Design of Printed RGW Crossover for Millimeter Wave Beam Switching Network

Mohamed Mamdouh M. Ali[1,2], Islam Afifi[1,3] , and Abdel Razik Sebak [1]
(1)ECE Department, Concordia University, Canada
(2)ECE Department, Assiut University, Egypt
(3)Cairo University, Egypt
mohamed.ali@ ieee.org, i_afifi@ encs.concordia.ca, abdo@ ece.concordia.ca

***Abstract*—In this paper, the design of a printed RGW crossover for mm-wave beam switching network is proposed. The proposed device can be considered a good candidate in the design of beam switching network as it has a low loss with a wide bandwidth. The simulated results of the proposed crossover show a 13% fractional bandwidth centered at 30 GHz with an impedance matching level less than -20 dB and isolation level less than -15 dB. In addition, the proposed design has an average transmission loss of 0.5 dB over the operating frequency band.**

***Index Terms*—Beam switching, crossover, unit cell, millimeter-wave, printed ridge gap waveguide.**

I. INTRODUCTION

Printed ridge gap waveguide is considered among the important microwave guiding structure technology for mmwave applications due to recently reported advantages which include low loss and minimum dispersion [1], [2], [3]. These features will allow the development of efficient and smart subsystems for high speed applications. Beam switching is considered one of the critical subsystems that will enable space diversity for future wireless communications [4]. Moreover, it will improve the signal to noise ratio (SNR), which results in a huge improvement of the data rate that will support high speed communication [5]. One of the essential device required to realize the beam switching network is a crossover [6]. Being low loss, wide bandwidth, and compact size will improve the performance of beam switching subsystems. Different realizations of a crossover based on traditional printed technology such as microstrip line and substrate integrated waveguide (SIW) are reported in the literature [7], [8]. However, these designs suffer from high losses at mmwave frequencies. Therefore, deploying a state of the art printed technology such as PRGW is mandatory to realize microwave devices operate at such high frequency bands.

Traditional crossover is designing by cascading two 3 dB hybrid couplers, which results in a large size and high losses. Several realizations of hybrid couplers in PRGW technology are reported in the literature [9], [10], while the design of crossover is visited few times [6]. In this paper, two hybrid couplers are merged in a proper manner to reduce the size of the crossover. As a result, the design of compact size crossover based on PRGW technology is achieved with low loss and wide bandwidth at 30 GHz.

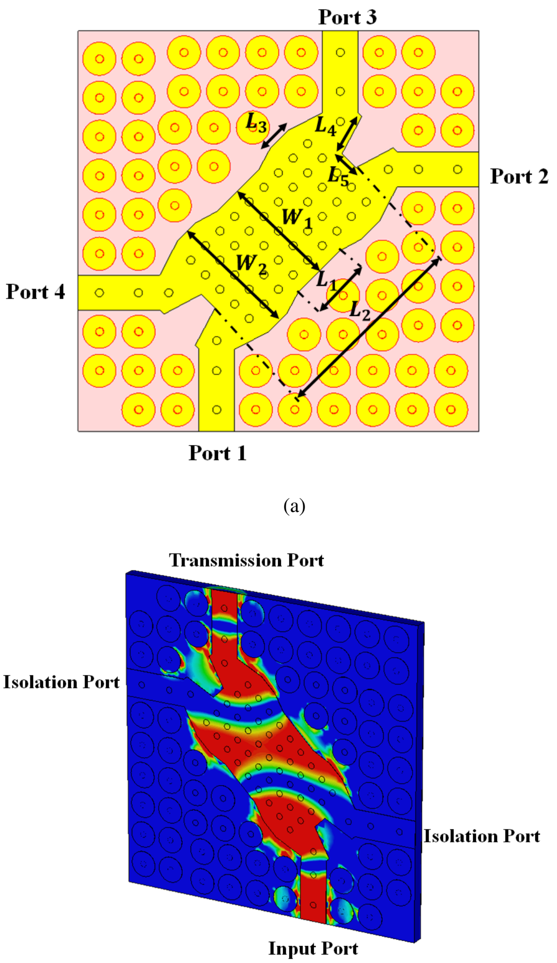
II. PROPOSED PRGW CROSSOVER DESIGN

The 3-D geometrical configuration of the proposed crossover is shown in Fig. 1(a). The proposed crossover consists of four PRGW lines connected to four corners of a rectangular patch. The electromagnetic band gap (EBG) mushroom-shaped unit cells that surrounded the proposed crossover structure are built on Roger RT 6002 ($\varepsilon_r = 2.94$, $tan\delta = 0.0012$) with a thickness of 0.762 mm. The size of the EBG unit cell is 1.7 $\lambda\times$ 1.7 λ with 0.508 mm air gap, where λ is the free space wavelength at 30 GHz. The dispersion diagram of the PRGW line is shown in Fig. 3, which shows a band gap from 22 to 38 GHz, where a Q-TEM mode is propagating within this frequency band. As mention before, the proposed design is based on merging two 3-dB PRGW hybrid couplers to reduce the overall crossover size.

The design of a 3-dB PRGW hybrid coupler is addressed before in [5], [9], where the width of the coupling section (rectangular patch) is selected to satisfy a small impedance difference between the even and odd mode characteristics impedances over the frequency band of interest. Then, the coupling section length is calculated to achieve an equal power division between the coupled ports. Based on the design procedure discussed in [9], [5], the initial dimensions of the coupling section used to design a 3-dB hybrid coupler shown in Fig. 1(a) are estimated. Finally, two 3-dB hybrid coupler are merged together to construct the proposed crossover shown in Fig. 1(a). The proposed design is optimized, where the final dimensions are listed in Table I. Also, the electric field distribution in Fig. 1(b) emphasizes the performance of the proposed crossover in terms of the isolation and transmission of the signal.

The proposed design is simulated, where the results in Fig. 2 shows an impedance bandwidth of 13% with a -20 dB matching level at 30 GHz. The isolation between input ports (1 and 2) as well as between the input port and crossing output ports (1 and 4) is better than 15 dB over the whole operating bandwidth. The transmit coefficient from port 1 to port 3 has an average value of -0.5 dB over the 13% relative bandwidth at 30 GHz.

978-1-7281-0695-3/19/$31.00 ©2019 IEEE



(a)

(b)

Fig. 1. (a) Geometrical configuration of proposed crossover (Upper ground is removed for clear illustration). (b) E-field distribution at 30 GHz.

TABLE I
DIMENSIONS OF THE COUPLING SECTION IN MILLIMETERS

Parameter	L_1	L_2	L_3	L_4	W_1	W_2	W_r
Value	2.8	9	1.2	12.1	1	5.6	6.3

III. CONCLUSION

A crossover implemented by PRGW technology at 30 GHz has been proposed. The proposed component is designed, where a wide bandwidth performance is achieved over a 13% at 30 GHz. This crossover can be considered as an excellent candidate for future wide bandwidth MMW beam switching networks.

REFERENCES

[1] H. Raza, J. Yang, P. Kildal and E. Alfonso Alos, "Microstrip-Ridge Gap Waveguide-Study of Losses, Bends, and Transition to WR-15," *IEEE Transactions on Microwave Theory and Techniques*, vol. 62, no. 9, pp. 1943-1952, Sept. 2014.

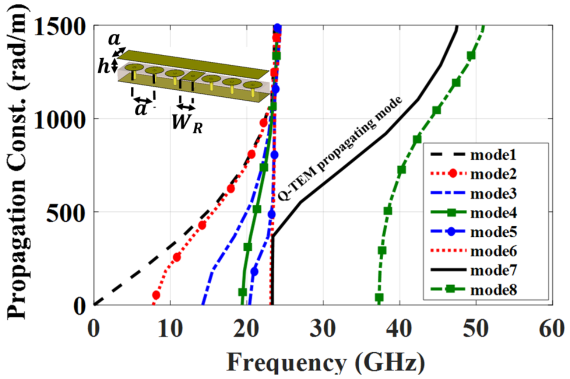


Fig. 2. Dispersion diagram of the PRGW line.

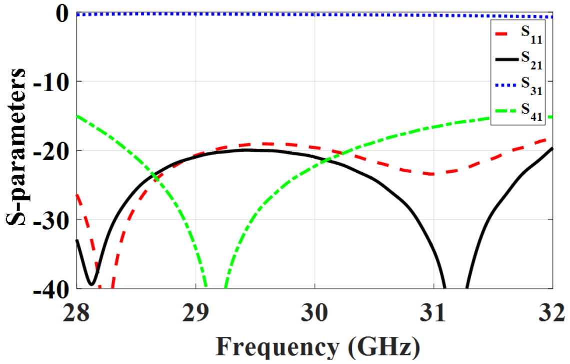


Fig. 3. Simulated S-parameter of the proposed crossover.

[2] S. I. Shams and A. A. Kishk, "Wideband Coaxial to Ridge Gap Waveguide Transition," in IEEE Transactions on Microwave Theory and Techniques, vol. 64, no. 12, pp. 4117-4125, Dec. 2016.

[3] I. Afifi, M. M. M. Ali and A. Sebak, "Analysis and Design of a Wideband Coaxial Transition to Metal and Printed Ridge Gap Waveguide," in IEEE Access, vol. 6, pp. 70698-70706, 2018.

[4] H. Wang, Z. Zhang and Z. Feng, "A Beam-Switching Antenna Array With Shaped Radiation Patterns," in IEEE Antennas and Wireless Propagation Letters, vol. 11, pp. 818-821, 2012.

[5] M. M. M. Ali and A. Sebak, "2-D Scanning Magnetoelectric Dipole Antenna Array Fed by RGW Butler Matrix," in IEEE Transactions on Antennas and Propagation, vol. 66, no. 11, pp. 6313-6321, Nov. 2018.

[6] M. M. M. Ali and A. Sebak, "Compact Printed Ridge Gap Waveguide Crossover for Future 5G Wireless Communication System," in IEEE Microwave and Wireless Components Letters, vol. 28, no. 7, pp. 549-551, July 2018.

[7] A. Tajik, M. Fakharzadeh and K. Mehrany, "DC to 40-GHz Compact Single-Layer Crossover," in IEEE Microwave and Wireless Components Letters, vol. 28, no. 8, pp. 642-644, Aug. 2018.

[8] S. Han, K. Zhou, J. Zhang, C. Zhou and W. Wu, "Novel Substrate Integrated Waveguide Filtering Crossover Using Orthogonal Degenerate Modes," in IEEE Microwave and Wireless Components Letters, vol. 27, no. 9, pp. 803-805, Sept. 2017.

[9] M. M. M. Ali, S. I. Shams and A. Sebak, "Printed Ridge Gap Waveguide 3-dB Coupler: Analysis and Design Procedure," in IEEE Access, vol. 6, pp. 8501-8509, 2018.

[10] S. I. Shams and A. A. Kishk, "Design of 3-dB Hybrid Coupler Based on RGW Technology," in IEEE Transactions on Microwave Theory and Techniques, vol. 65, no. 10, pp. 3849-3855, Oct. 2017.