Coupled Slot-Strip Coupler in Finline

M. Schoenberger[1], A. Biswas[2], A. Mortazawi[3] and V.K. Tripathi[4]

[1] University of Stuttgart, Stuttgart, Germany

[2] Indian Telephone Industry, Bangalore, India

[3] Department of Electrical Engineering
University of Central Florida, Orlando, FL 32816

[4] Department of Electrical and Computer Engineering
Oregon State University, Corvallis, OR 97331

ABSTRACT

Dispersion characteristics and impedances of strip-slot coupled lines in a shielded structure has been computed, using rigorous spectral domain technique. Using this data four port couplers in finline configuration are realized. The coupler represents a complementary structure to that, studied by Hoffman and Siegl [1]. The analysis and design procedure for coupler presented in this paper should be useful in millimeter-wave finline circuits.

INTRODUCTION

A compensated four port coupler in finline is described in this paper. The coupling region is realized in microstrip-slot configuration, which is based on the original work of de Ronde [2] and represents a complimentary structure to that studied in detail by Hoffman and Siegl [1]. The even and odd mode parameters of this structure are calculated by using a rigorous hybrid mode analysis [3]. The compensation, required due to different phase velocities for the even and odd mode, is made by an additional length of the printed strip line on the back of the substrate [4]. This length is evaluated by calculating the scattering parameters for this coupler and the comparison of the real and ideal case as in [1].

FORMULATION

The coupler represents a reciprocal passive linear four port network with double symmetry with respect to the two symmetry planes P_1 and P_2 (Figs. 1 and 2). The scattering parameters of this four port network are given by,

$$S_{11} = (\Gamma_{em} + \Gamma_{ee} + \Gamma_{om} + \Gamma_{oe})/4$$
$$S_{21} = (\Gamma_{em} - \Gamma_{ee} + \Gamma_{om} - \Gamma_{oe})/4$$
$$S_{31} = (\Gamma_{em} + \Gamma_{ee} - \Gamma_{om} - \Gamma_{oe})/4$$
$$S_{41} = (\Gamma_{em} + \Gamma_{ee} + \Gamma_{om} + \Gamma_{oe})/4$$

where r_{ij}s are the input reflection coefficients, referenced to Z_0 appearing at each of the four terminals by applying the required combinations of magnetic and electric walls and the two symmetry planes P_1 and P_2.

The reflection coefficients for the structure are,

$$\Gamma_{em} = \exp\left\{-j2\tan^{-1}\left[\frac{Z_0}{2Z_m}\tan\left(\frac{\theta_e}{2}\right) + Z_0\frac{B_L}{2}\right]\right\}$$
$$\Gamma_{ee} = \exp\left\{-j2\tan^{-1}\left[\frac{-Z_0}{2Z_m}\cot\left(\frac{\theta_e}{2}\right) + Z_0\frac{B_L}{2}\right]\right\}$$
$$\Gamma_{om} = \exp\left\{-j2\tan^{-1}\left[\frac{2Z_0}{Z_s}\tan\left(\frac{\theta_e}{2}\right)\right]\right\}$$
$$\Gamma_{oe} = \exp\left\{-j2\tan^{-1}\left[\frac{-2Z_0}{Z_s}\cot\left(\frac{\theta_o}{2}\right)\right]\right\}$$

Here Z_0 is the characteristic impedance of the termination slot lines, Z_s is the impedance of the odd-slot mode and Z_m is the impedance of the even microstrip mode, $\theta_e=\beta_e l$ and $\theta_0=\beta_0 l$ are the electrical length of the interaction region for the even and odd modes, $B_L = 1/(Z'_m \tan \theta'_m)$ with Z'_m being the microstrip impedance of the compensation stub line

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and θ'_m is the corresponding electrical length of the shorted stub.

These impedances and propagation constants are calculated by using a rigorous hybrid mode analysis of coupled slot-strip structure [3]. The slot impedance is defined in terms of voltage-power relationship and the strip impedance in terms of power-current relationship. The compensated values of the frequency dependent even and odd mode parameters are used to evaluate the scattering parameters of the four port leading to the design by trial and error or an optimization procedure. In addition, for a desired coupling, e.g., 3 dB or any other specified value, the coupler can also be designed by following analogous procedure complementary to that described in [2].

RESULTS

Figures 3 and 4 show the coupling and isolation for an uncompensated and compensated 3 dB slot-strip coupler. The even and odd mode parameters here correspond to a structure with $Z_0 = 150\ \Omega$, $Z_m = 180.1\ \Omega$ and $Z_s = 124.5\ \Omega$, $\varepsilon_{eeff} = 1.75$ and $\varepsilon_{oeff} = 1.2$ for the coupled section having a length $l = 8$ mm.

A 3 dB slot-strip coupler in finline is realized. The Structure is designed to operate at the center frequency of 10 GHz and is placed inside a X-band waveguide (Fig. 5). Because of the difficulties to realize a short circuit in microstrip lines, an open-circuited quarter wave stub is added to both ends of the microstrip line so that it acts as a short circuit at the desired location. The finline has a width $W_f = 0.5$ mm (Fig 1). From the slot strip propagation characteristics the widths of the slot and strip are calculated to be $W_s = 0.82$ mm and $W_m = 0.10$ mm. The coupled section has a length $l = 8$ mm and the compensation length is $l_m = 4.75$ mm. The coupler is fabricated on a substrate with dielectric constant of 2.3 and thickness of 0.5 mm. After subtracting the insertion loss of the finline transitions, the S_{21} and S_{31} are measured to be -3.2 dB at 9.7 GHz (Fig. 6).

CONCLUSION

In conclusion, four port coupled slot-strip coupler represents a complementary structure to that studied by Hoffman and Siegl [1] is presented. in the paper. The coupler can be realized in fin-line configuration and has similar properties as the compensated microstrip coupler with a ground plane slot.

REFERENCES

[1] R.K. Hoffman and J. Siegl, "Microstrip-Slot Coupler Design,", Part I and II, IEEE Trans. Microwave Theory and Tech., vol. MTT-30, pp. 1205-1216, Aug. 1982

[2] F.C. de Ronde, "A New Class of Microstrip Ddirectional Couplers," Proc. IEEE Int. Microwave Symp. 1970, pp. 184-186

[3] T. Itoh, "The Spectral Domain Method" in Analytical methods for Electromagnetic Problems, Ed. E. Yamashita,Artech House 1990

[4] B. Schiek, "Hybrid Branch Line Couplers - A Useful New Class of Directional Couplers," IEEE Trans. Microwave Theory and Tech., vol. MTT-22, pp. 864-869, Oct. 1974

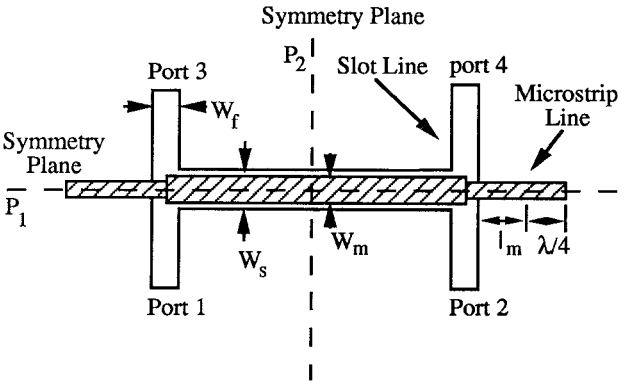

Fig. 1 Configuration of slot-strip coupler

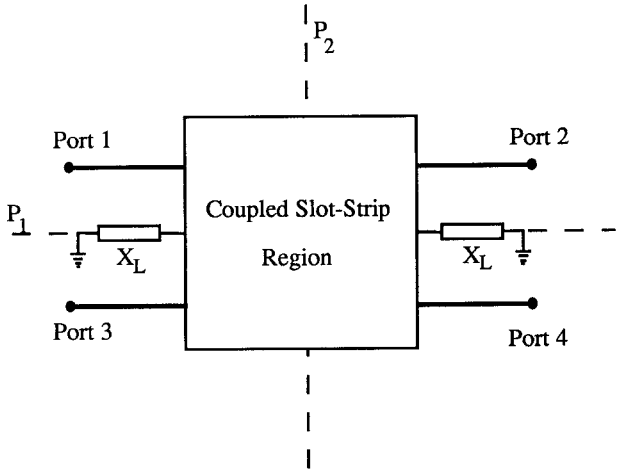

Fig. 2 Compensated slot-strip coupler

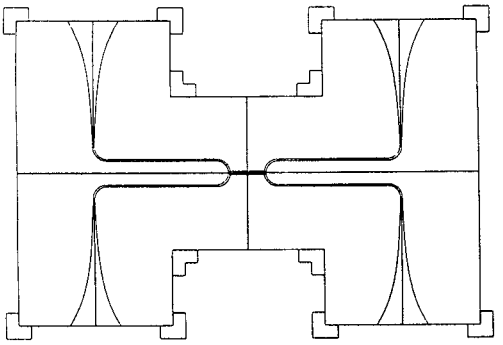

Fig. 5 A 3-dB finline coupler

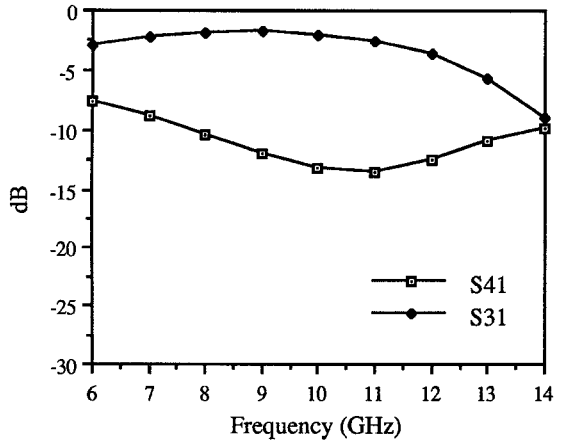

Fig. 3 Coupling and Isolation for an Uncompensated Coupler

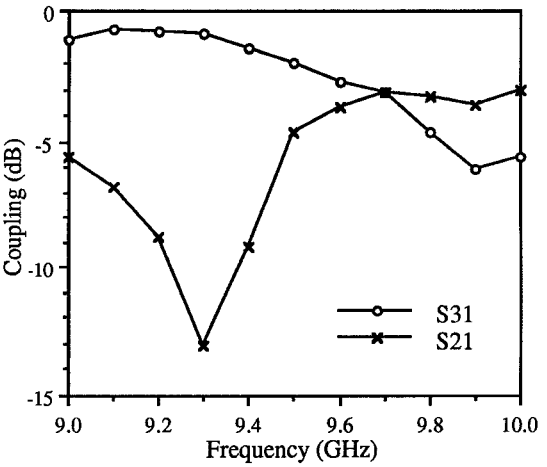

Fig. 6 Measured data for a 10 GHz 3 dB slot-strip coupler

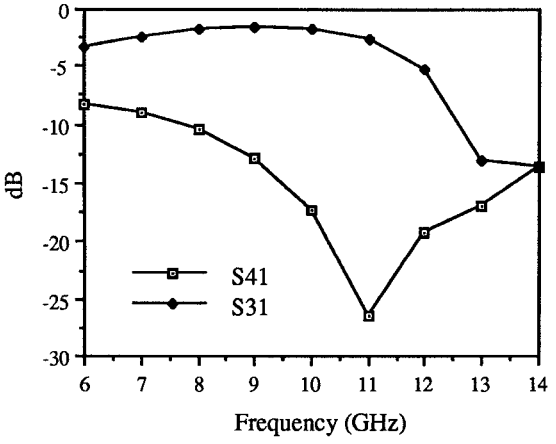

Fig. 4 Coupling and Isolation for a Compensated Coupler