Multiple Band Monopole Arm Microstrip Spiral Antenna for Cognitive Radio

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Abstract

The paper presents design of monopole arm microstrip spiral antenna that operates in the range of 2.93 to 7.25 GHz. The antenna is fed by an SMA connector from side, which is connected to a monopole i.e. main arm of spiral antenna. This monopole has a width of ????/4, which provide impedance matching thereby avoiding the need of balun for spiral antenna. To achieve enhancement in multiple band response, two designs have been proposed. The effect of increasing the number of turns of a spiral antenna is demonstrated here. The antenna is fabricated on FR-4 substrate with dielectric constant of 4.3 and loss tangent of ??=0.025. The designed antenna when tested, is working in 8 frequency bands ranging from 2 to 8 GHz providing the total bandwidth of 1.4 GHz. This multiple band antenna is suitable for upcoming cognitive radio systems.

Index terms— cognitive radio, spiral antenna, multiple bands, microstrip transmission line.

1 INTRODUCTION

URRENTwireless technologies require wide bands for personal wireless networks and selective bands for applications like WiMax (3.3-3.7 GHz), WLAN (5.15-5.825GHz), GSM (900-1800 MHz). Both wide band and selective band applications require different antennas. Today's wireless communication systems are expecting simple designs, higher data rates and low power consumption. The solution to these expectations was first proposed by Joseph Mitola III in 1998 which was cognitive radio. A cognitive radio is an intelligent radio that can be programmed and configured dynamically. It is transreceiver is designed to use the best wireless channel in its vicinity. Such a radio automatically detects available channels in wireless spectrum accordingly changes its transmission or reception parameters to allow more concurrent wireless communication in a given spectrum band at one location. Hence a multiple band response antenna is needed that can be used for cognitive radio. An antenna that operates over a wide frequency range with multiple bands separated by guard bands will be the most suitable one to support cognitive radio system. So that one single antenna can be used for above mentioned applications. Modern wireless communication systems that rely on multiple band antennas are becoming more popular for their ability to serve multiple standards using a single compact antenna, allowing a reduction in the dimensions of the wireless device and more space to integrate with other electronic components. Spiral antennas being the broad band antennas are the most suitable candidate for such applications.

Spiral antenna was first introduced by J.D. Dyson in 1959 which was based on Rumsey's principle [1] of frequency independent antennas [2]. Later, varieties of spiral antennas were introduced by many authors those were used for various applications [3][4][5][6].Different shapes of spiral antennas like Archimedean, rectangular, conical, logarithmic, slot spiral are being used for broad band applications to support high data rates [7][8][9][10][11]. Rectangular spiral antennas are the popular ones because of their geometry. Rectangular spiral antennas are easy to develop in simulation software, easy to fabricate. Many rectangular spiral antennas have been developed by authors that are useful for multiple purposes [12][13][14]. On the same lines a rectangular spiral antenna having multiple bands in different frequency bands that can be used for multiple applications is aimed to implement in this paper. Main aim is to get more number of resonances by increasing the number of turns.

2 II.

3 Design of Monopole Arm Rectangular Spiral Microstrip Antenna

The equation defining the well-known geometry of a round Archimedean spiral used in antenna designs is given as:? = a? + b (1)

Where ? and a are the conventional polar coordinates in the x-z plane (? is the distance measured from the origin and a is the angle measured from the x axis), a is the growth rate and b is the starting point of spiral curve on the x axis. From the equation it is obvious that the Archimedean spiral arms have a constant amount of growth rate at each turn. a) Basic Monopole Rectangular Spiral Antenna Square spiral approximates the round Archimedean spiral in this manner and therefore it always has the same distance between its arms [14]. The spiral arms are configured as rectangular monopole of ?g/4 width to provide impedance matching with standard 50? and this eliminates the need of wideband balun design to feed the antenna. For the design of C Index Terms:Global Journal of Researches in Engineering ( ) F Volume XIV Issue III Version I

monopole the dimension width is more important and since the antenna is spiral so it's independent of the total length and only depends of spiral rotation. Width of the antenna has been calculated using microstrip transmission line equation [15]. The resonant frequency ð ??"ð ??" ?? is chosen to be 9.2 GHz. The substrate used is FR4 so dielectric constant ?? ?? is 4.3, with these values ?? ð ??"ð ??" comes to be 0.02. Therefore, ?? ð ??"ð ??" 4 ? = 5mm. ?? ð ??"ð ??" is guide wavelength. The width and length of ground plane is given by ?? ð ??"ð ??" and ?? ð ??"ð ??" in Eq. (**??**) and Eq. (**??**) [15]. The ground plane should be greater than or equal to both ?? ð ??"ð ??" and ?? ð ??"ð ??" . The lowest frequency is taken into consideration while calculating the dimensions of ground plane. So the lowest frequency is considered to be 1 GHz. Height of the substrate is taken to be 1.6 mm since we are using FR4 substrate. The width comes to be 92 mm, effective dielectric constant is 2.65 and Width (Wg) and length (Lg) of the ground plane is calculated 101.6 mm and 100.14 mm respectively. Hence the ground plane dimensions are taken to be 157 mm and 126 mm. Assuming the higher operating frequency of spiral as 9.2 GHz the width is calculated. Fig. 1. shows the dimensions and geometry of microstrip spiral antenna. The current on spiral arm decays exponentially. More there's a scope for current to decay lesser are the multiple-resonances in frequency response. The bends of the spiral introduce sudden discontinuity in the current. When the next segment starts the current increases at the bend and again starts decaying till next bend. This increase and decrease of current gives multiple bands in the frequency response. So for more number of bands there should be more discontinuities i.e. more number of turns. The turns were too low in the previous design; when numbers of turns are increased the current distribution doesn't exponentially decreases incontinuous manner as its travel through the arms. As a result, multiple bands are obtained. The plot of reflection coefficient (S11) for basic monopole rectangular spiral antenna is shown in the Fig. 3. It is seen that the antenna is strongly resonating at four resonances at 3.74, 4.39, 4.78 and 5.8 GHz. The bands obtained below -10 dB are given in Table1. It is noted that the frequency response is weak above 5.5GHz due to the non-continuous decay of surface current along the spiral arms. Table **??** shows the frequency bands specifications for response shown in Fig. 3. The total bandwidth obtained is 1.92 GHz. The numbers of resonances obtained are 7. The plot of reflection coefficient (S11) for increased turn design is shown in Fig. 4. It depicts the changes in the frequency response due to increased turns. The antenna is resonating strongly at three resonances, 3.04, 3.73 and 4.34 GHz. Here, the number of selective bands that were observed below 5 GHz has been increased than previous design. This because, the current decays along each arm and experiences discontinuity at each bends. When the current distribution reaches a peak value we get resonance in the reflection coefficient. Increasing the number of turns increases the number of arms. At each arm, the current distribution reaches a peek value and again dies out at the end of the arm, which gives us more number of resonances in the reflection coefficient. Also increasing the number of turns causes the antenna size to increase which shifts the frequency response to lower frequency. In basic design the first resonance occurred at 3.74 GHz where in increased turn design the first resonance has occurred at 3.04 GHz. The analysis of bands obtained below -10 dB is shown in Table **??**. The total bandwidth obtained is 2.28 GHz. The increased turn antenna has been fabricated on FR4 substrate. The copper material on the substrate is coated with a thin layer of tin to prevent the oxidation of copper due to environmental affect. The fabricated antenna is shown in figure **??** A Standard 50 ? SMA connector has been used to feed RF signal to the antenna. Fig. 5. shows the photograph of fabricated antenna. The fabricated antenna is tested on a spectrum analyzer that can test the antenna up to 8 GHz. The results taken from the device are depicted in Fig. 6. The analysis of bands obtained below -10 dB is shown in Table **??**. Fig. 7. shows the test setup for fabricated antenna. Table **??** shows the comparison of bands obtained by simulating and testing the antenna. It can be seen from Table 7 that the numbers of bands have been increased in fabricated antenna. If Table **??** and Table **??** are compared it is seen that the number resonant bands increase if the number of turns are increased. This is because of the number of bends occurring at each turn of the spiral. IV.

4 CONCLUSION

The proposed antenna works in IEEE C band and IEEE S band as well with multiple resonances. The resonances obtained in result includes worldwide interoperability for microwave access i.e. WiMax (3.3 -3.7 GHz), IEEE 802.11a in the United States (5.15 -5.35 GHz, 5.725-5.825 GHz) and HIPERLAN/2 in Europe (5.15 -5.35 GHz, 5.47 -5.725 GHz). Since the antenna has multiple band response, the proposed antenna is also suitable to be used in future cognitive radio systems. This antenna can also be used for beam switching in a particular direction to increase the gain towards an access point. Beam switching can be implemented with use of switching action provided by the use of microwave switches to change the physical and electrical length of the antenna. [1] [2]

1

Figure 1: Figure 1 :

[3]

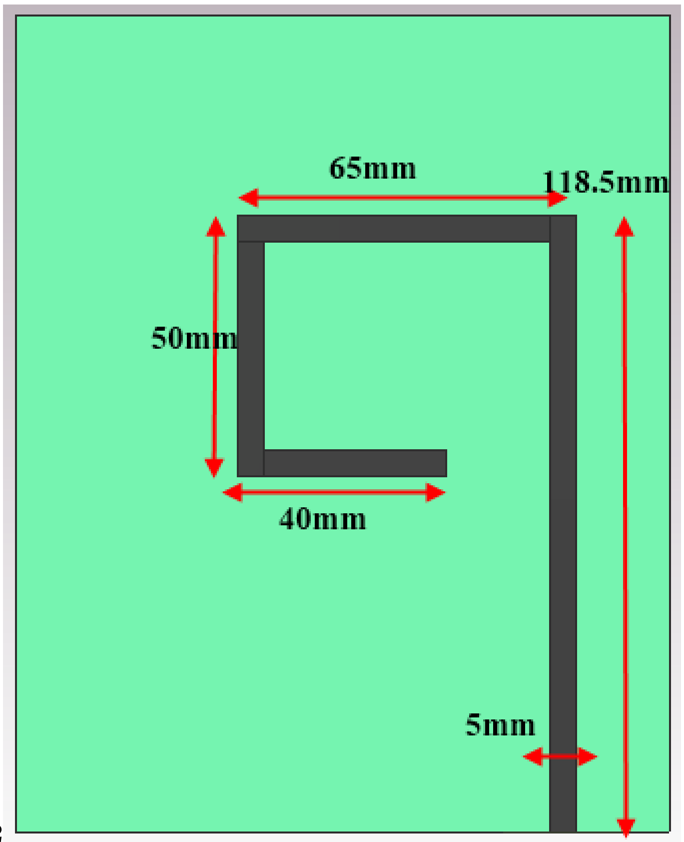

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Figure 2: Fig. 2 .

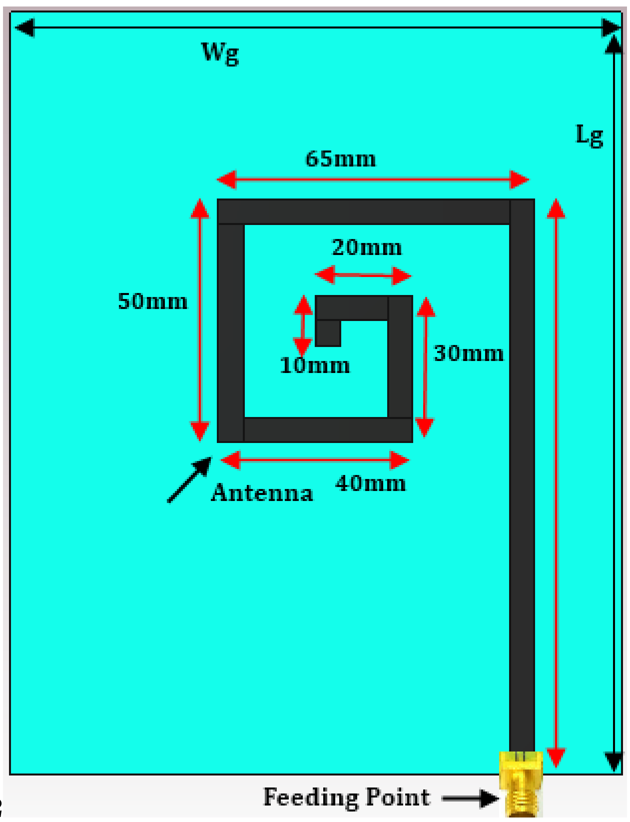

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Figure 3: Figure 2 :

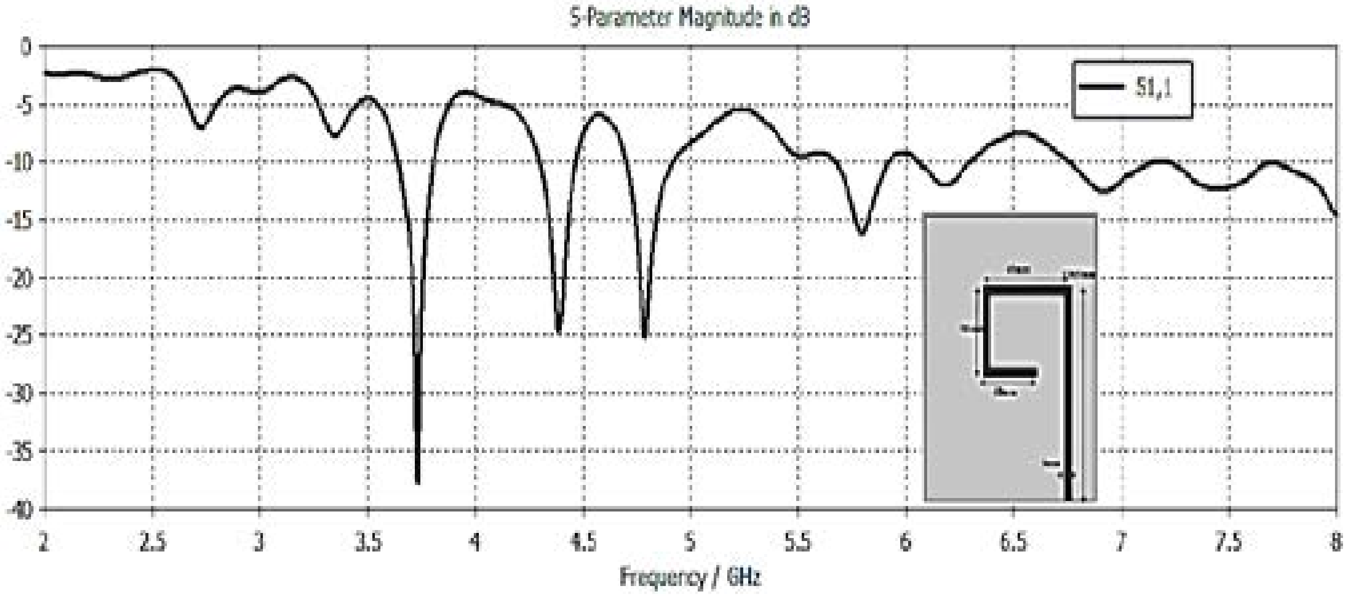

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Figure 4: Figure 3 :

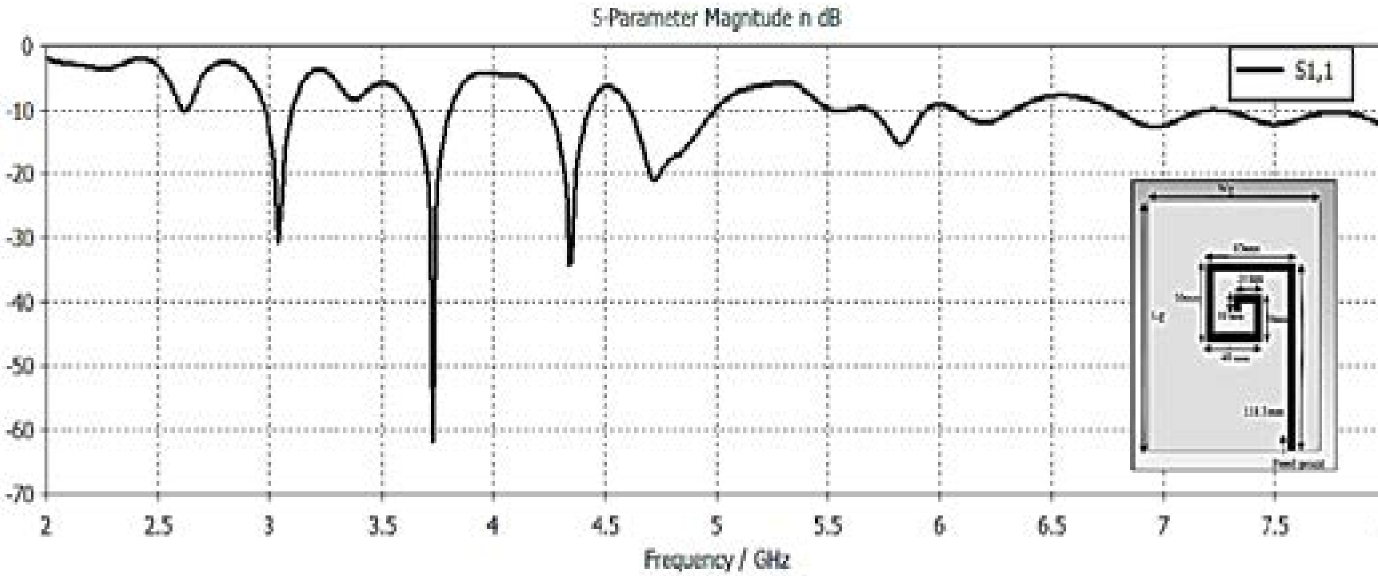

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Figure 5: Figure 4 :

Figure 6: Global

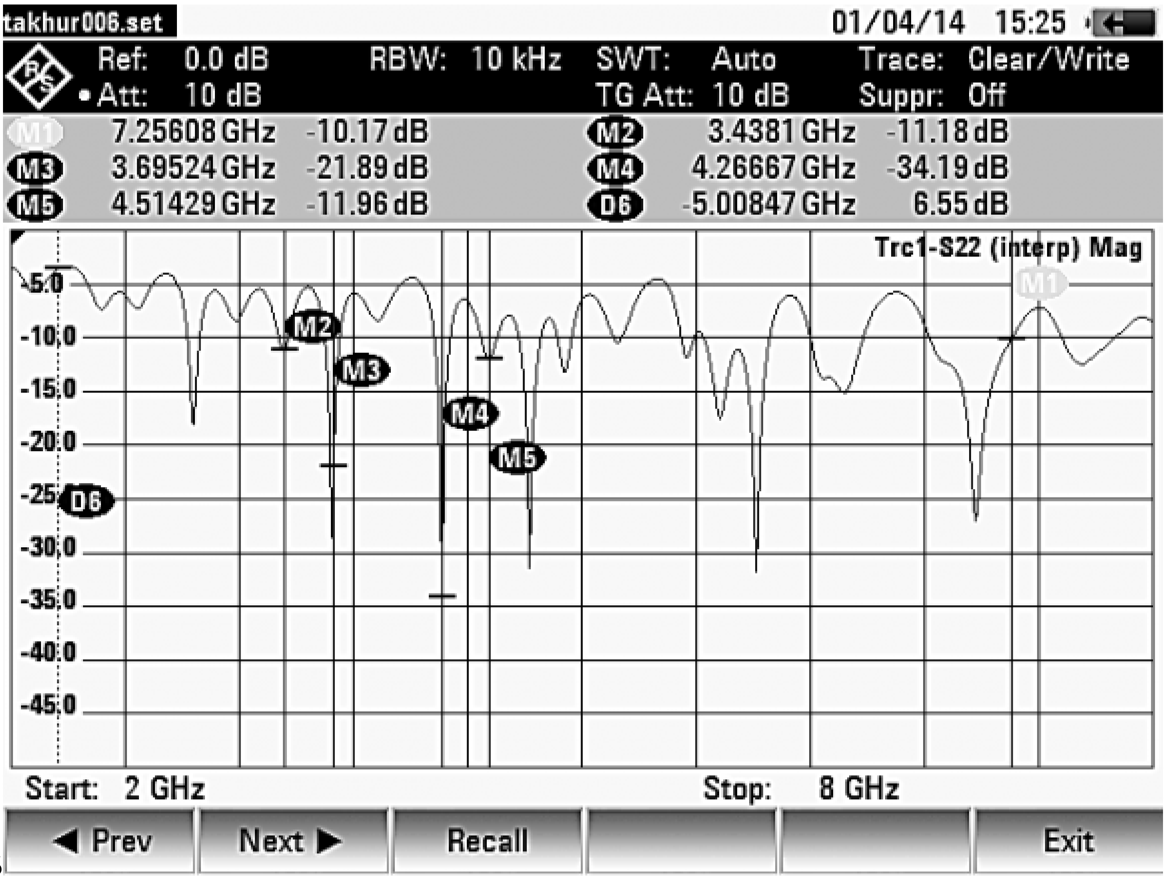

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Figure 7: Figure 5 :

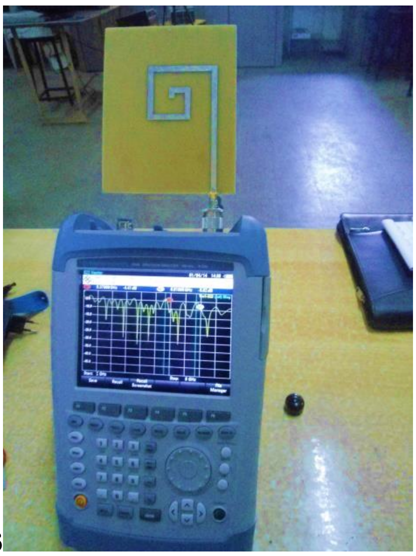
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Figure 8: Figure 6 :

I

Rectangular Spiral Antenna.(Simulated)

Sr. No.	Bands Obtained (GHz)	Resonances at (GHz)
1	3.64 to 3.81	3.74
2	4.3 to 4.47	4.39
3	4.7 to 4.92	4.78
4	5.66 to 5.93	5.8
5	6.02 to 6.31	6.21
6	6.75 to 7.16	6.91
7	7.23 to 7.62	7.45

b) Result of Increased Turns in Basic Monopole Rectangular Spiral Antenna (Simulated)

Figure 9: Table I :

II

Sr. No	Bands Obtained (GHz)	Resonances at (GHz)
1	2.94 to 3.1	3.049
2	3.63 to 3.8	3.73
3	4.24 to 4.42	4.34
4	4.6 to 4.98	4.75
5	5.7 to 5.93	5.82
6	6.09 to 6.32	6.21
7	6.78 to 7.1	6.96
8	7.32 to 7.6	7.5
9	7.84 to 8	7.94

Figure 10: Table II :

III

Sr. No	Bands Obtained (GHz)	Resonances at (GHz)
1	2.93 to 2.98	2.96
2	3.4 to 3.46	3.43
3	3.64 to 3.72	3.69
4	4.22 to 4.31	4.26
5	4.49 to 4.53	4.51
6	4.67 to 4.77	4.72
7	5.54 to 5.58	5.55
8	5.64 to 5.97	5.72
9	6.19 to 6.47	6.39
10	6.82 to 7.25	7.08

Figure 11: Table III :

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Figure 12: Table 7

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