Broadband Sub-6GHz Slot-based MIMO Antenna for 5G NR Bands Mobile Applications

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Abstract. A slot-based broadband single and MIMO antennas for 5G New Radio (5G NR) mobile applications are presented in this paper. The proposed MIMO antenna is investigated by loading two antennas into a low-cost material with the partial ground for sub-6GHz. Each antenna element is consisted of a hexagonal-shaped slot and is composed of a 50Ω microstrip feed line. The WLAN 5-GHz band and 5G NR Bands n77/n78/n79 are covered with good impedance matching. Besides, the mutual coupling between the adjacent elements is less than 15-dB whereas the desired antenna elements gains are 3.19 dBi and 3.09 dBi at 3.5 GHz 4.2 GHz respectively.

Keywords—MIMO antenna; 5G New Radio; WLAN 5-GHz band; Sub-6GHz

1. Introduction
The mobile communication system fourth-generation (4G), as well as identified as long-term evolution (LTE), has introduced many technologies using the smartphone platform to improve the efficiency of transceivers in wireless mobile networks. For instance, implementing MIMO (Multiple Input Multiple Output) technologies of antenna transmission can significantly enhance spectral efficiency and channel capacity, leading to a substantial rise in 4G-LTE systems. However, current LTE advanced systems are no longer able to meet the growing demand for high data rates with very low latency. Therefore, the fifth-generation (5G) communication system, known as the new radio
(NR) system, has been introduced, offering data rates 100 times faster and low-latency (< 1ms) than 4G LTE.

According to the technical characteristics (TS) 38.101 of the 3rd generation partnership project (3GPP), the frequency bands of 5G NR are divided into two frequency ranges FR1 and FR2. The FR1 is a 5G NR band that operates at sub-6GHz (or less than the 6GHz band), whereas the 5G NR band is considered as FR2 in millimeter-wave (mmWave) [1]. Within the sub-6 GHz band, the frequency bands operating below 3GHz are now utilized in 4G/3G wireless mobile communication systems, and the 5-6 GHz frequencies are now allocated to the 5GHz WLAN band at the frequency span of (5150–5825 MHz). Therefore, the 5G NR frequency bands n79 (4400–5000 MHz), n78 (3300–3800 MHz), and n77 (3300–4200 MHz) were intended for the upcoming 5G networks. Currently, most MIMO antenna designs for 5G mobile applications are a single type of operating frequency band functioning in the range from 3.4 GHz to 3.5 GHz C-band or a fractional bandwidth (FBW) of n78 5G-NR band [2]–[8]. Several antenna design methods such as open-slot, inverted F, monopole, hybrid, and loop type have been suggested among these designs that can handle around 8 to 12 antenna array elements. In [9], it is noteworthy that up to 16 antennas could be integrated into a smartphone using the concept of building blocks, but due to the coupling effect of very narrowly spaced antennas, the matching and isolating 16 antenna arrays over the entire operating band is slightly undesirable. Lately, some research has been conducted to further support the sub-6 GHz band by introducing a dual-band antenna array [10]–[12], using one of the design methods, such as open-slot or monopole antenna, that can cover FBW of the targeted 5G-NR n78 and 5-GHz bands, including WLAN at 5.8-GHz as well as LTE Band 46 in the range of (5.15–5.925 GHz). Recently, very wideband slot antennas have been suggested for 5G smartphones with metal frames, providing 6 dB with less than 50% efficiency [13]–[14]. Furthermore, several slots have been used to decrease the mutual coupling between elements of the antenna, and to improve the frequency band of the suggested antenna [15].

Here, a developed broadband single layer MIMO antenna for 5G NR bands n77/n78/79 and (5150–5825 MHz) WLAN 5-GHz band applications is presented. The simulated results show the slot effect in both patch radiator and parasitic elements which are placed close to the transmission line.

2. Antenna Design Configuration

Figure 1 shows the single-port antenna design. The structure is composed of a Printed Circuit Board (PCB) which is etching with a rectangular patch in the front side and an optimized partial ground plane of size 4.2 mm × 30 mm at the backside whereas two parasitic elements of 4.5 mm height are located surrounding the transmission line plane. Both etching on a 1.6 mm thick FR4 substrate (εr = 4.3 and loss tangent 0.025). The overall size is 25 mm × 30 mm. The antenna includes a hexagonal-star-shaped radiating slot with a diameter of 6 mm and a corner-to-corner angle of 135o. Moreover, an L-shaped slot is created in each parasitic element.

The whole slot MIMO antenna size is 25 mm × 38 mm as shown in Figure 2. The slot antenna array involves two printed rectangular patch radiators on the top layer of FR4 substrate. Each has 11 mm × 16 mm in size. It is fed by an aperture-coupled microstrip line printed on the top layer with 5 mm length and 3 mm width. The slots have been etched on the antenna patch with a view to exhibit the required wide bandwidth. Besides, slots will help to increase the current distribution paths (i.e., by creating extra functional for inductance) in the MIMO antenna which can grow the impedance BW. Furthermore, miniaturization at PCB technology can be realized using slots. The optimized spacing edge to edge between the two elements is 6 mm. MICROWAVE STUDIO (CST) software was used to design and simulate both antennas.
3. Result and Discussion

As obvious in Figure 3, the current distribution at 3.5 GHz and 4.2 GHz traveling from antenna 1 to antenna 2 in the case of port 1 is excited whereas port 2 has been terminated and vis versa. It can be observed clearly that high current density was obtained under the exciting port especially in the transmission line surface and surround the slot edge. The same situation will be found if port 1 is terminated by a matched load and port 2 is excited.
The performance of the proposed single port and MIMO antennas, in terms of (S11, S22) reflection coefficients is shown in Figure 4. The proposed hexagonal-star-shaped slot helps to perturb the current distribution and introduces wide impedance matching compared with a conventional antenna. An improvement has been accomplished of the impedance bandwidth by properly using so tiny individual parasitic elements near the transmission line. Similar characteristics of broadband impedance bandwidth matching can be clearly observed for both single and MIMO antennas in the range of 2.04 to 8.3 GHz which operates in 5G NR and WLAN 5-GHz frequencies bands.

Figure 3. Current distributions at: (a) 3.5 GHz, (b) 4.2 GHz.

Figure 5 shows the isolation characteristics of the MIMO antenna by displaying the S21 and S12 transmission coefficients. It is evident that the proposed antenna exhibits the best isolation over the bandwidth range. Choosing a different length of edge-to-edge space distance will increase the isolation between the two antennas. -20 dB is the best-observed isolation over wide bandwidth whereas -15 dB is considered as the minimum achieved transmission coefficient with 6 mm spacing between the elements.

Figure 4. Simulated reflection coefficient of the proposed MIMO and single antenna
The normalized radiation patterns at 3.5 GHz and 4.2 GHz are demonstrated in Figure 6 and Figure 7 respectively. In the case of vertical feed at 3.5GHz, the half-power beam widths (HPBWs) simulated results of the xy and xz-planes are 137.4° and 221.9°, respectively. The maximum realized gain values are 3.19 dBi and 3.09 dBi at 3.5 GHz 4.2 GHz respectively.

Figure 6. Radiation patterns at 3.5 GHz
4. Conclusion

In this paper, MIMO antenna array design for WLAN 5-GHz and sub-6 GHz 5G NR bands for mobile applications has been fruitfully presented. The proposed MIMO antenna has displayed very broadband operational impedance matching of 121.1 % (2.04 to 8.3 GHz) with less than 10-dB which can basically cover both WLAN 5-GHz and 5G NR (n77/n78/n79) bands. The archived gains are 3.19 dBi and 3.09 dBi at 3.5 GHz 4.2 GHz respectively, it is a good candidate for mobile applications at sub-6GHz 5G bands.
5. References

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