A Compact Substrate Integrated Waveguide Circularly Polarized Horn Antenna

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Abstract - **In this paper, we present a novel substrate integrated waveguide (SIW) circularly polarized (CP) horn antenna. The CP horn antenna is implemented on a single-layer substrate with a thickness of $0.12\lambda_0$ at the center frequency (1.524mm). It comprises a phase control and power divider structure, two waveguide antennas and an antipodal linearly-tapered slot antenna (ALTSA). The simulated results of the proposed horn antenna exhibit an 4.6% bandwidth (23.6GHz-24.7GHz) where the axial ratio is below 3dB and VSWR is below 2. The gain of the antenna is around 9dB over the operating frequency range.**

Index Terms — **Circularly polarized, horn antenna, substrate integrated waveguide.**

1. Introduction

Horn antennas are widely used in various applications such as communication systems, radar, imaging, and radio astronomy because of their well performances [1]. In these systems, the horn is used as an independent antenna or as a feeder for another reflector antenna. The three-dimensional horn antennas can be used in the above-mentioned systems [2], but they are usually bulky, more expensive, and not easy to be integrated with other devices in the circuit. The most common planar antenna solution is to use H-plane SIW horns [3-11]. Generally, an SIW H-plane horn antenna operates in vertical polarization, because only the TE0n mode can propagate inside the antenna.

On the other hand, circularly polarized (CP) antennas are useful in satellite and mobile communication systems, and most of the planar circularly polarized antennas presented to date are broadside structures, and this could be an obstacle in the design and implementation of SICs that require end-fire antennas. Moreover, many CP antennas have a complex feed network and require multi-layer structures that increase the overall cost and dimensions of the system. Therefore, a fully planar end-fire CP antenna on a single-layer substrate not only can help to reduce the overall size and cost of the system, but also provides a promising solution for applications involving SIC structures.

One possible solution for this problem is to combine two end-fire radiating elements with orthogonal polarizations on one substrate. In [12-13], a planar end-fire CP antenna on a single-layer substrate is presented. This design consists of an SIW aperture and an electric current ring/dipole connected to the SIW by a 90 degree of parallel plates line. However, because the electric current ring and the dipole have an omnidirectional radiation pattern, the presented antennas show low gains.

This work presents a compact circular polarized SIW H-plane horn antenna that is composed of only a single layer of substrate and can be manufactured using the standard PCB technology. The proposed antenna is composed of an SIW horn and tapered slot units that are connected to the horn. The SIW horn only supports TE_{m0} modes, and it is divided into several sub horn units by arrays of metallic via inside the horn. Two of these sub horns radiate vertically polarized waves while the polarization of the other sub horn is horizontal. The amplitude and phase of the vertically and horizontal waves can be controlled by the metallic via arrays so that a circularly polarized wave is obtained.

2. Structure of Circularly Polarized SIW Horn Antenna

A schematic view of the proposed circular polarized SIW horn is depicted in Fig. 1. The substrate is Rogers 4003 with the thickness of 1.524mm and the relative permittivity of 3.55. Metallic walls in the substrate are used to form a microstrip-fed SIW horn antenna. At the same time, these metallic walls also divide the horn into three sub-horns. The sub-horn in the middle of the original horn is loaded with a linearly tapered slot antenna that radiates horizontally polarized waves, while the other two sub-horns have vertical polarization. The final radiation wave is in fact the sum of three waves from the three sub-horns that includes both horizontal and vertical polarizations.

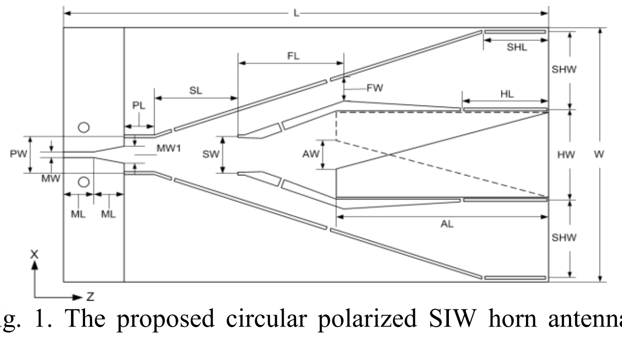


Fig. 1. The proposed circular polarized SIW horn antenna. Geometric parameters for the antenna are: L=93mm, W=50mm, ML=5mm, PL=7.35mm, SL=14.75mm, FL=22.8mm, AL=40.6mm, HL=19mm, SHL=13.8mm, MW=1mm, MW1=3mm, PW=6.35mm, SW=6mm, AW=5mm, FW=5.4mm, HW=17mm, SHW=15.35mm.

There are only TE_{m0} modes in the sub-horns, and the propagation constant of TE_{m0} modes depends on the width of sub-horn. Accordingly, it is possible that there is a 90 degrees phase difference between the radiated electromagnetic waves from the middle sub-horn and the side sub-horns. The middle sub-horn has much power to input than side-horns. In addition, the position of the metal-walls inside the horn is also related to the ratio of powers into the middle sub-horn and the side sub-horn. The wider are the mouth of a sub-horn and the sub-horn itself, the more power is into the sub-horn. In general, the amplitude and phase of the radiated vertically and horizontally polarized waves can be controlled by these metal walls so that a circularly polarized radiated wave is available.

3. Simulation Results and Discussion

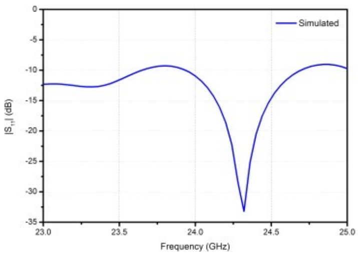


Fig. 2. ISAP2016 logo as a figure example.

The proposed circularly polarized SIW horn is simulated using CST Microwave Studio 2015. The reflection coefficient of the antenna is plotted in Fig. 2. According to the results, there is a good matching on the frequency range of 23 to 25 GHz.

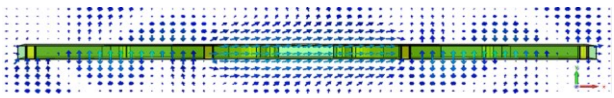
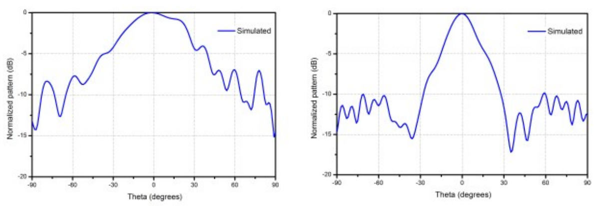


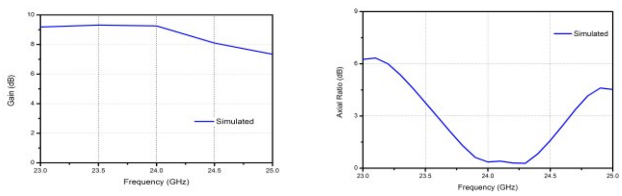
Fig. 3. The simulated polarization of the electric field in XY plane at the aperture of the antenna.

The simulated polarization of the electric field in the XY plane just outside the proposed antenna is shown in Fig. 3. According to the results, in the open area of the middle sub-horn the electric field is horizontally polarized, while for the two side sub-horns we can easily notice the vertical polarization.



(a) (b)

Fig. 4. Normalized simulated radiation patterns at 24.2GHz. (a) YZ-plane. (b) XZ plane.



(a) (b)

Fig. 5. Simulated gain and AR of antenna. (a) Gain. (b) AR.

The simulated normalized radiation pattern of the antenna in both E and H planes is plotted in Fig. 4. The antenna gain and AR versus frequency is plotted in Fig. 5.

4. Conclusion

In this paper, we presented a compact circular polarized SIW horn antenna. The presented structure is comprised of two waveguide antennas and an antipodal linearly-tapered slot antenna (ALTSA), with a phase control and power divider structure inside the horn antenna. Using this technique, two orthogonal electric fields with the equal amplitudes and 90^{o} phase difference are obtained at the aperture plane of the horn antenna. The simulated results of the proposed horn antenna exhibit a 4.6% bandwidth (23.6GHz-24.7GHz) where the axial ratio is below 3dB and VSWR is below 2. The gain of the antenna is around 9dB over the operating frequency range.

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