototype was used. The physical length of the coupled guide section is, however, much longer than the quarter wavelength normally used in filter design. Consequently five unit elements are transformed into the circuit from each port end, this being sufficient to fit in the coupled guide sections physically. After transformation of the unit elements across the end sections as shown in Fig. 4(a), the filter was realized as three coupled guides as shown in Fig. 4(b). Due to the very narrow relative bandwidth, the unit element impedance levels are only very slightly changed by each Kuroda transformation, and in practice the impedance level was taken as constant.

The filter was constructed using Polypenco Q200.5 crosslinked polystyrene as a dielectric, with a height of 10.16 mm, and a plate separation of 15 mm. The structure was connected to an X-band network analyzer through the pair of transitions described in [6]. (X-band is used for modelling because of the costs of machining involved at the millimeter-wave frequencies). Fig. 5 shows the measured and predicted transmission response for the filter.

References

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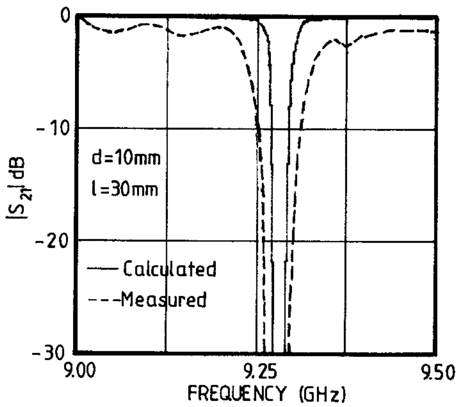

Fig. 2: Calculated and measured response of coupled section

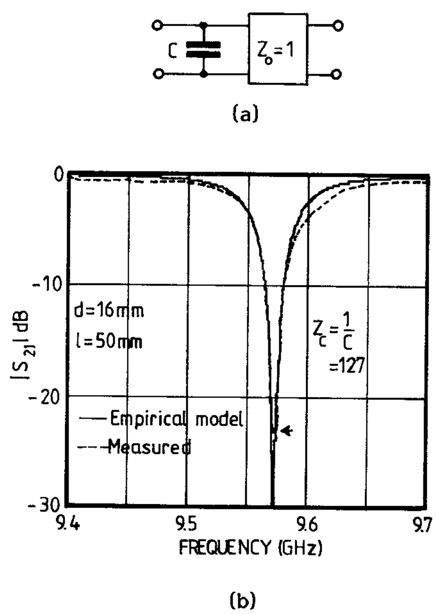

Fig. 3: (a) Equivalent circuit for shunt coupled section. (b) Comparison of measured response and empirical equivalent

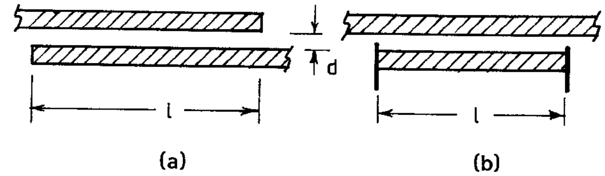

Fig. 1: Coupled NRD-guides.(a) Series coupled and (b) shunt section

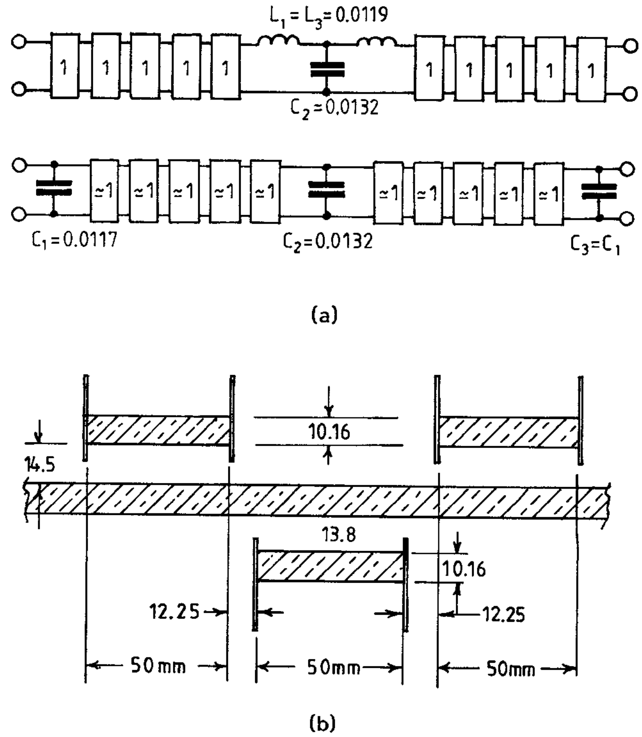

Fig. 4: (a) Development of a distributed prototype from a lumped element filter. (b) Realisation in NRD.

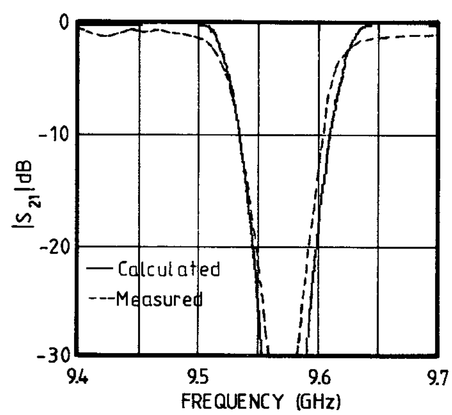

Fig. 5: Transmission response of fabricated filter