Active Quad band Antenna Design for Wireless Medical and Satellite Communication Applications

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Abstract

In this article, CPW fed circular slotted frequency reconfigurable antenna of 32mmx24mm applicable to multiband operations is designed and presented. It covers Medical wireless communication WiMAX (3.03-3.8GHz), (5.1-5.5GHz) WLAN, C-band (6.5-7.16GHz) and X-band (9.4-12.5GHz) for radio astronomy, space research and satellite applications. Resonating characteristics are realized by loading the two stage T-shaped stepped impedance resonator (TS-TSIR) in the circular ring and cross strip on the feed line. Frequency reconfiguration is achieved by switching action four PIN diodes placing at the circular slot. Maximum gain of 6.39dB at 10.7GHz is achieved.

Keywords: TS-TSIR (two-stage T-shaped Stepped impedance resonator), CPW (coplanar waveguide), Cross strip.

I. Introduction

Recently, the demand on communication system has risen greatly. For radar and communication system, antennas are capitious ingredients [V]. The system performance is prescribed due to antenna characteristics. By incorporating many antennas with various operating frequencies in the same working floor multiple frequencies are attained which increases cost, weight of the system and also cross talk will be increased.

To overcome all these drawbacks Reconfigurable antennas are preferred. In wireless communication, the reconfigurable antennas earned an extreme consideration as single antenna is sufficient to full fill the user demands [I]. By adjusting the antenna radiating field the antenna can be reconfigured [VII] [VIII]. Depending upon the activity, the reconfigurable antennas have efficiency to adjust the field characteristics.
Reconfigurable antennas are capable to reconstruct its attributes like frequency, bandwidth, polarization and pattern to modify the environment [XVII].

By adopting switching mechanism reconfiguration can be achieved. The approaches of Reconfigurable antennas are arisen in early 1930s [XXIV]. Frequency reconfigurable antennas have symbolic consideration due to initiation of future wireless communication approach. To attain frequency reconfiguration many switches are usually used such as PIN diodes, RF MEMS, varactor diodes etc., depending upon the user demands the switches are preferred. Frequency reconfigurable pixel slot antenna is described in [IX]. By utilizing band pass filter along with varactor diode, a frequency reconfigurable antenna is designed in [XXV]. Fractal dipole antenna [XXI], Slot antenna [VI]. Frequency tunable antenna [XVIII], U-slot antenna [IV]. Frequency reconfigurable antennas have excited attention and cognitive radio is the good example for frequency reconfigurable antennas [XXVI,III,XXVII,XXII,XXIII,II,XIX].

In this paper a CPW fed circular shaped frequency reconfigurable antenna is designed. By placing TSIR and cross strip multi band is realized. The final designed antenna covers the frequency range of 3.03-3.8GHz, 5.1-5.5GHz, 6.5-7.16GHz and 9.4-12.5GHz of WiMAX, WLAN, C band and X-band applications. PIN diodes are used for frequency shifting because it is more favourable easy to fabricate and low cost.

II. Antenna Design

The suggested reconfigurable antenna model is shown in below figure1 which is implanted on RT/Duriod 5880 with relative permittivity of 2.2 and loss tangent of 0.0009. In order to reduce the weight of the system the designed antenna is in compact size with overall dimensions of 32mmx24mm and the substrate height of 0.8mm.
On top of the substrate initially the iteration 1 of the proposed antenna subsists of a circular radiating patch with radius $p_2=6.7\text{mm}$ with inner circle radius of $p_3=5.1\text{mm}$ is engraved with CPW transmission line. There is $0.2\text{mm}$ gap between the CPW ground plane and the transmission line is shown in figure 1(a). TS-TSIR is fixed on both sides inside the circular ring radiation patch which is represented in figure 1(b). In figure 1(c) cross strip is infused in CPW transmission line. Three rectangular slots are implanted on CPW transmission line to improve the frequency coverage and to attain multimode which shows in figure 1(d) $50\text{ohms}$ is the characteristic impedance of the transmission line with width of $ws=3.6\text{mm}$.

![Diagram of proposed antenna models](image)

**Figure 1:** Geometry of proposed antenna (a) model 1 (b) model 2 (c) model 3 (d) designed antenna model 4 without switches (e) final designed model with switches

| Parameter | Dimension (mm) | Parameter | Dimension (mm) |
|-----------|---------------|-----------|---------------|
| L         | 32            | s 6       | 2             |
| W         | 24            | v 1       | 0.6           |
| $p_1$     | 11.4          | v 2       | 5.6           |
| $p_2$     | 6.7           | v 3       | 1             |
| $p_3$     | 5.1           | v 4       | 2.6           |
| $s_1$     | 0.3           | v 5       | 5             |
| $s_2$     | 3.1           | v 6       | 8             |
| $s_3$     | 2.8           | v 7       | 6             |
| $s_4$     | 4.5           | R         | 2             |
| $s_5$     | 1             | g 1       | 0.2           |

**Table 1:** Dimensions of the antenna
Four PIN diodes d1, d2, d3 and d4 are placed in the final design to achieve frequency shifting. Two switches are placed in TS-TSIR and two switches in rectangular slots on CPW transmission line. The dimensions of the suggested antenna is shown in Table 1.

III. Results and Discussion

The accomplishment of the suggested antenna was investigated and illustrated by using HFSS software. Multi band is achieved for the suggested antenna structure. The antenna analysis is inspected in terms of return loss, VSWR, radiation pattern, gain, surface current distribution, electric current distribution and input impedance. Frequency shifting is achieved by placing four PIN diodes. The S11 curves of four antenna models are shown in Figure 2. The antenna model 1 covers the frequency range from 2.95-4.25GHz, 8.49-11.65GHz. After placing TS-TSIR on opposite sides inside the circular radiation patch the antenna model 2 covers the frequency range from 3.01-3.9GHz, 6.02-6.5GHz and 9.7-12.5GHz. Cross strip is inserted in the CPW transmission line the antenna model 3 covers the frequency range from 3-3.8GHz, 6.04-6.4GHz and 9.77-12.6GHz. The suggested antenna model after placing three rectangular slots on the feed line covers the frequency range from 3.1-3.91GHz and 9.6-12.6GHz.

![Figure 2: S11 curves of four antenna models](image)

After placing four PIN diodes frequency shifting is achieved. The comparison of return loss curves before and after placing switches is shown in below Figure 3.
When all four diodes d1, d2, d3 and d4 are in ON condition the designed antenna model covers the frequency range from 3.03-3.8GHz with return loss of -12.4dB for WiMAX application, 5.11-5.57GHz with return loss of -13.5dB for WLAN application, 6.5-7.1GHz with return loss of -26.1dB for C-band and 9.47-12.5GHz with maximum return loss of -27.16dB for radio astronomy, space research and satellite applications. The length of d1 and d2 is 0.7mm and width is 0.6mm. The length of d3 and d4 is 0.5mm and width is 0.5mm.

The comparison of VSWR curves before and after placing switches is shown in Figure 4. ‘O’ means that the diode is in OFF condition and ‘1’ means that the diode is in ON condition.
When d1, d2, d3 and d4 are in OFF conditions the antenna covers the frequency range from 3.02-3.87GHz with return loss of -12.8dB, 5.14-5.55GHz with return loss of -13.3dB, 6.54-7.14GHz with return loss of -23.3dB and 9.47-12.58GHz with maximum return loss of -27.8dB. In case of d1, d4 OFF and d2, d3 are in ON condition the antenna covers the frequency range from 3.04-3.84GHz with return loss of -12.4dB, 5.23-5.69GHz with return loss of -12.5dB, 6.60-7.14GHz with return loss of -25.6dB and 9.48-12.4GHz with maximum return loss of -28.2dB. In case of d1, d3 are in ON condition and d2, d4 are in OFF condition the antenna covers the frequency range from 3.04-3.88GHz with return loss of -12.5dB, 5.19-5.62GHz with return loss of -12.3dB, 6.64-7.09GHz with return loss of -22.01dB and 9.4-12.3GHz with maximum return loss of -29.3dB. The resonant frequency values of three antenna variations are shown in below Table 2.

| Cases | d 1 | d 2 | d 3 | d 4 | Resonant frequencies |
|-------|-----|-----|-----|-----|----------------------|
| Case 1 | 0   | 0   | 0   | 0   | 3.39, 5.3, 6.6, 10.7GHz |
| Case 2 | 0   | 1   | 1   | 0   | 3.35, 5.36, 6.64, 10.6GHz |
| Case 3 | 1   | 0   | 1   | 0   | 3.4, 5.33, 6.66, 10.78GHz |

Table. 2: resonant frequencies of three antenna variations

The radiation pattern is used to represent the radiated energy by the antenna. The radiated characteristics are contrived in both E-plane and H-plane. The radiation pattern before and after placing switches are shown in Fig 3.

![Figure. 3(a) E-field and H-field radiation pattern before placing switches](image-url)
Figure 3(b) E-field and H-field patterns after placing switches

E-plane has achieved Omni-directional radiation pattern and H-plane has bi-directional radiation pattern. E-plane co-polarization and cross polarization before placing switches are shown in figure 3(a) and after placing switches are displayed in figure 3(b). The radiation patterns at resonant frequencies 3.3, 5.2, 6.5 and 10.7GHz are shown in Fig 3.

Figure 3(c) E-field and H-field curves at resonant frequency of 3.3GHz

Figure 3(d) E-field and H-field curves at resonant frequency of 5.2GHz
The gain of the designed antenna shows how much power is delivered in the peak radiation direction. The gain of the suggested antenna before and after placing switches is shown in Figure 4. At resonant frequencies the gain of the suggested antenna is shown in Figure 5.

Figure 3(e) E-field and H-field curves at resonant frequency of 6.5GHz

Figure 3(f) E-field and H-field curves at resonant frequency of 10.7GHz

Figure 4: Gain of the suggested antenna (a) without switches (b) with switches
Figure 5: Gain of the suggested antenna at resonant frequencies (a) 3.3GHz (b) 5.2GHz

Figure 5: Gain of the suggested antenna at resonant frequencies (c) 6.5GHz (d) 10.7GHz

Figure 6: Current distribution of suggested reconfigurable antenna (a) without switches (b) with switches

Figure 6, Figure 7 represents the electric and surface current distributions. The current distributions are inspected before and after placing switches. The distribution
of current is highly considerable after placing switches and maximum current is dissipated along the feed factor and circular patch.

Figure 7: Electric field distribution of the constructed reconfigurable antenna
(a) without switches (b) with switches

The impedance of the constructed antenna is shown in Figure 8 which displays that the impedance of the suggested antenna is near to standard impedance $50\,\Omega$ at resonant frequencies.

Figure 8: Impedance of the designed frequency reconfigurable antenna

Parametric analysis is consummated by changing the radius of outer circle $p2$ from $6.5\,\text{mm}$ to $6.9\,\text{mm}$ of suggested antenna is shown in Figure 9.
By decreasing the radius from actual radius 6.7mm to 6.5mm the resonant frequency values obtained round 3.1, 4.8, 11.9GHz with maximum return loss of -20.9dB. At 6.6mm radius the resonant frequency values achieved around 3.3, 5.2, 6.5 and 10.8GHz with maximum return loss of -27.08dB. By increasing the radius of circle to 6.8mm the resonant frequency values obtained around 3.3, 6.6, 5.2 and 10.6GHz with maximum return loss of -28.2dB. At 6.9mm the resonant frequency value achieved around 3.4, 5.2, 6.5 and 10.5GHz with maximum return loss of -28.5dB.

By varying the radius of circle ‘p3’ from 4.9mm to 5.2mm parametric analysis is performed. By minimizing the radius to 4.8mm from actual radius 5.1mm the resonant frequency values obtained around 3.4, 5.7, and 10.6GHz with maximum return loss around -22.2dB. At 5mm the resonant frequency values attained around 3.3, 5.4, 6.6 and 10.7GHz with maximum return loss around -24dB. By increasing the
radius to 5.2mm the resonant frequency values obtained around 3.46, 8.97 and 14.08GHz with maximum return loss around -23.5dB.

IV. Conclusion

For wireless communication applications a frequency reconfigurable circular slot antenna is presented in this paper. To realize multi band operation at WiMAX, WLAN, C-band and X-band applications with centre frequencies of 3.3/5.2/6.5/10.7GHz. By placing four PIN diodes inside the radiator frequency shifting is attained. The designed structure shows good return loss (S11<-10dB) and VSWR criteria (VSWR<2) is satisfied at operating bands. The suggested antenna exhibits good radiation and impedance characteristics with acceptable gain.

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