Analysis and design of a 30 GHz printed ridge gap Ring-crossover

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***Abstract*—Nowadays there is much interest in working at the millimeter wave range. Crossover is an important component in microwave systems and beam forming networks. In this paper, a planar simple design crossover is presented with analytical analysis. It is built using the printed ridge gap technology which has low dielectric losses as the wave propagated mainly in an air gap region. The crossover has a bandwidth of 0.5 GHz (from 29.75 to 30.25 GHz) with insertion loss less than 0.6 dB and the isolation and return loss are better than 15 dB.**

I. INTRODUCTION

Millimeter wave has a good potential for 5G communication and imaging systems. Crossover is an essential component in microwave systems [1] and hence its implementation with the state of the art technology suitable for millimeter wave range is presented in this paper. The most common technologies at this band are the substrate integrated waveguide (SIW) [2] and the ridge gap waveguide [3]. Here, the printed ridge gap waveguide technology is used, which is featured with low losses as the wave propagates mainly in the air gap region, low signal distortion as the propagating mode is quasi-TEM, and compatibility with printed circuit board technology. Crossover can be classified according to implementation technique into two categories, single layer and multilayer. The first category uses just one layer such as 0-dB coupler [5], but it has a big size. The other category uses transitions between different layers and featured with small size [4]. In this paper, a one layer crossover analysis and design is presented (the design procedure is valid for any technology). Then it is implemented in the printed RGW technology.

II. THEORY

The principle of the proposed structure depends on the fact that the input impedance of a line is not changing after a $\lambda/2$ length that is [6]

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta l}{Z_0 + jZ_L \tan \beta l} \tag{1}$$

So $Z_{in} = Z_L$ regardless of the value of the transmission line impedance (Z_0). In this work, we will have a very high impedance for the input lines and a very low impedance for the crossover lines. The structure of the Ring crossover is shown in Fig 1 (a). The proposed structure operates as follows: 1) the input signal enters the crossover-ring and it is divided equally between the two arms, (2) after a $\lambda/4$ it will face an unequal T junction power divider and the power is split between them (most of the power goes to the opposite output port), (3) the power is summed at the opposite side of the cross-ring. Taking an even symmetry plane along the line in Fig 1 (a), The even circuit model of the proposed structure can be obtained as shown in Fig 1 (b). The input impedance is calculated as follows

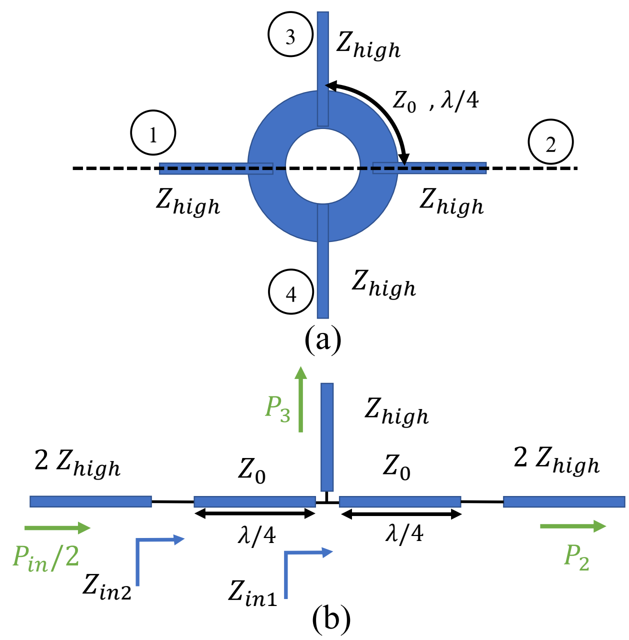

Fig. 1. (a) The ring-crossover structure. (b) The circuit model by taking even symmetry along the dashed line

$$Z_{in1} = Z_{high} // \frac{Z_0^2}{2Z_{high}} = \frac{Z_0^2 Z_{high}}{2Z_{high}^2 + Z_0^2} \tag{2}$$

$$Z_{in2} = \frac{Z_0^2}{Z_{in1}} = 2Z_{high} + \frac{Z_0^2}{Z_{high}} \tag{3}$$

where Z_{in1} is the input impedance of the unequal Tjunction and Z_{in2} is the input impedance of the structure. From

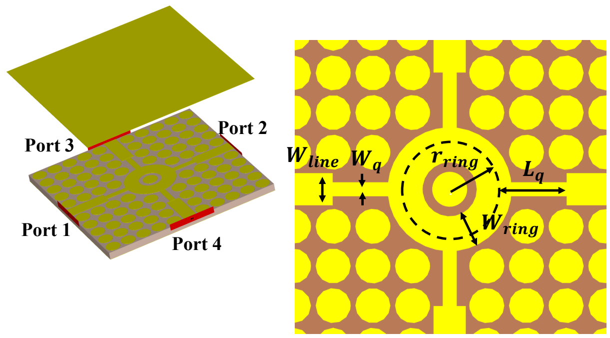

Fig. 2. The ring crossover design in the printed RGW technology

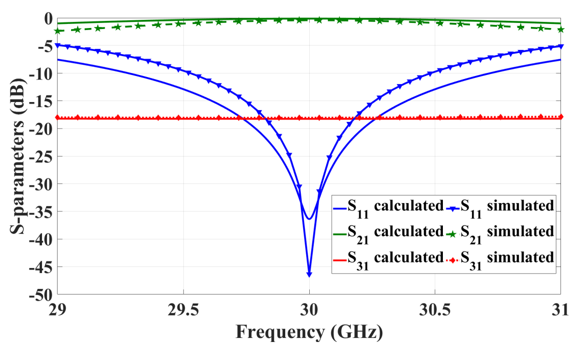

Fig. 3. The simulated and calculated s-parameters of the ring-crossover.

Equation (3), it is clear that when Z_0 is very low, the total input impedance $Z_{in2} \approx 2Z_{high}$ and hence it is matched to the input line. The isolation can be calculated from the output powers as follows

$$P_3 + P_2 = \frac{P_{in}}{2}(1 - S_{11}^2) \quad , \quad \frac{P_3}{P_2} = \frac{Z_0^2}{2Z_{high}^2} \tag{4}$$

$$S_{31}^2 = \frac{P_3}{P_{in}} = \frac{1}{2}\frac{1 - S_{11}^2}{1 + \frac{2Z_{high}^2}{Z_0^2}} \tag{5}$$

Where P_2 and P_3 are the output powers in the even symmetry case, and $P_{in}/2$ is the input power (because of the even symmetry). In the following section, the design is validated through comparison between simulated and calculated results .

III. Simulation and Results

The configuration of the crossover structure using the printed ridge gap waveguide technology is shown in Fig 2. The ridge gap unit cell and the associated bandgap are in [7], where the bandgap is from 22.307 to 43.095 GHz, and the used substrate is RT6002 (ε_r=2.94 and $\tan\delta$=0.0012) with 0.762 mm thickness. The parameters of the crossover are listed in Table I. The input line impedance is 50 Ω for matching with other circuit components. A quarter wavelength matching transformer is used to obtain a high impedance at the input to the crossover. The quarter wave transformer has an impedance of 84 Ω (corresponding to the minimum line width for our fabrication facility) which results in a 141 Ω zero-length line impedance at the input to the crossover. The computer simulation technology (CST) is used to simulate the proposed structure. The calculated and simulated results are shown in Fig 3, where the impedance of the crossover lines has been taken equal to 35 Ω (for the calculated results). The S_{41} is equal to S_{31} from the symmetry of the device and is not shown. There is a good matching between simulated and calculated results.

TABLE I
Parameters of the crossover.

Parameter	r_{ring}	W_q	L_q	W_{line}	W_{ring}
Value (mm)	1.9085	0.6	3.1	1.435	1.5

IV. Conclusion

Analysis and design of a simple planar crossover are presented. The proposed device has been designed in the printed ridge gap waveguide technology. The device has been simulated using CST software and there is a good matching between simulated and calculated results. The structure has 0.5 GHz bandwidth around 30 GHz (With $S_{11} < -15$ dB, $S_{31} < -15$ dB, and $S_{21} > -0.6$ dB). The analysis can be used for any type of guiding structure.

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