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A NEW MIMO SLOT ANTENNA FOR 5G APPLICATIONS

Arwa Abdulkareem Hamad[1] ***Malik Jasim Farhan[1]**

1) Electrical Engineering Department, College of Engineering, Mustansiriyah University, Baghdad-Iraq

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Abstract :A new MIMO slot antenna is proposed in this paper, the proposed antenna consists of tuning stub with certain dimensions in the top layer of the FR-4 dielectric substrate to increase the matching between the feed line and slot in the ground plane, this antenna feeds with 50-ohm characteristic impedance microstrip feed line. The dimensions of the proposed antenna are (50×50×1.6) mm2, the FR-4 epoxy substrate has a relative dielectric constant of εr=4.3, the tangent loss of tan (δ) =0.025. A bandwidth of 9.083 GHz (25.917–35) GHz and gain (6.33) dBi compatible with 5G applications are achieved with this antenna. To get the desired gain and bandwidth, several slots are etched on the ground, Using CST tools, the simulation results are collected. And the proposed antenna is manufactured in the Ministry of Science and Technology's- Electronic Manufacturing Center, a reasonable agreement is reached between simulation and measured performance.

Keyword: *MIMO, slot antenna, MIMO slot antenna, s-parameter, group time delay, and envelope correlation coefficient*

1. Introduction

Relatively large near-fields of electricity occupied by patch antennas enable them to merge with objects nearest.
By comparison, Introduced the fifth generation of mobile technology (5 G), which is expected to be available in 2020[2].

To meet the rapid growth of wireless communication capability due to the growth of smartphone users, web growth and high-velocity streaming, 5G technologies are getting attention and massive research is underway [3]. In the 5G age, a lot of things such as electronic devices, vehicles and offices, and home devices can connect wirelessly over the internet. When compared with the 4G technology, a higher frequency shift is one of the main differences in the 5 G cellular system, where a wider bandwidth is easier to obtain [4]. The Multiple Input Multiple Output (MIMO) system [5] is the most promising approache to the proposed problem. It has a substantial ability to increase data throughput without extra bandwidth or transmitter power [6]. The antenna type that can be used to improve a MIMO channel capability is a microstrip antenna [7].
microstrip antennas are widely used because of many good features are have like lightweight, low profile, wide frequency bandwidth ,ease of fabrication and lower cost and compactness [8,9,10] , radiation patch at top of the dielectric substrate while the ground plane at the bottom ,and these are the components of microstrip antenna, This antenna is also called a patch antenna, The popular literary designs are E

*Corresponding Author: malik.jasim@uomustansiriyah.edu.iq

shaped patch antenna [11], H shaped patch antenna [12], U slotted patch antennas [13], etc., A microstrip slot antenna is simple in structure, it contains a certain shape of the slot that locates in the bottom side of the dielectric substrate which represents the ground plane, and microstrip line with tuning stub is set on the top side of the dielectric substrate of the printed circuit boards (PCBs). In some configurations the slot in the ground plane, the microstrip line and the tuning stub on the same side of the dielectric substrate are coplanar [14].

Based on the slot shape, there are several types of this type of antennas like a circle, rectangle, triangle, and arc-shape etc. Microstrip line or coplanar waveguide may be the feed line of these antennas [15].

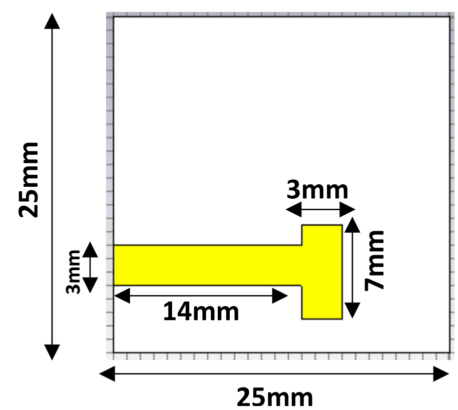
In this paper, the MIMO array slot antenna is proposed to be used in the 5G application. The antenna consists of a slot in the ground plane and tuning stub on the other side of the substrate, 50Ω microstrip line is a feed of the tuning stub and used to increase the match between the microstrip line at the top of the substrate and the slot at the bottom of the substrate.

2. Antenna Design and Simulation

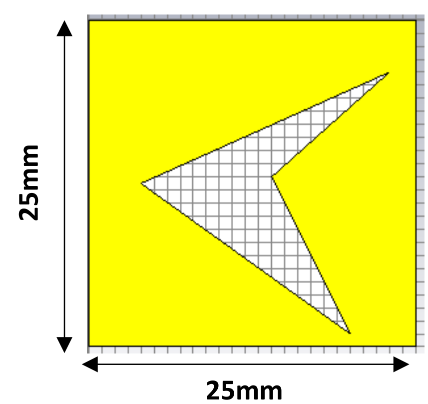
This design starts with a single element, two-element with achieve isolation between each port and then translating to four array elements of microstrip antenna for 5G applications.

2.1 Single element Microstrip slot antenna

The antenna consists of four parts (substrate, tuning stub, ground plane and feed line) operating at 5G frequency 28GHz band (27.5-29.5) GHz, the single element microstrip slot antenna as shown in fig (1) a,b in the proposed antenna is printed on FR-4 substrate with a thickness of (1.6)mm, εr=4.3, δ=0.025 with dimension (25×25×1.6)mm3 CST microwave studio tool has been used. On one side of the dielectric substrate there is a ground plane with dimensions of (25×25) mm3 and on the other side there is a tuning stub (which is a length of transmission line or waveguide connected only at one end and can be used to match a load impedance to the transmission line characteristic impedance) with length (Lt=3 mm) and width (wt=7 mm) was connected to 50Ω microstrip feed line, the dimensions of feed line were Li=14 mm and Wi=3mm.



(a)



(b)

Figure 1. The proposed single antenna (a): front view (b): back view

To show their effect many different enhancement techniques are used to optimize the design of the proposed antenna to cover the entire bandwidth allocated for 5G applications. Many parameters and their effects are studied on the antenna response, and a parametric study is used to conduct to optimize antenna performance.

The first parameter that optimized is the width of the tuning stub, the obtained bandwidth shown in figure 2 for different values of Wt

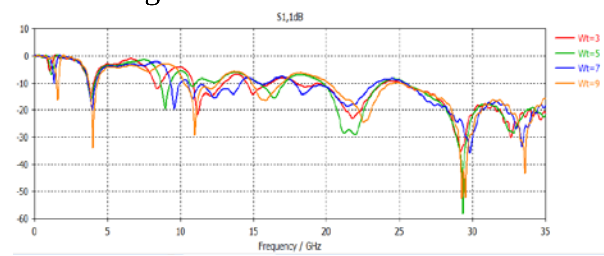


Figure 2. Simulated s-parameter of the slot antenna with different values of Wt

In the figure above, the value of the Wt parameter was modified to achieve the target bandwidth required for 5G application, the best value is 8mm because all other values don't achieve the required bandwidth

The other value that improved is the length of tuning stub by changing this parameter the band obtained is shown in figure (3), Therefore the best value obtained is when Lt = 22.5 mm i.e. when obtaining the target bandwidth that required for 5G.

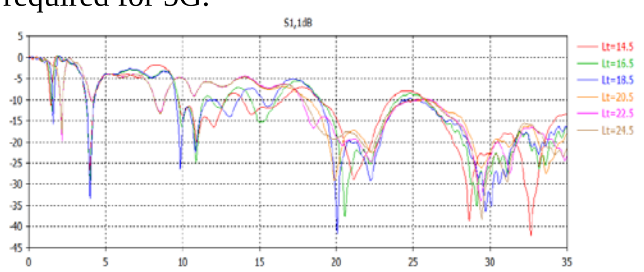


Figure 3. Simulated s-parameter of the slot antenna with different values of Lt

By changing all dimensions of slot in the ground plane, the sweep parameter design that achieves a target bandwidth which is required in the 5G applications is shown in figure (4)

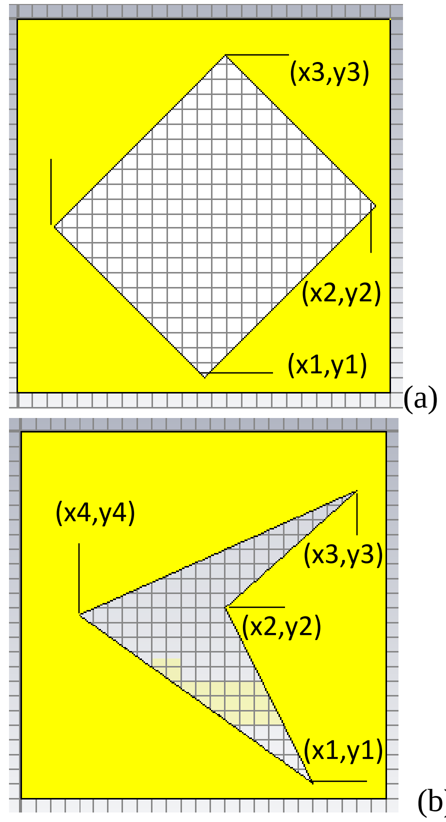


Figure 4. A Slot at the ground plane (a): before sweep parameter (b): after sweep parameter

Table (1) provides the best values for a single element of all parameters influencing the efficiency of the proposed antenna. While table (2) presents the dimensions of the ground plane before and after sweep parameter.

Table (1). Optimal design parameters of the slot antenna

W	L	Wt	Lt	Wi	Li
25	25	7	22.5	3	14

Table (2). Dimensions of the ground plane before and after sweep parameter

Points at the ground plane	Before sweep parameter	After sweep parameter
(x1,y1)	(12.5,24)	(20,24)

(x2,y2)	(24,12.5)	(14,12)
(x3,y3)	(12.5,1)	(23,4)
(x4,y4)	(1,12.5)	(4,12.5)

The input reflection coefficient of the optimal design of the single element microstrip slot antenna is shown in figure (5), the band from this curve covers the desired bandwidth for 5G applications.

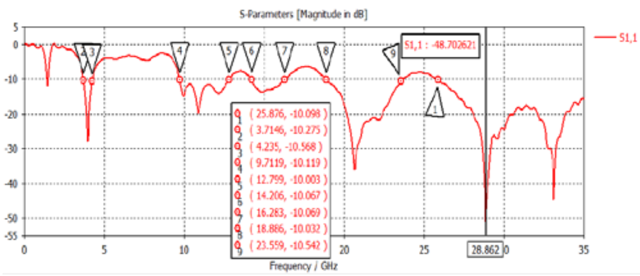


Figure 5. Simulated s-parameter of single element slot antenna with sweep parameter dimensions

The gain of the proposed single element microstrip antenna is around (4.54) dBi, which is suitable for 5G applications as shown in fig (6)

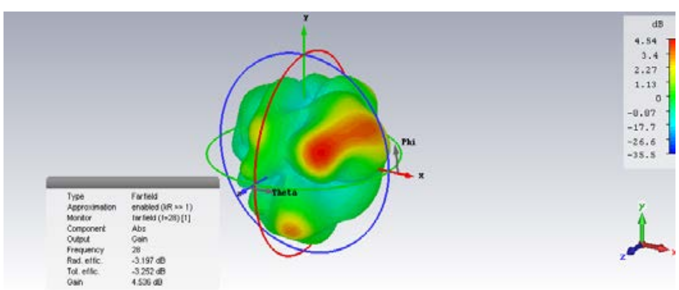
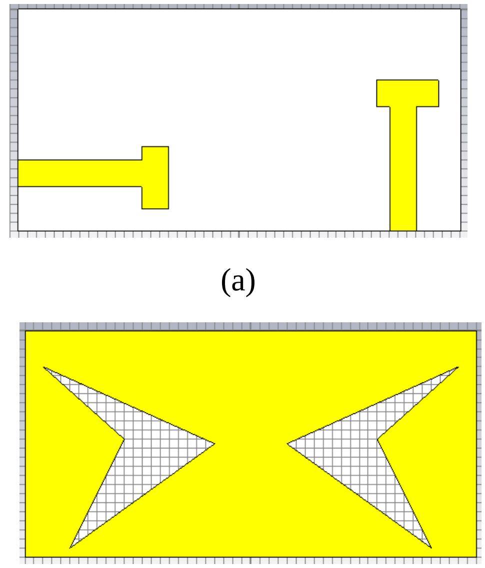


Figure 6. The simulated gain for the single element microstrip slot antenna

2.2. Two element microstrip slot antenna

A modified microstrip slot antenna of 2 elements is shown in Fig. (7) a,b, this model is implemented to improve the antenna's performance such as increasing its gain, directivity, along with other functions that are difficult to achieve in the case of a single element [16].



(a)

(b)

Figure 7. Two element array antenna (a): front view (b): back view

The tuning stub has a similar dimension with a single slot antenna and it's connected with a 50Ω microstrip feed line of dimensions Li=14 mm and Wi=3mm, and it's printed on FR-4 substrate with a thickness of 1.6 mm, tangent loss (δ=0.025) and dielectric constant (εr=4.3). Fig(8) shows the simulated reflection coefficient of a two-element array antenna

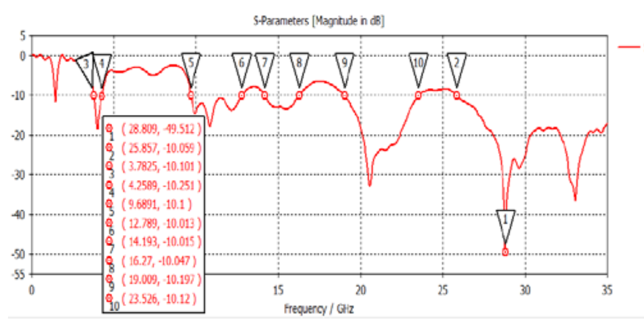


Figure 8. Simulated S11 of the two-element array antenna resonating at 28 GHz

From this curve, it can be claimed that this antenna is capable of covering the reflection coefficient from frequency 25.857 GHz to 35 GHz for less than -10 dB.

The input reflection coefficient that a single slot antenna can cover is just 9.124 GHz. While the two-element array antenna is covered 9.143 GHz.

The gain of the single element slot antenna is (4.54 dB) while the two-element array antenna increase the resulting antenna gain to (4.6dB) as shown in fig (9)

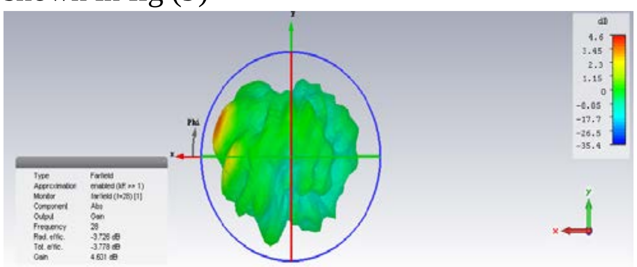
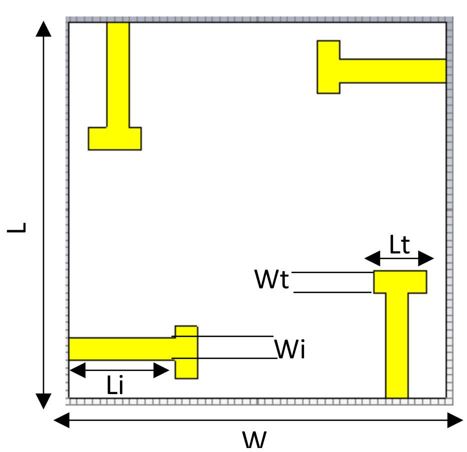


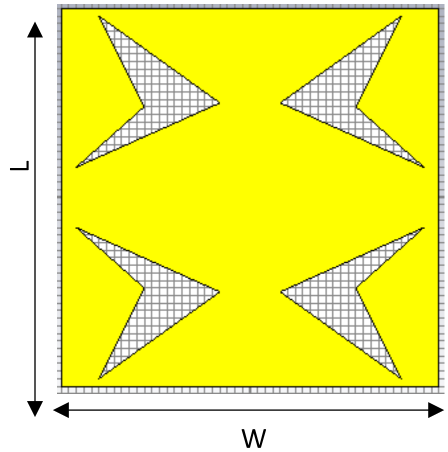
Figure 9. The simulated gain for two-element array microstrip slot antenna

2.3. Four Elements Microstrip Slot Antenna

The single element antenna is incorporated into a MIMO four-element assembly for potential 5G MIMO systems to benefit multi-path propagation to improve data rate, efficiency, and link reliability, the four-element MIMO antenna is shown in figure (10), and table (3) summarize the dimensions of it.



(a)



(b)

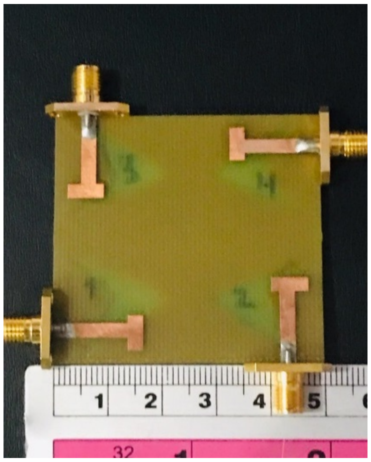
Figure 10. Proposed four-element array MIMO antenna (a) front view (b) back view

Table (3). Proposed dimensions for MIMO antenna

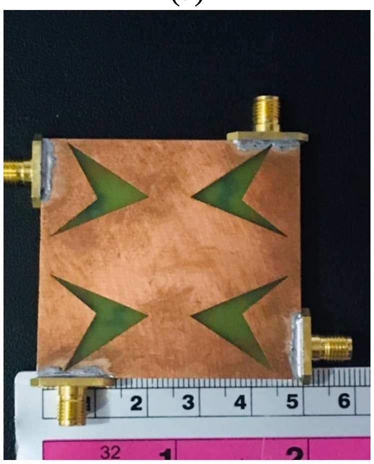
parameter	L	W	Li	Wi	Lt	Wt
mm	50	50	14	3	7	3

The MIMO array antenna proposed is designed, manufactured and tested (to verify the result of the simulation) as shown in figure (11) a,b and the results of the antenna that is practically made are shown in Fig(12).

20GHz is the sensible reflection coefficient over frequency Because of the reality that no vector network analyzer extra 20 GHz is available in the laboratory, the process results and simulation differed slightly, due to the feeder soldering as well as the connections of the vector network analyzer.



(a)



(b)

Figure 11. The practical proposed MIMO array antenna (a) front view (b) back view

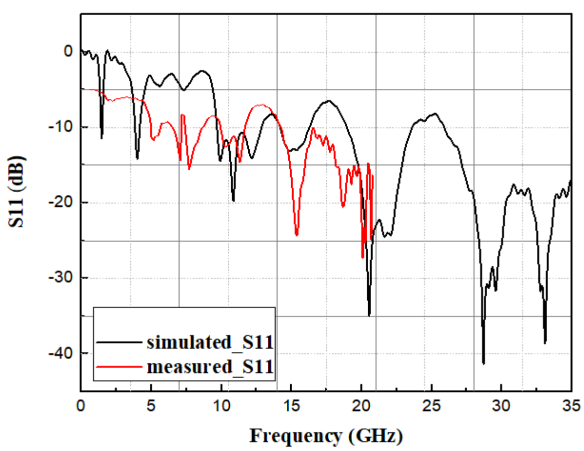


Figure 12. Compression of s-parameter simulation and practical

Figure 13 shows the isolation between each port of the proposed MIMO system, which is greater than or equal to -20 dB that has a good isolation between each port (where the isolation was achieved by making the angles between all the ports 90 degrees to get rid of the cross polarization).

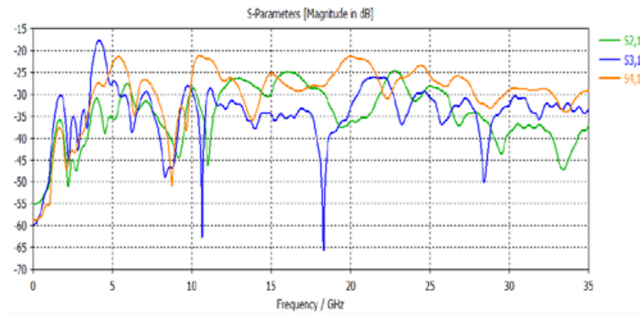


Figure13. Co-reflection coefficient of MIMO array system

Fig (14) shows the simulated reflection coefficient of four-element array antenna that explains the MIMO array antenna covered 9.083 GHz

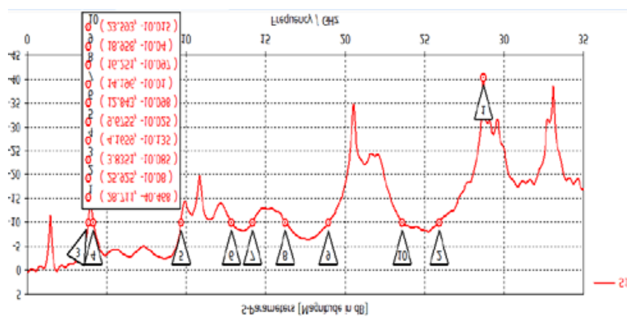


Figure 14. Simulated the s-parameter of MIMO array antenna

When the two-element slot antenna has gain around (4.6 dB) while the four-element array antenna increase the resulting antenna gain to (6.33 dB) as shown in fig (15)

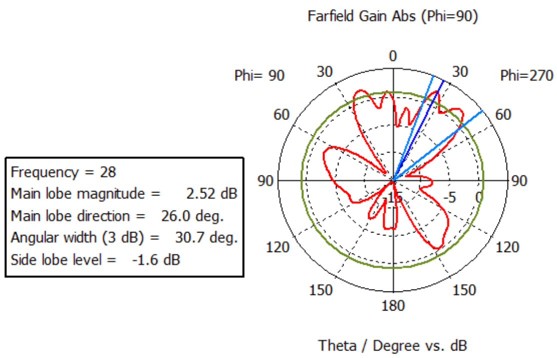


Figure 15. The simulated gain for four element array microstrip slot antenna

The group time delay of the proposed antenna is evaluated and for the appropriate band (27. 5-29.5) GHz it has approaches to zero as shown in the figure below.

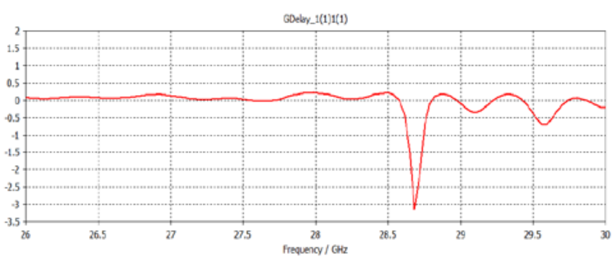


Figure 16. The group time delay of the proposed MIMO array antenna

the ideal antenna has impedance value 50Ω to get the best matching, here , the real part of the impedance is around (81.5Ω) and the imaginary part is around (-6.7Ω) which is near to the ideal case, as shown below

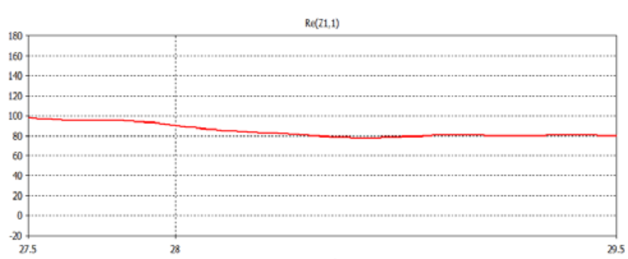


Figure (17). Impedance real part for MIMO array

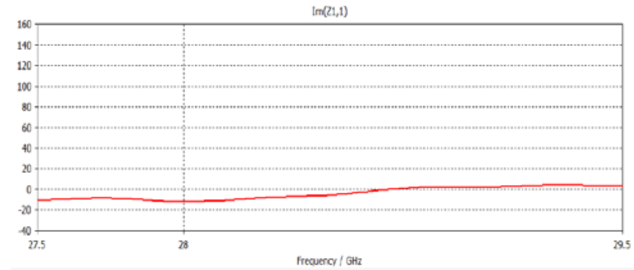


Figure 18. Imaginary part for MIMO antenna

The parameter that indicates the MIMO antenna performance is the envelope correlation coefficient ECC, it determines how independent MIMO antennas are in their performance, including the radiation pattern, antenna polarization, diversity gain and phase between the antennas in the MIMO system, the value of ECC should be very low and it varies from 0 to 1[17], as shown in figure (19)

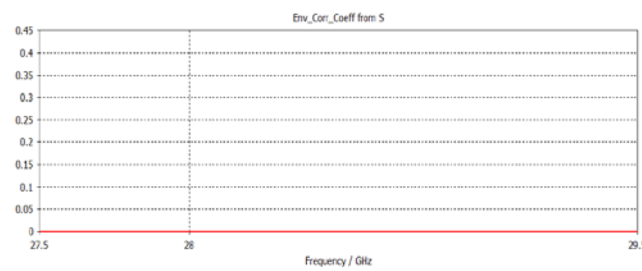


Figure 19. The envelope correlation coefficient for MIMO array antenna

2.4. Conclusions

The high data rate for the next generation of mobile communication is required. The multi path loss at mm-wave frequencies should be resolved with a high gain. A wide coverage area for data exchange is provided with a high gain antenna. Since the gain obtained by the array procedure is much higher than that of the antenna with single element, this paper suggests a new slot array antenna with four elements targeted at 5G mobile communications. This antenna is designed to operate at 28 GHz on a low-cost substrate (FR-4).

The proposed antenna has good performance regarding the characteristics of S-parameter, gain, characteristic impedance, envelope correlation coefficient and group time delay. Using CST tools, the antenna is designed and stimulated. The proposed four array antenna has a high gain of around 6.33dBi and a good matching impedance. The introduced antenna also has reasonable and good characteristics.

Comparing the results of this research with other, In 2018 S.Saxena and et al [18] presented a four ports MIMO antenna and focused on the sub-6GHz 5G applications, the proposed antenna operate at frequency range (3.4-3.8) GHz and the simulated gain is 3.8 dBi.

In 2019 Ayman Ayd R. Saada and Hesham A. Mohamed [19] suggested a MIMO broadband millimeter wave (mm-wave) antenna for 5th Generation networks, the MIMO antenna network consists of two ports and is implemented of two antenna arrays, set in reverse directions. Each array consists of three individual elements. the prototyped antenna is clearly had a high isolation over a wide impedance bandwidth of over 81.7 percent ranging from 22.5 to over 50 GHz for a 10 dB return loss and provided low envelope correlation values across the entire operating band.

3. Acknowledgments

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Conflict of interest

There are not conflicts to declare.

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