A Micromachined Y-band 4.4 dB Directional Coupler Based on Cavity-Backed Coplanar Waveguide (CBCPW)

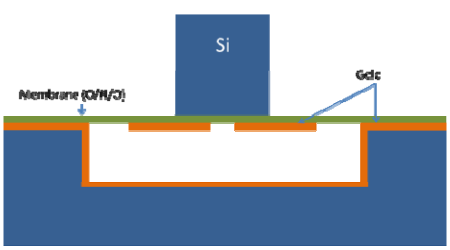
Meysam Moallem*, and Kamal Sarabandi
EECS Department, University of Michigan, Ann Arbor, MI 48105
Email: {moallem, saraband}@umich.edu

Directional couplers are essential components in implementation of many radar and communication systems. Our research group is engaged in developing an ultra-lightweight, sub-MMW beam scanning radar system operating at Y-band frequencies for collision avoidance and navigation of micro autonomous robotic platforms. In the radar front-end, a single Y-band signal is generated through a multiplier chain to provide the FMCW waveform for both the transmitter and the receiver local oscillator in order to maintain the coherence in the system. To split the signal, an integrated directional coupler is required.

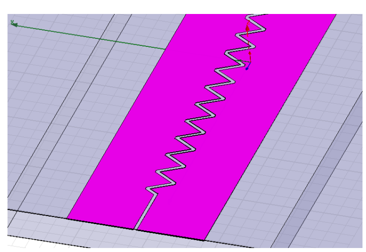
The objective of this study is to design, a micromachined coupled line 4.4-dB directional coupler using an optimally designed CBCPW transmission line (M. Moallem et al. APSURSI 2009). The challenge is to achieve a high coupling coefficient while maintaining the loss to within 1 dB. The schematic of the proposed coupler is shown in Fig. 1 (a). The silicon block (ε=12) above the two strips facilitates high capacitive coupling between the two adjacent coupled lines. Design of the directional coupler is based on even and odd mode analysis of the coupled line structure. The dimensions of the strips and the gaps have been optimized to achieve perfect matching to the CBCPW line ($\sqrt{Z_{0e}Z_{0o}} = 50\Omega$). The full-wave analysis of the structure shows that the effective dielectric constant of the odd mode is higher than the even mode. This result in lower phase velocity for the odd mode compared to the even mode. It is known that in order to achieve a perfect impedance match and maximum coupling, the electrical length of the even and odd modes must satisfy the following equations:

$$\theta_e = \left(\frac{1}{2} + m\right)\pi \;\; , \;\; \theta_e - \theta_o = 2n\pi \qquad m, n = 0, \pm 1, \pm 2, \dots$$

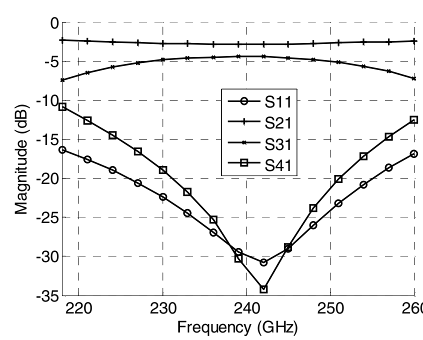
By wiggling the gap, as shown in Fig. 1 (b), the electrical length of the odd mode can be increased while the even mode electrical delay remains unchanged. The dimensions and design of the wiggle pattern are then optimized to achieve in-phase even and odd modes. Full-wave analysis of the optimized structure shows that the return loss and the insertion loss are below 20 dB and the coupling factor is 4.4 dB in the (230 GHz-245 GHz) band (Fig.1 (c)).



(a)



(b)



(c)

Fig. 1. (a) Schematic of the coupled line structure (b) wiggly coupled line (c) S-parameters of the optimized directional coupler