A New Reconfigurable Multi Band Patch Antenna

J. Costantine*, C. G. Christodoulou*, S. E. Barbin †

*University of New Mexico, Albuquerque, NM 87131 - USA, christos@ece.unm.edu

† Universidade de São Paulo, São Paulo - Brazil, barbin@usp.br

***Abstract* — A new reconfigurable multi band microstrip antenna is presented in this paper. The patch has the shape of a 6 armed star printed on a hexagonal substrate. The reconfigurability of the antenna is obtained by inserting small switches on rectangular slots cut in the patch. Different switch configurations were investigated and different functionalities of the antenna were obtained. The antenna has many practical applications, like in GSM, wireless LAN, WIMAX and many other systems, as illustrated in detail herein. The antenna changes its application according to which switches are activated.**

***Index Terms* — Microstrip antennas, reconfigurable architectures, switches, wireless LAN.**

I. Introduction

Reconfigurable antennas are a new generation of antennas that will not be limited to a certain function or resonance but will change their functionality depending on the implementation requirements. Compared to broadband antennas, reconfigurable antennas offer many advantages, such as compact size, similar radiation patterns for all designed frequency bands, and frequency selectivity which helps in reducing adverse effects like co-site interference and jamming [1].

Several interesting approaches for the design of tunable antennas were presented. In [1] a slot antenna utilizing shunt switches that effectively change its electrical length having a very wide bandwidth is proposed. In [2] a tunable small patch antenna able to switch between 800 MHz and 900 MHz was designed, using variable capacitors and transistors. This antenna was controlled via a radio baseband processor sending commands to a digital antenna control unit implemented with FPGA. The technique in [3] constitutes of loading a slot antenna with two lumped variable capacitors (varactors) placed in proper locations along a slot. A dual band antenna was obtained whose first and second resonances can be controlled individually. The frequency ratio ranges from 1.3 to 2.67. In [4] ohmic contact cantilever RF-MEMS switches integrated with self-similar planar antennas provided reconfigurable properties to them. The antennas radiated similar patterns over a wide frequency range.

The switches used in [4] exhibited better performance compared to PIN diodes and FET transistors. Also in [5] RF MEMS were used to design a reconfigurable triangular microstrip patch antenna for monolithic integration with RF MEMS phase shifters to demonstrate a low-cost monolithic passive electronically scanned array (PESA). In [6] a switching diode was mounted at the center of a slot cut on a patch antenna. The antenna operation was controlled using DC bias. The antenna operates at 4.20 GHz with right-hand circular polarization and at 4.55 GHz with left-hand circular polarization. A modified monopole with added sleeves was presented in [7]. The sleeves were added to gain more versatility in the antenna and RF MEMS switches were introduced in order to control the lengths of the monopole and of the sleeves. Different resonant frequencies were obtained according to the state of the switches.

This paper introduces a new reconfigurable microstrip antenna design, based on a structure with switches mounted at different slots cut on a star shaped patch antenna. The states of the switches change the functionality of the antenna cutting or allowing certain frequencies of operation. The radiation patterns for different switches configurations are very similar.

II. Antenna Structure

The basic structure of the proposed antenna, shown in Fig. 1, consists of 3 layers. The lower layer, which constitutes the ground plane, covers the entire hexagon shaped substrate with a side of 2.915 cm. The middle substrate, which is made of FR4 epoxy resin, has a relative dielectric constant ε_r=4.4 and height 0.32cm. The upper layer, which is the patch, completely covers the hexagonal top surface. Six triangle slots of sides 1.2 cm and 1.4 cm and a base of 0.73 cm are cut out of the patch giving it the shape of a six armed star.

In the star patch six rectangular slots of length 1.4 cm and width 0.2 cm were cut on each branch of the star as shown in Fig. 1. Six square switches of side 0.2 cm were mounted at the center of the rectangular slots, as shown in Fig. 1. The antenna is fed by a coaxial probe with 50 Ω input impedance.

III. Antenna Operation

The radiation pattern and functionality of an antenna are related to the current distribution on its surface. Any slight change in the geometrical configuration of the structure will create new current paths and new radiation edges, which give the antenna new resonances and different operation.

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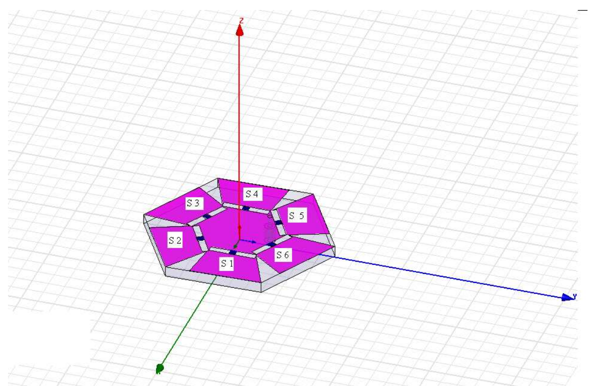

Fig. 1. Geometry of the star antenna showing the different slots and the switches.

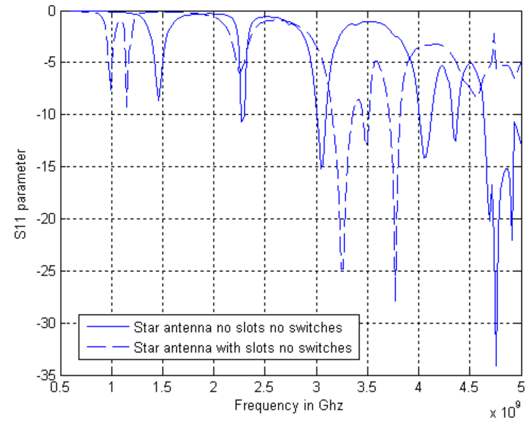

Fig. 2. S11 parameter with and without slots.

When the switches are activated links between the center area of the star and the branches are established, changing the surface current distribution and creating new radiating edges that lead to a new antenna functionality.

There are several possibilities of changing the antenna functionality and operation. In this work, the inserted switches were switched two at a time, following a certain pattern. At first, two switches were activated at slots having a 180 degrees phase difference. Then 4 and 6 switches were activated following a 60 degrees phase difference.

The feeding position was optimized for each case and at the end one feeding position was chosen for a comparison of the results, which was executed for the determination of the resonances, for different antenna configuration.

IV. Antenna Results and Applications

Simulations were firstly made for the antenna without slots and the results are shown in Fig. 2. These results show that the antenna is suitable for UMTS, satellite, WIMAX, wireless LAN and broadband radio access network applications. Then slots were cut as shown in Fig. 1, and simulations were executed for the same feeding position as before. The results for the S_{11} parameter compared with the previous ones are shown in Fig. 2. The antenna presented a new set of resonances, especially between 3 GHz and 4 GHz, which makes it useful for practical applications such as wireless LAN and WIMAX.

While maintaining the same feeding position, the switches 1 and 4 were activated, and the antenna presented new resonances between 4 GHz and 5 GHz. The antenna regained its wireless LAN and broadband radio access network domain applications.

Then switches 1 and 4 were deactivated and 3 and 6 were switched on. The new configuration presented good results for GSM, wireless video links, wireless LAN and WIMAX applications, eliminating some frequencies between 4 GHz and 5 GHz. All the switches were then deactivated and 2 and 5 were switched on. The GSM application was cutoff and a small shift in the resonant frequencies occurred. The applications now are restricted to WIMAX and wireless LAN. These results are all compared in Fig. 3.

When the switches 2, 3, 5 and 6 were activated, the antenna regained its GSM operation capability in addition to wireless LAN and WIMAX. It is important to note, that the S_{11} parameter presented some band widening for particular frequencies, especially around 3 GHz and 4.5 GHz. Then, all the 6 switches were activated maintaining the same feeding point. The antenna presented wide band operation, from 3.5 to 3.8 GHz and from 4.3 to 4.7 GHz, in addition to GSM, wireless video, wireless security links, Wireless LAN, satellite, WIMAX, and military applications. A comparison between these S_{11} results is shown in Fig. 4. The total directivity of the antenna for Phi=0˚ and for Phi=90˚ with all switches activated is shown in Fig. 5.

All simulations were executed using Ansoft HFSS V10.1 in the facilities of the ECE Department of the University of New Mexico in Albuquerque, USA.

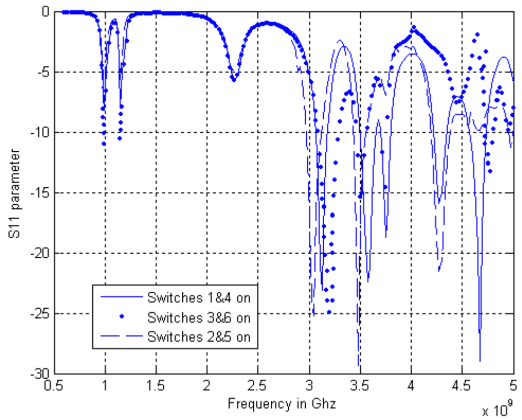

Fig. 3. S_{11} parameter for different switches activation, two at a time.

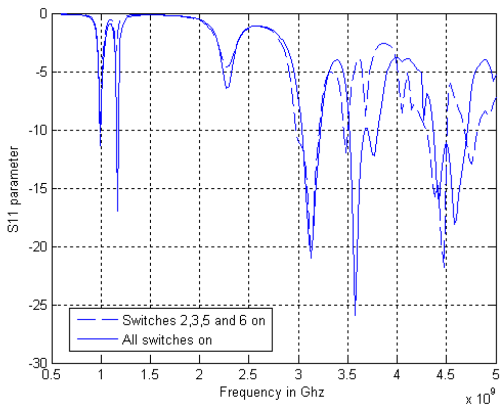

Fig. 4. S_{11} results when switches 2, 3, 5 and 6 are activated and when all the switches are activated.

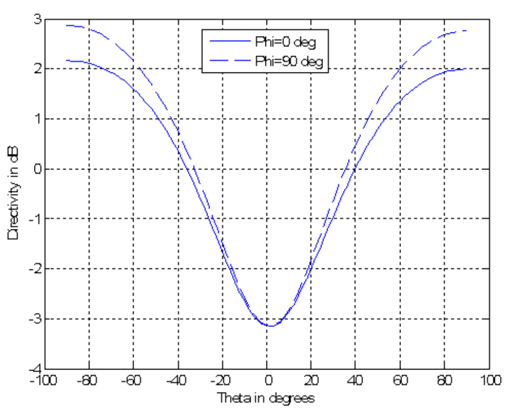

Fig. 5. Total directivity of the antenna as a function of the angle theta.

Even though different antenna configurations gave different and alternate functions, the radiation patterns for the different configurations were very similar. Fig. 6 presents the radiation patterns of the antenna for Phi=0˚ and for Phi=90˚ with all the switches on and for the same feeding position that was used in the other simulations.

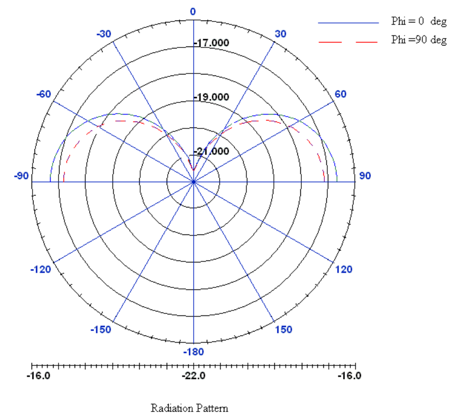

Fig. 6. Radiation Patterns for phi=0˚ and for phi=90˚ with all switches activated.

V. Summary and Conclusion

This paper presented a new reconfigurable multi-band micrsostrip antenna design. Slots were cut in a hexagonal patch giving it the shape of a 6 armed star and further rectangular slots were inserted for achieving multi-band operation. The antenna was made reconfigurable by the use of switches that were activated and deactivated two at a time, following a certain angular pattern. The resonances of the antenna changed with the switch configuration. The star shaped is a new antenna design that has many applications depending on its configuration.

Some major practical applications are in GSM, UMTS, wireless LAN, wireless video links, satellite, WIMAX, military and broadband fixed radio network systems. The antenna is also easy to fabricate and the implementation of switches can be easily achieved. Reconfigurable antennas, like the one presented in this paper, will constitute the basis of new technological developments in the near future. The concept of reconfigurable designs is an important challenge for researchers working on antennas nowadays and in the coming years.

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