Design of dual ports coplanar waveguide MIMO system for UWB applications

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Abstract. In this research, a compact of four elements of dual ports coplanar wave guide (CPW) ending with T-shape stub are installed each one on a corner of 85x134 mm² printed circuit board (PCB). Each element is connected through the SMA connector “panel mount jack receptacle-2-hole flange- tap terminal”. A twin of opened circular parasitic rings are installed in front of each T-stub. A large number of try and error are applied to select the optimum geometry dimensions of the proposed paradigm. The result of paradigm show that each element operated with a resonance frequency 6.35 GHz, 7.1 GHz is the operating frequency overall system. Also, by utilizing the twin of opened circular parasitic ring, a good isolation is achieved with -48 dB. The obtained band frequency 1.74 (6.64-8.38) GHz are covered an important part of UWB which may be used at a sub band of 5G. In addition, the size of the prototype is suitable for future smartphone applications

1. Introduction
In 2002, the federal communication commission (FCC) authorized the frequency range (3.1-10.6) GHz for Ultra-Wideband (UWB) system with a signal limit below -6 dB [1]. UWB has actually experienced well over 40 years of technological advancement, it has been expanding rapidly as a promising technology for radar applications, localization and data communications. However, the transmission link can significantly distort the UWB due to its low powered and weak pulses [2]. So, to achieve a good solution for bottleneck UWB limited power problem multiple-input multiple-output (MIMO) technique has been introduced in order to achieve multiple diversity such as increases the channel capacity without the need for more spectrum [3]. On the other hand, MIMO system can be strength the attenuation in the UWB signal by using a diversity technique like space-time block code [4]. To integrate an array of MIMO system with an alternative small size PCB, a polarization technique is adopted effectively to deal with a large number of antenna arrays in small space. Among multi-antenna models that deal with UWB applications is the slot antenna type [5,6]. The slot antenna offers more than one benefit like low cost and covers a wide band frequency which matches the UWB requirement, so the current research is attempt to utilize such technique. Accordingly, to design an antenna that approaches the wideband frequencies of UWB, the band can be widen by either tapered [7], or fork-like stub [8], which will be adopted in this research. However, the stub model requires accurate choosing of dimension values to approach a suitable model. On the other hand, it is not easy to modify the design of the antenna for the rejection band functionality which is an UWB favors system feature. Several researches have deal with a similar approach such as [9], that the researcher design a compact of an orthogonal port with good isolation of MIMO antenna system. A wideband aperture with a dual-polarized port operated in 5G millimeter waves is proposed in [10]. In this research, a prototype of MIMO antenna will be designed to cover an important part of UWB range frequency. In order to increase the data rate, the polarization has been used. While a good isolation can be obtained by using
a twin of parasitic opened ring circles. A CPW with T-shape will be adopted in this paper to exploit the facilities of such technique in order to match the UWB properties.

2. Single antenna design

CPW means the antenna microstrip feeding line is combined with ground plane in one side of substrate with a two similar coupled slot lines. Also, a passive element and active device in relative case [11-13], that would be leading the antenna to characterize with small size and low fabrication cost. ‘Figure 1’ shows the geometry details of the single antenna which comprises of two polarized ports to increase the spectrum efficiency. Each port has a radiator of a stub have a T-shape with 50Ω CPW feeding line printed on a substrate of FR-4 with 4.4 permittivity and 0.025 thermal conductivity. Such T-shape is excited in a 14.4×14.4 mm² square slot to increase the band frequencies. A “panel mount jack receptacle-2-hole flange- tap terminal” is used as a connector illustrated in ‘Figure 2’. To mitigate the mutual coupling, two parasitic of opened circular ring has used. The proposed model does not need third ground layer which leads to reduce the size and cost in addition to simplify its fabrication. All geometric dimensions are listed in Table 1.

Figure 1. Single antenna element (a) Front view and (b) Side view.

Figure 2. Panel mount jack receptacle -2 -hole flange - tap terminal.
Table 1. Parameter values of the antenna design.

| Parameter | Value (mm) | Parameter | Value (mm) |
|-----------|------------|-----------|------------|
| $W_s$     | 30         | $W_T$     | 5.85       |
| $W_L$     | 14.4       | $C$       | 0.75       |
| $W_1$     | 4          | $r_1$     | 1.5        |
| $W_2$     | 6.6        | $r_2$     | 1.125      |
| $P$       | 0.4        | $L_m$     | 9          |
| $T$       | 1.2        | $W_m$     | 3          |
| $L_T$     | 2.25       | $h$       | 1.6        |
| $d$       | 2.55       |           |            |

3. MIMO design

Four replica of a single antenna element which proposed in (Section 2) has integrated on an $85 \times 134$ mm$^2$ of PCB which is made of FR-4 as in each single element’s substrate layer. Such PCB covered by copper element as a ground that shows in ‘Figure 3’.

![Figure 3. Antenna array system.](image)

Table 2. Different lengths and widths of PCB with resonance frequency for each port

| PCB Length in mm | Frequency for four ports in GHz | PCB Width in mm | Frequency for four ports in GHz |
|------------------|--------------------------------|-----------------|--------------------------------|
| 155              | 7.22                           | 75              | 7.34                           |
| 147              | 7.15                           | 83              | 7.20                           |
| 137              | 7.14                           | 80              | 7.16                           |
| 134              | 7.10                           | 85              | 7.10                           |

There are many challenges of choosing the PCB dimensions, the best one is matching the size of mother smartphone design. Also, the mutual coupling is affected by the distance between the two groups which
leads to a great effect on the final prototype of the proposed MIMO design. According to [14], the current surface of the PCB is influencing by the distance between each element antenna. So, the dimensions of such PCB have a significant role on the mutual coupling. In this research, an optimization has applied to a large number of results which obtained by many trying of various dimensions (length and width) of PCB which has summarized in table 2. So, the size of 85×134mm² has been chosen as optimum dimensions which highlighted with orange color.

4. Results
The proposed model has simulated using CST STUDIO 2019 in order to evaluate its performance. It is worth to mention that all previous results listed in table 2 has applied during the design steps which has led to optimize the better geometry of the proposed model. The following results are obtained by running the final proposed model.

4.1. Single element simulation
‘Figure 4’ illustrates the S-Parameter of a proposed single element which comprises of two polarized ports of CPW.

![Figure 4. S-Parameter for antenna single element.](image)

The model is covering a band width of 1.74 (8.38-6.64) GHz at -10 dB of $S_{1,1}$ and $S_{2,2}$ with a good isolation representing with -48 dB of $S_{1,2}$ and $S_{2,1}$. The voltage stand wave ratio (VSWR) is an important indicator to measure the performance of any antenna which must be less than 2 [15]. ‘Figure 5’ shows VSWR of the single antenna element which doesn’t approach 2.

![Figure 5. VSWR for single antenna element of both port1 and port2.](image)
It is worth to mention that the concluded dimensions in ‘Figure 1’ have selected as a better choice among many results obtained from a lot of other experiences values. Also, the separation distance between the two T-stub has a significant role on the performance of the double polarization ports. ‘Figure 6’ shows two results as a sample of distance separated the two T-stub while the resultant of the optimum distance showed in ‘Figure 4’ which has obtained after multiple attempts with various closed numbers, that obviously explicit the cause of selection $d$ of 2.55 mm in order to deal with less isolation from others in ‘Figure 6’. On the other hand, the dimensions of T-stub have an effective impact on the performance of any T-stub model, for more information see [16]. Also, the direction of the circular parasitic gab has significant impact on a mutual coupling. Note that such a circular parasitic was not presented by [16].

**Figure 6.** Multiple results with different distance in mm between the two T-Stub (a) 2.42 and (b) 3.29.

The radiation pattern for each port shown in ‘Figure 7’ it is clearness has a bubble shape which that can cover the top and bottom of the antenna with -33.3 dB as a maximum radiation at the resonance frequency.
4.2. MIMO antenna system simulation

The simulation of the integrated of four elements has illustrated as a return loss of eight ports \( S_{nn} \) about -18 dB with resonance frequency of 7.1 GHz and the isolation \( S_{Tn} \) are all under -20 dB as shown in ‘Figure 8’.

‘Figure 9’ shows the VSWR of eight ports of the proposed MIMO antennas system which illustrated that the value doesn’t approach 2.
Figure 10 shows the 2D polar radiation pattern of the MIMO system which has omni-direction shape of the PCB with a side lobe magnitude of -2.1 dB and 11.3 degree of the main lobe angular width. At the same time, 3D view of the radiation pattern has been covering the top and bottom of the smart phone with H-max. of -20.1 dB, while the gain of the proposed MIMO is 7.75 dBi.

5. Conclusion
In this paper, a prototype of MIMO system antenna with four elements each one has a dual-polarized CPW. Each antenna element has been installed on one corner of the smartphone with 85×134 mm² PCB. The most geometries of the proposed model have been obtained by trying a large closed number of dimensions in order to optimize the better model. The final paradigm has simulated by CST-STUDIO 2019 to evaluate its performance. The result shows that each element is operated with 7.34 GHz as a resonance frequency, while the overall model has operated with 7.1 GHz. The isolation can be achieved of a single element and overall system is -48 dB and under -20 dB respectively. On the other hand, the result of the radiation pattern can cover all sides of PCB which matching the significant of the smartphone 5G applications.

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