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DESIGNANDMANUFACTURINGOFANARRAYANSINGLMICROSTRIPPATCHANTENNATOTRANSMITANDRECEIVEBYUSINGSAMEPATCHSHAPE

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Design and Manufacturing of an Array an Single Microstrip Patch Antenna to Transmit and Receive by using Same Patch Shape

Ahmed Jameel Abdulqader [α] & Yaser Ahmed Ali [σ]

Abstract- In the last years, the progress in communication systems requires the development of high gain and low-cost Microstrip array antennas with suitable feeding technique and a dielectric substrate for applications in 2.1 GHz. The array antenna and single antenna were constructed on a substrate FR4 with a relative permittivity of 4.3. The suggested single antenna is benefited of a compact size of 50×30 mm2 at 2.1GHz frequency band and the suggested dimension array antenna is 160*52 mm2. The antenna is Microstrip line feeder and is simulated on CST software. Performance parameter evaluated are increased by using reflection, the array design has directivity up to 8.955 dBi and Gain up to 8.506 dB with satisfactory radiation characteristics. The single design has directivity up to 2.352 dBi and Gain up to 2.206 dB with satisfactory radiation characteristics. Been fabricated the array and single Microstrip antenna using CNC Machine. The practical results of radiation patterns and gain for two cases (array and single) are approximately similar to theoretical results. The computer simulation results show that the antenna having good impedance bandwidth (S11< -10 dB) at the resonant frequency.

Keywords: microstrip array antenna, single microstrip antenna, patch shape, 3g applications.

I. Introduction

Modern wireless communication system requires simple structure, lightweight, low profile, and high gain antennas to assure high efficiency, mobility, and reliability characteristics. Microstrip antenna satisfies such requirements. This antenna provides all of the advantages of printed circuit technology. These features of Microstrip antennas create them public in many wireless communication applications such as radar, satellite communication, medical applications, etc. [1]. The restrictions of Microstrip antennas are narrow frequency band and disability to operate at high power levels of a coaxial line, waveguide or even strip line.

Therefore, the defy in Microstrip antenna design is to increase the bandwidth and gain [2]. Different array configurations of Microstrip antenna can give high gain, wide bandwidth and improved efficiency. The distribution of voltages through the elements of an array depends on feeding network. Suitable feeding network cumulate all of the induced voltages to feed into one point [3]. The proper impedance matching over the series and corporate feeding array configurations supplies high efficiency Microstrip antenna. Power distribution through antenna elements can be modified by corporate feed network. The corporate feed network can lead beam by introducing phase change [2].

In the array antennas, elements can be fed by a single line or by several lines in a feed network configuration. Based on their feeding methods, arrays are classified as Series feed network and T-shaped corporate feed network. Series-feed Microstrip array is molded by intersecting all the elements with high impedance transmission line and feeding the power at the first element. Because the feed arrangement is compact the line losses related to this type of array are lower than those of the corporate-feed type [2]. Series-fed arrays can be conveniently fabricated using photolithography for both the radiating elements and the feed network. However, this technique is limited to arrays with a fixed beam or those which are scanned by varying the frequency, but it can be applied to linear and planar arrays with single or dual polarization. Also, any changes in one of the elements or feed lines affect the performance of the others. Therefore in a design, it is important to be able to take in to account these and other effects, such as mutual coupling, and internal reflections. Those who have been designing and experiment arrays antennas mention that radiation from the feed line, using either series or corporate-feed network, is an earnest problem that limits the cross-polarization and sidelobe level of the arrays. Both cross polarization and sidelobe levels can be improved by isolating the feed network from the radiating face of the array. This can be accomplished using either probe feeds or aperture coupling. The main limitation in series-feed arrays is the big variation of the impedance and beam-pointing direction over a band of frequencies [2].

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II. Arrays and Feed Networks

Performance of antenna arrays depends on our ability to feed the array elements with input currents having accurate phase relationships. This can be accomplished by using appropriately designed "feed networks" consisting of transmission line (TL) segments. We continue our study of antenna arrays with examples illustrating feed network design issues. The Microstrip antenna can be agitated either by a Microstrip line or coaxial probe. It can also be excited indirectly using electromagnetic coupling or aperture coupling and a coplanar waveguide feed, in which case there is no direct metallic contact between the feed line and the patch [4]. Feeding technique effective the input impedance and characteristics of an antenna and is an influential parameter. Elements of an array can be fed by a single line, known as a series-feed network, or by multiple lines, known as a corporate-feed network, shown in Fig 1.

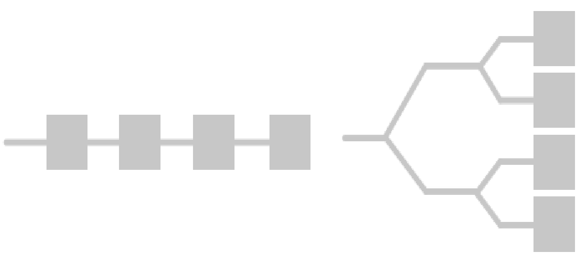

Fig. 1: Series Feed and Corporate Feed Networks.

III. Corporate Feed Network

This Network gives more control of the feed of each element (amplitude and phase) and they are perfect for multi-beam arrays or formed-beam arrays. The amplitude can be changed with an amplifier or an attenuator when the phase can be controlled using a phase shifter. This network is used to supply power division of 2n (i.e. n = 2, 4, 6, etc.). This idea can be checked by using either tapered lines as shown in Fig 2 or by using (λ/4) quarter wavelength transformers as shown in Fig 3 [2].

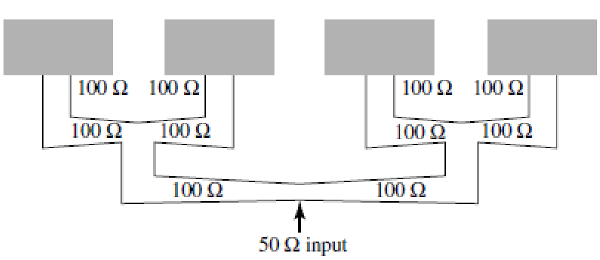

Fig. 2: Corporate-Feed Networks with Tapered Lines.

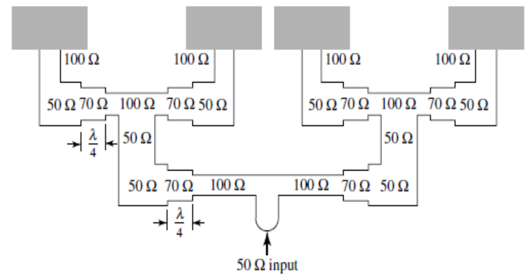

Fig. 3: Corporate-Feed Networks with Λ/4 Transformers.

This power split can be achieved by using three port power dividers of equal division (3dB) with the use of a T-junction power divider. An ideal power divider is lossless, reciprocal and matched at all ports. A T-junction power divider is reciprocal and can be considered lossless if the transmission line loss is not taken into account [5]. Helmholtz reciprocity theorem (generalized by Carson) states that "If an emf (electromagnetic force) is applied to the terminals of an antenna A and the current measured at the terminals of another antenna B, then an equal current (in both amplitude and phase) will be obtained at the terminals of antenna A if the same emf is applied to the terminals of antenna B [6]". A T-junction can be modeled as a junction of three transmission lines as shown in Fig 4.

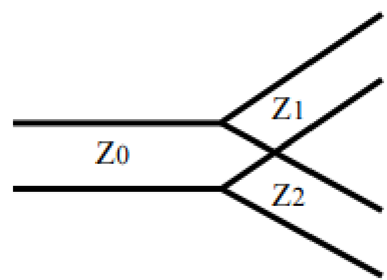

Fig. 4: Lossless T-Junction Models.

The divider, illustrated in Fig 4, is matched to the input characteristic impedance „Z0" by the following formula:

$$\frac{1}{Z1}+\frac{1}{Z2}=\frac{1}{Z0}$$

For an input impedance of Z0 = 50Ω, Z1 and Z2 = 100Ω. Quarter-wave transformers are introduced into a corporate-feed network to connect two transmission lines with different impedances together without causing an impedance mismatch. Fig 5 shows a quarter-wave transformer between the load impedance Z_L and input impedance Z_C'.

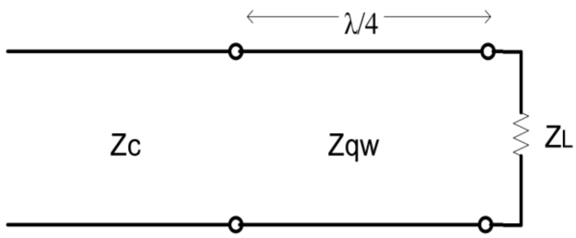

Fig. 5: λ/4 Matching Transformer.

The following formula is applicable when the transformer is a quarter-wavelength or an odd multiple of a quarter-wavelength for a perfect impedance match:

$$Z_{qw} = \sqrt{Z_c Z_L}$$

A quarter-wave transformer with the input impedance of ZC = 50Ω and load impedance of ZL = 100 Ω is equal to Z0 = 70.71Ω. These formulas explain the values used in Fig 3.

IV. Beeds In Transmission Lines

There is no best way to bend a Microstrip or stripline transmission line. The first problem is that the discontinuity changes the line characteristic impedance; without compensation, the bend adds shunt capacitance. But in reality, the small capacitance that is usually a result doesn't change the circuit's performance very much. The other problem associated with bends it can cause far more damage to the intended performance of a highly tuned circuit: the effective length of the transmission line becomes shorter than the centerline length. Show Fig 6.

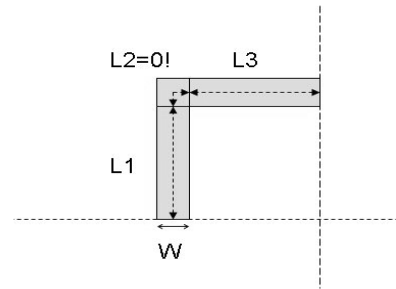

Fig. 6: Model of Corner Bend.

V. Quarter-Wave Transform

In the case of mismatch in impedance between two points on a transmission line can be compensated with a (λ/4) quarter-wave transformer [7]. The quarter-wave transformer (λ/4) is a very profitable matching technique that also explains the properties of standing waves on a mismatched line. First, an impedance-based illustration of how a quarter-wave transformer works will be qualified; then a more intuitive illustration that is similar to ruinous interference in thin films will be discussed. A quarter wave transformers (λ/4) in Microstrip are shown in Fig 7.

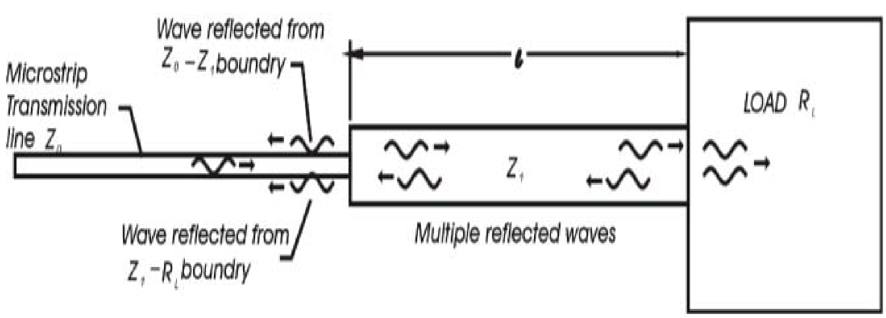

Fig. 7: Quarter wave Impedance Transformer.

In a quarter-wave transformer, a load resistance RL needs to be matched to the characteristic feed line impedance Z0 through a short length of transmission line of unknown length l and impedance. The input impedance Z1 looking into the matching section of line is given by:

$$Z_{in} = Z_1 \frac{R_L + jZ_1 \tan\beta l}{Z_1 + jR_L tan\beta l}$$

In the case of an ideal transition with no reflections at the interface between Microstrip Zin = Z0 and load, and this gives us characteristic impedance Z 1 as:

$$Z_1 = \sqrt{Z_0 R_L}$$

which is the geometric mean of the load and source impedances. From this conFig, there will be no standing

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waves on the feedline although there will be standing waves on the quarter wave transformers (λ/2) matching section. In fact, any odd multiple (2n + 1) of l= λ/4 will also work.

When the line length is precisely λ/4 the reflected wave from the load destructively interferes with the wave reflected from Z0, Z1 the interface and they cancel each other out. It should be noted that this method can only match a real load. If the load has an appreciable imaginary component, it must be matched differently. It can be transformed into a purely real load, at a single frequency, by adding an appropriate length of feedline. Fig 8 shows the complete feed network with the patches. There are many transmission lines, V grooves, power splitters, and quarter wave transformers.

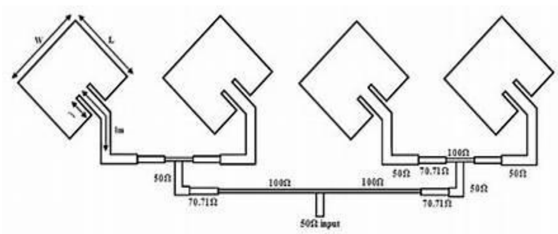

Fig. 8: Feed Network for the Array.

VI. Design Procedure

A Microstrip antennas is designed to resonate at 2.1 GHz frequency with dielectric constant εr =4.3, substrate thickness h=1.6 mm, L=50 mm, W=35 mm on a ground plane. All dimensions of the antenna are in mm. Fig 9, A.B shows the design of microstrip antenna (single and array antenna) .Table 1 shows the value of the parameter for microstrip array antenna.

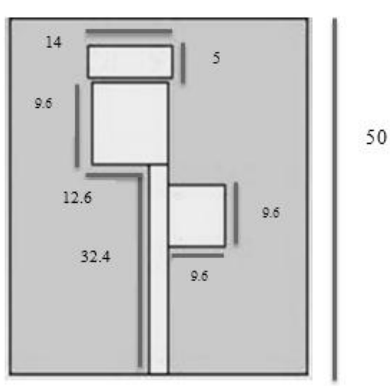

Fig. 9: (A) Suggested Single Microstrip Antenna.

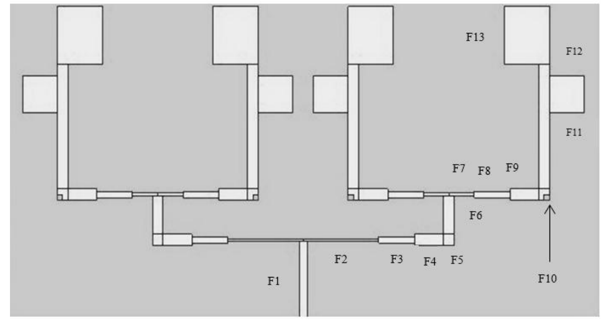

Fig. 9: (B) Suggested Array Microstrip Antenna.

Table 1: Various dimensions of patch, ground plane and corporate feed line network

1.Patch dimensions:	
Length of the patch	160 mm
Width of the patch	52 mm
2.Ground plane dimensions:	
Length of the ground plane	160 mm
Width of the ground plane	30 mm
3. Corporate feed line dimensions	
F1 feed dimensions (WxL)	(2.22*19.8
F2 feed dimensions (WxL)	(0.67*21) mm
F3 feed dimensions (WxL)	(1.6*10) mm
F4 feed dimensions (WxL)	(3*8) mm
F5 feed dimensions (WxL)	(3*3) mm
F6 feed dimensions (WxL)	(3*10) mm
F7 feed dimensions (WxL)	(0.67*7) mm
F8 feed dimensions (WxL)	(1.6*10) mm
F9 feed dimensions (WxL)	(3*8) mm
F10 feed dimensions (WxL)	(0.67*0.67) mm
F11 feed dimensions (WxL)	(3*42) mm
F12 feed dimensions (WxL)	(9.6*9.6) mm
F13 feed dimensions (WxL)	(9.6*9.6) mm

VII. Simulation Results for Single and Array Antenna

Fig 10 (A, B), shows the return loss of the single element antenna and Array antenna. From the diagram it has been observed that the value of return loss is -24.44 dB at 2.1 GHz with bandwidth equal to 339MHz for a single and return loss is -18.65 dB at 2.1 GHz with bandwidth equal to 181MHz for an array. This parameter is determined that how well devices are matched. A match is good if return loss is high in negative value.

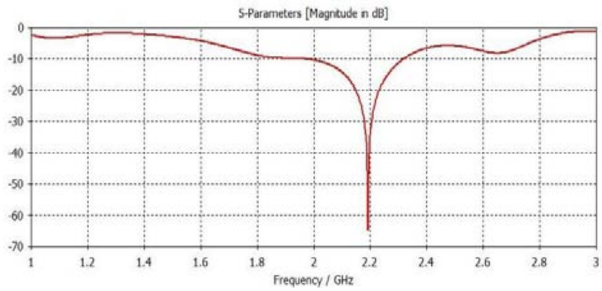

Fig. 10: (A) Return Loss for a Single Antenna.

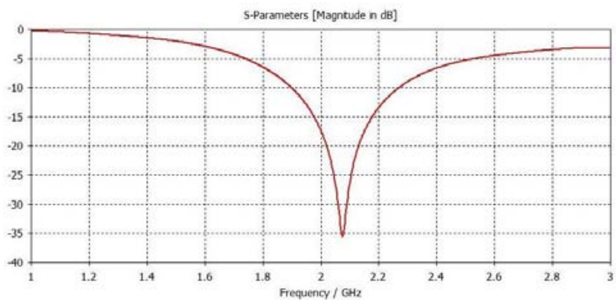

Fig. 10: (B) Return Loss for an Array Antenna.

Fig 11 (A), (B), shows the input impedance of the suggested single and array antenna. The real impedance nearest from 50Ω and the imaginary from 0Ωand also the real impedance of the array nearest from 50Ω and the imaginary from 0 Ω and this means that the antenna has a good matching.

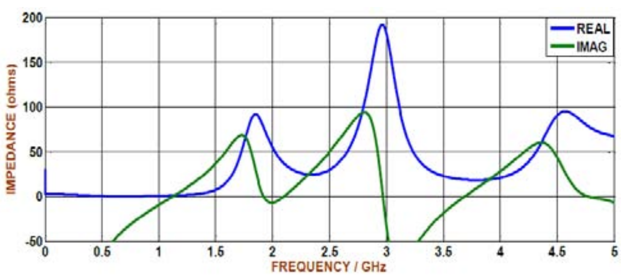

Fig. 11: (A) Input Impedance of Single Antenna.

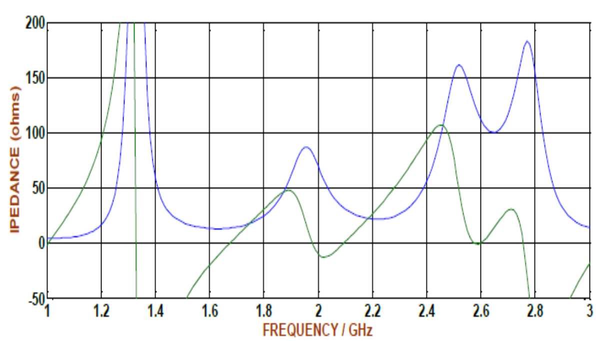

Fig. 11: (B) Input Impedance of Array Antenna.

Fig 12 (A), (B), shows the gain versus frequency for the single and array antenna. The gain of the antenna is the quantity which describes the performance of the antenna or the capability to concentrate energy through a direction to give a better picture of the radiation performance. In this suggested design we obtained gain are 2.2 dB and 8.5dB respectively.

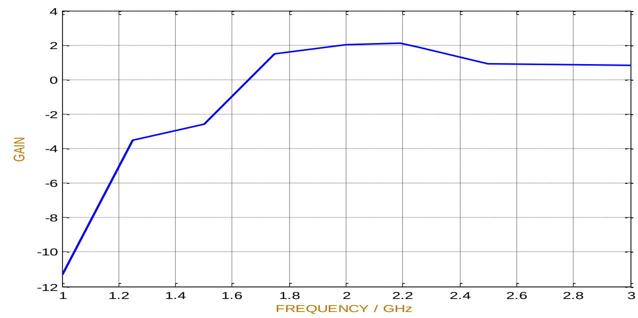

Fig. 12: (A) Gain of a Single Antenna.

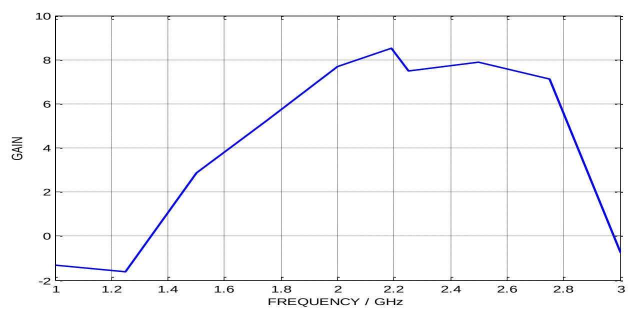

Fig. 12: (B) Gain of an Array Antenna.

In this design we obtained the directivity for the single and array antenna. The directivity of a single and the array are 2.235 dBi and 8.955 dB respectively. Show Fig 13 (A), (B).

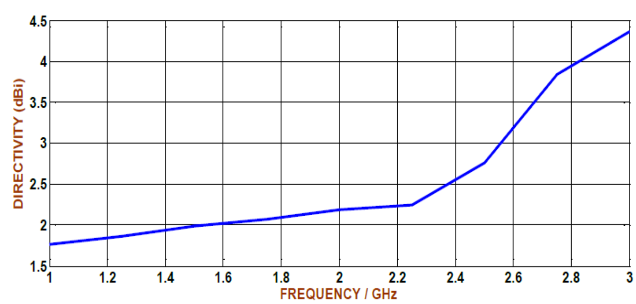

Fig. 13: (A) Directivity of Single Antenna.

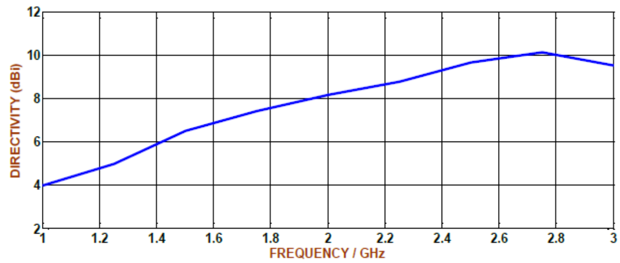

Fig. 13: (B) Directivity of Array Antenna.

Fig 14 (A), (B), shows the efficiency of the single antenna and array antennas. From fig. 12 the efficiency of single antenna is 94% at 2.1 GHz and the efficiency of array antenna is 82%.

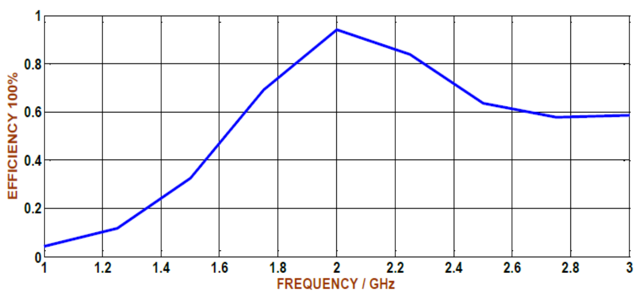

Fig. 14: (A) Efficiency of Single Antenna.

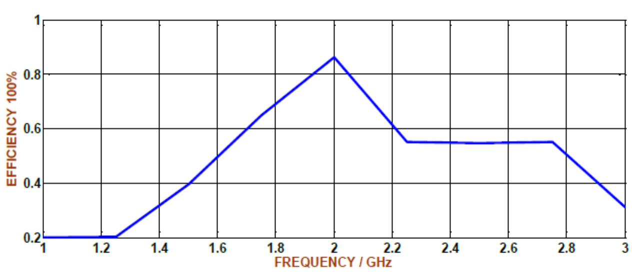

Fig. 14: (B) Efficiency of Array Antenna.

The 2D far - field radiation patterns at E – plane (x-y plane) and H - plane (x- z plane) for the center frequency of single antenna and array antenna are plotted in Fig 15 (A), (B). The simulated results show that the radiation patterns at single and array antennas are similar to that of a conventional simple monopole antenna radiation patterns. Established on these radiation patterns, the proposed antenna demonstrate omnidirectional radiation characteristics in the E-plane, and broadside radiation characteristics in the H-plane at the considered frequencies.

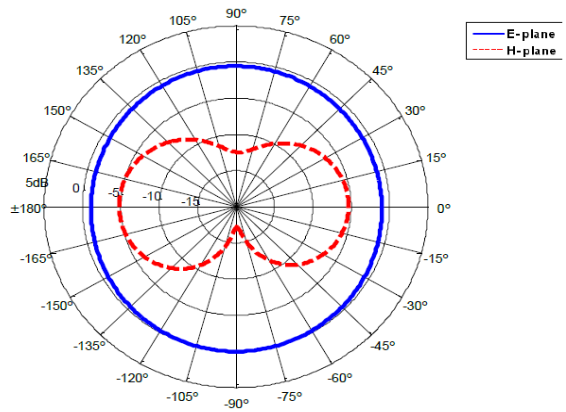

Fig. 15: (A) Radiation Pattern of Single Antenna.

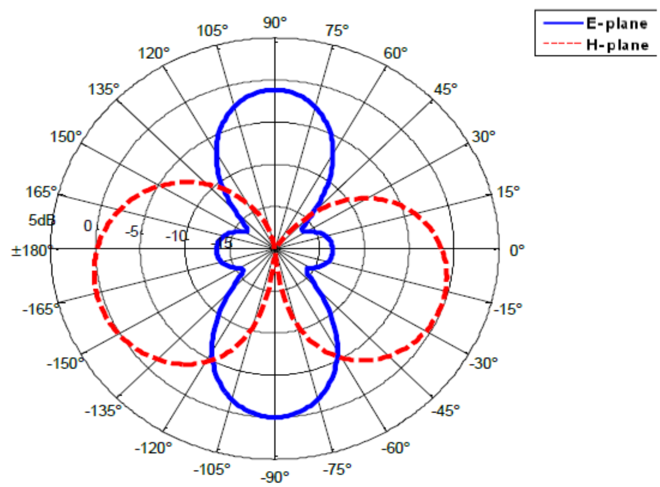

Fig. 15: (B) Radiation Pattern of Array Antenna.

VIII. Manufacturing Of Array And Single Microstrip Antenna

In this section I will manufacture the array and single antenna, and then I obtained the practical results of the antennas in the laboratory after the manufacturing and compare with simulation results. In the Fig 16 you can see the final prototype of antennas after manufacturing by using CNC machine. Been connect Transmitting (Array Antenna) and Receiving (Single Antenna) as shown Fig 17.

Fig. 16: Manufacturing of Antennas.

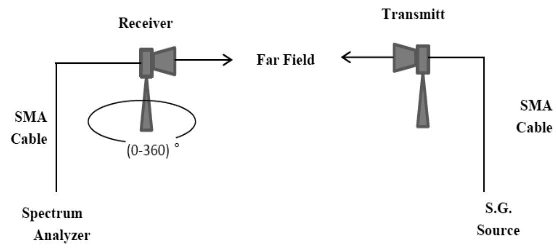

Fig. 17: Connection methods inside of lab.

IX. Radiation Pattern Measurments

Radiation patterns measured in side anechoic chamber. Practically, Radiation patterns measured on two planes (E- Plane & H- Plane). The practical results of radiation patterns for two cases (array and single) are approximately similar to theoretical results. Fig 18 shows the comparison between the practical and theoretical results for the single patch antenna.

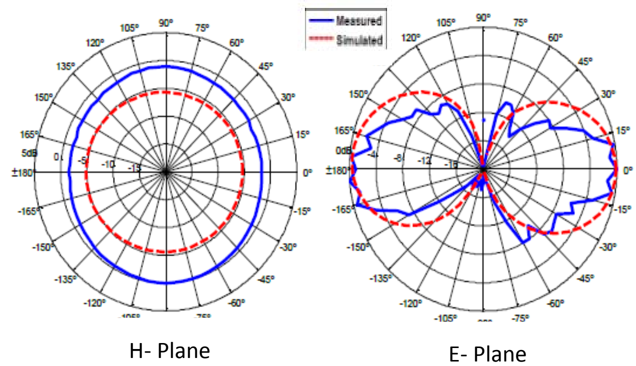

Fig. 18: Compare between the practical and theoretical Radiation patterns results for single.

Fig 19 shows the practical and theoretical radiation patterns for Array Antenna

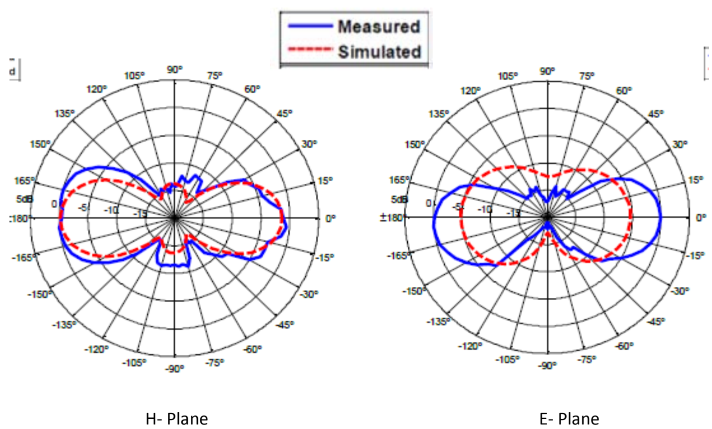

Fig. 19: Compare Between the Practical and Theoretical Results for Array.

X. Gain Measurements

To gain measurements, we use the friis formula.

$$P_r = P_t G_t G_r FSL$$

By writing the Friis formula as (dB), we obtained:

$$P_r = P_t + G_t + G_r - FSL$$

$$FSL = 20\log(\frac{4\pi D}{\lambda})$$

Where FSL is Free Space Loss. Pr, and Pt are received and transmitted power respectively. Gr and Gt are received and transmitted Gain respectively. D, the distance between transmitter and receiver, λ is Wavelength. From the measuring the transmitted and received power

Table 2: Comparison Between Simulated and Measuring Gain

Antenna	Simulated gain (dB)	Measuring gain (dB)
Single Microstrip Antenna	2.206	2.04
Array Microstrip Antenna	8.506	8.313

XI. Conclusion

In this research, single and four elements Microstrip patch antenna array by corporate (parallel)-feed network at 2.1 GHz application are presented. This suggested array antenna is investigated and successfully simulated in this research; the simulated return loss, radiation pattern and bandwidth showed well performance for the single antenna at 2.1GHz. They investigate higher directivity, gain and better bandwidth with practical technology and theoretical analysis. The results of the array antenna are compared with those of single antenna of novel patch Microstrip antenna. It is found that there is an important change in the radiation features of array antenna. It can be concluded from the top results that, designing a proper feed network and impedance matching are very important parameters in Microstrip patch antenna design (single and array). Selection a proper position for ending the feed line affects the overall performance of the antenna. The simulation results show return loss of -64.45 dB for the array antenna and -36.44 dB for the single antenna.

From the results, it is seen that the suggested array and single antenna achieve good value of directivity, gain performance and the antenna has good bandwidth, this makes the suggested antenna design suitable for use in the 2.1GHz applications as a transmitting and a receiving.

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