Dual Circularly Polarized Radial Line Slot Antenna

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Abstract – A dual circularly polarized radial line slot antenna (RLSA), built up on a very thin parallel-plate waveguide cavity, is here proposed and analyzed. The antenna radiating surface consists of several concentric arrays of crossed slots etched on the upper waveguide plate. This configuration allows to radiate both a symmetric left-hand (LHCP) and right-hand (RHCP) circularly polarized wave by properly exciting corresponding rotational field inside the cavity. The exciting fields are launched through a concentric annular slot cut on the lower waveguide plate and fed by four microstrip lines with identical amplitudes and 90° rotating phases. A simple planar network provides the required clockwise/anticlockwise phasing at the four microstrip ports. Input S-parameters behavior and antenna radiation performances have been simulated in the 9.5 to 10.5 GHz frequency range.

I. INTRODUCTION

Nowadays, the radial line slot antenna (RLSA) represents one of the most interesting planar radiating structures for its low cost, high efficiency, and mass-producible features. In the field of microwave and millimeter-wave applications, RLSA is considered an attractive candidate for replacing high gain microstrip patch arrays, where the high conductor losses of the feeding network lines remarkably reduce the radiation efficiency.

The layout geometry of the annularly arrayed slot radiator was firstly proposed by Kelly and Goebels [1], and later improved by Ando and Goto by realizing a highly efficient circular [2] and linear [3] polarization antenna for DBS applications. Two quite similar monopulse RLSA have been recently proposed [4] [5], employing different types of feeding network to obtain both broadside and conical beam.

Only few works on double circular polarization antennas based on the slot pair design procedure carried out by Ando and Goto [6] have been presented. However, these structures are not suitable to radiate both LHCP and RHCP waves unless using a complex double layer planar waveguide structure.

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In this work we propose a structurally simple dual circularly polarized parallel plate RLSA architecture where the radiating elementary sources, consisting of a couple of crossed slots, are distributed on the upper plate in concentric rings.

II. CONFIGURATION

In a standard RLSA structure the feeding element is constituted by a metallic post protruding into the cavity, while the radiation element is formed by two spatially offset orthogonal slots. The post launches a field spreading radially into the cavity that can be represented by Hankel functions. It is worth to note that such a configuration allows to radiate only one kind of circular polarization.

By feeding the radial cavity through an aperture instead of a post, the inner field can be represented by a Bessel function of the first kind, with both radial and circumferential magnetic components. In this case an orthogonal crossed slot pair can radiate whichever circular hand polarized field is established into the cavity, simply by placing the pairs at the proper radii where the radial and the circumferential magnetic field components are in phase quadrature.

This latter configuration, depicted in Fig.1, is here adopted to design a 22cm-diameter antenna centered at 10GHz and composed by five rings of crossed slots placed on the upper plate of an hollow radial waveguide, terminated on a shorting wall. In order to achieve an in-phase radiating contribution, the radial spacing of the rings has been tuned by a Finite Integration Technique (FIT) 3D simulator [7], reproducing an equivalent slice of the whole structure. The launcher, depicted in Fig. 2, consists of a annular slot, cut on the lower plate and fed by four microstrip lines with identical amplitudes and 90° rotating phases. The microstrip lines are printed on a dielectric substrate and connected through vias to the lower cavity plate, performing as ground plane reference. Dimensions and shape of both the annular slot and the feeding microstrip lines have been tuned to optimize matching and bandwidth. Nevertheless, the continuity of the slot ring determines a strong coupling effect between opposite ports (1-3 and 2-4), responsible of polarization purity degradation and mismatching. Fig. 3 shows a modified launching structure aimed to reduce the above undesirable phenomena. The slot has been subdivided in four sections, providing a further electromagnetic decoupling between the opposite ports. The stubs added to the slot sections guarantee a good input matching without affecting the purity of the rotational field inside the radial cavity.

The pertinent clockwise or counterclockwise phasing is achieved through a simple planar feeding network etched on a further substrate layer, schematically shown in Fig.4 and composed of a matrix of two 180° and two 90° properly connected hybrids.
III. NUMERICAL RESULTS

In order to confirm the validity of the proposed design procedure, some simulations with a MoM commercial code [8] have been performed.

Radiation patterns for both LHCP and RHCP have been calculated by feeding the four microstrip ports with the proper rotating phase. The radial symmetry of the structure along with the equal amplitude rotating phase excitation, assures that far field radiation patterns are identical and symmetrical with respect to the $\theta=0^\circ$ axis, whichever circular polarization is excited. Fig 5 shows the co-polar and cross-polar E-field patterns on the $\varphi=0^\circ$ cut plane for both LHCP and RHCP polarizations. Side lobe level of co-polarized component is 16dB below the main lobe and a low cross-polarization near broadside direction is observed. The back radiation due to the ring slot has been eliminated by a metallic screen placed at a quarter wavelength below the lower cavity plate. The calculated gain is close to 25dB and comparing it to that of an uniformly illuminated aperture having the same diameter, we estimate an efficiency of 60%, essentially due to the not optimized aperture field distribution. Unfortunately the optimization procedure requires multiple full-wave simulations of the whole radiating structure and therefore is numerically demanding.

The input four ports scattering matrix has been also calculated and results graphically shown in Fig. 6.

At center frequency the return loss on each input line is below -28dB, while the coupling between the feeding lines is maintained below -10dB by properly adjusting the slot stub lengths. The impedance matching bandwidth (VSWR=2) is close to 10%, so the operational bandwidth of the RLSA is only limited by the radiating performances.

IV. CONCLUSIONS

In this paper a new parallel plate RLSA configuration, suitable to radiate both LHCP and RHCP, has been presented and discussed. Besides, a fully planar feeding structure has been introduced in substitution of the standard four-probe feeder. This allows to easily integrate in the same substrate the microstrip matrix network required for the rotational phasing, the polarization and T/R switches and all the other passive or active microwave circuits pertaining the TX/RX front-end.
Figure 1 – The upper plate of the radial waveguide, with five concentric rings of radiating crossed slot.

Figure 2 – The annular slot cut on the lower waveguide plate, with the four feeding microstrip ports.
Figure 3 – The modified feeding structure

Figure 4 – The phasing matrix network.
Figure 5 – Far field radiation patterns on the $\varphi=0^\circ$ cut plane. Co-polar (solid line), Cross-polar (dashed line).

Figure 6 – Scattering parameters of the four port antenna. $S_{ii}$ (solid line), $S_{31}$ and $S_{22}$ (dashed line), $S_{21}$ and $S_{34}$ (dashed-dotted line).

REFERENCES


[7] CST Microwave Studio v.4.3, Computer Simulation Technology GmbH, D-64289 Darmstadt, Germany

[8] ENSEMBLE v.5.1, Boulder Microwave Technologies Inc., 1996