"Design Method, Analysis and Prototypes of Radial Line Slot Antennas"

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Abstract: *The authors propose a design procedure and an analysis method for radial line slot antennas. Several prototypes have been fabricated to validate these methods. The design procedure is very simple, and can be included in a software. The analysis method is required to be very fast, in order to design this kind of antennas. It considers only one variable per slot and calculates the coupling between the elements of the antenna. It has been validated with measurements and Method of Moment simulations. The first prototypes are for TV-DBS Reception at 12.1 GHz. They have a narrow broadside beam. The last prototype is a monopulse antenna. Monopulse capability can be obtained by comparing two simultaneous beams. Two simultaneous beams are obtained, a sum one and a difference one.*

I. Introduction

A parallel plate slot antenna is an attractive candidate for high-efficiency and mass-producible planar phased array antennas for microwave and millimeter-wave applications. Generally, the transmission loss in a waveguide is very small in comparison with other feed lines such as a microstrip line and a suspended line. During the last five years we designed some prototypes of RLSA. A broadside radial line slot antenna working at 12 GHz was proposed in [1]. This design had higher efficiency than other designs [2], due to the higher uniformity of the electric field inside the waveguide because of the symmetry of the antenna. This kind of antennas can be used for monopulse antennas [3]. Prof. Ando has designed different antennas for other applications using RLSA [4], in both circular and linear polarization, and Prof. Bialkowski and P. Davis showed in [5]a design for linear polarization.

This paper begins with a brief explanation of RLSA. The next part explains the design procedure, the fourth one the analysis method and it finishs with some prototypes. All the prototypes have been designed to get left hand circular polarization, but the method would be similar to right hand circular polarization or linear one.

II. Radial Line Slot Antenna Structure

Figure 1 shows the structure of the antenna. A Radial Line Slot Antenna is formed by a parallel plate structure, whose height is less than half a wavelength to avoid the propagation of upper modes. A radial TEM mode is generated through a coaxial probe (or several probes). This TEM wave excites the, placed on the upper plate. These slots are designed to get the required amplitude and phase. The Radial Line is finished in a short circuit.

The slot element (figure 2) is a couple of slots separated one quarter of wavelength and tilted 90º one respect the other in order to get the left hand circular polarization. These elements are placed forming an Archimedes Spiral or concentric rings, depending on the phase of the TEM wave generated by the feeding structure. In all the cases a circular polarization is obtained. The material of the RLSA could be air between two metallic plates, or a foam substrate, or a glass PTFE substrate. All these materials have been used for the different applications.

III. Design Procedure.

The design procedure is divided in three steps. A more detailed explanation of the procedure can be found in [2].

- Design of the excitation circuit: the simpler excitation circuit is one simple coaxial probe. If circular polarization is required this requires the situation of the slots in a Spiral. In other applications could be interested to have a symmetrical radiation structure; this means we have to modify the phase of the incident wave in order to compensate this position. This can be realized with four coaxial probes excited in contra phase.
- Design of slots: the design of the slots depends on the phase and amplitude at the apertures. All the prototypes are designed for uniform amplitude and phase, although similar procedure can be used for other excitations.
    - The radial distance between radiation elements (two slots) is one wavelength. The slots will be placed in concentric rings or in an Archimedes Spiral.
    - The length of the slots is calculated to get the required amplitude on each slot.
    - The position of the slots is roughly modified in order to compensate the variations on the phase due to different lengths of the slots.
- The short circuit is placed optimizing the directivity of the antenna.

IV. Analysis Method

The analysis of the antenna is realized with the method published in [6] and [7]. This method has been validated with measurements and comparing with simulations based on Method of Moment.

At first, a simple equivalent circuit for slots and coaxial probes is obtained. The short circuit is simulated with some pins separated less than a quarter of wavelength. The second step is the calculation of the coupling between all the slots, probes and pins. A system of equations is obtained and its solutions gives the current on each probe and the electric field on each slot. The radiation and input impedance parameters are obtained from these values.

V. Prototypes

Some prototypes were designed, analyzed and fabricated with this method. The first and the second ones are for the reception of Spanish DBS TV system, from Hispasat satellites at 12.3 GHz. The first one is excited through one coaxial probe while the second one is excited through four different probes. This second design has a higher directivity due to the symmetry of the radiation structure, but the losses of the feeding circuit are higher and the price is also higher. The last one is a monopulse antenna for radar applications, at 13.7 GHz. This performance is obtained by exciting with four probes. Comparing both beams elevation and azimuth angle can be found. The sum beam is obtained exciting the four probes with of a difference of phase equal to 90 deg, and the difference beam exciting the four beams in phase.

In figures 3 , 5 and 7 the picture of the prototype is shown while in figures 4, 6 and 8 a radiation pattern is shown.

VI. Conclusions

A design procedure and an analysis method have been proposed for radial line slot antennas. These methods have been validated by the construction of several prototypes. They have been built in the facilities of Universidad Politécnica de Madrid and the antennas have been measured at the anechoical chamber of the same University.

Acknowledgements

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REFERENCES

[1] M Sierra Pérez, J.M. Salamanca, M. Vera Isasa, M. Sierra Castañer. "Synthesis of circularly polarised multiprobe feed radial line slot antenna". 1998 AP-S Digest Vol.2 Pag. 1184-1187.

[2] M.Vera Isasa "Diseño de Antenas de Ranuras sobre Guía Radial". Doctoral dissertation. Universidad de Vigo (1996)

[3] M. Sierra Castañer, M. Sierra Pérez, M. Vera Isasa. "Design of Monopulse Radial Line Slot Antenna". 1999 AP-S Digest. Pag 2774- 2777

[4] M Ando, K. Sakurai, N.Goto. "Characteristics of a Radial Line Slot Antenna for 12 GHz Band Satellite TV Reception". IEEE Trans. on Antennas and Propagation, Vol. 34, No. 10, Oct. 1986.

[5] P Davis, M.E. Bialkowski. "Linearly Polarized Radial-Line Slot Array Antennas with Improved Return-Loss Performance". IEEE Antennas and Propagation Magazine, Vol. 41, No. 1, pp. 52-61 Feb. 1999.

[6] M.. Sierra Pérez, M. Vera Isasa, A.G. Pino, M. Sierra Castañer, "Analysis of slot antennas on a radial transmission line", International Journal of Microwave and Millimeter-Wave Computer-Aided Engineering. vol.6, nº 2, pp.115-127, Feb. 1996.

[7] M. Sierra Castañer. "Contribución a las Técnicas de Diseño y Análisis de Antenas de Ranuras sobre Placas Paralelas". Doctoral dissertation. Universidad Politécnica de Madrid (2000)

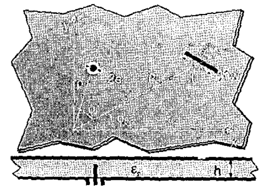

Figure 1: Geometry of RLSA.

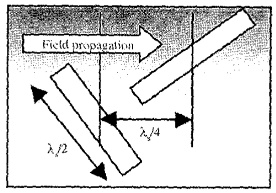

Figure 2: Slot pair.

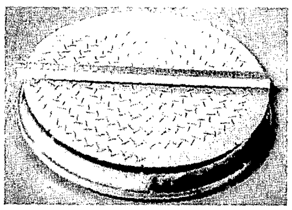

Figure 3: Antenna 1 for DBS reception

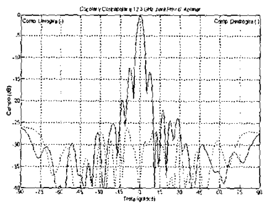

Figure 4: Simulation at 12.3 GHz

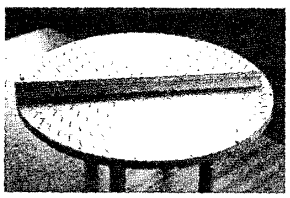

Figure 5: Antenna 2 for DBS reception

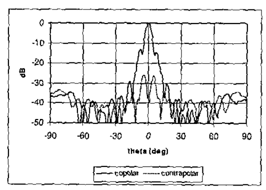

Figure 6: Measurements at 12.1 GHz

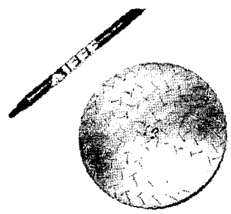

Figure 7: Monopulse antenna

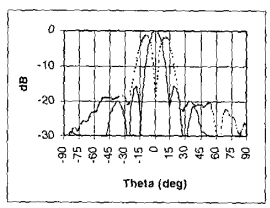

Figure 8: Measurements at 13.7 GHz