A MIMO Antenna Using Interdigital Technique for LTE and Wi-MAX on Mobile Applications

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Abstract— *Demand of high data rate and channel bandwidth is concerned for modern wireless communication systems. All applications are rapidly shifting towards multiple input multiple output (MIMO). This paper focused on MIMO antenna using interdigital technique for GSM, 4G LTE and WiMAX on mobile applications. Interdigital capacitor technique can control the second harmonic as desired and reduce size of antenna from λ/2 to λ/4. However, this antenna has unidirectional radiation in both 0 and 180 degree directions. The fabricated antenna can be operated at GSM, 4G LTE (1.71-1.88 GHz) and WiMAX (3.6-3.8 GHz) frequencies with return loss (S_{11}) below -10 dB. The simulation gain is 3.0 dB. The antenna is designed on an FR-4 substrate. The experimental results of the fabricated antenna agree very well with simulation expectations using CST package.*

Keywords; *MIMO antenna, Interdigital, Dual band antenna*

I. Introduction

Wireless communication systems are considerably important to human life and have been rapidly developed with more and more requirements. Antenna is one of key devices used to transport electromagnetic energy between transmitter and receiver. In present, microstrip antenna structure is popularly utilized due to using same technology of PCB, suitable for designing on MMICs. Also it has compact size, light weight, and low cost. It is also easy to be installed into modern electronic devices which spaces are limited such as notebooks, mobile phones, tablets, etc. In recent years, there has been development of antenna to achieve different properties to meet the needs of users such as fractal, step-impedance resonator, capacitive load and interdigital antennas. MIMO antenna systems have been used for high speed transmission [1],[2]. MIMO is a method that uses multiple transmitting and receiving antennas for multipath propagation, which becomes an essential element of wireless communication for sending and receiving more than one data signal on the same radio channel at the same time. MIMO is developed to enhance performance of QoS (Quality of service) and speed of data transfer. However, on mobile devices, antennas must have compact size and should be placed in suitable positions to make systems more efficient.

This paper proposes a MIMO antenna using interdigital structure applied for GSM, 4G LTE (1.71-1.88GHz) and Wi-MAX (3.6-3.8GHz) on mobile systems. The interdigital technique can reduce size of the MIMO antenna from λ/2 to λ/4 due to slow wave effect of capacitive value [3],[4] and can control harmonic frequency as desired by increasing or decreasing capacitive values of fingers between feeding line and ground plane in transmission line. The antenna will be designed on FR-4 substrate with (ε_r) = 4.4, thickness (h) = 1.6mm, and loss tangent ($tan\delta$) = 0.018. This paper will be separated into 3 parts. First, we design the MIMO antenna using interdigital patch monopoles to control dual-band operations [5] and also to reduce size [6]. Next, simulation results of the MIMO antenna with interdigital structure will be demonstrated and compared with the conventional MIMO antenna. Lastly, implementation and measurement of the proposed antenna will be performed.

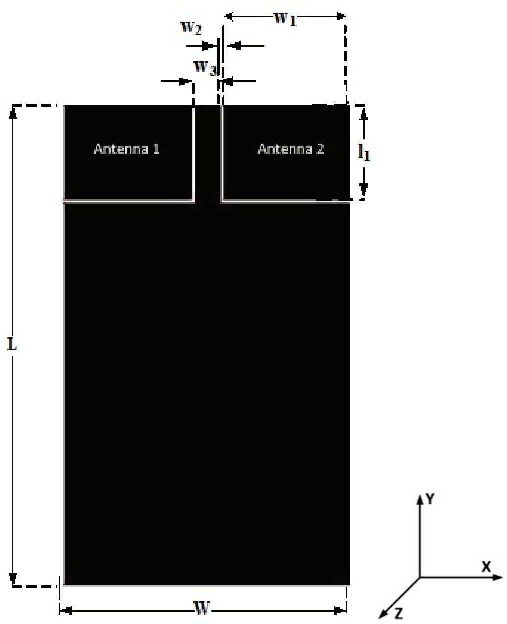


Figure 1. Layout of the conventional MIMO antenna.

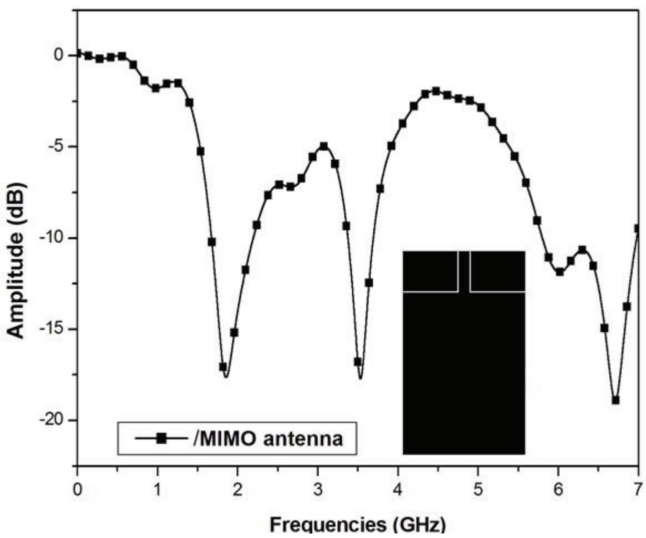


Figure 2. Simulation result of the conventional MIMO antenna.

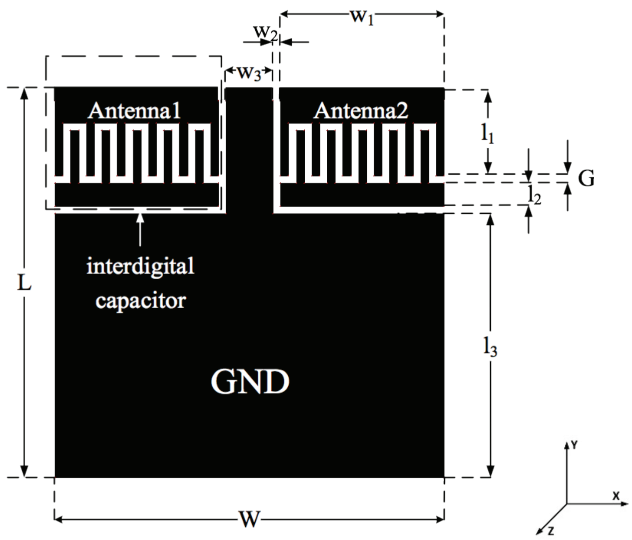


Figure 3. Layout of the MIMO antenna with interdigital structure.

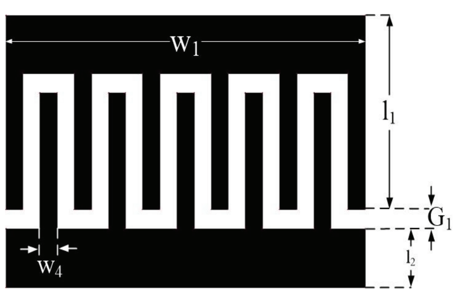


Figure 4. Intedigital structure details of the proposed MIMO antenna.

II. MIMO Antenna Design

The proposed MIMO antenna has been designed, which is based on a fundamental monopole path structure [5]. It consists of 2 patches, which each one has a resonance at same fundamental frequency of 1.8 GHz. A large ground plane is placed below and between of antennas 1 and 2, which have electrical length of $\lambda/2$ as a layout shown in Fig.1. By using the CST Microwave Studio Suit, the parameters of path antenna can be obtained as follows: W=8cm, W_1=3cm, W_2=0.25cm, W_3=1.5cm, L=12cm, l_1=3.2cm. Then resonant harmonic frequency is occurred at 3.6 GHz as shown in Fig.2. With interdigital technique [4],[6], a new antenna has been designed as shown in Fig.3. This technique can reduce size of the conventional patch antenna. Details of interdigital structure can be also seen in Fig.4. This structure can control harmonic frequency by varying capacitive value of interdigital structure. In our design, the gap G has been chosen to shift the resonant frequency from 3.6 to 3.7 GHz, which is the operating frequency for Wi-MAX as a result shown in Fig.5. It is found that the patch size is then reduced from $\lambda/2$ to $\lambda/4$ caused by the slow wave effect of inner interdigital structure [6]. Comparison of antenna sizes between the conventional and the proposed MIMO antennas is shown in Fig.6 All key parameters of the proposed MIMO antenna are shown in Table1. It can be noticed that the parameters that affect to harmonic frequency and antenna size are W_4 and L_4, and G_1. Fig.7 shows the antenna prototype.

Radiation patterns of the proposed MIMO antenna are uni-directional along x and –x axes, respectively. The effect of ground plane between antennas 1 and 2 is the same as reflector, which increases gain as shown in Fig. 8. At 1.8 GHz, it is found that antenna gain is 3.02 dB with an angle of radiation of 90 degree, return loss (S_{11}) is about -24.11dB and bandwidth is 190 MHz (1.7-1.9 GHz). While at 3.7 GHz, the gain is 3.44 dB, the angle of radiation is 114 degree, the return loss (S_{11}) is -14.02 dB and the bandwidth is about 600 MHz 3.42-3.86 GHz)

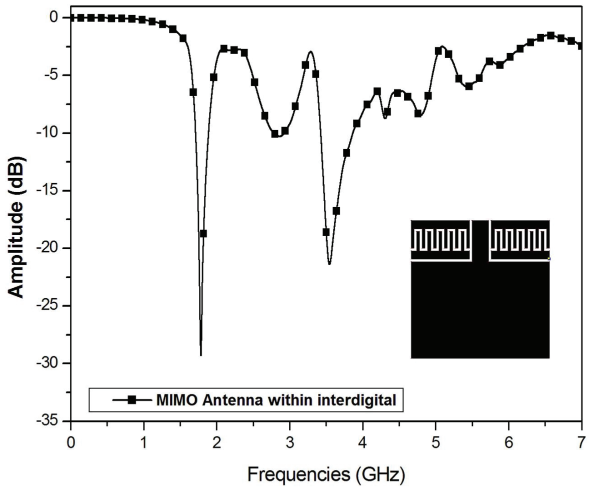


Figure 5. Simulation result of the proposed MIMO antenna.

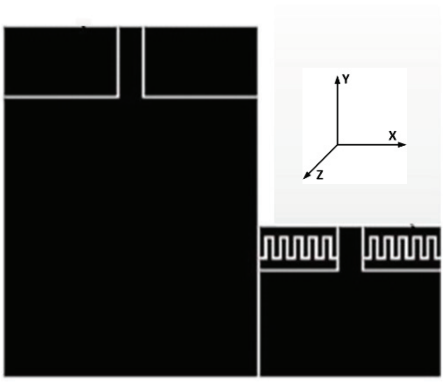


Figure 6. Comparison of the conventional and the proposed MIMO antennas.

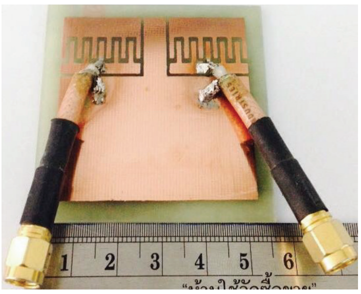
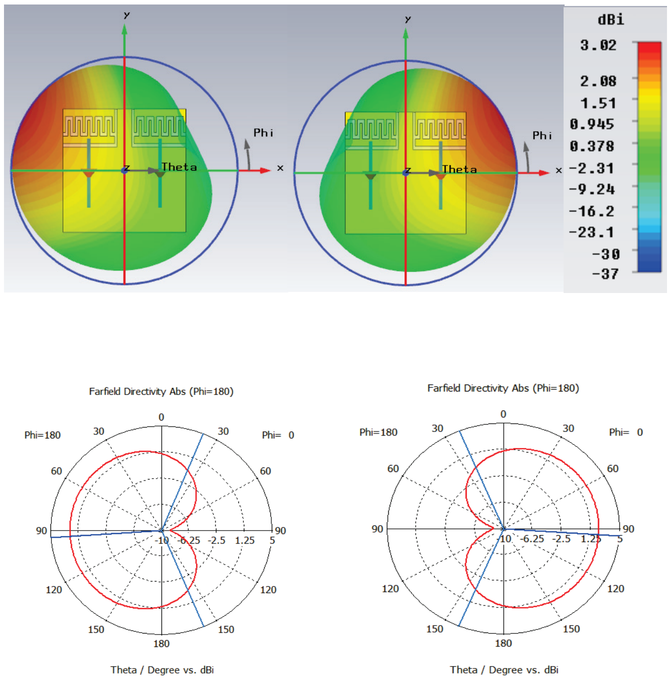


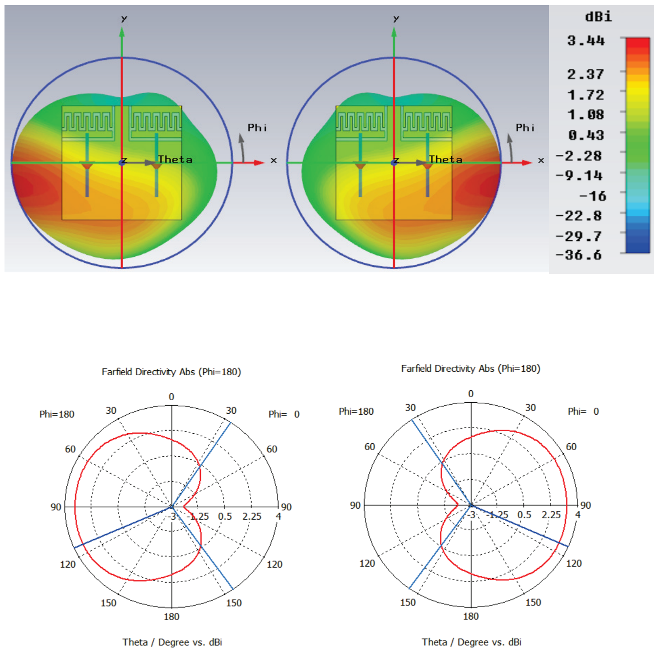
Figure 7. A photograph of the proposed MIMO antenna.

Table 1 Parameters of the proposed MIMO antenna.

Parameter	Description	Physical size (mm.)
L	Length of MIMO antenna	51
W	Width of MIMO antenna	50
w_1	Width of antenna	21
w_2	Width of gap between antenna and GND	1
w_3	Width of GND between Antenna	6
w_4	Width of finger	1
l_1	Length of finger	12.5
G_2	Gap between interdigital	1
l_2	Length of antenna	3
l_3	Length of GND	34.5



(a)



(b)

Figure 8. Patterns of the proposed MIMO antenna at

(a) 1.8 GHz and (b) 3.7 GHz.

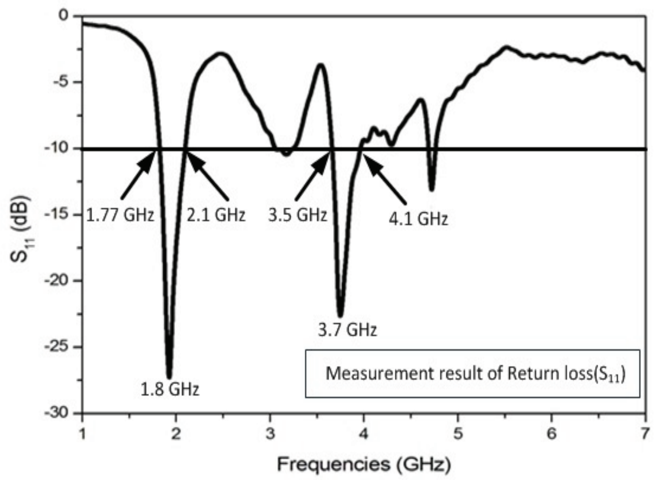
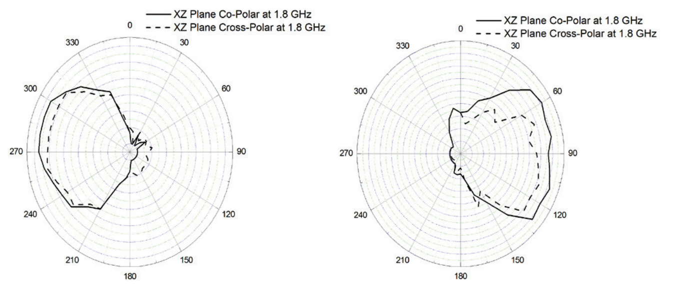
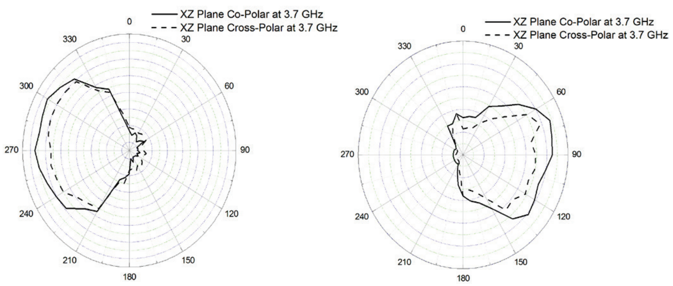


Figure 9. Measurement result of the proposed MIMO antenna.



(a)



(b)

Figure 10. Measured radiation patterns of the proposed MIMO antenna at (a) 1.8 GHz and (b) 3.7 GHz.

III. Implementation and Results

After designing the proposed MIMO antenna using the interdigital technique as mentioned in prior section. All parameters can be obtained by CST Microwave Studio Suit in Table1. Then, this proposed MIMO antenna was fabricated on FR-4 substrate. The size of antenna is 5x5 cm^2 as shown in Fig.7. The patterns are uni-directional, which radiate on left and right planes along x and –x axes at all frequency bands. Also, the measurement result as shown in Fig.9 has a good agreement with simulation result in Fig.8. The key measurement results include return loss (S_{11}) of -27 dB and bandwidth of 330 MHz for 4G LTE band and return loss (S_{11}) of -23 dB and bandwidth of 600 MHz for Wi-MAX band. The measurement results of radiation pattern are shown in Fig.10, which are similar to simulation results. The patterns at frequency 1.8 GHz and 3.7 GHz are radiated along X and −X axes for all co- and cross-polarizations in XZ Plane.

IV. Conclusion

The MIMO antenna using interdigital technique has been proposed to operate for GSM, 4G LTE and WiMAX on mobile applications. The proposed technique can reduce size of the antenna for about 50% compared with the conventional one. The results show good agreement between simulation and measurement with return loss less than 10 dB at all frequency bands. This antenna demonstrates good performance suitable for such systems.

Acknowledgement

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