Extreme Wide Band MIMO Antenna System for Fifth Generation Wireless Systems

Haitham Alsaif
Electrical Engineering Department
College of Engineering
University of Hail
Hail, Saudi Arabia
hal-saif@hotmail.com, h.alsaif@uoh.edu.sa

***Abstract*—A new compact 2×2 Multiple Input Multiple Output (MIMO) antenna is presented in this paper, suitable for the new wireless communications. The proposed design also covers the complete ultra-wideband for short wireless systems. The antenna system is characterized by a super wideband covering radio frequency (RF) band starting from 2.97GHz to 19.82GHz. The MIMO system contains two ship-shaped monopoles with trimmed edges. These antennas are printed on a single layer of Rogers Duroid RT5880Lz with relative permittivity εr=1.96 and loss tangent δ of 0.0009. The overall size of the MIMO system is 20mm×47mm×1.6mm. The peak-achieved gain is 8.12dB with nearly omni-directional isotropic far field patterns. The design and simulation has been performed via an industrial simulation code.**

Keywords-5G; ultra-wide band; planar antenna

I. INTRODUCTION

A dramatic increase in data rates is mandatory by the new generation wireless systems, which ga rise to challenges of the communication systems industry. Long-Term Evolution (LTE) in Fourth Generation commercial services is at the border of meeting these high data rate requests. Presently, in order to overcome such problems, the industry is launching sub-6GHz for the 5th Generation mobile devices. However, it is aimed to use the current networks and then shift to higher bands or millimeter bands from 28GHz to 85GHz by the end of 2020 [1-4]. The present spectrum bandwidth, which is lower than 6GHz is not enough to meet the future requirements. Therefore, new spectrum allocations above 6GHz are essential in order to alleviate the existing spectrum lack which is the main motivation in introducing the 5G in wireless communications systems. In the last few years studies for the 5G have started to move up from ultra-high frequencies (UHF) (300MHz-3GHz) to new frequency bands in the microwave range, counting millimeter-wave spectrums. Henceforth, the spectrum range above 6GHz and mm-wave bands are the chief bases in solving 5G challenges [5-9].

Different new ultra-wideband antennas with variety designs (rectangular, circular, elliptical, etc.) have been designed [5-13]. The designs differ in terms of parameters such as frequency bands, radiation, gain, and physical size. Some of these designs have shortages in their operating frequencies which do not include UWB set by FCC (3.1 to 10.6GHz). The suggested planar antenna in this paper is competitive with many of the previously published designs and has a reduced structure size.

Aiming to satisfy this new challenge of intensely increasing data rates, a 2×2 MIMO antenna system is proposed. The system has been designed and simulated in order to evaluate and test its performance. MIMO antenna systems are enormously employed in wireless devices to enrich the channel capability and multipath propagation and to improve high data-rates [10-15].

II. ANTENNA DESIGN

The geometrical arrangement of the proposed MIMO antenna along with design parameters for two feeding ports UWB MIMO are shown in Figure 1. The microstrip antennas have a simple and reduced structure size, which is 24mm long and 20mm wide, printed on a Rogers Duroid RT5880Lz substrate with 1.6mm thickness with relative permittivity εr=1.96 and loss tangent δ=0.0009. As shown in Figure 1, the MIMO consists of two shipshape radiators with truncated edges in order to enrich the impedance matching and to improve the bandwidth up to 17GHz [17]. Table I illustrates he optimized values of the geometric variables. The ship-shape antennas cover a radio frequency band from 2.97GHz to 19.89GHz, which includes IEEE 802.11 a/b/g/n/ac standards and sub-6GHz 5G bands as well. Additionally, this compact super wide band MIMO antenna system fulfills the frequency operating regulations of the Federal Communication Commission (FCC) for UWB communication systems [16-17]. Thus, the designed system is a model candidate for use in the UWB, Wi-Fi and sub-6GHz, i.e. 5G mobile due to its very compact design and characteristics.

III. PARAMETRIC STUDY AND SIMULATION RESULTS

Parameter investigation and optimization have been conducted in order to discover the key parameters and to enhance the MIMO antenna's performance in terms of bandwidth, isolation, power gain, and radiation pattern. Figures 2 and 3 show the optimized reflection coefficients (S11) and (S22) in dB versus the operating frequency in GHz. They display the super ultra-wide bandwidth that varies from 2.97GHz to 19.82GHz, which covers the whole bandwidth allocated for short wireless systems and the entire lower 5G

Corresponding author: Haitham Alsaif

bands. The covered bandwidth holds all bands in Europe, Japan, China, Korea, and United States. The reflection coefficient has multiple resonant frequencies of 3.48GHz, 7.32GHz, 9.89GHz, and 17.62GHz. A part of the parametric optimization process for the proposed antenna system for different values of the feeding strip line width is demonstrated in Figure 4. It is observed that the greatest impedance matching is attained at a line width of 2.7mm.

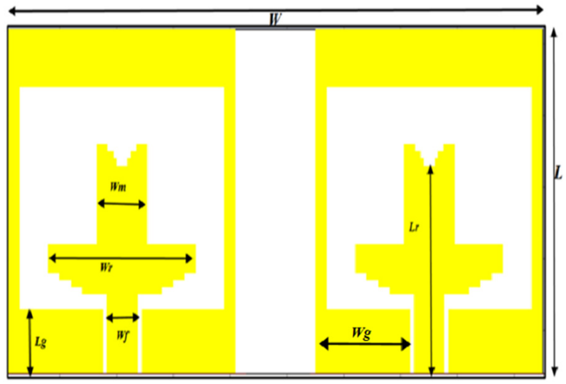

Fig. 1. Geometry of the proposed MIMO antenna

TABLE I. PARAMETERS OF THE DESIGNED 2×2 MIMO ANTENNA

Parameter	W	L	Wg	Lg	Wr	Lr	Wf	Wm
Value (mm)	45	20	8.3	4.5	13	17	2.7	4.5

Multiple substrate materials such as FR-4 (εr=4.3), Rogers RT 5880Lz (εr=1.96), and Polymide (εr=3.5) have been investigated for optimization purposes. The reflection coefficients S11 for these materials are plotted in Figure 5. It can be clearly noticed that the antenna's bandwidth has been optimized by using Rogers Duroid RT 5880lz as a substrate material and during this super wide bandwidth the reflection coefficient is lower than -10dB. Figure 7 displays the normalized radiation pattern at resonant frequencies 3.35GHz, 7.31GHz, and 9.89GHz for the main perpendicular planes (elevation (E) and azimuth (H)) in polar form. Generally, the presented antenna has an omni-directional radiation pattern with minor distortion at a higher part of the bandwidth as a result of the high growth in the power gain. Consequently, the proposed MIMO antenna can be inserted inside wireless systems at any position due to its radiation feature. The antenna is characterized by its high gain, which exceeds 8.12dBi. Figure 8 displays the proposed MIMO system power gain in dB versus the entire operating frequency in GHz.

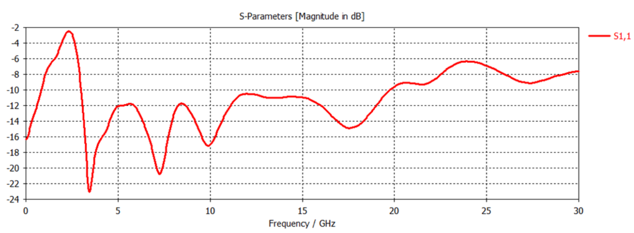

Fig. 2. Simulated reflection coefficient (S11) vs operating frequency

The key factor in MIMO performance and the major effort in designing MIMO antennas is obtaining lower transmission coefficient (S12 and S21) values between the two ports. In Figure 8 it can be observed that both antennas have well decoupled, which have S12 and S21 less than -16dB as well as good mutual coupling between the monopoles elements in the entire bandwidth.

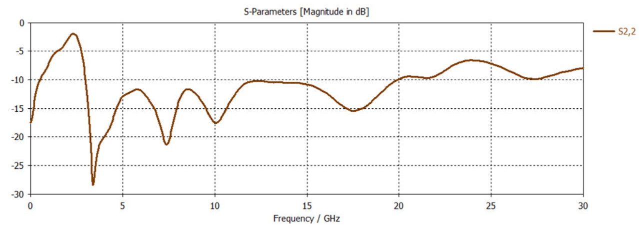

Fig. 3. Simulated reflection coefficient (S22) vs operating frequency

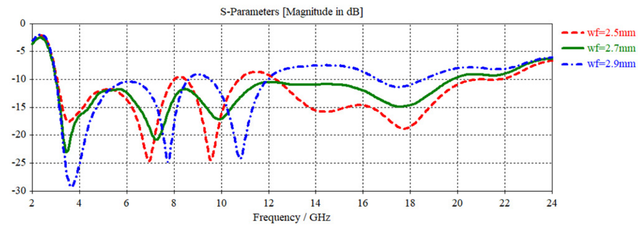

Fig. 4. Reflection coefficients for several values of feeding line width

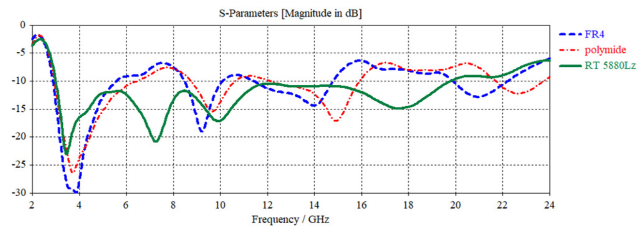

Fig. 5. Several substrate materials for the proposed MIMO antenna

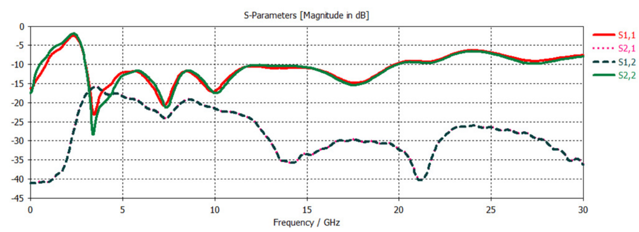

Fig. 6. Reflection and transmission coefficients for the monopole system vs operating frequency

A brief performance comparison between the proposed MIMO antenna system with similar MIMO antennas available in literature in terms of bandwidth, isolation, power gain, and structure size is presented in Table II. The Table clarifies that the suggested antenna is compact in size with extremely wide bandwidth, high power gain and isolation in comparison with similar existing antennas.

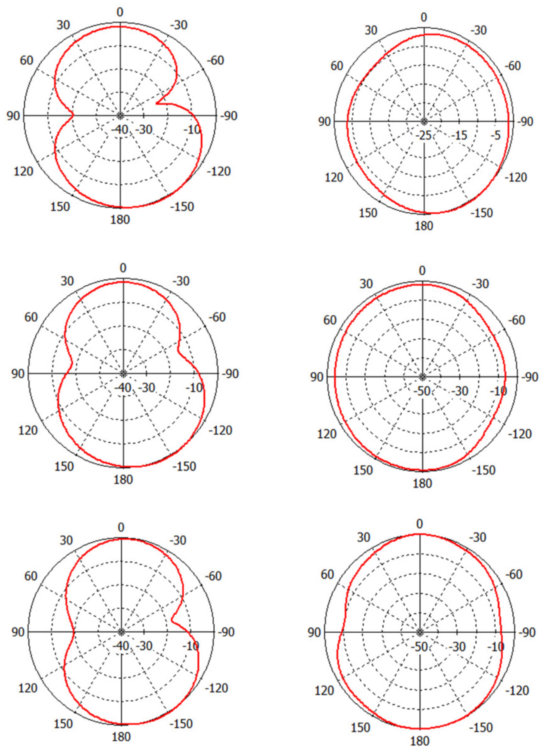

Fig. 7. Simulated power radiation pattern in polar form (elevation and azimuth planes) of the proposed MIMO antenna at 3.48GHz, 7.32GHz, 9.89GHz, and 17.62GHz

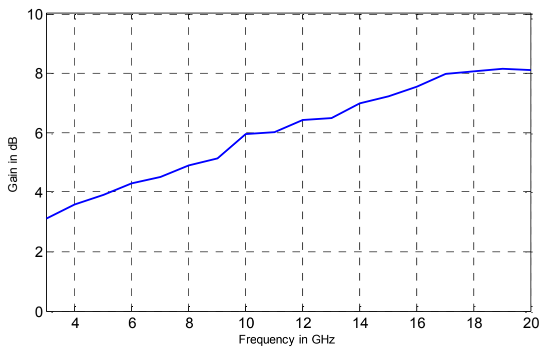

Fig. 8. Simulated power gain during the operating frequency with maximum gain of 8.12dB

TABLE II. PERFORMANCE COMPARISON BETWEEN THE PROPOSED ANTENNA AND PREVIOUSLY PUBLISHED DESIGNS

Reference	Size (mm^2)	Bandwidth (GHz)	Isolation (dB)	Power gain (dB)
[18]	35×40	3.1-10.6	-16	-
[19]	50×30	2.5-14.5	-20	7.4
[20]	32×32	3.1-10.6	-15	-
[21]	27×28	3-10.6	-16	-
Proposed	20×45	2.97-19.82	-16	8.12

IV. CONCLUSION

A new compact 2×2 MIMO antenna system is proposed in this paper. The antenna system has been designed, simulated using an industrial standard simulation code, and optimized. The proposed ship-design MIMO system has s bandwidth of 16.85GHz ranging from 2.97GHz to 19.82GHz with S12 parameter less than -16dB. The design is simple single layer and compact with total structure size of 20×45×1.6mm^3. The overall fractional bandwidth of the antenna was measured as 148.1%. Also, the obtained peak gain value of the presented antenna system was measured as 8.12dB with nearly omni-directional radiation pattern.

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