E-band One-step 45 Double wing Gap Waveguide Twist for Waveguide WR12

E-band One-step 45° Double–wing Gap Waveguide Twist for Waveguide WR12

Jian Yang
Department of Electrical Engineering
Chalmers University of Technology
Goteborg, Sweden
Jian.yang@chalmers.se

***Abstract*—This paper presents a novel double-wing one-step 45° Gap waveguide twist at E-band. By employing an optimal double-wing structure for Gap waveguide flange, only one gap waveguide section is needed for the polarization transform between diagonal polarization and horizontal/vertical polarization, which does not require good conductive contacts between the connected flanges. This new waveguide twist is in particular useful and of low cost at millimeter wave frequency and up to THz.**

***Keywords*—Gap waveguide twist; polarization transform; Millimeter waves**

I. INTRODUCTION

Hollow metallic waveguide step twist is a conventional waveguide device which finds applications in waveguide systems [1]. However, with the frequencies go up to millimeter wave (mmW) and Terahertz (THz) regime, the manufacture of such waveguide step twist becomes very difficult or very expensive, because a good conductive contact between all sections is required, which imposes very strict tolerance on surface smoothness and flatness. In addition to the difficult manufacture, the assembly of a multiple step waveguide twist at mmW and THz presents another challenge: tiny pieces of waveguide sections need to be bonded by some means with balanced force strength. For example, it is very difficult to use screws to combine multi-step twist with very good conductive contact for a tiny waveguide twist. Even it can be done so, it is very time consuming and not efficient for large systems. Soldering and diffusion bonding are also very difficult to be applied in mmW and THz waveguide twist fabrication.

Gap waveguide technology is a new transmission line technology introduced recently for mmW and THz applications [2]-[7]. This technology does not require the good conductive contact between the upper and the lower plates by utilizing the stop band created with the parallel plate waveguide made of PEC and PMC plates spaced less than a quart wavelength. This technology has been applied to make gap waveguide contactless flange [8],[9] and a 7-step 90° waveguide twist at Ka band, reported in [10].

This paper presents a new structure design of 45° gap waveguide twist. Contrast to the 7-step 90° waveguide twist in [10], the new design use a double-wing gap waveguide structure for the polarization transform by only one step, a lot reduction for the number of steps and complexity, which leads a much simpler device for mmW and THz systems.

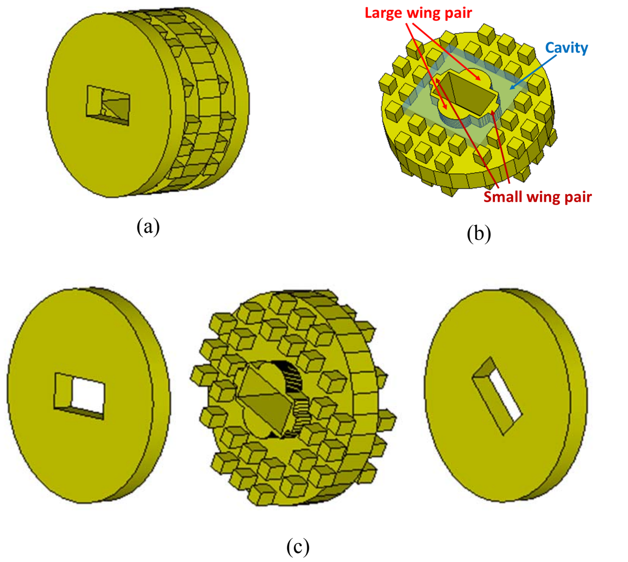

Fig. 1 Geometry of the one-step 45° double-wing gap waveguide twist: (a) the assembly set; (b) pin flange section with cavity; (c) separate view of the one-step twist.

II. GEOMETRY AND WORKING PRINCIPLE

Fig. 1 shows the geometrical structure of the E-band one-step double-wing 45° gap waveguide twist. The twisted angle of the pin flange sector is 22.5°, a half of the total twisted angle of 45° of the twist. The pin dimensions are chosen as follows for creating the stop band over E band. The length of pins is 0.88 mm (quart wavelength), the width of pins 0.65 mm, the period of pins 1.308 mm, the gap between flanges 0.05 mm, and thickness of pin flange 1.49mm, very much following the empirical formulas in [11].

As it is known, the working principle for waveguide twist can be described as follows [1]. Each twisted waveguide section introduce a pure shunt inductance. With a thickness of each twisted waveguide section being a quart wavelength, this introduced inductance is transformed by the quart wavelength thick sections to capacitance to compensate the inductance of the previous twisted section. Therefore, in order to have a wideband low reflection, the twisted angle for each twisted section should have an optimal value, which cannot be very large. Thus, multi-step twisted sections are required to achieve an acceptable performance with low reflection and low insertion loss, such as done in [10] with 7 steps for 90º twist. With the new gap waveguide technology, contrast to the conventional waveguide twist, one new capacitance mechanism is introduced. A cavity around the waveguide side-wall board is made by using pins along the cavity outer board, as shown in Fig. 1b where the transparent blue volume of air is added just to mark the cavity (no dielectric material added in the cavity). With a small gap between flanges, the electromagnetic wave can be weakly coupled to the cavity, which introduces a capacitance to compensate the inductance introduced by the twisted waveguide section. The shape of the cavity plays an important role for obtaining a wideband performance of low reflection coefficient and low insertion loss. Therefore, a double-wing geometry for one optimal shape of the cavity is introduced: one (large) wing pair are along the wide side wall of the waveguide, and one (small) wing pair along the narrow side wall. Only one wing pair along the wide side wall or narrow side wall have been investigated, and no optimal shapes were found so double-wing shape was introduced. Note that there is no proof that the double-wing shape is the unique one which can achieve good performance. Other possible solutions may exist.

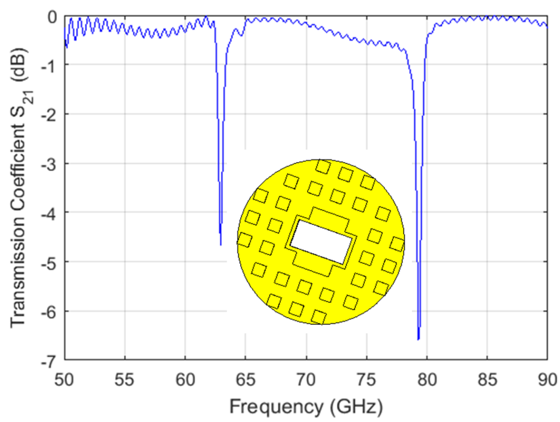

Fig. 2 Effect of the cavity shape on insertion loss of one-step gap waveguide twist

III. SIMULATION RESULTS

Fig. 2 shows the simulated result of insertion loss for a one-step 45º gap waveguide twist with non-optimal shaped cavity which is also shown in the figure. It can be seen that there are two dips for the transmission coefficient (S_{21}) around 63 GHz and 79 GHz. This is due to that the shape of the cavity is not optimal for a wide band to cover the whole operation band of standard waveguide WR12 so resonances arise. Therefore, the shape of the cavity has to be gone through optimizations.

Fig. 3 shows the simulated reflection coefficient S_{11} and transmission coefficient S21 of the optimized double-wing one-step 45º gap waveguide twist. It can be seen that the reflection coefficient is below -20 dB and the transmission coefficient is above -0.1 dB over 50-90 GHz.

The prototype is under fabrication and measured results will be presented at the conference.

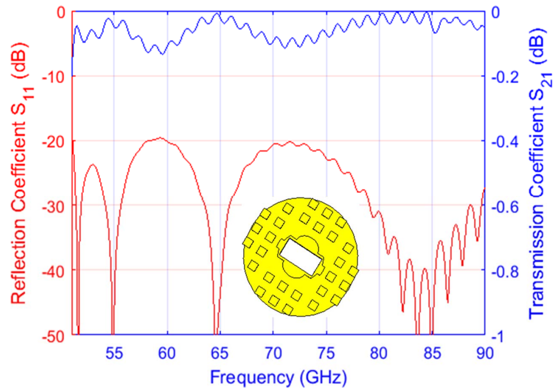

Fig. 3 Simulated reflection coefficient and insertion loss of the optimal double-wing one-step 45º gap waveguide twist

IV. CONCLUSIONS

This paper presents a new one-step 45º double-wing gap waveguide twist of standard waveguide W12 over 50-90 GHz with a very good performance.

ACKNOWLEDGMENT

This work has been funded by the European Research Council (ERC) via an advanced investigator grant ERC-2012-ADG 20120216.

REFERENCES

[1] H. A. Wheeler and Henry Schwiebert, "Step-twist waveguide components," *IRE Transactions on Microwave Theory&Techniques*, vol. 3, No. 5, pp. 44-52, October 1955.

[2] P.-S. Kildal, E. Alfonso, A. Valero-Nogueira and Eva Rajo-Iglesias, "Local metamaterial-based waveguides in gaps between parallel metal plates", *IEEE Antennas & Wireless Propagation Letters*, vol. 8, pp. 84-87, 2009.

[3] H. Raza, J. Yang, P.-S. Kildal, and E. Alfonso, "Resemblance between gap waveguides and hollow waveguides," *IET Microwaves, Antennas& Propagation*, vol. 7, no. 15, pp. 1221-1227, 2013.

[4] J. Liu, A. Vosoogh, A. U. Zaman, and J. Yang, "Design and fabrication of a high gain 60-GHz cavity-backed slot antenna array fed by inverted microstrip gap waveguide," *IEEE Transactions on Antennas &Propagation*, vol. 65, no. 4, pp. 2117-2122, april 2017.

[5] A. Vosoogh, M. Sharifi, A. U. Zaman, J, Yang, and A. Kishk, "An integrated ka-band diplexer-antenna array module based on gap waveguide technology with simple mechanical assembly and no electrical contact requirements", *IEEE Trans. MTT*, 2017.

[6] M. Ferrando-Rocher, A. U. Zaman, J. Yang, A. Valero-Nogueira, "A dual-polarized slotted-waveguide antenna based on gap waveguide technology", *EuCAP 2017*, Paris, 2017.

[7] P. Taghikhani, J. Yang, A. Vosoogh, "High gain V-band planar array antenna using half-height pin gap waveguide", *EuCAP 2017*, Paris, 2017.

[8] E. Pucci and P.-S. Kildal, "Contactless non-leaking waveguide flange realized by bed of nails for millimeter wave applications," *6th European Conf. on Antennas and Propag*., pp. 3533-3536, Prague, 2012.

[9] E. Alfonso, S. Carlred1, S. Carlsson1 and L.-I. Sjoqvist, "Contactless flange adapters for mm-wave measurements," 10*th European Conf. on Antennas and Propag*., Paris, 2016.

[10] D. Sun and J. Xu, "Real time rotatable waveguide twist using contactless stacked air-gapped waveguides," *IEEE Microwave&Wireless Components Letters*, 2017.

[11] J. Yang and H. Raza, "Empirical formulas for designing gap-waveguide hybrid ring coupler," *Microwave Opt. Tech. Lett.*, vol. 55, no. 8, pp. 1917–1920, August, 2013.