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# Steering Wheel Shaped Frequency Reconfigurable Antenna for Cognitive Radio

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## ABSTRACT
This paper depicts an outline to design a novel compact and low profile frequency reconfigurable microstrip patch antenna for possible applications in cognitive radio systems to act as a fast switching antenna capable of operating in seven different frequencies in the range of 6.25 to 8.25 GHz. The antenna structure comprises a center rectangular encircled patch, in which rectangular patch is driven patch and the encirclement is for frequency reconfigure ability. The reconfiguration ability of the antenna is obtained by placing four radio frequency micro-electromechanical system (RF-MEMS) switches in between encircled patch and driven patch. Different switch configurations were investigated and the same was evaluated for diverse frequency ranges.
***Keywords*** - Cognitive radio, CST, MEMS, Microstrip antennas, Software Define Radio.

## I. INTRODUCTION

The electromagnetic spectrum is a shared resource, limited and regulated, that is more and more congested with the increasing number of users of wireless devices. The further exploitation of the available frequencies by other services possesses practical and regulatory difficulties. According to recent literature, a significant amount of the licensed spectrum remains unused or underutilized for more than 90% of the time [1], [2]. This fact has triggered the wireless communication community to find new and more efficient ways of utilizing the frequency spectrum. The concept of Cognitive Radio (CR) [3] has emerged as a possible solution.

In general, CR refers to full communication system architectures that are able to sense the environment for primary (licensed) users and utilize available spectrum not currently being used. The basic architecture of a cognitive radio system generally includes two antennas. One is wideband antenna that continuously senses the wireless medium and simultaneously searches for unused frequency bands. The other is a reconfigurable narrowband antenna that dynamically modifies its resonance frequency to perform the required communication within the unused frequency bands. Also, wide-narrowband reconfigurable antennas can be used for both sensing and communication purposes. But due to the difficulty in providing sufficient isolation between sensing and communication antennas, it is suggested to use two different antennas for quick sensing and filtering operation in limited space. These required features of cognitive radio systems provide many unique challenges to antenna designers. Some of these challenges and requirements are detailed in [4]. Frequency reconfigurable antennas have received increasing attention for such type of software defined radio (SDR) applications, where it is required to have a single common aperture antenna that can be dynamically reconfigured to transmit or receive on multiple frequency bands. Such common-aperture antennas lead to considerable savings in size, weight and cost.

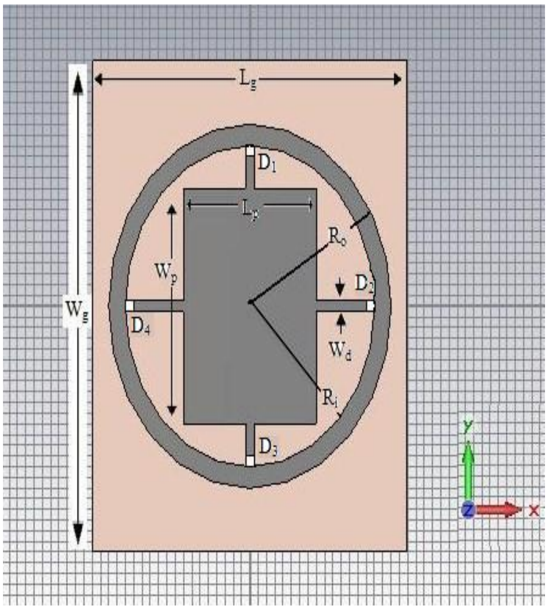
In the recent years various frequency reconfigurable patch antennas for cognitive radio has been reported [5]-[17]. In general the reconfiguration is obtained by adjusting the path of currents on the antenna or by altering the geometry of the radiating device. This can be done either mechanically or electrically. Mechanically reconfigurable antennas consist of mechanically movable parts in which frequency reconfiguration is obtained by adjusting the movable parts [6], [11]. The shortcoming of such design was that the overall antenna size required was distinct with respect to the tuned frequency. Moreover, the actuator used to produce the mechanical movements was very problematical and engaged much space, which led to a bulky and expensive structure. Electrically reconfigurable antennas are found more popular. The switching mechanisms used in electrically reconfigurable antenna are solid state switches such as PIN diodes [5], [10], [17], varactors [13] and radio frequency micro-electromechanical system (RF-MEMS) switches [9], [14], [16]. RF-MEMS switches are chosen as the switching elements for antenna reconfiguration due to their satisfactory RF properties including low insertion loss (0.1-0.2 dB) in the on state and high isolation (25-35 dB) in the off state over an extremely wide band (DC to 40GHz) that makes them a perfect contender among all[18], [19].

In this paper, a novel steering wheel shaped frequency reconfigurable antenna design is presented as a new band switching patch antenna. The antenna structure comprises a rectangular encircled patch with four RF-MEMS switches capable of operating in seven different operating frequencies in 6.25 to 8.25 GHz. In this present simulation study, shorting pins are used as switching element for verification, but scaling in frequency allows the use of MEMS switches for future study. The proposed antenna design is studied and simulated using CST Microwave Studio.

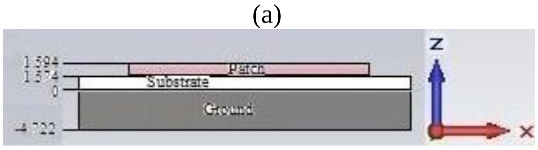
The paper is organized as follows. Section II discusses the frequency reconfigurable concept and introduces our newly proposed design, Section III discusses the results.

## II. ANTENNA DESIGN

The proposed frequency reconfigurable patch antenna consists of rectangular encircled patch with four MEMS switches $D_1$, $D_2$, $D_3$ and $D_4$, as shown in Fig. 1. A 50Ω coaxial feed is located at the center of patch with external and internal diameter of 5.7 mm and 1 mm respectively. The antenna is designed on a low cost FR4 (lossy) substrate which is 1.574 mm thick and having dielectric constant $\in_r$ = 4.3. The dimensions of the optimized antenna are given in Table 1.




(a)




(b)

Figure1 (a), 1(b): Front and bottom view of antenna design

Table 1: Parameter description of antenna design

| Parameter | Description | Dimensions(mm) |
|---|---|---|
| $L_g$ | length of ground and substrate | 37.8 |
| $W_g$ | width of ground and substrate | 45.8 |
| $L_p$ | length of rectangular patch | 16 |
| $W_p$ | width of rectangular patch | 22 |
| $W_d$ | width of diode connecting strips | 1 |
| $R_o$ | outer radius of circular patch | 17 |
| $R_i$ | inner radius of circular patch | 15 |

## III. RESULT AND DISCUSSIONS

By the implementation of RF-MEMS switches, one can vary the dimension of radiating patch and hence the resonating frequencies. The frequency reconfiguration concept is introduced by changing the dimensions of the radiating patch, which further culminates in variation of current and the resonating frequency. Thus alteration in patch dimensions strongly controls the resonant modes of the patch antenna, and this altered patch dimensions results in a desired operating frequency bands.

In the given antenna design we proposed four RF-MEMS switches amid rectangular patch and circular patch. The switches will offer $2^4$ i.e. 16 different configurations as given in Table 2. For simulation of antenna ideal switching mode of RF-MEMS switches is considered i.e. in ON state the switch is replaced by short circuiting a conducting pin and in OFF state the switch is considered as open circuit.

Table 2: Different switching configuration of RF-MEMS switches

| Case | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|
| C-1 | OFF | OFF | OFF | OFF |
| C-2 | OFF | OFF | OFF | ON |
| C-3 | OFF | OFF | ON | OFF |
| C-4 | OFF | OFF | ON | ON |
| C-5 | OFF | ON | OFF | OFF |
| C-6 | OFF | ON | OFF | ON |
| C-7 | OFF | ON | ON | OFF |
| C-8 | OFF | ON | ON | ON |
| C-9 | ON | OFF | OFF | OFF |
| C-10 | ON | OFF | OFF | ON |
| C-11 | ON | OFF | ON | OFF |
| C-12 | ON | OFF | ON | ON |
| C-13 | ON | ON | OFF | OFF |

| | | | | |
|---|---|---|---|---|
| C-14 | ON | ON | OFF | ON |
| C-15 | ON | ON | ON | OFF |
| C-16 | ON | ON | ON | ON |

For all the sixteen cases mentioned above, the proposed antenna design is simulated for return loss, resonance frequency, band-width, surface current, directivity and radiation pattern.

The return loss, radiation pattern, surface current and smith chart is shown in Fig. 2, 3, 4 and 5 respectively for case-1, when all the switches are OFF.

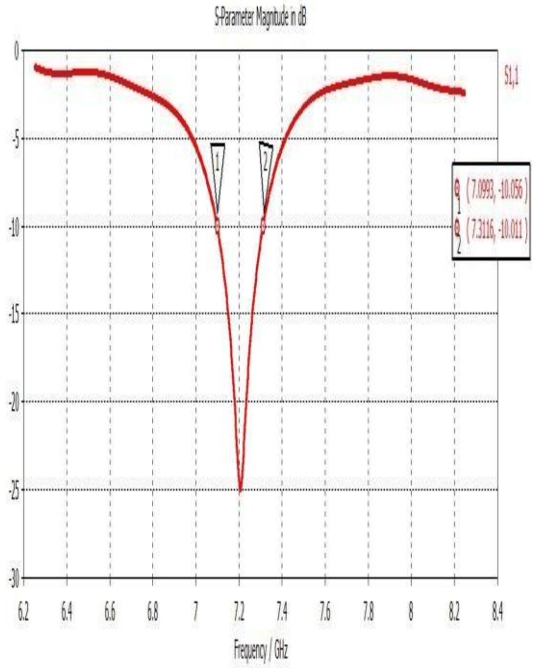



Figure 2: Return loss for case-1

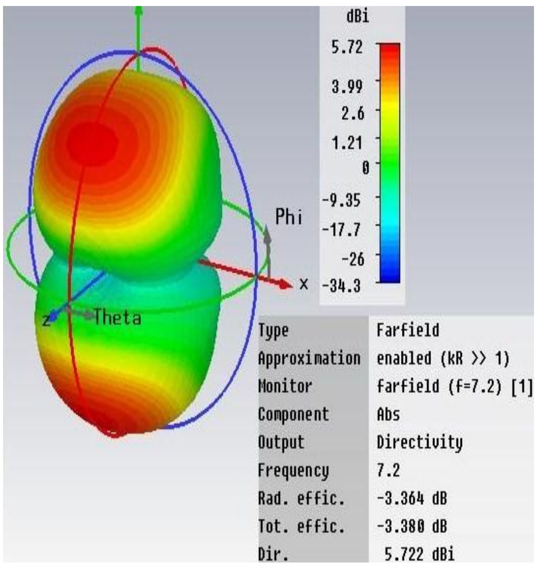



Figure 3: Radiation pattern and directivity for case-1

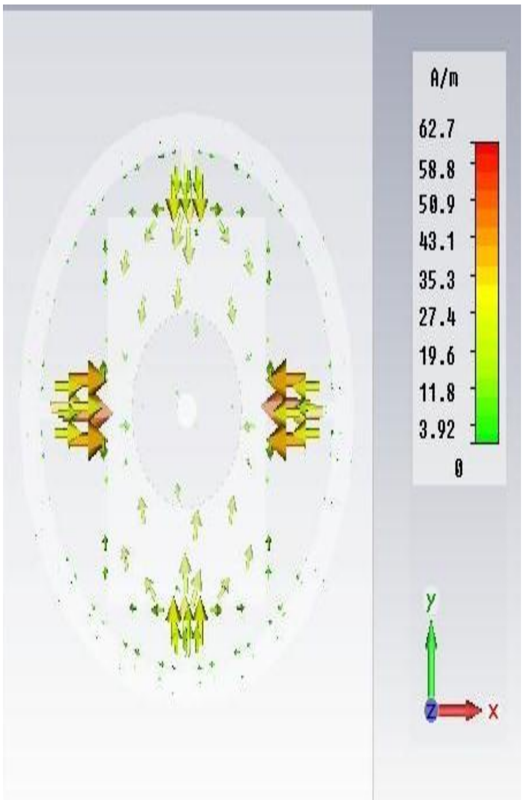



Figure 4: Surface current for case-1

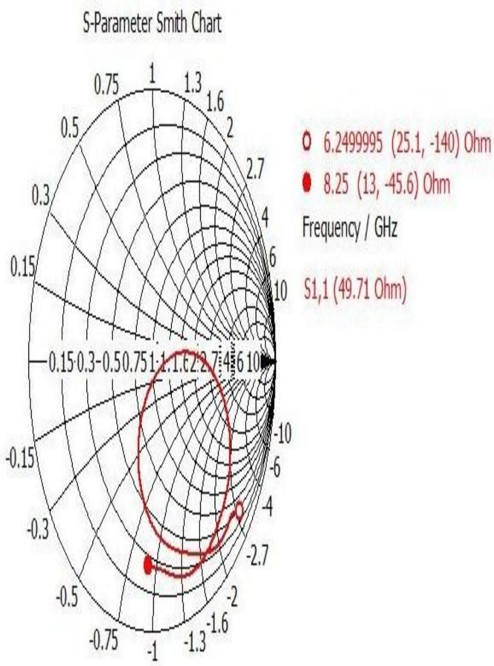



Figure 5: Smith chart for case-1

The resonating frequency for case-1 is 7.2 GHz with a return loss of -25 dB and bandwidth of 210 MHz as depicted in Fig 2. The radiation pattern at resonant frequency of 7.2 GHz with a directivity of 5.722 dBi is shown in Fig 3. Surface current and smith chart in Fig 4, 5 imparts the information regarding the current flowing through patch and input impedance respectively.

The remaining cases are simulated similarly and are summarized in Table 3.

Table 3: Summarized result for all the sixteen cases

| Case | Resonance frequency $f_r$ (GHz) | Return loss (dB) | Band-width (MHz) | Directivity (dBi) |
|---|---|---|---|---|
| C-1 | 7.2 | -25 | 210 | 5.722 |
| C-2 | 6.82 | -17.5 | 120 | 5.361 |
| C-3 | 7.37 | -19 | 210 | 5.871 |
| C-4 | 6.94 | -15.5 | 160 | 6.010 |
| C-5 | 6.82 | -17.5 | 120 | 5.361 |
| C-6 | 6.64 | -11 | 50 | 5.355 |
| C-7 | 6.94 | -15.5 | 120 | 6.010 |
| C-8 | 6.69 | -15 | 110 | 5.217 |
| C-9 | 7.37 | -19 | 200 | 5.871 |
| C-10 | 6.94 | -15.5 | 120 | 6.010 |
| C-11 | 7.85 | -45.5 | 250 | 4.731 |
| C-12 | 7.2 | -25 | 210 | 5.722 |
| C-13 | 6.94 | -15.5 | 120 | 6.010 |
| C-14 | 6.69 | -15 | 110 | 5.217 |
| C-15 | 7.2 | -25 | 210 | 5.722 |
| C-16 | 6.94 | -15.5 | 120 | 6.010 |

The return loss for all the sixteen cases are shown in fig. 6 representing seven different resonance frequencies with related return loss and band-width.

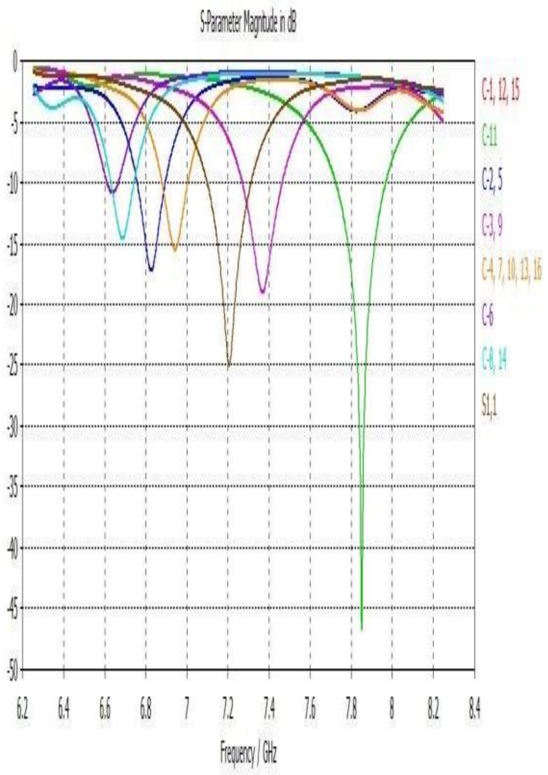



Figure 6: Return loss for all the sixteen cases

The antenna design resonates at seven different frequencies in the range of 6.25 to 8.25 GHz. It is evident from the table given above the resonance frequency of 6.64 GHz is obtained in case-6 and 6.69 GHz is obtained in Case-8, 14. Similarly resonance frequency of 6.82 GHz is obtained in case-2, 5 and 6.94 GHz is obtained in case-4, 7, 10, 13, and 16. Also, the resonance frequency of 7.2 GHz is obtained in case-1, 12 and 15 and frequency of 7.37 GHz is obtained in case-3 and 9 and that of 7.85 GHz is obtained in case-11.

For all of the configurations, the antenna input impedance is 49.71Ω, thus the design does not requiring any extra matching device.

## IV. CONCLUSION

A new novel frequency reconfigurable steering wheel shaped microstrip patch antenna with four RF-MEMS switches has been presented. The antenna provides frequency reconfiguration with sufficient radiation characteristics, band-width, directivity and minimum return loss without any extra impedance matching device. The design takes the advantage of both circular and rectangular shape patch design. The paper detailed the concept of frequency reconfiguration with the help of RF-MEMS switches by altering patch shape. The design can be used in cognitive radio for fast frequency

switching in the range of 6.25 to 8.25 GHz, capable of operating in seven different frequencies.
Future work includes comparison of measured and simulated result by implementation of RF-MEMS switches

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