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CIRCULARLY POLARIZED MICROSTRIP ANTENNA COUPLED ON AN ASYMMETRICAL CROSS COPLANAR SLOT

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Abstract

A new compact multilayer planar structure is proposed to obtain circular polarization (CP) for the direct broadcast satellite (DBS) reception applications. The use of a circular planar antenna fed by asymmetrical coupling slot integrated on a coplanar−waveguide (CPW) feed line allows to achieve a 3dB axial ratio (AR) bandwidth greater than 2% and a −10dB reflection coefficient bandwidth greater than 20%. The antenna design is presented and the comparison between simulations and experimental results are done.

Introduction

Microstrip antennas have several desirable features for DBS reception (10.7GHz − 12.75GHz), such as low profile, low cost and ease of fabrication. For this application, the reflection parameter and the AR must be respectively less than −10dB and 3dB in the whole band. Moreover, the microstrip antennas benefit of the advantages of CPW−fed antennas, like a simplified configuration with feed line and ground plane on the same layer. It is also possible with CPW feed line to integrate active devices on one side of the substrate avoiding via hole connections (no backside processing).

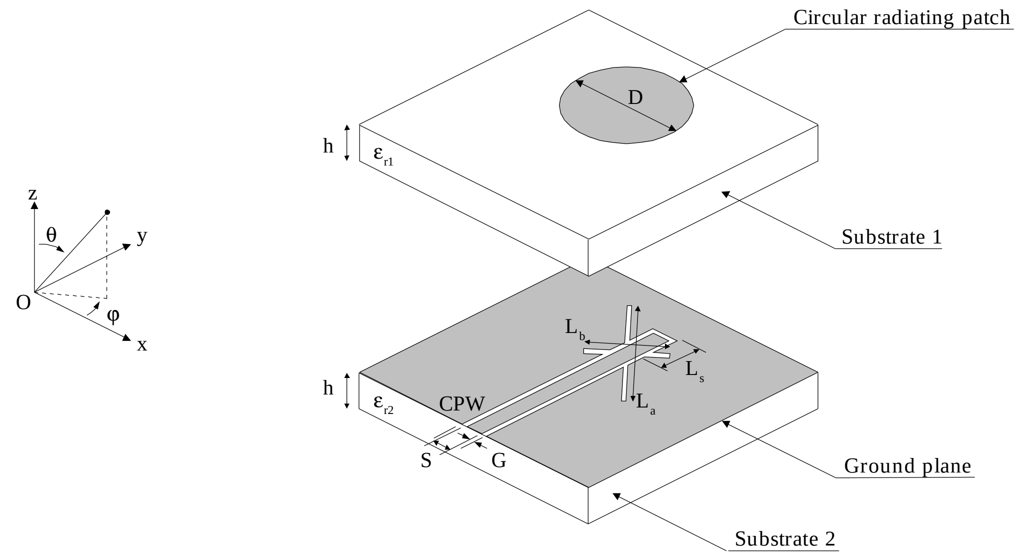

Fig. 1: Geometry of the circularly polarized microstrip antenna using asymmetrical cross coplanar slot (D = 9.2mm, ε_{r1} = 2.2, ε_{r2} = 4.5, h = 1.6mm, S = 1.2mm, G = 0.2mm, L_s = 2.1mm, L_a = 8.6mm, L_b = 4.3mm).

For circular polarization, several studies have been led on coupling between microstrip antenna and CPW feed line. But usually, a modification is performed directly on the radiating element in order to achieve CP (by slot or tuning stub) [1, 2]. The originality of the proposed antenna is the use of a perfectly circular patch antenna (in order to maintain symmetrical radiation) coupled with an asymmetrical cross coplanar slot line to increase reflection coefficient bandwidth and generate CP. We use two different substrates with specific dielectric constant to enhance the electromagnetic coupling between the slot and the radiating element but also to minimize the back radiation from the slot. Details of the design considerations and simulations results are presented and discussed. The AR and the radiation patterns of the proposed antenna is measured and compared with the simulations.

Antenna design

The geometry of the circularly polarized microstrip antenna using asymmetrical cross coplanar slot is shown in Fig. 1. The circular radiating patch, with a diameter of D = 9.2mm, is printed on the upper side of the first substrate. The CPW feed line and the 45°−inclined asymmetrical cross coupling slot are on the upper side of the second substrate. The first and the second substrates have respectively a relative permittivity of $\varepsilon_{r1} = 2.2$ and $\varepsilon_{r2} = 4.5$, and both have the same thickness (h = 1.6mm).

The permittivity of the upper substrate has been chosen small to favor the patch radiation and the coupling between the patch and the cross slot. The permittivity of the lower substrate has been chosen high to reduce the back radiation of the cross slot and the size of the CPW feed line. The characteristic impedance of this CPW feed line is 50Ω. The strip width S = 1.2mm and the slot width G = 0.2mm. The cross coupling slot, whose dimensions are given on the Fig. 1, is centered below the patch with a 45° inclination angle in relation to the y−axis. Through the cross coupling slot, the electromagnetic energy can be coupled from the CPW feed line to the circular patch. In fact, the use of asymmetrical cross coupling slot allows the apparition of two near−degenerate modes and right−hand circular polarization (RHCP) radiation appears.

Moreover, left−hand circular polarization (LHCP) radiation can be obtained when the inclined cross coupling slot is rotated with a 135° inclination angle in relation to the y−axis.

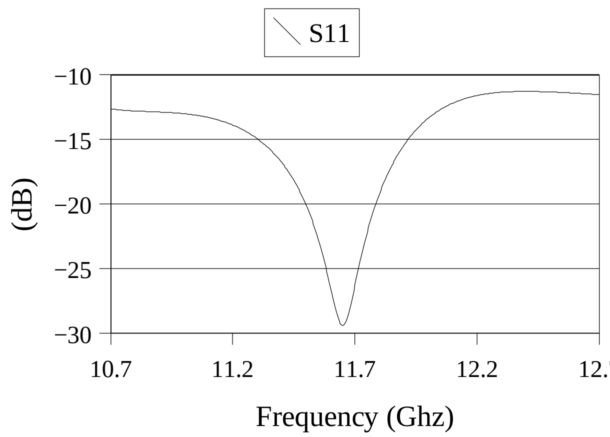

Fig. 2: Simulated reflection coefficient versus frequency.

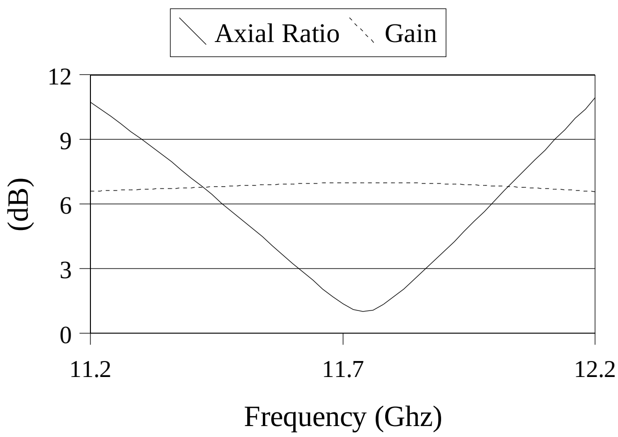

Fig. 3: Simulated axial ratio and gain versus frequency.

Simulation results

The proposed circularly polarized microstrip antenna using asymmetrical cross coplanar slot for CP radiation has been simulated using the software Ensemble [3]. The reflection coefficient (in the 10.7GHz − 12.7GHz band) is shown in Fig. 2 and the axial ratio of the RHCP and the gain of the antenna (in the 11.2GHz − 12.2GHz band for best reading) are shown in Fig. 3. Good reflection matching at the resonance frequency is obtained, and a very good impedance bandwidth (−10dB reflection coefficient) is found, greater than 20% in relation to the center frequency (11.7GHz). The RHCP bandwidth, determined for a 3dB axial ratio, is 256MHz or 2.17%. It is small for the DBS reception, but like it is shown in the references [4] and [5], it is possible to improve significantly AR bandwidth using the antenna in an array. The simulated maximum gain is 7dB and can be enhanced by means of the same way that previously described.

Finally, the simulated radiation patterns for φ = 0° at 11.74GHz (corresponding to the minimum simulated AR) are also presented in Fig. 4. In this figure, the front to back radiation ratio of 12dB is mainly due to the use of the second substrate.

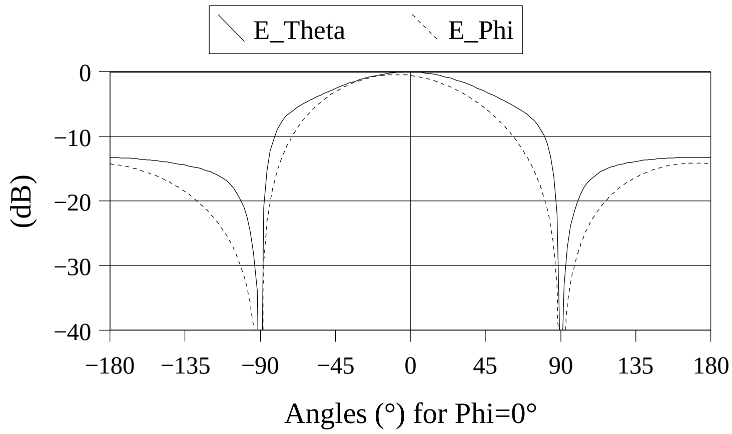

Fig. 4: Simulated radiation patterns at 11.74GHz.

Experimental result

A first antenna has been realized in considering that the alignment between the circular patch and the cross coplanar slot can't be rigorously correct. In addition of this, the dimensions of this antenna have been measured and didn't perfectly agree with these of the simulated one (mainly due to the fine dimensions of the CPW feed line and the coupling slot).

We have also re−simulate the antenna with the measured dimensions. The AR has been measured in 11.2GHz − 12.2GHz frequency band and compared with the new simulation results (Fig. 5). We can observe a slight frequency shift (2.25%) of the minimum AR in comparison with simulated results. The RHCP bandwidth of this antenna is 224MHz or 1.9%. The simulated and measured radiation patterns for φ = 0° at 11.56GHz and 11.82GHz respectively (corresponding to the minimum AR) are also presented in Fig. 6.

From these encouraging results, a new realization of the antenna is actually performed to improve the low reflection matching (−9.7dB) observed for the minimum axial ratio with the first one.

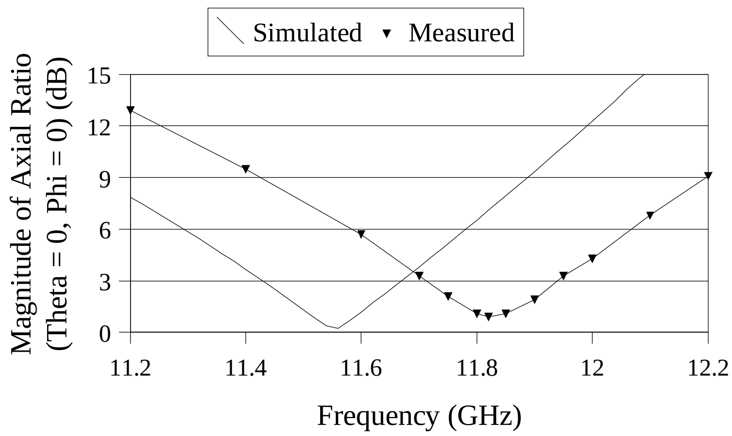

Fig. 5: Simulated and measured axial ratio versus frequency.

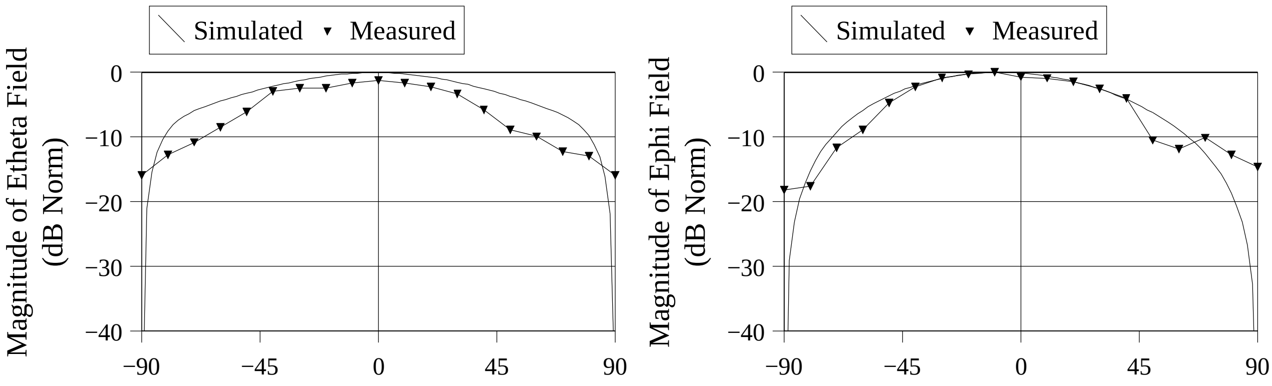

Fig. 6: Simulated and measured radiation patterns.

Conclusion

A new CPW feed design for circularly polarized microstrip antennas have been proposed. The symmetry of radiating patch allows to minimize radiation patterns modifications and the CP is obtained by the asymmetry in the coupling slot directly integrated on the CPW feed line. Experimental results have shown good CP performances of the proposed antenna. It is now possible to improve AR bandwidth and gain by combining four (2x2) basic radiated elements in a sequentially rotated subarray, and in this way to use these arrays for the DBS reception.

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