Multiband corrugated circular microstrip antenna for Long Term Evolution and 5G applications

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Abstract. Multiband corrugated circular microstrip antenna is purposed for LTE and 5G applications. The antenna is designed of 150x150x1.6 mm³ with loop feeding to reach higher bandwidth. The corrugated structure is added to advance the multiband frequency and gain performance. Variation of the structure of the Circular Microstrip Antenna (CMA) patch is analyzed. The slit, loop feeding, ring slot and corrugated slot is simulated to get the performance of return loss and radiation pattern. Impedance bandwidth in more than nine band of frequency is achieved by corrugation structure. The antenna can provides 11 dBi of directivity and can cover in the middle/high band of LTE frequency in multiband frequency.

1. Introduction
Wireless technology is growing rapidly with recent development. The increasing use of wireless communication systems encourages researchers to built up communication systems and devices. The antenna as the important devices of the telecommunication system must be designed to cover certain bandwidth and high gain. The applications of the antenna are for long term evolution (LTE) and 5G application. LTE, as the fourth generation has various band number of frequency in each country i.e: 600, 700, 850, 900, 1800, 2100, 2300, 2600, 3500 and 3700 MHz. Some of the 5G application also uses the same band of LTE i.e: 2300-2400, 3300-3800, 4400-5000 MHz in some channel bandwidth that cover L, S or C band application [1]. LTE and 5G applications are widely used in mobile devices such as laptops and mobile phones [2] for data communication, video chatting, MMS, voice, and digital video broadcasting for mobile and wireless communication [3].

Generally, the type of antenna that widely used for LTE application is a microstrip antenna. The microstrip antennas for LTE have been designed such as rectangles, circles, and triangles. Research provides a certain bandwidth to cover LTE operation that has been discussed in Wong and Huang using the open slot in rectangular patch antenna [4]. Research about circular patch antenna also has been discussed in Nayna et al. for X band [5], in Curto and Ammann for medical application [6], in Hasan et al. for GPS application [7], in Zhong et al. for satellite communication [8] and also in Camacho-gomez for LTE and 5G [9]. They have different shapes for different applications and also can be designed by a reconfigurable antenna to reach a certain application.

There are many wireless applications using circularly polarized (CP). CP can be applied for many useful applications such as satellite communications, radars, and RFID [10]. Conventional circularly polarized antennas have a square or circular shape to produce two orthogonal linear components with
the same strength and a 90˚ out of phase [11]. The advantages of a CP antenna do not require alignment between the transmitter and receiver polarization fields [12].

We developed circular microstrip antenna by adding a corrugated slot to get multiband frequency that can be applied in some LTE and 5G applications. This antenna has a dimension of 150x150x1.6 mm³ with loop feeding, ring slot and corrugated slot to achieve multiband frequency and higher bandwidth at certain frequency.

2. Methods

We have designed a circular microstrip antenna with FR4 substrate, with the thickness of the substrate of 1.6 mm and the thickness of patch 0.0035 mm. Figure 1 is the Circular Microstrip Antenna (CMA) with dimension of a=150 mm, b=3 mm, c=18.5 mm, d= 51.66 mm, e=150 mm, f= 40 mm, g= 10 mm, h= 3 mm and i=21.26 mm.

![Figure 1. Dimension of circular microstrip antenna.](image)

![Figure 2. (a). CMA type-A(Ci-A), (b) CMA type-B (Ci-B), (c) CMA type-C(Ci-C), (d) CMA type-D(Ci-D), (e) CMA type-E(Ci-E), and (f). CMA type-F(Ci-F).](image)
We designed six types of CMA elements with some modification of the patch as shown in Figure 2. Figure 2(a) displays the Circular Microstrip Antenna with no structure i.e. Ci-A (Circular-A). Figures 2(b), (c) and (d) are CMA by adding some structure but without corrugated in surrounding of the CMA that is Ci-B, Ci-C and Ci-D sequentially. Ci-B is circular antenna with two straight slit in the end of its transmission line feeding. Ci-C is circular antenna with loop feeding and circular ring but without two straight slit in the circular patch. Figure 2. (e) and (f) are CMA with corrugated and circular ring in the center of circular patch. They have different depth of corrugated that is Ci-E and Ci-F. All of this type of CMA is compared in return loss, axial ratio, and directivity performance.

3. Return and discussion

3.1. Return loss and axial ratio performance
The comparison of the return loss performance of six types of CMA is shown in Figure 3. By adding structures there have been an increasing the performance of impedance bandwidth, especially in higher frequency. Adding the corrugation will increase multiband frequency. It can be seen in Figure 3(b) and (c).

**Figure 3.** Return loss performance (a) Ci-A and Ci-B, (b) Ci-C and Ci-D and (c) Ci-E and Ci-F.

Axial ratio is the parameter that determines the polarization type of the antenna i.e: circular or linear polarization. Although CMA has a circular shape of the patch, but not necessarily, it have circular polarization. Circular polarization fulfills if it has an axial ratio of less than 3 dB. We can see in Figure 4, CMA with corrugated has a tendency circular polarization as displays in Figure 4 (b) and (c). The lowest axial ratio at 6 GHz of 0.2 dB is reached for Ci-E. Ci-E has an axial ratio of less than 3 dB from 5.76 – 6.1 GHz. The circular polarization is also grasped in Ci-F at 5 GHz of 2.24 dB. It can be concluded that the ring slot structure, the loop feed and corrugated can change the polarization to be circular polarization.
3.2. Surface current and radiation pattern discussion
The surface current of the CMA Ci-A and Ci-E can be shown in Figure 5(a) and (b). By adding the structure, the surface current will be trapped in the structure. At frequency 2.5 GHz, Ci-E has a higher of directivity than Ci-A. CMA has a different shape of radiation pattern at each frequency work. It has directional and omnidirectional radiation pattern depends on its frequency work.

![Surface current and radiation pattern discussion](image.png)

**Figure 4.** Axial ratio performance.

**Figure 5.** A surface current of (a) CMA without structure (Ci-A), (b) CMA with structure Ci-E and polar plot diagram of (c). Ci-A at 2.5 GHz and (d). Ci-D at 2.5 GHz.
Antenna gain from some type of circular patch antenna can be an appearance in Figure 6. It has shown the difference of gain performance of circular element at low frequency and high frequency. In some part of the frequency the deeper of corrugated, the better of gain especially at 2 until 3.5 GHz. Figure 6 shows the increasing of gain is not consistance at all of frequency band. Although circular patch antenna with the transmission line feeding can reach multiband impedance bandwidth, it only occupies in narrow frequency band at low frequency. To get the wider bandwidth can be done by modification of the groundplane or set the feeding location by using sma connector.

4. Conclusion
Circular Microstrip Antenna (CMA) with some structures i.e Ci-A,Ci-B,Ci-C,Ci-D and Ci-F, have been designed and analyzed from the simulation result. We compare circular patch antenna with no structure, with two stright slit, loop feeding, slot ring and corrugated to get return loss and radiation pattern performance. The increasing number of impedance bandwidth is reached for corrugated structure. The antenna is simulated from 1-6.5 GHz and reached more than nine impedance bandwidth and also grasped 11 dBi of directional of the antenna. The performance of CMA could be developed and also be considered to be applied in LTE application.

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