Experimental Investigation of a Varactor Loaded Reflectarray Antenna

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ABSTRACT — **A new approach for beam steering in reflectarray applications is introduced in this paper. The progressive phase distribution is achieved by loading each microstrip patch element with a varactor diode on the radiating edge. In the following, the scattering characteristics of a single varactor loaded patch antenna will be presented. As a proof of concept, the beam steering capability of a five elements linear reflectarray has been experimentally investigated.**

I. INTRODUCTION

A microstrip reflectarray is a low profile reflector, consisting of an array of microstrip patch elements and an illuminating feed. This type of antenna combines some of the best features of the microstrip antenna technology together with the ones of the conventional reflectors. Reflectarray are flat, inexpensive, easy to install and to manufacture; they can be conformal to the mounting surface, their main beam can be designed to point at a large fixed angle (up to 60°) from broadside direction and the spatial feeding eliminates the complexity and the losses of a microstrip feed network. Thanks to their features the reflectarrays have several attractive applications such as Direct Broadcast Satellite (DBS) services or application in microspacecraft missions, where high-gain antennas with small volume and low mass are needed [1].

The reflectarray concept is based on the scattering properties of microstrip patches. The elements printed onto the reflecting surface are designed to reradiate the electromagnetic energy with a prescribed beam shape and direction. When the phase of the field scattered from the single element is adjustable, the main reflected beam can be steered to a desired location. In literature, different methods to design reflectarrays have been proposed and discussed. The reflection phase of the individual radiator can be controlled using patches of the same size with passive delay lines of different lengths, by varying the patch resonant sizes or with the introduction of a rotation in the elements position [2-4]. All these methods introduce a small shift in the resonant frequency of the element so changing the phase of the reflected field [5].

When beam scanning capabilities are required, reflectarray antennas can give significant advantages if compared to the conventional phased array.

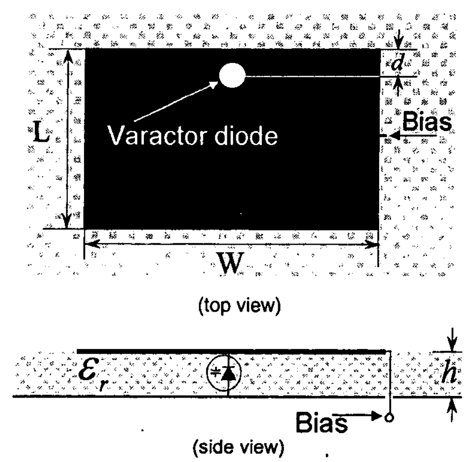

Fig. 1. Varactor loaded microstrip patch antenna.

As literature shows [1], the main beam of microstrip reflectarrays can be electronically scanned by implanting low-bit and low-loss phase shifters into the printed elements or mechanically scanned by placing miniatures motors under the patches when circular polarization is required.

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Even if good results can be achieved with the mentioned techniques, they significantly increase the complexity and the costs of the scanning system.

A simpler method to steer the main reflectarray beam, consisting on loading each microstrip patch antenna with a varactor diode, is here introduced. The main advantage of this technique is that it allows for a considerable reduction of the system architecture complexity and cost and, additionally, the phase of the single element is dynamically governed by using only a voltage control.

II. Array Element Design

The variable-phase element is presented in Fig. 1. It consists on a microstrip patch antenna printed on a dielectric substrate over a ground plane and loaded by a varactor diode on one radiating edge.

The voltage controlled tuning varactor introduces at the open end of the antenna a variable capacitive reactance which modifies the electrical length of the patch. By electrically adjusting the capacitance of the diode, the resonant frequency of the antenna can be varied within a specified range [6]. This capability is beneficial for reflectarray antennas because the small shift in the resonant frequency introduced by the tuning diodes changes the reflection phase of the single element, so allowing a dynamic phase control.

The reflection phase vs. diode capacitance has been studied considering a rectangular microstrip patch antenna of width W=13mm and length L=9.2mm, printed on a substrate 0.762mm height and with $\varepsilon_r = 2.33$. A Microsemi GC15006 diode, with a tuning range of 1.8-0.3pF when reversed biased between 0 and 11V, has been inserted at d=1mm.

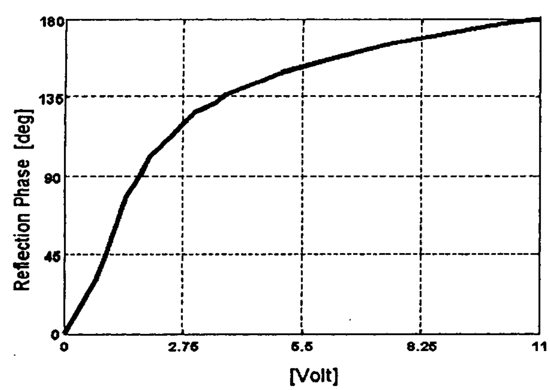

Fig. 2. Reflection phase versus varactor bias.

The effect of the change in the varactor capacitance on the phase of the reradiated field has been estimated by performing several measurements. A transmitting and receiving horn antennas, both connected to a Vector Analyser Anritsu 37255B, have been set up in a way that the instrument detects the amplitude and the phase of the field scattered by the patch in the broadside direction.

In fig. 2 is presented the phase variation versus diode bias measured at 10.8GHz, which is the resonant frequency of the patch when the varactor presents a capacitance at the centre of the allowed range. As it can be seen the phase varies within a range of 180 degrees, which is the maximum expected value in the case of a purely capacitive load.

III. Linear Reflectarray Design

A linear reflectarray of varactor loaded microstrip antennas has been prototyped and tested as a proof of principle of the previously introduced beam steering technique.

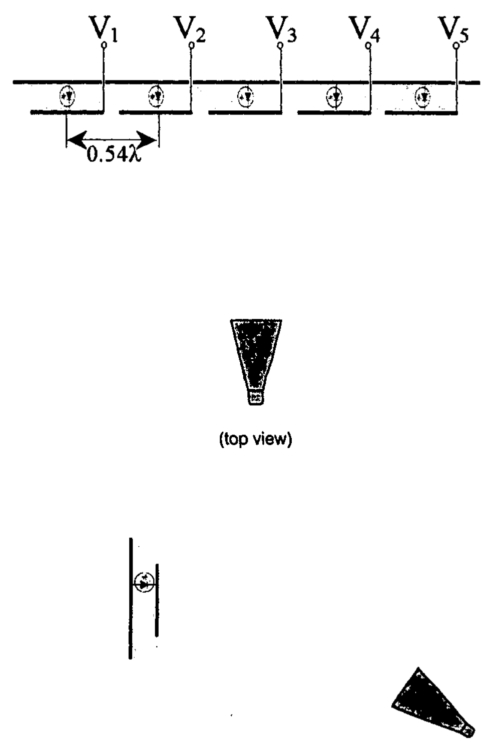

Fig. 3. Linear varactor loaded reflectarray antenna.

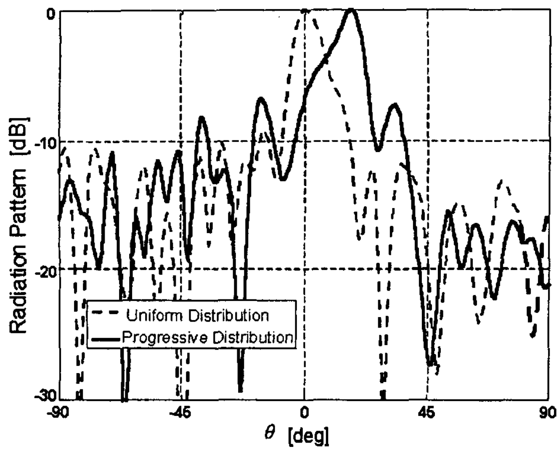

Fig. 4. Measured radiation patterns of the reflectarray antenna.

The array is made of five patches spaced 0.54 λ at 10.8GHz. In this configuration, the available reflection phase range permits at most to continuously scan the array main beam within a range of ± 15 degrees from broadside direction.

The reflectarray is fed using a horn placed in the far field of the array. As it can be seen from Fig. 3, the horn is located in a way that it does not interfere with the array pattern in the broadside direction.

Two measurements to verify the beam scanning capability of the reflectarray have been carried out. Firstly the radiation pattern of the reflectarray has been measured with the capacitive loads fixed to an identical value. In this case each element gives approximately the same phase contribution thus the main beam is located in the broadside direction. A second configuration has been chosen to scan the reflectarray main beam 15 degrees off broadside. According to Fig. 2, the required progressive phase shift can be achieved by tuning the diode bias to the following listed values: V1=0V, V2=1V, V3=1.75V, V4=3.75V, V5=11V.

The measured radiation patterns in the two cases are presented in Fig. 4 showing that the reflectarray main beam scans, as expected, from 0 to 15 degrees off when the diodes are reconfigured.

IV. CONCLUSIONS

A simple method for reflectarray beam steering has been outlined. The main features of the proposed technique are that it dramatically reduces complexity and costs in the scanning system architecture while providing a continuous phase variation. The presented arrangement allows only for limited beam scanning and it is not applicable to large reflectarray in its actual form. Thanks to its reduced costs it can be used as an additional control to empirically tune the phase distribution on the array elements. Solutions to make the varactor controlled patch arrays fully functional are under investigations. In particular, a stacked patches configuration seems to be particularly attractive and it promises to give larger steering ranges.

REFERENCES

[1] J. Huang, "Capabilities of Printed Reflectarray Antenna" *JPL*, 1996 IEEE

[2] D. Pozar, T.A. Metzer, "Analysis of a reflectarray antenna using microstrip patches of variable size", *Electron. Lett.*, 1993, 29, 8, pp.657,658

[3] J. Huang, "Microstrip Reflectarray", *IEEE Int. Symp. on A.P.*, 1991, 45, 2, pp.287,656

[4] J. Huang, R.J. Porgorzelsky "A Ka-band microstrip reflectarray with elements having variable rotation angles", *IEEE A.P.*, 1998, 46, 5,pp.650,656

[5] D. M. Pozar, S. D. Targonski H. D. Syrigos, "Design of millimetre wave microstrip reflectarrays", *IEEE Trans.on Antennas and Propagation*, vol. 45, February 1997.

[6] P. Barthia, J. Bahl, "Frequency agile microstrip antennas", *Microwave Journal*, October 1982.