Circularly Polarized Slotted Waveguide Leaky Wave Antenna at W Band for Radar Application

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***Abstract*- This article presents a circularly polarized leaky wave antenna at W band for radar and imaging applications. For achieving circular polarization, a dielectric layer with array of patches is introduced above rectangular slotted waveguide antenna. The proposed prototype antenna shows simulated gain around 17 dB and axial ratio below 3 dB over the frequency band of operation. Both left hand polarized and right hand polarized beam shows 7° continuous beam scanning from broadside to endfire direction.**

***Keywords*- Leaky wave antenna (LWA), circular polarized (CP), slotted waveguide antenna, W band, wideband radar, WR-10**

I. Introduction

LWAs inherent beam scanning capabilities have reduced the many system complexities that require beam steering capability. For radar system like monopulse radar, collision avoidance radar and surveillance, slotted waveguide LWA are promising candidate for beam scanning [1]. In modern communication system, circular polarized (CP) antenna has attracted many researchers due to its several advantages over linear polarized antenna. CP antenna suppress polarization mismatch, reduce multipath interference and high link reliability [2].

Antenna targeting W band range [3] are generally linearly polarized, whereas for space application circular polarization is often required. Several SIW cavity based CP antennas [4-5] were already reported but these are not suitable for high performance radar systems. [6] is promising candidate for CP slotted waveguide LWA, but fabrication of these type of dual mode hollow waveguide at W band is very difficult.

This paper proposes a high gain circularly polarized slotted waveguide leaky wave antenna to overcome the fabrication and performance limitations of W band antenna. A single dielectric layer is used to convert linear polarization to circular polarization, polarization converter layer consists of dipole array which is placed on broad wall of longitudinal slotted waveguide array.

II. Antenna Design

The structure of the proposed CP slotted LWA for imaging application is shown in Fig. 1(a). In the first step 20 pair of longitudinal slots are cut on the broad wall of WR-10 (a = 2.54mm x b = 1.27mm) waveguide. Longitudinal slots of width 0.3 mm with offset position 0.4 mm from the center of the waveguide axis are cut. 1.8 mm is the length of each slot and λ/2 is the distance between consecutive slots. Height of broad wall of waveguide is kept at 0.3 mm to increase the radiation and antenna efficiency and to reduce effective length of antenna. WR10 waveguide of 15 mm length is added at both ends of LWA to feed the proposed antenna structure as shown in Fig. 1(b).

Rogers//Duriod 5880 (ε=2.2, tanδ=.0009) substrate with 20 mil thickness is placed 0.1 mm above the WR-10 slotted LWA section. The number of slots and the number of dipoles are kept same. To achieve CP dipoles are tilted and placed exactly above the slots as demonstrated in Fig. 1(d)

Circular polarization is achieved by placing a dielectric layer with rotated dipoles above slotted rectangular waveguide and by maintaining air gap between slotted waveguide and substrate. Substrate with rotated dipoles is acting as linear to circular polarization converter. Dipole width and length are effecting the axial ratio and impedance matching. Presented CP slotted waveguide LWA is designed on CST Microwave Studio and the effect of various parameters on antenna performance were studied.

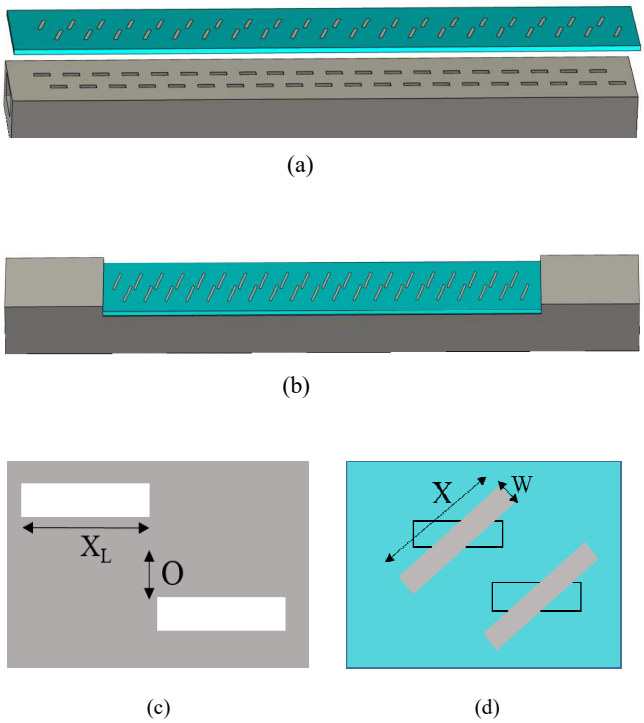
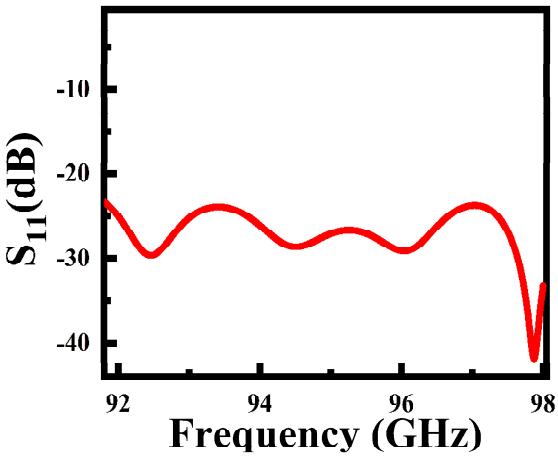
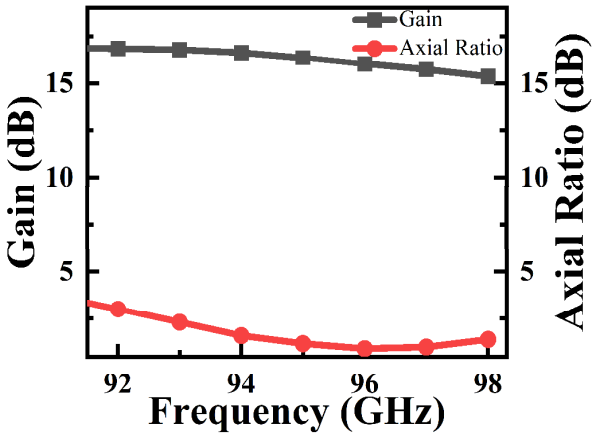


Fig. 1 Design of proposed antenna (a) Side view (b) Proposed antenna design (c) Slotted waveguide dimension (d) Polarization convertor dimension (XL = 1.8mm, O = 0.4 mm, X = 2.2 mm, w = 0.3 mm)

III. Results



(a)



(b)

Fig. 2 Simulated result of prototype antenna (a) Return loss (b) Gain and axial ratio

It is evident from S parameter that proposed CP LWA has good matching over the complete operating band which is shown in Fig 2. The presented antenna is matched below -20dB over the full band from 92 GHz to 98 GHz. Simulated realized gain and axial ratio of proposed antenna are represented in Fig 3. Maximum gain of 17 dB is achieved and gain is almost constant over entire operating band. Because of limitation of available anechoic chamber, the length of antenna is restricted to 70mm which has significantly underestimated the true gain. Simulated radiation efficiency above 90 % is obtained in the entire operating band. Moreover, in the frequency range 92GHz – 98GHz axial ratio is below 3 dB.

Fig. 3 shows the frequency scanning performance of simulated antenna prototype in actual radar application. Beam is steering from broadside to endfire direction and its scan range is approximately 7°. HPBW is around 2°-3° and it is purely circularly polarized in the entire beam scanning plane. Simulated side lobe level (SLL) in E plane is below -12 dB and -16 dB in H plane for the span of frequency between 92 GHz and 98 GHz. When port 1 is fed right hand circular polarization with beam scanning from 9° to 15° is achieved. On excitation of port 2, antenna shows left hand circular polarization and allows scanning from -9° to -15°.

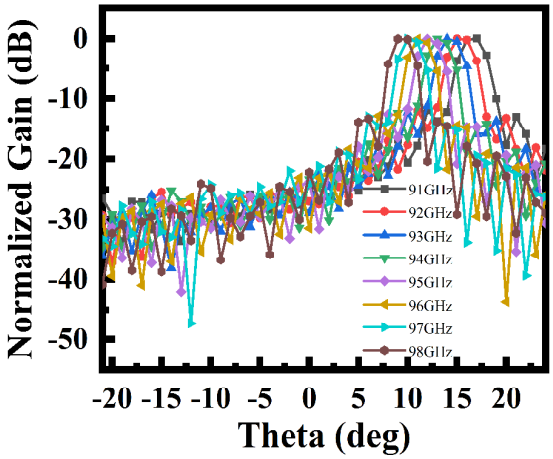


Fig. 3 Normalized gain pattern of antenna

IV. Conclusion

This paper presents a circularly polarized leaky wave antenna operating at W band frequencies between 92 GHz - 98GHz. Circular polarization is achieved by placing tilted dipoles exactly above longitudinal slots of waveguide. This antenna offers left and right hand circular polarization by using a single polarization converter. Gain of 17 dB, radiation efficiency above 90 % and return loss below 20 dB are achieved in the proposed frequency band. Moreover, the antenna shows high radiation performance with side lobe level below -12 dB in both E plane and H plane. This class of high gain circularly polarized slotted waveguide leaky wave antenna presents well-functioning option to system engineers in the field of wideband radar application.

References

[1] A. A. Oliner and D. R. Jackson, “Leaky-wave antennas,” in Antenna Engineering Handbook, New York, NY, USA: McGraw-Hill, 2007.

[2] C. A. Balanis, Antenna Theory: Analysis and Design, 2nd ed. New York, NY, USA: Wiley, 1997.

[3] D. A. Schneider, M. Rosch, A. Tessmann and T. Zwick, “A Low-Loss W-Band Frequency-Scanning Antenna for Wideband Multichannel Radar Applications,” IEEE Antennas and Wireless Propag. Lett., vol. 18, no. 4, pp. 806-810, April 2019.

[4] M. Asaadi and A. Sebak, “High-Gain Low-Profile Circularly Polarized Slotted SIW Cavity Antenna for MMW Applications,” IEEE Antennas and Wireless Propag. Lett., vol. 16, pp. 752-755, 2017.

[5] Q. Zhu, K. B. Ng and C. H. Chan, “Printed circularly polarized spiral antenna array for miilimeter wave applications,” IEEE Trans. Antennas Propag., vol. 65, no. 2, pp. 636-642, Feb. 2017.

[6] A. Dorle , R. Gillard , E. Menargues , M. V. D. Vorst, E. De Rijk, P. M. Iglesias , and M. G. Vigueras, “Circularly Polarized Leaky-Wave Antenna Based on a Dual-Mode Hollow Waveguide,” IEEE Trans. Antennas Propag., vol. 69, no. 9, pp. 6010-6015, Sept. 2021.