مجلة جامعة بني وليد للعلوم الإنسانية والتطبيقية
تصدر عن جامعة بني وليد – ليبيا
Website: https://jhas-bwu.com/index.php/bwjhas/index
العدد التاسع والعشرون، 2023

Design and Implementation of 2x1Microstrip Patch Antenna Array for with Parasitic Element Structure Isolation for 4G Applications

Lubna. A. Attelisi[1], Mohamed, S, Alshulle[2*], Belqees. M. Hanad[3]
[1,3]College of Electronic Technology, Bani-walid, Libya.
[2]Military Industries Organization, Bani-walid, Libya.
*Crosspnding author: dr.engineeralshole@gmail.com

تاريخ الاستلام: 2023-06-17 تاريخ القبول: 2023-06-27 تاريخ النشر: 2023-09-07

Abstract: For 4G-LTE applications, this study presents an integrated design with an array antenna system. With cut rectangular shape and a slightly sloped ground, a two-shared radiator for 2.1 GHz is presented. A 2-element slot is included in each port of the suggested design. Two antenna system components are housed on a single, inexpensive FR4 substrate that is fed by a 50 microstrip. In order to construct tiny antennas for communications, it is essential to provide enough antenna isolation. The findings show that the antenna has a better than 10 dB return loss at 2.1 GHz. The cancellation of current between any two antennas is a novel method for reducing mutual coupling. The suggested antenna achieves greater isolation than -26.7 dB between a pair of inputs. Additionally, the suggested antenna has a compact size reduction of around 60% compared to traditional patch antennas operating at the same frequency. This is due to the tiny spacing between antenna pieces.

Keywords: (Fourth generation (4G), Voltage Standing Wave Ratio (VSWR), Return Loss (S))

Introduction

Typically, each element offers modest values of directivity (gain) and has a rather broad radiation pattern. To address the needs of long distance communication, it is often required to construct antennas with particularly directional properties (quite high gains). Only by expanding the antenna's electrical size would this be possible. Increasing the size of individual pieces frequently results in more directive properties. Forming an assembly of radiating elements in an electrical and geometrical structure is another technique to increase the antenna's size without necessarily increasing the size of the individual elements. An array is the name given to this novel multi-element antenna. An array's elements are frequently the same. Although it is not required, doing so is frequently more practical, easier, and convenient. An array's constituent components, such as its wires and apertures, can take on any shape. The vector sum of the fields emitted by the individual elements yields the array's total field. The fields from the array's elements must interact constructively (add) in the appropriate directions and destructively (cancel each other) in the empty space in order to produce extremely directed patterns. In theory, this is possible, but in reality, it can only be approximated.

An antenna array is made up of a number of antenna components that are spatially dispersed according to a common fixed point at predetermined places. It is possible to electronically scan the main beam and/or place nulls in any direction by adjusting the phase and amplitude of the exciting currents in each of the antenna elements. The arrangement of the antenna components is flexible, with linear, circular, and planar arrays being the most popular geometries. When using a linear array, The array's elements' centers are arranged in a straight line. It is referred to be a uniformly spaced linear array if there is identical distance between each element of the array. A circular array is one whose elements' centers are located on a circle. The centers of the array elements of a planar array all lie on the same plane. The planar array includes both the circular array and the linear array as special examples. The radiation patterns of the individual elements, their orientations and relative locations in space, and the amplitude and phase of the feeding currents all affect the radiation pattern of an array [1].

The three definitions that appear in literary works the most are presented. The classification of various types of adaptive antenna systems in Figure 1 is the sole distinction between them.

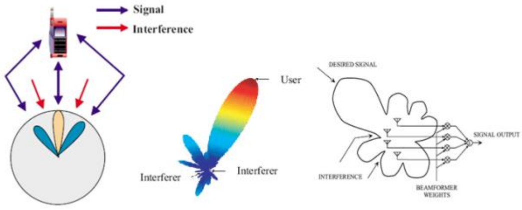

Fig. 1: Adaptive antenna array definition a- Adaptive array. b- Adaptive array coverage c- Different adaptive array concepts.

By integrating the impacts of multipath propagation or by effectively using the various data streams from various antennas, adaptive antenna systems can enhance connection quality. The advantages of adaptive antennas are best summed up as follows [2].

1. Increased range/coverage.
2. Increased Capacity.
3. Lower power requirements and/or cost reduction.
4. Improved link quality/reliability.
5. Increased spectral efficiency.
6. Security.
7. Reduction of handoff .
8. Spatial information.

In this study, a 2x1 array antenna for wireless applications (4G-LTE applications) is provided. The two elements have modest sizes and very low mutual coupling, and each one is mounted on a FR4 substrate with a dielectric constant of 4.4. The antenna has 2.1 GHz bandwidth coverage. The electromagnetic full wave simulations HFSS have been used to validate the designed outcomes.

1. Basic single patch Microstrip antenna for 2.1 GHz band (G-LTT applications)

The relative permittivity (also known as the dielectric constant) of the substrate, substrate height (h), and operating frequency (also known as the resonance frequency) are the three key factors for the operation of a microstrip patch antenna.Following evaluation of these three factors, length, width, patch input impedance, and fed dimensions are measured. Then, the antenna's performance, including its radiation pattern, S parameter, efficiency, and gain, is discovered.

Utilizing HFFS software, the 4G-LTE microstrip patch antennas were created. The antenna's shape was decided to be a square patch antenna with the dimensions W L and FR4 substrate with a dielectric constant of 4.4, and its height is equivalent to 1.6 mm. The antenna is intended to function at 2.1 GHz. Using a microstrip transmission line is the feeding method. The microstrip calculation website made it really easy and useful to determine the dimensions of the microstrip feed line for matching.

Figure (2) depicts the antenna, whose dimensions were determined using the microstrip antenna transmission line analysis model (3). Figure (2) displays the final dimensions following simulation using HFFS Software.

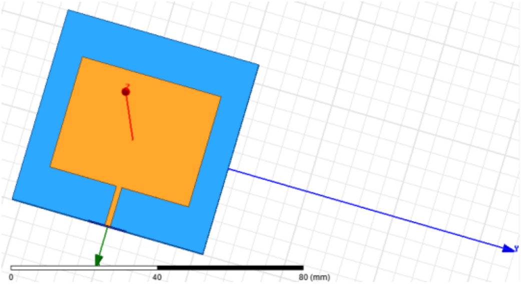

Fig. 2: Front View of 2.1 GHz -Band Microstrip Antenna, Dimensions in (mm).

The 2.1 GHz microstrip antenna's design parameter parameters are shown in Table (1) below.

Table 1: Design Parameter Specifications of the 2.1 GHz Microstrip Antenna

Parameter	**Value**
Operating frequency	2.1 GHz
Dielectric Constant	4.4 (FR4)
Height of the substrate	1.6 mm
Width of the patch (W)	42.46mm
length of the patch (L)	32.93mm
Width of the ground (Wg)	100mm
length of the ground (Lg)	95mm
Z_0	50
Feeding method	Microstrip Line

In HFSS, the published structure is implemented. To acquire the scattering parameters, the required simulations are run. The collected findings lined up with the data that had been published, completing the antenna validation.

2.1 Simulation results

For designing, simulation is employed, which is quite common for designing antennas. Several simulated graphs, including those for antenna gain, return loss, VSWR, total directivity, and current distribution (mapped 2D and 3D view), are produced and displayed in the figures. Using electromagnetic full wave simulation (HFSS), this has been verified.

A- Antenna Return Loss

The operating band is cantered at 2.1 GHz (under -10 dB) with -12 dB, making it obvious that this operating band satisfies the design criteria of the 4 G-LTE standard operating frequency. Figure 3 shows the return loss in dB for 2.1 GHz microstrip antenna.

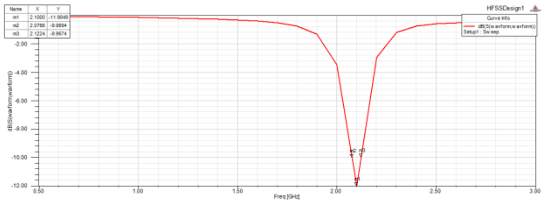

Fig. 3: Microstrip antenna return loss at 2.1 GHz

B- Voltage Standing Wave Ratio VSWR

Figure (4) displays a microstrip antenna's good values for the VSWR (dimensionless), which was 1.67 at 2.1 GHz.

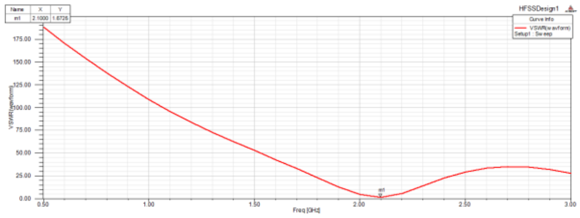

Fig. 4: Microstrip antenna VSWR at 2.1 GHz.

Microstrip patch antennas were the ideal choice for communication systems engineers based on performance and benefits such as low weight, low profile, and cheap cost from planned and simulated findings. However, it has a few shortcomings, including low gain, poor efficiency, and a small (3-6%) core frequency bandwidth, which is insufficient for the majority of modern wireless communication systems. Being able to reduce the size of different wireless equipment, including antennas as a crucial component of wireless communication systems, is one of the primary problems in antenna design for contemporary wireless communication systems. However, developing the radiation qualities throughout the whole frequency range presents greater difficulties and is important to get good results.

A typical definition of antenna gain is the ratio of the power generated by the antenna from a distant source on the beam axis to the power generated by an idealized lossless isotropic antenna that is equally sensitive to signals coming from all directions. Decibels are typically used to indicate this ratio. Due to the influence of substrate thickness and relative dielectric constant on antenna gain, microstrip antennas are infamous for having low gain. Thickness is inversely related to gain and directivity. Many techniques, including Left Handed Material (LHM) and array antenna, are employed to increase antenna gain [6].

To offer more thorough information on the antenna design and optimization, the proposed antenna is changed to explore the influence on gain. Parametric analyses of the proposed antenna are also presented. The variables under investigation include slot addition and antenna size reduction. to more clearly grasp how the settings affect the antenna's performance.

2. Optimization of conventional microstrip antenna for 4G-LTE applications

The simulated antenna model displayed in the preceding section had a reasonable return loss and VSWR over the whole antenna band, but the band was tiny and the radiation pattern was weak. This section makes a novel design suggestion to increase the performance of a standard microstrip patch antenna by increasing bandwidth and radiation pattern. This slotted microstrip patch antenna is brand-new. Modern design elements including slotted patches, microstrip line feeding, and patch structures are used. The combined impact of using these methods with the suggested patch results in a low profile, high gain, and decreased size. Utilizing HFSS software, theoretical simulations are carried out.

Figure (5) depicts the proposed antenna's configuration. The antenna's r = 4.4 low-cost FR4 substrate served as the design foundation. It was fed by a microstrip-line, which can be readily integrated on the same substrate. The single patch's dimensions were constructed with a rectangular patch's shaped slot on it; these measurements are: W = 14.7 mm, L = 12 mm, a = 4 mm, b = 10 mm, and c = 3x2 mm. A 11.5 mm x 3.11 mm microstrip line is used to obtain the feed. The proposed antenna has a ground plane that measures 20.3 mm by 17.4 mm and is hung 1.6 mm above it. The size of the patch antenna is being reduced by around 50%. The suggested can be simply made at a very minimal cost.

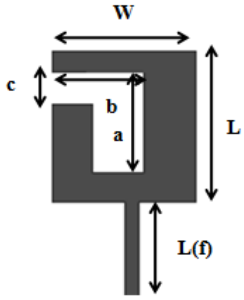

Fig. 5: Optimization of conventional microstrip antenna.

The simulated antenna model using HFSS software is shown in Figure (6).

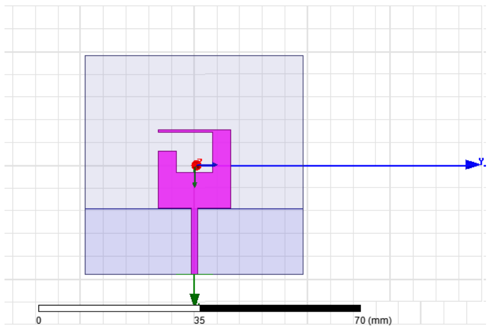

Fig. 6: Geometry of Proposed microstrip antenna at 2.1 GHz in (mm).

The right choice of loading left-handed components was made when designing the suggested antenna. Using electromagnetic full wave simulation (HFSS), this has been verified.

Figure (7) displays the proposed antenna's simulated reflection coefficient. The described antenna can obviously function in the 2.1 GHz frequency. The bandwidth ranges from 1.94 GHz to 2.23 GHz (FBW 13.8%), and the operational band is cantered at 2.1 GHz (under -10 dB) with -18.49 dB. Therefore, it is evident that this operating band complies with the 4 G-LTE standard operating frequency's design criteria..

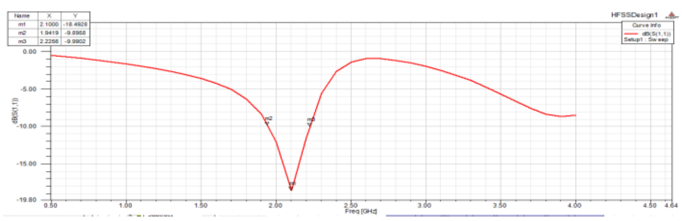

Fig. 7: The return loss of the proposed microstrip antenna at 2.1 GHz.

The construction known as a single element microstrip patch antenna is often made for low power applications. Additionally, it is restricted by its low gain, constrained bandwidth, and lossy directive. The most popular way to boost the bandwidth, directivity, and gain for applications that call for high gain and high directivity in small and conformal devices is to use multi-element devices, often known as arrays. Because of its straightforward production and adaptability with MMIC (Microwave Monolithic Integrated Circuits) technology, a microstrip patch antenna array is employed. Microstrip patch antenna's cost is one of the main considerations when selecting an array element. because it is inexpensive and widely accessible. The goal of this work is to create a microstrip antenna with a high directional gain for use in the 2.1 GHz band. Initially, we configured our antenna as a single-element microstrip patch, but after analyzing the results for antenna characteristics, operation frequency, radiation patterns, reflected loss, efficiency, and antenna gain, we changed it to a 4-pot array antenna with two elements per port. This produced better results than the original single-element antenna because the gain and directivity of the rectangular microstrip shape increase as the number of elements increases. The design and analysis of 4x1 linear antenna arrays to improve directivity, gain, efficiency, and radiation patterns are covered in the following section.

3. Microstrip Antenna Array (2x1) Design for 4G-LTE Application

Making tiny, inexpensive, high gain, compact antennas is one of the problems in antenna design. The microstrip antenna has several benefits over traditional microwave antennas, which have led to its widespread application. Numerous benefits of microstrip antenna arrays, including their low profile, light weight, and low price, make them popular. Microstrip antennas have poor power handling capacity, low efficiency, and low gain. This section proposes and uses a high gain antenna array with 2x1 components activated using probe-feeding for 4G-LTE and WLAN applications.

The suggested array's architecture is based on a traditional antenna that operates in the 2.1 GHz cantered 4G-LTE and WLAN frequency spectrum. A rectangular patch with a microstrip feed line was employed, and its dimensions are depicted in Figure(8).

There are two components to the array computation. The patch calculation comes first, followed by the 50-, 70-, and 100- transmission lines.

The following equation may be used to calculate the Impedance for a Quarter-Wave Transformer by substituting Z0 for 50 and R_{in} for 100. The characteristic impedance of a transformer is shown in equation [4] as follows.

$$Z_o = \sqrt{R_{in} Z_o} \qquad (1)$$

For an antenna array system that makes use of a power-splitting network, such as a parallel or corporate feed system, the employment of a 3-port power divider is particularly crucial. The corporate feed is just a device that maintains equal route lengths between input and output ports while dividing power amongst n output ports with a specific distribution. Here, a 2x1 antenna array power divider circuit was employed. Due to impedance matching, power dividers may be used with microstrip lines of various resistances. Two-antenna arrays should have a 50 ohm input impedance since a single microstrip patch antenna has that. For impedance matching, the maximum power theorem is used. Figure (8) below shows the 2x1 antenna array's power divider. Table (2) contains the dimensional parameters for the planned power divider.

Table (2). Dimensional Parameters of Designed Fed Network.

Connection	Parameters Value (Ω)	Dimensions Value (mm)
(1)	50	transmission line 13.85x3.11
(2)	100	transmission line 1.7x11.73
(3)	70	transmission line 9x0.49

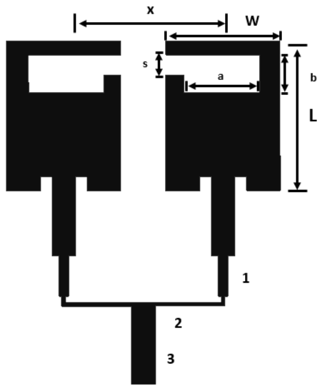

Fig. 8: Proposed 2x1 array geometry microstrip antenna.

The parasitic element in this array antenna is an element of a certain size and form that is put between other elements (nonphysically linked) or attached to the ground plane [16]. In order to lessen the reciprocal coupling between the elements, a parasitic element with a non-physical connection is employed in this research. The antennas are not really linked to parasitic components. By generating an opposing coupling field, these devices are utilized between the antennas to terminate some of the coupled fields, hence reducing the overall coupling on the target antenna. They might be floating, shorted stubs, or resonator-type devices. Additionally, parasitic components are created to regulate the coupling, isolation range, and bandwidthThis parasitic element will produce opposing coupling fields on both of its sides in order to weaken the original field and minimize coupling overall [5]. The stub enhances antenna matching, and the slot inside it reduces radiation from the environment and enhances ground plane isolation strips are used to construct a stop band to reduce interference in the WLAN spectrum. An element with a certain shape and size that is connected to other components in an unphysical way or that is connected to the ground plane as a resonator is known as a parasitic element. To lessen the reciprocal coupling between the elements, a parasitic element with a non-physical connection is employed. In order to weaken the initial field, this parasitic element will produce an opposing coupling field on both sides of itlowering the total coupling in the process. It is suggested to use a parasitic element with a new spatial form, as shown in Figure (9).

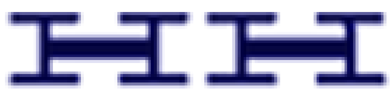

Fig. 9: Geometric Shape of the proposed parasitic element.

The parasitic stub is 40mm × 5mm in size and is situated in the center of the substrate 6.5 mm from each patch's border. There are two parasitic components, each measuring 2mm x 4mm.

Figure (10), which depicts the final dimensions following simulation and optimization using HFFS Software, shows these dimensions.

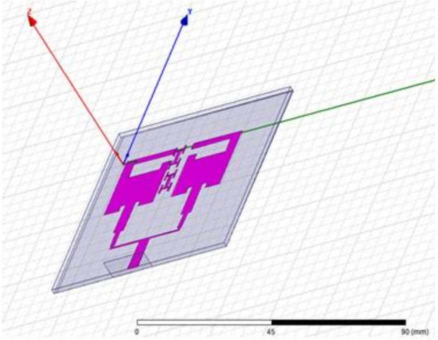

Fig. 10:View of Microstrip Antenna Array 2x1, Dimensions in (mm).

In HFSS, the published structure is implemented. To acquire the scattering parameters, the required simulations are run. The collected findings lined up with the data that had been published, completing the antenna validation.

4.1 Simulated Results

Antenna gain, total directivity, return loss, VSWR, current distribution, and radiation patterns are only a few of the simulated graphs that are created and displayed in the images. Using electromagnetic full wave simulation (HFSS), this has been verified.

a- Antenna Return Loss

Figure (11) displays the microstrip antenna array's 2x1 simulated reflection coefficient. The reported antenna's operational band is clearly under -10 dB at cantered 2.1 GHz (-17.58 dB), and its bandwidth spans 2.056 GHz to 2.14 GHz (FBW 4.28%). Therefore, it is abundantly obvious that this operating band satisfies the 4G-LTE standard operating frequency design criteria.

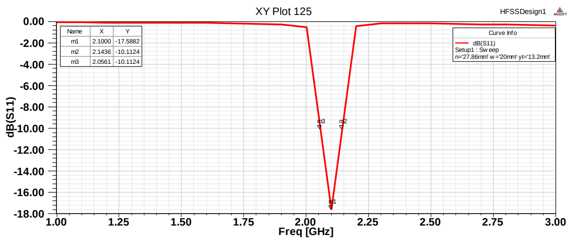

Fig. 11: Return Loss of the Microstrip Antenna Array 2x1.

b- Radiation Pattern in 3D

Figure (12) depicts the radiation patterns for the 2x1 microstrip patch antenna array designed for 4G-LTE. Since the antennas are patch type, they exhibit directional radiation patterns in the phi=0 deg (x-y plane) and phi=90 deg (y-z plane) planes. There is a directional pattern on the antenna.

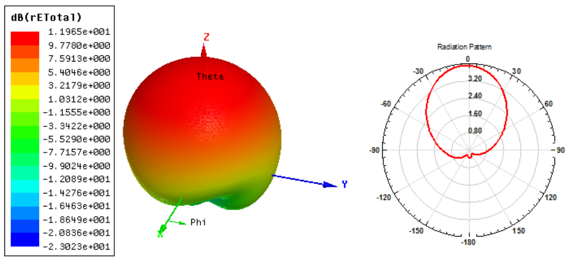

Fig. 12: 3D Radiation pattern of the 2x1microstrip antenna array.

c- Gain and Directivity

The intended antenna radiates with a gain of 4.91 dB and a directivity of 6.32 dB in the broadside direction. Figure (13), which shows 3D far field plots of gain and direction, is shown below. High directivity and gain characterize the antenna.

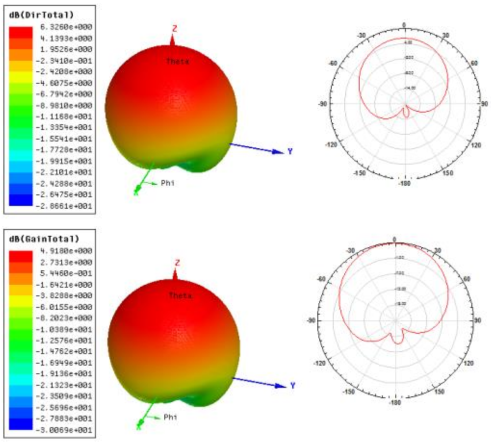

Fig. 13: Gain and Directivity of the microstrip antenna array 2x1.

d- Voltage Standing Wave Ratio (VSWR)

The VSWR for a 4G-LTE microstrip antenna array is shown in Figure (14). At 2.1 GHz, we had 1.3 with excellent values, indicating good received signals.

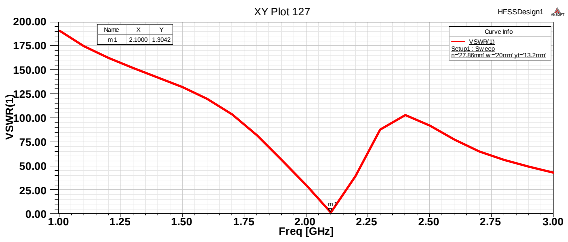

Fig. 14: VSWR of the Microstrip Antenna Array 2x1.

e- Current Distribution on the Antenna.

The field distribution between the patch and the ground plane is referred to as the current distribution, and it is employed as a measure of the radiation from microstrip patches. According to Figure (15), the highest current distribution is 155(A/m) at 2.1 GHz.

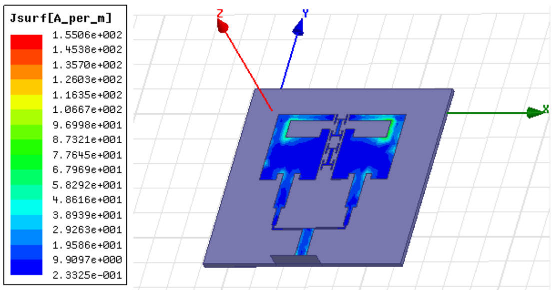

Fig. 15: Current distribution for microstrip antenna array.

4.2 Mutual Coupling Reduction of an Antenna using Parasitic Element Technique

The antennas are not really linked to parasitic components. By generating an opposing coupling field, these devices are utilized between the antennas to terminate some of the coupled fields, hence reducing the overall coupling on the target antenna. They may be floating, shorted stubs, or resonator-type devices [16].

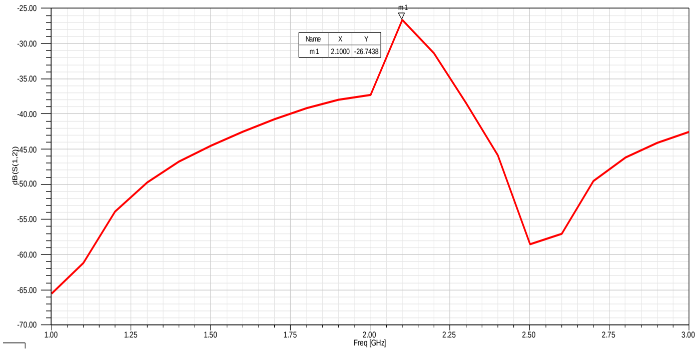

Fig. 16: The Return Loss and Mutual Coupling (S11-S12) of the microstrip antenna array with parasitic at 2.1 GHz.

Additionally, parasitic components are made to regulate coupling, isolation range, and bandwidth. Based on the simulation presented in figure (16), the values of isolation with parasitic components are -22.22 dB. Because of the tiny size of the antenna, this approach is effective for isolation and is ideal for small devices like mobile phones.

The present 2.1 GHz dispersion pattern is seen in Figure 17. At 2.1 GHz, the patch antenna's maximum current is 22.8 (A/m), and the E-field is 52.9 (kv/m), as illustrated in Figure (16). The surface current distribution and E-field distribution with parasitic elements are clearly terminated at the parasitic stub, indicating that the parasitic element approach is effective at lowering the electric field spread between antennas.

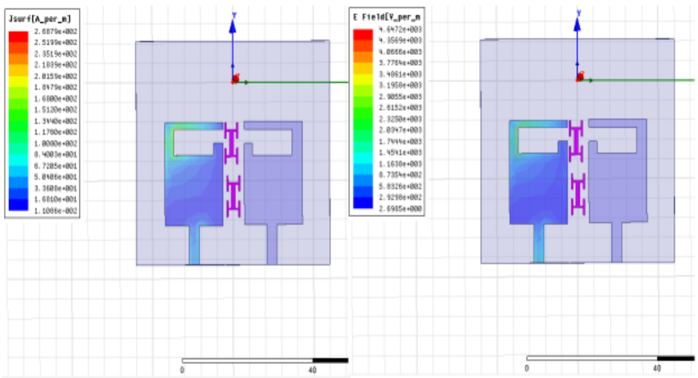

Fig. 17: Current Distribution and E-field on the array antenna at 2.1 GHz with parasitic element.

4. Conclusion

In this article, a 2x1 array antenna for 4G-LTE and other wireless communication technologies is presented. As a radiating element, a low profile antenna with microstrip has been employed. A band operation was successfully simulated in order to accomplish. The suggested design offers a two-element system for one port and is low profile, small, simple, and only requires one substrate. The 2.1 GHz band is covered by the integrated antenna system. The findings show that a suitable balance between the reflection coefficient and radiation pattern led to a frequency range with acceptable matching properties starting at about 2.1 GHz. A high isolation two-antenna system has been suggested and researched. Through the application of the suggested shaped structure and parasitic network element, satisfactory isolation performance was attained. This indicates a strong receiving signal and a directed radiation pattern because the return loss S11 is -18.49 dB. The suggested antenna's features include compactness (just 110 x 93 mm in dimension, a size decrease of about 50%). Additionally, at the working frequencies, the developed antenna offers greater coupling isolation between any two ports than 26.7 dB. Additionally, there is a 4.91 dB gain and a 6.32 dB directivity. A promising contender for 4G-LTE wireless communication equipment, the given antenna is also very small, inexpensive, conformal, and easy to construct. It exhibits excellent radiation properties across its working frequency spectrum.

References

S. Ali, "Design and Development of Fractioal Microstrip Antenna Array for Applications", Thapar university, 2016.

G. Mejda, "Multiband Microstrip Patch Antenna for 4G (LTE)", Mohamed Khider Biskra University, 24 June 2018.

C. A. Balanis "Antenna theory analysis and design", John Wiley & sons, inc., Publication, 3rd Edition, ISBN: 0-471-66782, 2005.

S. Weigand, G. Huff, K. Pan, and J. Bernhard, "Analysis and Design of Broad-band Single Layer Rectangular U- Slot Microstrip Patch Antennas", IEEE Trans. Antennas and Propag.,vol. 51, No.3, pp. 457-468, March, 2003.

M. A. Abdalla1 ,. " Small size high isolation CRLH meta- material closely spaced MIMO antenna"., 30th national radio science conference (NRSC 2013).