MEMS INTEGRATED RECONFIGURABLE ANTENNA FOR COGNITIVE PUBLIC SAFETY RADIOS

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***Abstract*— The frequency reconfigurable volumetric PIFA presented in this paper is designed to switch between two US public-safety bands, one operating at 700MHz and the other having a bandwidth of 17% around 850MHz - in effect covering a range from 800MHz to 900MHz. The reconfigurability is limited to only the ground and patch layers as an aim to minimize the number of MEMS switches used. The radiation pattern of the antenna maintains its shape and the maximum gain over this reconfigurable band of operation, 700 – 900 MHz**

I. INTRODUCTION

The Public Safety community (police, firefighters, etc) in controlling natural or human-caused catastrophes requires a robust, low-cost, cognitive wireless communication system. Interoperability, which enables interoperable communication among various emergency personnel, is also a key concern. The antenna presented in this paper, is to provide a spectrally efficient, low-cost, robust, and compact solution to the interoperability, adaptability, and reliability needs of public safety wireless communications systems. In general, PS community needs to provide voice, data, and video communications across different PS bands – 150, 400, 700, 800, 900 and 4900 MHz The interoperability between two bands - one operating at 700MHz and the other covering a range from 800MHz to 900MHz (conveniently named as mode1 and mode2 respectively), is achieved by a reconfigurable antenna [1] which uses MEMS DC-contact series type switches. Section II describes in brief the type and design of antenna used individually in the two modes. Section III explains the reconfigurability between the two modes. Finally, sections IV and V illustrate the challenges in reconfiguring and the results of the design, respectively. At this stage of our ongoing work, for simplicity, the MEMS are replaced by ideal short and open strips for the two modes and from the previous experience it is understood that introduction of the real architecture of MEMS in the design does not cause a significant change in the operational frequency.

II. TYPE OF ANTENNA

Planar Inverted F Antenna (PIFA) [2] popularly used in mobile communications, is used individually for each mode as it reduces the size of the patch to half when compared to the microstrip patch antenna. This half-size reduction is due to the shorting plane used in the antenna structure. Two bandwidth enhancement techniques of PIFA namely *T-shaped ground-plane* [3] and *patch tapering* [4] are combined and optimized. Quartz is the dielectric substrate (ε_r = 3.9, tanδ = 0.0002) and feeding is through coaxial cable. A capacitive coupling [5] is used in conjunction to coaxial cable to decrease the inductance effect thereby increasing the matching over a wider frequency range. For the purpose of further reduction of size of PIFA we use a slit etching technique to increase the electrical path length of the surface current and the slit is L-shaped located on the patch layer. A volumetric antenna employing all these techniques is shown in Fig. 1. The effect of including different techniques in the same design to achieve better results lead to an increase in the number of design parameters in each mode.

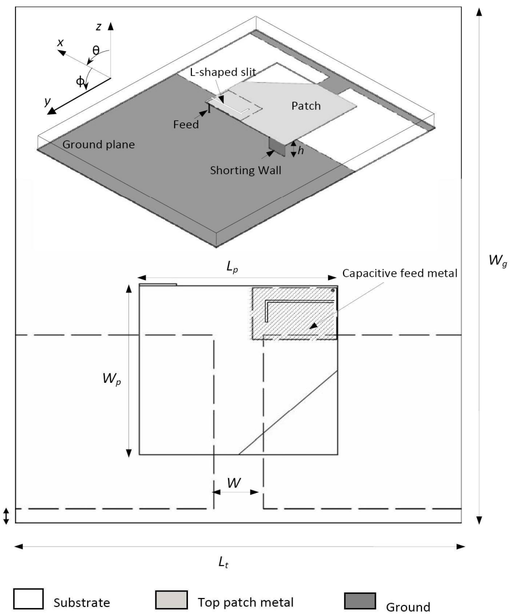
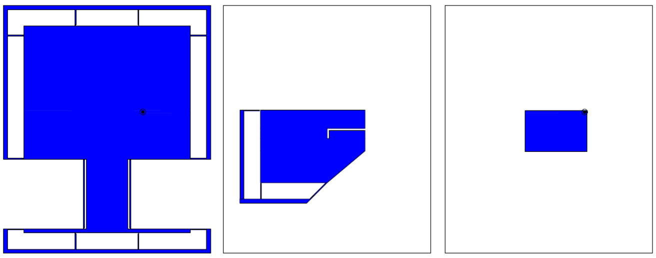


Fig. 1 2 & 3D overview of the volumetric PIFA

All the layers are separately optimized and the final design is obtained. The design methodology described in this section is employed individually for both the modes.

III. RECONFIGURABLE PIFA

The number of MEMS switches used to reconfigure between different modes is directly proportional to the complexity of the design, the reason being the difficulty in placing and subsequent fabrication of the bias lines of each MEMS switch. Hence, our goal is to reduce the number of MEMS switches in the over-all design. For this reason, frequency reconfigurability in the final design is constrained only to the ground plane and radiation patch layers while fixing the dimensions and the location of the coaxial-feed, L-shaped slit and the capacitor patch. Mode2 is designed first as it is targeted to span over a wider frequency range covering 800MHz to 900MHz and then mode1 is obtained by extending the size of radiation patch and the ground-plane.



Ground layer Radiation Patch layer Capacitive Patch layer

Fig. 2 Overview of the different layers of reconfigurable volumetric PIFA

The design methodology of the frequency-reconfigurable antenna switching between modes 1 and 2 is described in the Figures 2-4. Fig. 2 gives the overview of all three layers of the reconfigurable antenna namely ground-plane, radiation-patch and capacitive patch. The hatched area in Fig. 3 and Fig. 4 indicates that the layer is connected to the feed and the switches are on. Table I explains role of MEMS switches in reconfiguring between different modes. The ground-plane size is dominating which can be seen from the figure and the border in Fig. 3 indicates the patch size relative to the ground plane. G_i and P_i represent the switches used in the ground plane and radiation patch respectively, as illustrated in Figures 3 and 4. In Fig. 3 and Fig. 4 the switches are indicated only in one mode to avoid redundant detail and for the sake of clarity, the actual shape of MEMS switch and the width of the long metallic strips are exaggerated from their original dimensions.

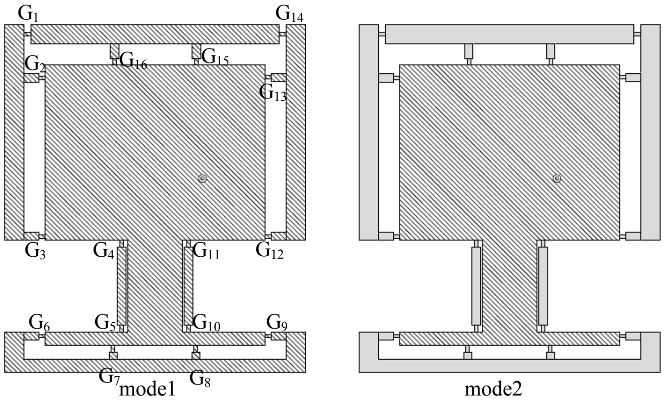
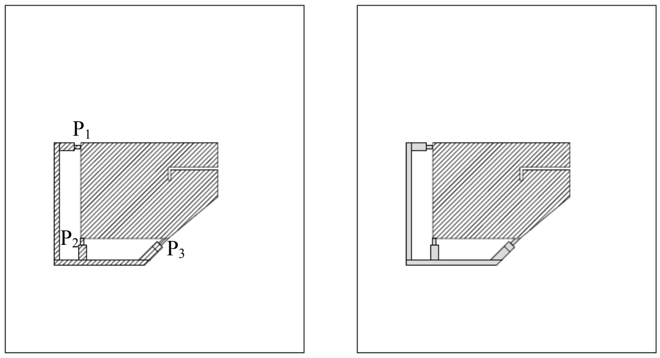


Fig. 3 Reconfigurable ground layer



mode1 mode2

Fig. 4 Reconfigurable radiation patch layer

Switch	mode1	mode2
$G_{i=1to16}$	on	off
$P_{i=1to3}$	on	off

Table I Switch Operation

IV. CHALLENGES IN THE DESIGN

As the PIFA operates at a low frequency, i.e., in a range of 700 MHz to 900 MHz and also due to the small gap (0.5mm) between the two ground planes (or the two radiation patches corresponding to modes 1 and 2) to facilitate the MEMS, the coupling effect between the two modes is significant, which is a major design challenge. To alleviate this challenge, we increased the gap between the two ground planes (or radiation patches) and placed a long narrow metallic strip (made of the same material as the radiation patch) which is connected to the other ground-plane (or radiation patch) by small MEMS switches as shown in Figures 3 and 4. This method significantly decreased the coupling effect and improved the result. The final dimensions in mm of the optimized reconfigurable layers of the PIFA are shown as follows for easy representation: (mode1, mode2) - radiation patch (45.5 x

61, 35.5 x 51); overall ground plane size (121x 101, 101 x 81); width of the T-shape, W – (26, 10); and parameter W_t – (12, 2) as shown in Fig. 1. The long metallic strips are 8 mm x 0.5 mm; the height of the substrate h = 10mm and the MEMS switches are approximated by 0.5mm x 0.2 mm metallic strips in Fig. 1.

V. Results

The reflection coefficient of the reconfigurable PIFA in mode1 and mode2 is depicted in the Fig. 5. Mode1 has a bandwidth of 22% at 700 MHz and mode2 a bandwidth of 17% at 850MHz for reflection coefficient less than -8 dB. Fig. 6 clearly shows that the radiation pattern (in □ = 0^0 and □ = 90^0 planes) of the designed antenna maintains its integrity and the maximum gain is about 3dB irrespective of the mode of operation. These results correspond to hfss simulations and further investigation in fabrication, test and measurement needs to be done in the future.

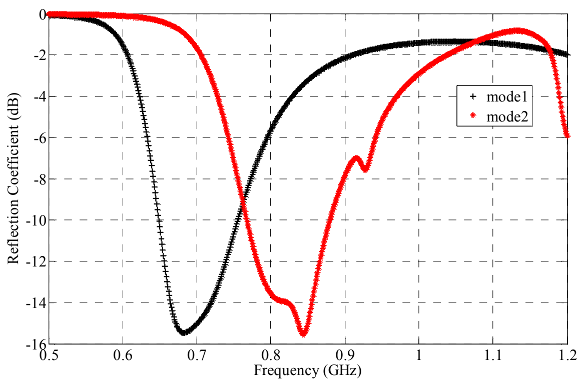
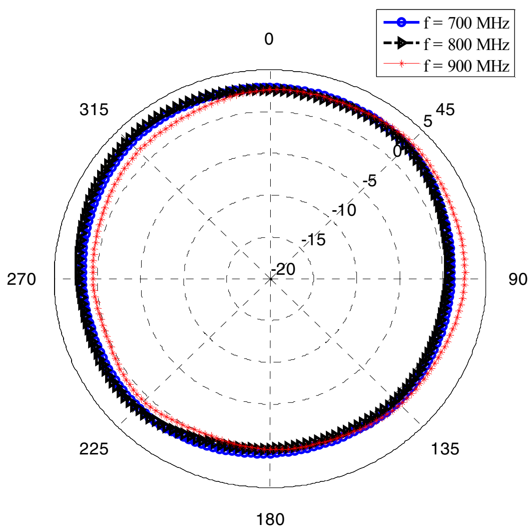
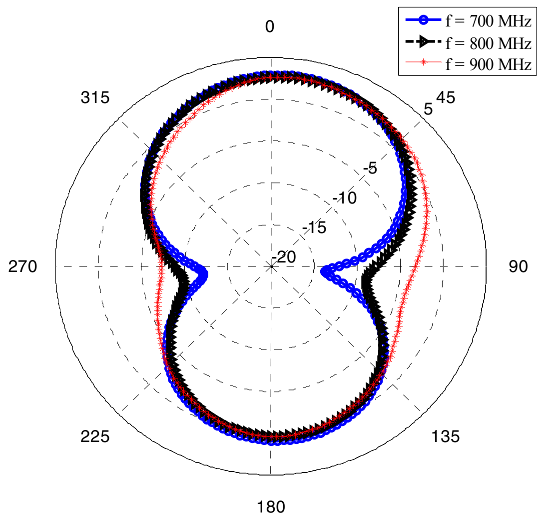


Fig. 5 Reflection Coefficient of modes 1 and 2



a) □ = 0^0



b) □ = 90^0

Fig. 6 Radiation patterns of the antenna in two modes

VI. Conclusion

The designed frequency reconfigurable PIFA operating in the bands 700 MHz and 800 MHz to 900 MHz with minimum number of switches suits well to the interoperable communication needs of Public Safety personnel in times of emergencies.

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