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Review and Analysis of Microstrip Patch Array Antenna with different configurations

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Abstract - Microstrip patch antenna in wireless communication is gaining importance as a most powerful technological trend. Its immense potential promises significant change in near term future of wireless application fields. Current technological trend has focused much more attention towards microstrip patch antenna. Single microstrip patch antenna has some advantages (low cost, light weight, conformal & low profile), but it has little disadvantages too- like low gain, low efficiency, low directivity and narrow bandwidth. These disadvantages can be overcome by implementation of many patch antennas in array configuration. Here term array stands for geometrical and electrical arrangements of patch elements. As we increase number of patch elements to form an array, improvement in performance is observed. In this review paper, performance characteristics for 2, 4, 8, 16 patch elements configured in 2x1, 2x2, 8x1 and 4x4 (respectively) array format has been analyzed and compared.

Index Terms- Microstrip Patch antenna, Array, Feed Mechanism, Impedance Matching, Return Loss, Radiation Patterns, Gain, Directivity and Bandwidth.

1. INTRODUCTION

Microstrip patch antenna is a single layer design which contains mainly these four parts - Patch, Ground plane, Substrate and Feeding part. It is very simple in construction using conventional microstrip line feed. Patch can be given any shape but rectangular and circular configurations are mostly used. Ground Plane can be finite or infinite according to model (Transmission line - model, cavity model, full wave Model or method of moments) used for analysis of dimensions [1-4].

Relative Permittivity and height are two important characteristics for substrate, Feeding Part can be implemented in these ways - Microstrip line, coaxial probe, Aperture coupled and Proximity coupled Feed [5].

An Antenna is an essential component in Radio communication system that is needed in both transmitting and receiving terminals. Each type of antenna is good in its own way with different uses and properties. Microstrip patch antenna array is set of two or more patch elements. Signals from the individual patch elements are processed-in order to achieve improved performance over single antenna. To obtain highly directive Patterns, it is required that fields from elements of array are added positively in desired direction and cancel each other in other directions [6].

When the patch is excited by the Feed mechanism, charges are accumulated at edge of the patch. These charges create fringing fields and these fringing fields at edge of microstrip antenna add up in phase and produce radiation of the microstrip antenna [7-8].

2. MICROSTRIP PATCH AND OPERATION

Microstrip antenna is also known as Patch antenna. Fig.1 shows structure of patch antenna with 3 axes X, Y, Z. it has 3 layers: top layer is the Patch, middle layer is substrate (with suitable height and dielectric constant), and bottom layer is the ground.

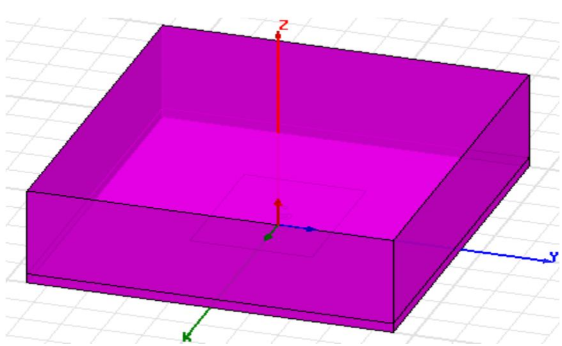

Fig.1 Microstrip patch antenna.

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Three essential parameters for operation of microstrip patch antenna are : frequency of operation (resonance frequency), relative permittivity (dielectric constant) of substrate, height of substrate (h).after these three parameters length, width, input impedance of the patch and fed dimensions are evaluated. Then performance of antenna i.e. Radiation pattern, S parameter, Efficiency and Reflected loss is obtained by simulating it on software [9-14].

3. PATCH ARRAY ANALYSIS

3.1. Design and analysis of 2x1 Array

Here 2x1 (2 elements) Array configuration has been designed & analyzed at 2.4 GHz for wireless application field.

Rectangular microstrip Patch antenna has been taken here for 2x1 Array arrangements. Resonance frequency (f0)=2.4 GHz, Relative Dielectric constant (Єr)=2.2 and height of substrate (h) is 1.588 mm.
Dimensions for single patch Element are shown below [6].

- The width of the patch W = 49.41069.
- Effective Dielectric Constant of the patch = 2.11106.
- Extension of the patch length, ΔL of the patch = 0 .2885 mm.
- Actual length of the patch, L = 41.35621 mm.
- The value of the y_0 = 10.457 mm.
- Input impedance of the patch Z_{in} = 204 Ω.

Above dimension is used for both elements in the array. Formation of an array requires feeding arrangement with proper impedance matched network (as shown in fig.3) Inset Fed has been used here, dimensions for feeding line are: width (w_1) of 50 ohm impedance line is 4.8125 mm and of 100 ohm (w_2) is 1.4079 mm.

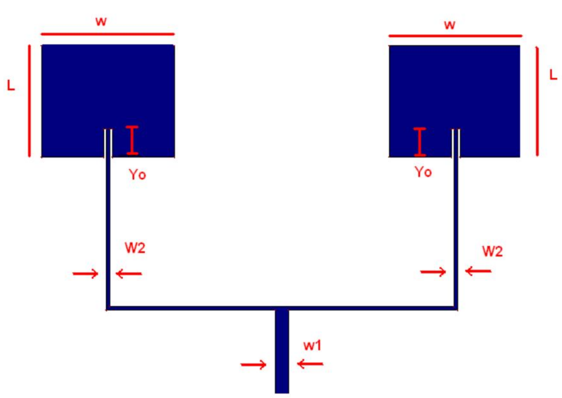

Fig.2 design for 2x1 arrays [9].

After simulating this 2x1 array on software S-parameter & Radiation patterns are obtained which are shown in fig.3 and Fig.4.

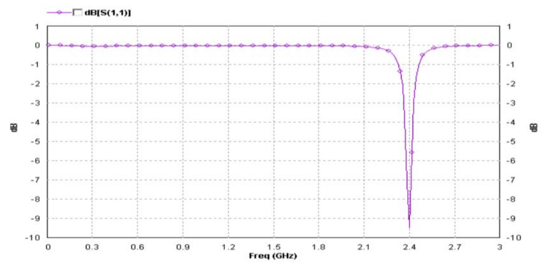

Fig.3 S Parameter for 2x1 arrays [9].

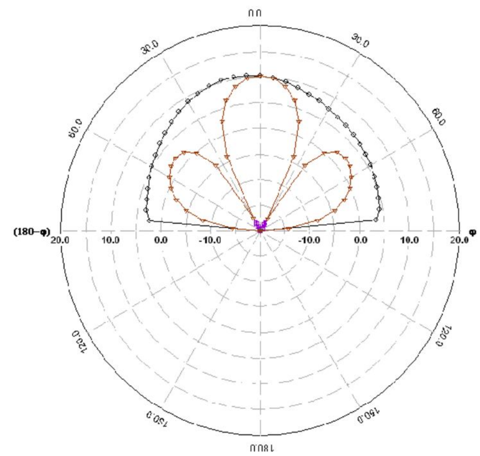

Fig.4 Radiation Pattern for 2x1 arrays [9].

As we see from above graphs Return loss achieved is -9.5 dB and obtained Gain is 9.186 dB.

3.2. Design and analysis of 2x2 Array

A multi element microstrip patch antenna array applicable to WLAN/MIMO has been designed here which operates at 2.45 GHz frequency band [10].

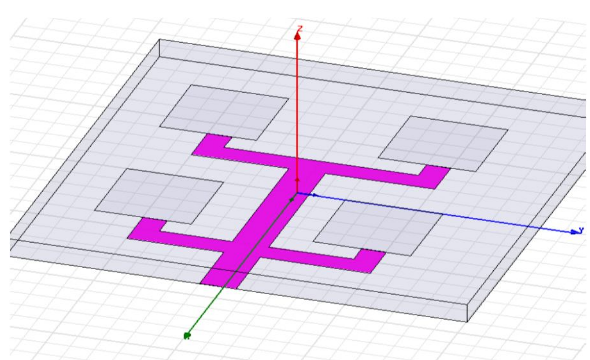

Fig.5 Geometry of 2x2 arrays with feed point [13].

Geometrical arrangement of 2x2 arrays (4 elements) is shown in Figure 9. Dimensions of Patch element is taken as: length (L) = 24.6 mm, width (W) = 19.8 mm, Resonance frequency = 2.45 GHz, relative permittivity=10, h=1.5875. Distance between antenna element is set at 6.2 cm. antenna is fed by 50 ohms coaxial probe through a connector [10].

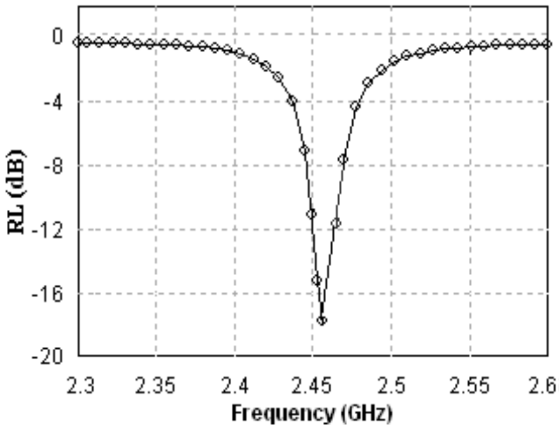

Fig.6 Return loss for 2x2 array [10].

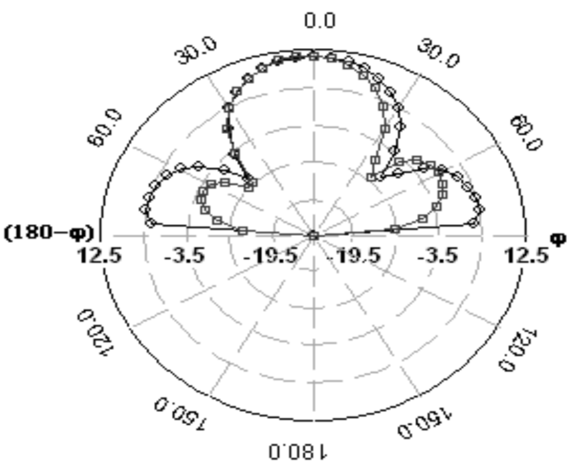

Fig.7 E-plane & H plane for 2x2 array [10].

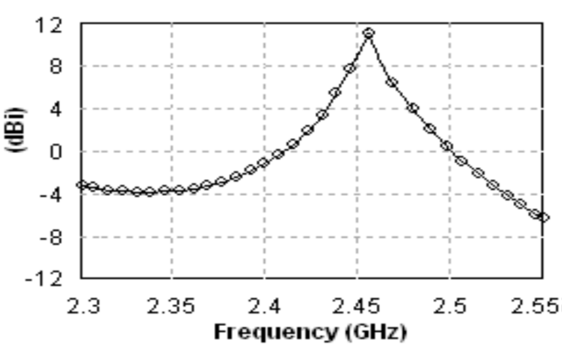

Fig.8 Total field gain vs. frequency for 2x2 array [10].

Fig.(6, 7 & 8) shows Return loss, Radiation pattern and total field gain for 2x2 Array.

With proposed 2x2 array 11.80 dbi peak gains is achieved. Simulation gives 25.24 db band-widths centered at 2.4546 GHz for VSWR lower than 1.5. Antenna array shows good radiation efficiency at WLAN band (2.40-2.48 GHz [10].

3.3. Design and analysis of 8x1 arrays

An array with 8 elements configured in an 8x1 is designed here. With this large antenna array narrow beams are obtained which are applicable for direction accuracy in wind profiling Radars [11].

Here an 8x1 linear array (8 elements) has been designed. First step in design is to specify dimensions for single patch; here single patch taken is square patch. Dimensions for this square patch are: operating frequency=1.28 GHz, relative dielectric constant (Єr) is 2.2, height of substrate (h)=3.175 mm, w=7.6 cm and a=9.5 cm [11].When inter-element distance is selected to be 0.73λ, 8x1 arrays satisfies initial design requirements (Beamwidth = 9 degree & operating frequency=1.28 GHz).

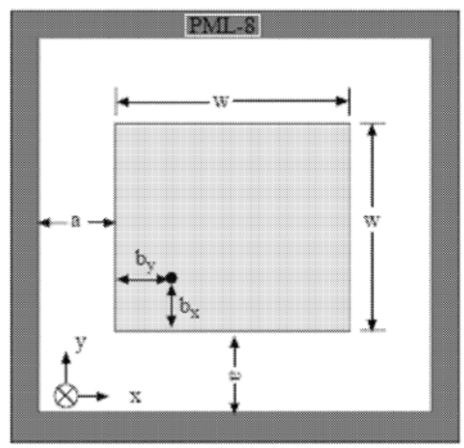

Fig. 9 Square patch element used for 8x1 arrays [11].

With all above shown specifications an 8x1 Array is formed and simulated on software, after simulation obtained results are shown in fig.11 & Fig.12. Fig.11 shows total field gain obtained at 1.28 GHz frequency and fig.12 shows radiation patterns obtained (E plane & H plane).

Fig.12 (a) shows E field at 1.28 GHz for 8x1 arrays with phi=0 degree and Fig.12 (b) shows E field at 1.28 GHz for 8x1 arrays with phi=90 degree.

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An 8x1 array has been designed; maximum gain reaches to 16.75 dbi at 1.28 GHz (Fig.11), antenna exhibits 20 MHz bandwidth and beam-width achieved is 9 degree [11].

Fig. 10 an 8x1 array formed with square patch [11].

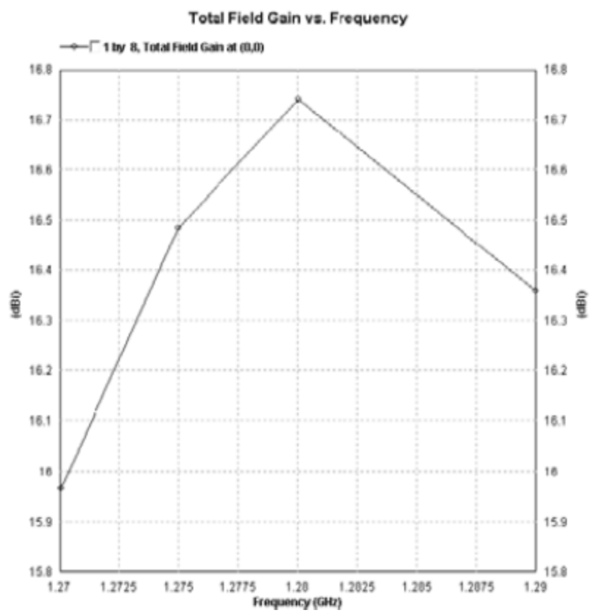
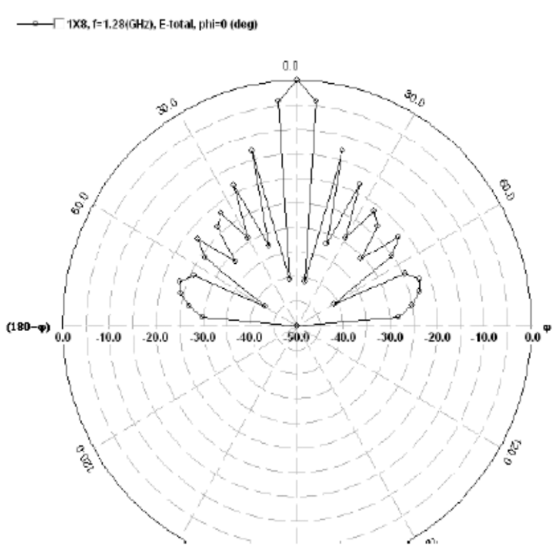
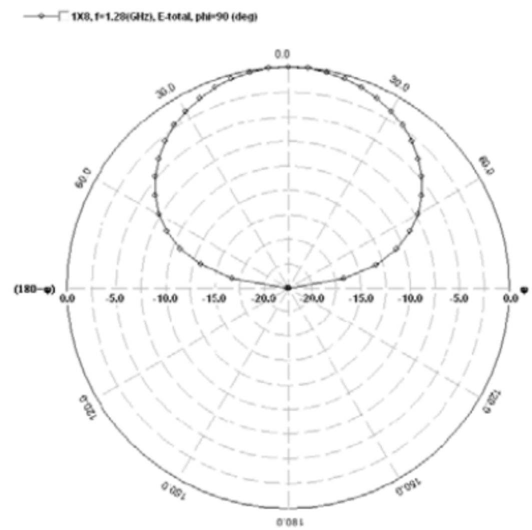


Fig.11 Gain vs. frequency for 8x1 arrays.



(a)



(b)

Fig.12 (a) and (b) shows radiation pattern of 8x1 arrays that operate at 1.28 GHz [11].

3.4. Design and analysis of 4x4 Array

4x4 (16 patch elements) microstrip patch antenna array is designed with operating frequency at 5.8 GHz for point to point communication. WLAN Point to Point application is based on IEEE 802.11a standard and operates in upper unlicensed national information infrastructure band [12].

Fig.13 shows configuration of 4x4 patch antenna array. Dimension for single patch is 15.5 mm x11.5 mm, with inset feed at 4.3 mm; width of transmission line is 3 mm. A co-axial feed is connected to center of array from other side of substrate. Quarter wave transformer impedance matching and power divider section is used to provide power to each element of the array. Here for 50 ohms input line a 3 db power divider can be made using two 100 ohms lines [12].

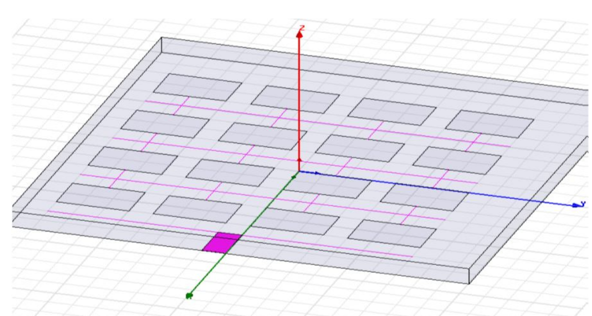


Fig.13 4x4 Patch antenna array [12]

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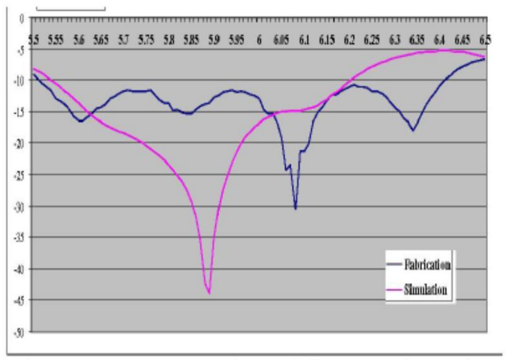
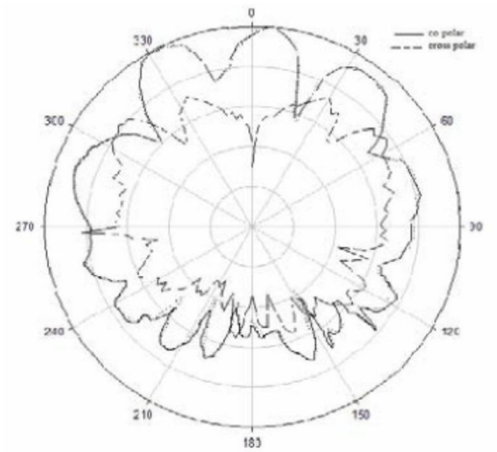
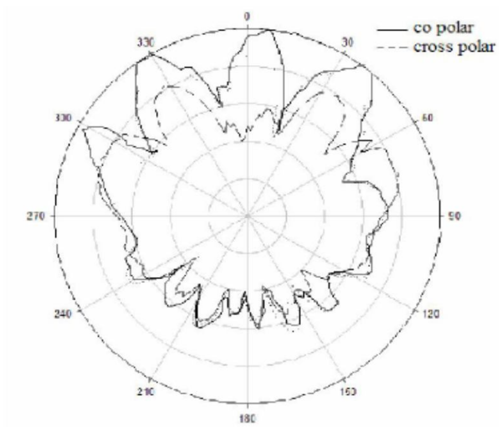


Fig.14 Return loss for simulation and fabrication of 4x4 array [12].



(a)



(b)

Fig.15 a) E-plane b) H-plane [12].

Simulation result gives a return loss of -43 db at 5.88 GHz, Bandwidth achieved is 15%. Half power beam-width obtained from E-plane and H-plane radiation pattern is 8.92 degree & 9.33 degree respectively. Gain obtained from E-plane and H-plane radiation pattern is 16.071 db. Thus 4*4 array of microstrip antenna with inset feed has been designed and return loss of the antenna array is within designed frequency band [12].

4. RESULTS AND DISCUSSION [9-12]

S.N.	Array Type	Obtained Output
1.	2x1 (2 elements)	At 2.4 Ghz, Return loss = -9.5(dB), Gain = 9.186 (dB).
2.	2x2 (4 elements)	At 2.45 GHz, Return loss= -18.05 (dbi), Gain = 11.80 (dbi), V.S.W.R. = 1.35 & bandwidth for return loss > 9.5 db is 25.24 dB.
3.	8x1 (8 elements)	Bandwidth = 20 MHz, maximum gain =16.75 dbi at 1.28 GHz, beam-width = 9 degree.
4.	4x4 (16 elements)	Return loss up to -43 dB at 5.88 GHz, Bandwidth obtained = 11%, Gain = 16 dB & H.P.B.W. (half power beamwidth) = 9 degree.

Table 1 shows obtained output from 2x1, 2x2, 8x1 and 4x4 Arrays [9-12].

- If we are increasing number of patch elements in the array Gain is enhanced so directivity will also be improved.
- Return loss up to -43 dB has been achieved with 16 elements in 4x4 arrays.
- Element spacing is nearer in 4x4 arrays as compared to 2x1, 2x2 and 8x1 array, so mutual coupling loss is more in 4x4 Arrays.
- Proper impedance matching is required for feeding network arrangement. If we are using large number of patch elements in array then we will be needed more calculations for length & width of impedance line. So complexion increases for feed network with increase in number of patch elements in arrays.
- Power consumption is more in 4x4 arrays as compared to smaller arrays(2x1(2 elements), 2x2(4 elements), 8x1(8 elements).

5. CONCLUSION

Microstrip Patch antenna configured in an array format with different number of patch elements has been analyzed. Larger number of patch antenna elements, better gain of antenna array is achieved. Return loss up to -43 dB has been achieved by 4x4 arrays at 5.8 GHz. Improved Bandwidth, Directivity and radiated power is also achieved by implementing more number of patch elements in the arrays. Here 2x1, 2x2 and 4x4 patch arrays are inset fed so further analysis work would be done by inserting coaxial feed to these arrays. Due to its small size, light weight and conformal properties, these analyzed microstrip patch antenna arrays are useful for WLAN/MIMO and 3G communication systems.

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