Design Equations for Broad-Band Planar Aperture Coupler

K. Rambabu and A. T. Kalghatgi

Abstract—**In this letter we present design equations for coupling and directivity of a stripline-to-microstrip line coupler with apertures in their common ground plane. The concept of broadbanding using multiple aperture and supporting experimental results are presented.**

Index Terms—**Aperture coupler, multilayer coupling.**

I. Introduction

PLANAR couplers are best suited for applications like integrated antennas, synthesizers, and feedforward correction techniques. Usage of planar couplers are limited by the requirement of multiple quarterwave sections for achieving broad-band performance and their low power-handling capabilities. Stripline-to-microstrip planar aperture couplers with a single aperture in their common ground plane [1] can handle large powers due to their novel construction: Most of the input power will be in the stripline media, and only the coupled power will be handled by microstrip media. This kind of power distribution is not possible in microstripline proximity couplers because both the main line and coupled line are in the microstrip medium. But it is still limited by its narrow bandwidth and the maximum coupling that can be achieved. The proposed multiaperture stripline-to-microstrip planar coupler overcomes the above limitations.

II. Design Equations

The geometry of the proposed multiple aperture coupler is shown in Fig. 1. Equation (7) for coupling [1] is applicable to the configuration in which thickness of the microstrip substrate is one-fourth that of stripline substrate and characteristic impedance of the microstripline is 50 Ω. With some modifications to the coupling equation [1] the generalized equations for forward coupling D and backward coupling C for a multiple aperture coupler are given by

$$D(\mathrm{dB}) = 20\log_{10}\left[\frac{Z_c}{120\lambda h^2 b\sqrt{F(m)}} \cdot \left|\sum_{i=1}^{N}\left\{\frac{\alpha_e \varepsilon_r' \varepsilon_{r_{\mathrm{eff}}}''}{\varepsilon_r' + \varepsilon_{r_{\mathrm{eff}}}''} + \alpha_m\sqrt{\varepsilon_r' \varepsilon_{r_{\mathrm{eff}}}''}\right\} \cdot e^{-j(|d_{Ni}|\beta_{gms} + |d_{li}|\beta_{gs})}\right|\right] \quad (1)$$

Manuscript received May 8, 1998.

The authors are with the Central Research Laboratory, Bharat Electronics, Bangalore, India.

Publisher Item Identifier S 1051-8207(98)07955-0.

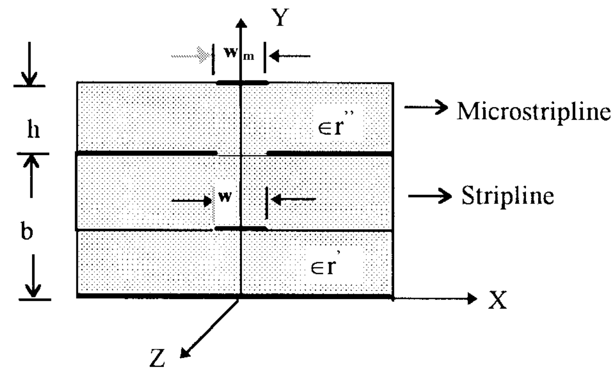


Fig. 1. Stripline-to-microstripline aperture coupler.

$$C(\mathrm{dB}) = 20\log_{10}\left[\frac{Z_c}{120\lambda h^2 b\sqrt{F(m)}} \cdot \left|\sum_{i=1}^{N} \cdot \left\{\frac{\alpha_e \varepsilon_r' \varepsilon_{r_{\mathrm{eff}}}''}{\varepsilon_r' + \varepsilon_{r_{\mathrm{eff}}}''} - \alpha_m\sqrt{\varepsilon_r' \varepsilon_{r_{\mathrm{eff}}}''}\right\} \cdot e^{-j(\beta_{gms} + \beta_{gs})|d_{li}|}\right|\right] \quad (2)$$

$$F(m) = \frac{8}{b^2}\int_{-b/2}^{b/2}\int_{-\infty}^{\infty}\frac{dx\,dy}{\left|1 - m^2\cosh^2\left(\frac{\pi(x+jy)}{b}\right)\right|}$$

$$m = \mathrm{sech}\left(\frac{\pi w}{2b}\right) \quad (3)$$

where

w	width of the stripline;
w_m	width of the microstripline;
ε_r'	dielectric constant of stripline;
ε_r''	dielectric constant of microstripline;
$\varepsilon_{r\mathrm{eff}}''$	effective dielectric constant of microstripline substrate;
Z_c	characteristic impedance of the microstripline;
β_{gms}, β_{gs}	phase constants in microstrip and stripline mediums;
d_{ki}	Distance between centre of kth aperture to the centre of ith aperture;
d_{kk}	0;
N	number of apertures;
α_e, α_m	electric and magnetic polarizabilities of the aperture [2], [3], respectively.

III. Results

Generally, for a given structure coupling can be increased to a certain extent by increasing the aperture dimension. Any further increase in coupling would require a change in h and b.

Experiments have been performed on substrate with $\varepsilon_r' = \varepsilon_r'' = 2.32, h = 0.8$ mm, and $b = 1.6$ mm. Fig. 2(a) and (b) shows the theoretical and measured performance of a single-circular-aperture coupler and six-aperture couplers, respectively.

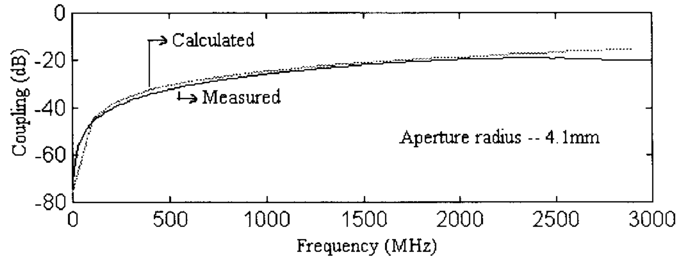
The accuracy of the equation proposed can be seen from the results of a single-aperture coupler shown in Fig. 2(a). The deviation in the results beyond 2.5 GHz can be attributed to the saturation of the coupling. In Fig. 2(b) in the lower side of the band a difference of 0.9–1.5 dB is observed between theoretical and experimental results which can be attributed to inaccuracies in fabrications and assembly.

IV. Conclusions

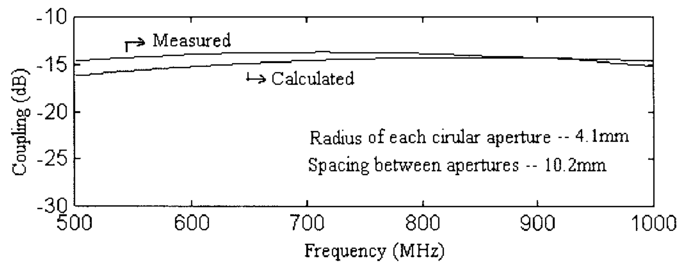
Generalized design equations for a multiple aperture coupler are presented. Designed and tested is a six-aperture planar coupler which shows a significant improvement in bandwidth over a single-aperture coupler.

Acknowledgment

The authors wish to thank H. Ramakrishna, Chief Scientist of Central Research Laboratory, and Management of BEL for their encouragement during this work. They also wish to acknowledge the suggestions and support from M. Ramesh and M. M. Basha.



(a)



(b)

Fig. 2. (a) Single-aperture coupler. (b) Six-aperture coupler.

References

[1] G. V. Jogiraju and V. M. Pandharipande, "Stripline to microstrip line apertures coupler," *IEEE Trans. Microwave Theory Tech.*, vol. 38, pp. 440–443, Apr. 1990.

[2] N. A. McDonald, "Polynomial approximations for the electric polarisabilities of some small aperture," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-33, pp. 1146–1149, Nov. 1985.

[3] ——, "Simple approximations for the longitudinal magnetic polarizabilities of some small aperture," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-36, pp. 1141–1144, Nov. 1988.