



## Radiation Pattern Reconfiguration Using Parasitic Elements

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**Abstract**— A parasitic surface based reconfiguration technique for microstrip antenna beam steering has been presented and discussed in this paper. This concept can be used in reconfigurable antennas without additional modification on the basic design of an antenna. This parasitic layer based antenna is designed using array of 5 by 5 pixel surface which can be connected or disconnected depending upon required configuration so as to steer antenna beam in particular direction such as  $-30^\circ$ ,  $0^\circ$  and  $+30^\circ$ .

**Index Terms**— Reconfiguration, Beam Steering, Microstrip antenna, Parasitic pixel surface, Antenna array, RF MEMS switches, Radiation pattern.

The wireless network with rapidly increasing demands of high data rate and increasing popularity of smart gadgets requires the smart techniques and technologies to support their smart and fast functions. So a self reconfigurable antennas which can modify their frequencies and or radiation pattern depending upon requirement of network becomes the best solution [11].

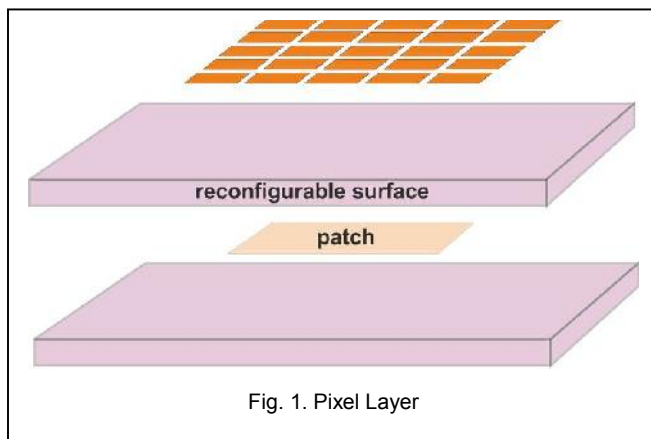


Fig. 1. Pixel Layer

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This paper presents a technique to reconfigure the antenna beam in particular direction using an array of parasitic pixel surface placed over the driven element. The RF MEMS switches are used to provide connectivity between the pixels. Here the selection of MEMS switches over PIN diode and FET is made because of its advantage of possibility of monolithic integration and low power consumption. Fig 1 describes the basic structure of the proposed antenna.

### 2 RECONFIGURABLE PIXEL SURFACE

#### 2.1 Pixel Surface

Fig 1 shows the geometry of the pixel layer for a 5 by 5 pixel surface. In this section, the geometrical properties of the metallic pixel grid, the switching technology are discussed.

To couple significant amount of energy from the driven element, the pixel surface must have a significant electrical size while the individual pixel dimensions are required to be much smaller than the wavelength. Typical dimensions are grids larger than half a wavelength with a pixel size smaller than a tenth of a wavelength.

#### 2.2 RF MEMS Switches

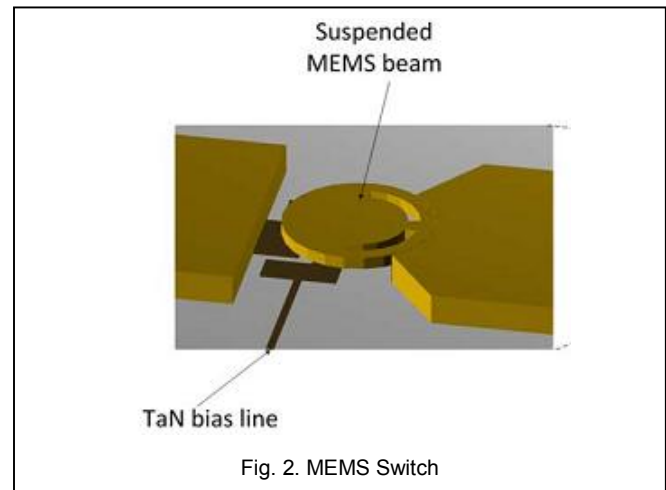


Fig. 2. MEMS Switch

RF-MEMS, PIN diodes and FET transistors are the most common techniques used for switching. The large number of switches required for pixel surfaces compared with other reconfigurable antenna. The large number of switches increases

the switch insertion losses results in a severe impact on the antenna efficiency. A similar situation occurs when considering the switch power consumption, leading to the requirement of switching technologies with near-zero level of power consumption. It has also consequences on the fabrication process. The one by one external attachment of switches becomes rather unrealistic. Thus, these requirements (low insertion losses, reduced power consumption and possibility of monolithic integration) make RF-MEMS the preferred switching technology for pixel antennas. The choice of monolithically integrated switches has significant advantages regarding the biasing network design [8]. The zero-current consumption of this technology makes possible using highresistive materials to manufacture bias lines, minimizing the undesired coupling with the radiation pixels. Furthermore, the multilayer nature of the switch microfabrication process enables the possibility of locating bias lines and metallic pixels in different layers. These two different layers can be effectively isolated by taking advantage of the sacrificial layer used for the microfabrication of suspended structures like RF-MEMS switches.

The interconnecting switches used in the simulations are DC contact type MEMS switch of which schematic is given in the Fig. 2. A circular metallic membrane made out of gold (Au) is suspended over an actuation electrode to which the DC control voltage is applied [3]. The applied DC voltage creates an electrostatic force between the membrane and the bias electrode. When this force becomes larger than the mechanical force due to the stress of the Au membrane, the membrane moves down and makes a DC contact, thereby connecting the pixels. With no voltage applied the pixels are disconnected.

### 3 ANTENNA STRUCTURE AND WORKING MECHANISM

A schematic of reconfigurable patch antenna is shown in fig 3. The driven element is standard patch antenna designed to operate at 10 GHz frequency using a RT/Duroid substrate with 1.575mm thickness. And the pixels are placed over a 1 mm thick quartz substrate layer. The selection of quartz substrate is made to ensure the monolithic integration of MEMS switches. The overall dimensions of pixel surface is approximately selected as 0.65 times of the resonating wavelength and individual pixel dimension is selected as 0.10 times of the resonating wavelength. The distance between the driven element and the pixel surface is selected as 0.14 times of the wavelength[5].

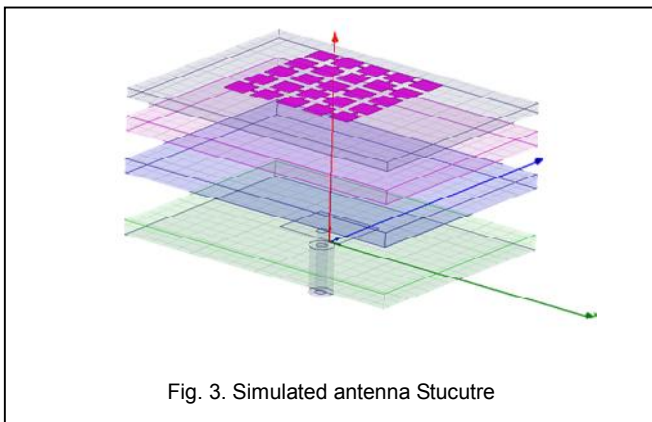


Fig. 3. Simulated antenna Structure

Hence the designed antenna has the substrate diameter as of  $40 \times 30 \text{ mm}^2$ . The driven element has diameter as  $9.20 \times 3 \text{ mm}^2$ . The overall distance between driven element and the pixel surface is 4.15 mm. Each pixel has diameter as  $3 \times 3 \text{ mm}$  with inter-pixel separation of 1mm.

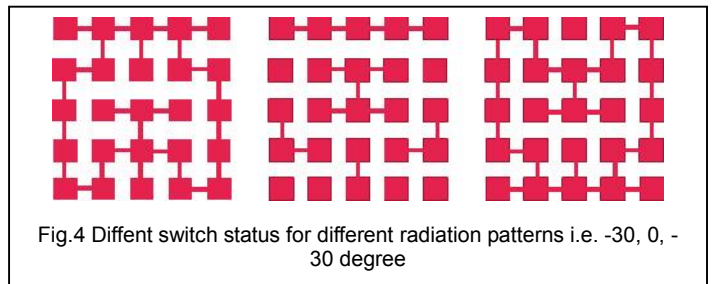


Fig.4 Different switch status for different radiation patterns i.e. -30, 0, -30 degree

Fig 4 shows the three different configurations of a pixel surface for the beam angles of  $-30^\circ$ ,  $0^\circ$  and  $+30^\circ$ . Where squares represent the pixel elements and lines represent switch connections which are found out by Genetic Optimization Algorithm.

### 4 SIMULATED RESULTS AND DISCUSSIONS

The described geometry is simulated in HFSS 14 and following results are obtained.

The radiation patterns for the different configurations (fig 3) are shown in fig 5. The different directions for the three different geometries are clearly achieved in simulation i.e.  $-30^\circ$ ,  $0^\circ$  and  $+30^\circ$ . The reflection coefficient parameter ( $S_{11}$ ) for the discussed geometry shows the value of -21dB at resonant frequency 10.77 GHz. From the plot of  $S_{11}$  it is clear that the bandwidth is ranging from 10.275 to 10.975 GHz which is approximately 500MHz (see fig. 6).

Fig 7 shows the VSWR for the simulated Antenna geometry which is 1.5 at resonating frequency.

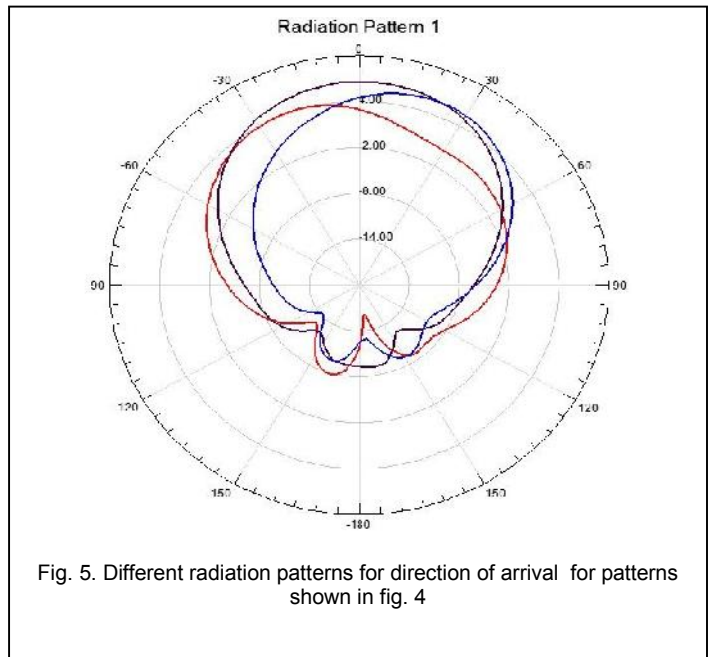


Fig. 5. Different radiation patterns for direction of arrival for patterns shown in fig. 4

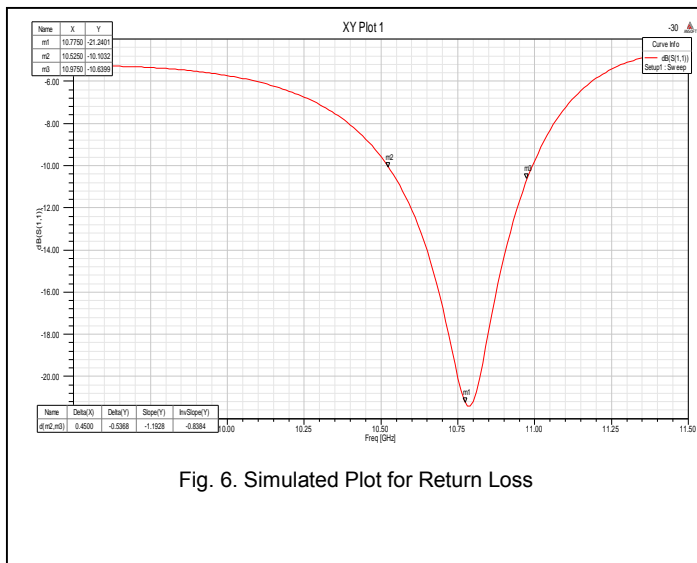


Fig. 6. Simulated Plot for Return Loss

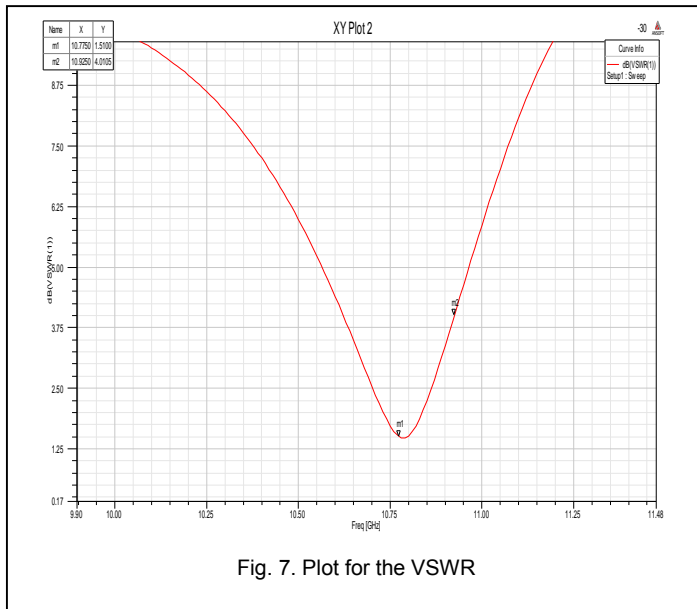


Fig. 7. Plot for the VSWR

#### 4 CONCLUSION AND FUTURE SCOPE

This paper presents a parasitic element based reconfiguration technique having significant advantages regarding integration and generality. A specific microfabrication compatible example for a patch antenna operating at 10 GHz is optimized, demonstrating simultaneous frequency and radiation pattern reconfiguration. Results indicate that this structure is better suited to provide radiation pattern reconfigurability rather than frequency reconfiguration.

It should be noted that although in this project the steering angles are chosen to be  $-30^\circ$ ,  $0^\circ$ ,  $+30^\circ$  steering in other direc-

tions such as  $\pm 5^\circ$ ,  $\pm 10^\circ$ ,  $\pm 15^\circ$ ,  $\pm 20^\circ$  etc., along with polarization configurability would be possible by further optimizing the parasitic pixel surface.

#### 5 REFERENCES

- [1] Zhouyuan Li, Student Member, IEEE, Daniel Rodrigo, Student Member, IEEE, A “New Class of Antenna Array With a Reconfigurable Element Factor”, *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*, VOL. 61, NO. 4, APRIL 2013
- [2] Jeremy B. Muldavin, Student Member, IEEE, and Gabriel M. Rebeiz, Fellow, IEEE, “High-Isolation CPW MEMS Shunt Switches—Part 1: Modeling”, *IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES*, VOL. 48, NO. 6, JUNE 2000. This paper presents a parasitic element based reconfiguration technique
- [3] Xiaoyan Yuan, Zhouyuan Li, “A Parasitic Layer-Based Reconfigurable Antenna Design by Multi-Objective Optimization”, *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*, VOL. 60, NO. 6, JUNE 2012
- [4] Daniel Rodrigo, Student Member, IEEE, Lluís Jofre, “Circular Beam-Steering Reconfigurable Antenna With Liquid Metal Parasitics”, *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*, VOL. 60, NO. 4, APRIL 2012
- [5] Daniel Rodrigo, Student Member, IEEE, and Lluís Jofre, Fellow, IEEE, “Frequency and Radiation Pattern Reconfigurability of a Multi-Size Pixel Antenna”, *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*, VOL. 60, NO. 5, MAY 2012
- [6] Siwen Yong and Jennifer T. Bernhard, Fellow, IEEE, “A Pattern Reconfigurable Null Scanning Antenna”, *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*, VOL. 60, NO. 10, OCTOBER 2012
- [7] Carlos Moreno De Jong van Coevorden, Salvador G. Garcia, “Microstrip-Patch Array Design Using a Multiobjective GA”, *IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS*, VOL. 4, 2005
- [8] B. A. Cetiner, Member, IEEE, J. Y. Qian, H. P. Chang, M. Bachman, G. P. Li, and F. De Flaviis, “Monolithic Integration of RF MEMS Switches With a Diversity Antenna on PCB Substrate”, *IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES*, VOL. 51, NO. 1, JANUARY 2003
- [9] D. Rodrigo, Y. Damgaci, N. Biyikli, B.A. Cetiner, J. Romeu, L. Jofre, “MEMS-Reconfigurable Antenna based on a Multi-Size Pixelled Geometry”

- [10] Alfred Grau Besoli, Member, IEEE, and Franco De Flaviis, Senior Member, IEEE, "A Multifunctional Reconfigurable Pixelated Antenna Using MEMS Technology on Printed Circuit Board", *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*, VOL. 59, NO. 12, DECEMBER 2011
- [11] J. T. Bernhard, "Reconfigurable Multifunction Antennas: Next Steps for the Future", *Invited plenary talk for the IEEE 2007 International Symposium on Microwave, Antenna, Propagation, and EMC Technologies for Wireless Communications (MAPE2007)*.