A Simple Multiband Microstrip Circular Ring Antenna for WiMAX, WLAN, X, and Ku Band Applications

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Abstract. In this paper, a multiband concentric circular ring antenna that works at six frequency bands with wide bandwidth is presented. The proposed antenna contains four circular rings to provide multiband operation and a partial ground plane to increase the multiband frequency bandwidths. The designed antenna is compact in structure, having a dimension of 30x30mm². The proposed antenna can serve six bands of frequencies, including 2.98-3.61GHz, 4.15-7.02GHz, 8.08-9.06GHz, 10.50-11.59GHz, 13.3-14.94GHz, and 15.46-16.65GHz. The antenna achieved a peak gain of 4dB and radiation efficiency of 172%.

Keywords: Circular ring, partial ground, multiband, WiMAX, WLAN, Ku band.

1. Introduction
I n the past decades, demand for wireless devices has been increased due to the need for wireless technology for most of applications. Users are expecting a single device to serve many wireless applications instead of a separate device for each. The solution for this demand is a single multiband antenna that can serve many wireless bands. In recent years many works have been reported in the literature on antenna works at multiple bands of frequencies. A Hexa-band antenna with dipole and split ring resonators for S and C band described in [1]. A resonator-based four-band antenna in the C band is discussed in [2]. A defective ground antenna for triband WiMAX and WLAN applications are described in [3]. In reference [4], a rectangular ring stacked T shape strip with the slotted ground has been illustrated for WiMAX, WLAN and future 5G band applications. A complementary split-ring resonator (CSRR) loaded dual-band antenna is described in [5]. A pentaband slotted antenna loaded with stubs for UMTS, WLAN, and WiMAX frequency ranges is discussed in [6]. Reference [7] explained about slot-loaded antenna for Ku band applications [8]. A six-band slotted circular antenna for X and Ku bands analyzed in [9]. A stacked substrate-based antenna for X, K, Ku bands applications has been reported in [10]. A triband antenna loaded with slots in the ground and patch for WiMAX and WLAN applications is discussed in [11]. Reference [12] analyzed slotted ground and gap[13] coupled radiator antenna for partial C and complete X band applications. In the above-reported works, the antennas have been loaded[14] with strips, split ring resonators slots, stacked substrate, and achieved multiple frequency bands in any two or three-band combinations of S, C, X, and Ku bands[15].

This paper presents a compact antenna which works for atS, C, X, and Ku bands. The concentric circular rings were adopted to achieve multiple bands of frequencies and compact structure. The simple partial ground plane is used to increase the frequency bands.
2. **Antenna Design**

The proposed circular ring antenna is constructed on an economical FR4 substrate with $\varepsilon_r = 4.3$ and a loss tangent of 0.025. The antenna is smaller in size, having the dimensions of 30x30x1.6mm$^3$. The radiating patch is made up of four circular rings, each of width 1mm. A partial ground and a 50Ω feed line having the dimensions of $G_L$ x $G_W$ and $F_L$ x $F_W$, respectively, are used to construct the antenna. The proposed antenna geometry is shown in Figure 1, and the dimensions are specified in Table 1. The 1.6mm thick substrate has the length $S_L$, and width $S_W$. $D_1$, $D_2$, $D_3$, and $D_4$ are the diameter of circular rings 1, 2, 3, and 4, respectively. The difference between every ring's inner and outer diameter is 1mm and is denoted by $G$.

![Figure 1: The geometry of circular ring antenna (a) Patch, (b) Partial ground.](image)

**Table 1**: Dimensional values of the proposed antenna

| Parameters | Dimensions(mm) | Parameters | Dimensions(mm) |
|------------|----------------|------------|----------------|
| $S_L$ $S_W$ | 30             | $F_W$      | 3              |
| $G_W$      | 30             | $D_1$      | 22             |
| $G_L$      | 5.5            | $D_2$      | 15             |
| $G$        | 1              | $D_3$      | 10             |
| $F_L$      | 7.2            | $D_4$      | 6              |

3. **Steps In Design Of Antenna**

The design of the antenna has been carried out by following four steps in the radiating microstrip patch without any change in the partial ground structure. The step-by-step design of antenna configurations is illustrated in Figure 2. The simulations have been carried out using the 3D Electromagnetic simulation tool CST MWS. The antenna 1 is constructed with a single circular ring and works at five frequency bands with a peak gain of 3dB, out of which four have a good reflection coefficient, whereas the first band 2.4-2.8GHz operates with -11.4dB. In order to increase the first frequency band's return loss and to introduce a new band at WLAN, which lacks at antenna 1, circular ring two have been added to antenna 2 configuration? The gain obtained in antenna 2 at 8.06-9.11GHz
band is 0.24dB, which is less than other frequency bands. In antenna 3 configuration, circular ring three is added to improve the gain and return loss further on a few frequency bands. The antenna 4 configuration also improved return loss and the gain in all the frequency bands to an appreciable level using circular ring 4.

![Antenna Configurations](image)

**Figure 2:** Step by step design of antenna configurations (a) Antenna 1, (b) Antenna 2, (c) Antenna 3, (d) Antenna 4 (Proposed).

The antenna 4 configuration operates at the frequency bands 2.98-3.61GHz, 4.15-7.02GHz, 8.08-9.06GHz, 10.50-11.59GHz, 13.3-14.94GHz, 15.46-16.65GHz as shown in Figure 3. The gain characteristics graphs for all the antenna configurations are illustrated in Figure 4, and it is evident that antenna 4 has greater than 0dB gain for all band of frequencies and attained a peak gain of 4dB. The antenna 1-3 has not reached better gain in X and Ku frequency bands. The operating frequency bands return loss and peak gain of antenna configuration 1-4 is given in the Table 2. The antenna 4 configuration has been considered as the proposed structure based on the good gain and return loss characteristics in all the frequency bands.
Figure 3: S11 versus frequency characteristics of the antenna configurations

Figure 4: Gain characteristics of the antenna configurations

Table 2: Frequency bands and peak gain of various antenna configurations

| Configuration | Frequency bands | Return loss (dB) | Peak gain (dB) |
|---------------|----------------|-----------------|----------------|
| Antenna 1     | 2.4-2.8, 7.94-8.74, 10.61-11.36, 13.35-14.53, 15.45-16.66 | 11.42, 15.89, 29.56, 33.25, 19.18 | 1, 1.76, 2.93, 0.64, -0.38 |
| Antenna 2     | 3.3-3.68, 4.34-6.98, 8.06-9.11, 10.55-11.61, 13.33-14.98, 15.46-16.68 | 16.37, 26.50, 19.61, 29.21, 21.22, 16.13, 15.37 | 3.8, 3.64, 0.24, 2.43, 2.45, 0.26 |
| Antenna 3     | 3.3-6.14, 6.22-7.09, 8.04-9.20, 10.58-11.57, 13.19-14.98, 15.48-16.63 | 21.8, 18.52, 26.5, 41.18, 20.42, 17.96, 15.03 | 4.48, 3.08, -2.12, 2.2, 3.4, 1.17 |
| Antenna 4     | 2.98-3.61, 4.15-7.02, 8.08-9.06, 10.50-11.59, 13.3-14.94, 15.46-16.65 | 21.3, 27.29, 27.91, 50.17, 19.38, 17.76, 14.46 | 4.38, 0.26, 2.6, 3.88, 1.37 |
4. **Parametric Analysis**

The effect of various lengths of partial ground on the proposed antenna gain characteristics is shown in Figure 5. The gain response of the proposed antenna configuration for the ground length $G_L$ from 5mm to 7mm is analyzed in steps of 0.5mm. The decrease in length increases the gain of the antenna. The parametric analysis of varying ground lengths on return loss is shown in Figure 6. The return loss is good for 5.5mm ground length than all other cases due to a better impedance match. The gain is high at 5mm compared to 5.5mm by 0.4dB for the frequency band 15.46-16.65GHz, whereas for all other bands, both show approximately equal values. Based on the high return loss and good gain on all the frequency bands, the ground length of 5.5mm is taken to construct the antenna.

![Gain Characteristic](image1)

**Figure 5:** Gain characteristics of the antenna for varying ground lengths

![Return Loss Characteristic](image2)

**Figure 6:** Return loss characteristics of the antenna for varying ground lengths

5. **Results And Discussions**

The radiation patterns simulated at the far-field for the antenna proposed on different resonant frequencies are shown in Figure 7. The radiation patterns are omnidirectional for lower resonant frequencies and gradually deviate from omnidirectional to slightly directional at higher resonant frequencies. The radiation patterns are approximately omnidirectional in nature, which is suitable for many wireless applications. The proposed antenna can resonate at the bands 2.98-3.61 GHz, 4.15-7.02 GHz.
GHz, 8.08-9.06 GHz, 10.50-11.59 GHz, 13.3-14.94 GHz, 15.46-16.65GHz, which is applicable for various wireless applications.

![Far field radiation patterns at resonance frequencies](image)

**Figure 7:** Far field radiation patterns at resonance frequencies (a) 3.25 GHz, (b) 4.40GHz, (c) 6.62GHz, (d) 8.58GHz, (e) 11.24GHz, (f) 13.88GHz, (g) 16.14GHz.

The operating bands, resonant frequencies, fractional bandwidth, peak gain, radiation efficiency, application and frequency bands of the designed antenna is displayed in Table 3. The circular ring antenna works with a peak gain of 4 dB, Peak radiation efficiency of 172.7% and appreciable -10dB impedance bandwidths. The multiband circular ring antenna proposed in this work is simple, compact and suitable for WiMAX, WLAN, X and Ku band applications.

The various techniques adopted to produce multiband operations, operating bands; peak gain, -10dB impedance bandwidth, and applications of the existing works have been compared with this work shown in Table 4. The proposed work shows good peak gain, radiation efficiency, and better bandwidth with a simple circular ring antenna made of cost-effective FR4 substrate in six bands of operations covering S, C, X and Ku bands compared to other reported works.
### Table 3: The results of the proposed antenna.

| Operating bands (GHz) | Resonant Frequency (GHz) | -10dB bandwidth (%) | Peak gain (dB) | Peak η (%) | Applications | Bands |
|-----------------------|--------------------------|----------------------|----------------|------------|--------------|-------|
| 2.98-3.61             | 3.25                     | 19.38                | 4              | 172.7      | WiMAX       | S     |
| 4.15-7.02             | 4.40, 6.62               | 65.22, 43.35         | 3.85           | 93.3       | WLAN, C band uplink | C     |
| 8.08-9.06             | 8.58                     | 11.42                | 0.26           | 75.4       | X band satellite uplink | X     |
| 10.50-11.59           | 11.24                    | 9.69                 | 2.6            | 67.8       | FSS         | X     |
| 13.3-14.94            | 13.88                    | 11.8                 | 3.88           | 64.4       | Ku band uplink | Ku    |
| 15.46-16.65           | 16.14                    | 7.37                 | 1.37           | 62.49      | Ku band applications | Ku    |

### Table 4: Comparison between the existing works and the proposed work

| Ref. | Substrate | Operating bands (GHz) | Techniques adopted | Peak gain (dB) | Radiation efficiency (%) | -10dB impedance bandwidth (%) | Applications |
|------|-----------|-----------------------|--------------------|----------------|--------------------------|--------------------------------|---------------|
| [3]  | FR4       | 2.35–2.52, 3.2–4.16, 5.13–5.87 | Defected ground, Rectangular ring and patch | 4.06 | 99 | 7.26, 1.13, 5.1 | WiMAX and WLAN |
| [4]  | FR4       | 2.41–2.54, 3–6.65 | Rectangular ring stacked T shaped strip with slotted ground | 2.3 | 70 | NA | WiMAX, WLAN, forthcoming 5G |
| [5]  | FR4       | 2.41–2.56, 3.12–3.18 | CSRR | 1.09 | NA | 6.04, 1.9 | WLAN, WiMAX |
| [8]  | ceramic filled bioplastic composite material | 11.67–14.0, 18.19–19.75 | Slotted | 4.13 | 86.4 | 18.4, 8.2 | X, Ku |
| [11] | FR4       | 2.4–2.5, 2.5–2.69, 3.4–3.7, 5.1-5.8, 2.98-3.61, 4.15-7.02, 8.08-9.06, 10.50-11.59, 13.3-14.94, 15.46-16.65 | Slotted | 2.5 | 98.16 | 13.27, 4.28, 19.42 | WLAN, WiMAX |
| This work | FR4 | Circular ring | 4 | 172.7 | 3.25, 4.40, 6.62, 8.58, 11.24, 13.88, 16.14 | WiMAX, WLAN, C, X, Ku |
6. Conclusion

The proposed antenna discussed in this paper is simple in structure, compact in design and can serve six different frequency bands. The wide frequency bands of operation are attained by incorporating a partial ground plane. The antenna achieved a peak gain of 4dB and a peak radiation efficiency of 172.7%. The proposed hexa-band antenna works over six frequency bands, including 2.98-3.61GHz, 4.15-7.02GHz, 8.08-9.06GHz, 10.50-11.59GHz, 13.3-14.94GHz, 15.46-16.65GHz, which can serve WiMAX, WLAN, X and Ku band applications.

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