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Research paper

Design of array antenna for wireless communication

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Abstract

As antenna plays a major role in communication, it paves a way towards wireless communication. Use of antenna array in wireless communication for different application is the focused area of research in current years. In this paper, an attempt is taken to design an antenna array with rectangular parasitic patches around the modified rectangular patch at the centre. The gap is maintained within the central patch. Further to achieve better performance, optimization of the parasitic elements is considered. Using popular genetic algorithm the patch dimensions are optimized. The performance in terms of bandwidth, gain and return loss found better than the un optimized design. The result shows the efficiency and observed.

Keywords: *Array Antenna; Patch; Optimization; Bandwidth*

1. Introduction

In the recent years wireless communication plays a vital role in transmission of data in the form of voice, image etc. due to the recent development in the mobile technology. Microstrip antenna plays a vital role in wireless communication as being used in military, radar and satellite communication due to its light weight, small size, and good bandwidth. Its limitation includes low impedance gain, low efficiency are the challenges for researchers. Since last decades numbers of micro strip antennas are designed and were utilized in wireless communication. Microstrip antenna was designed considering different shapes of the patches and slots such as rectangular, circular, and triangular to enhance the performance of the antenna [1-3]. Author also suggested the application of patches in different area such as circular patch having less area but complicated to design as compared to triangular patch [4]. In the recent years microstrip antenna are analyzed to improve its performance resulting the use of array to enhance the bandwidth [5]. Another possible design of antenna was proposed consisting of patches of different shape where the effectiveness of the patch is decided by the geometry and the substrate material [6-8]. Authors also proposed a comparison of performance of rectangular and circular patches to be used in wireless communication [9]. In [10], authors projected a method to enhance the bandwidth of microstrip patch antenna through parasitic patch where the patches are positioned head-to-head to the radiating patch along with the slots. The results claimed that the design was suitable for X-band applications. Similarly, many researchers in recent years focused on variation of geometry and use of parasitic elements. Some of them also analyzed the feeding type and position to enhance the result [11].
The paper organization is as, Section I introduces the effectiveness of the work along with some related literatures. Section II described the design method of the antenna. Section III explains the optimization used to design the antenna Section IV discusses the result and Section V concludes this piece of work.

2. Antenna design

2.1. Design of proposed array antenna

The dimensions of the antenna can be extended without increasing the size of the antenna by the geometrical arrangements associated with the shape of the radiating components. Array (multiple component) are considered in this proposed method to shape the antenna. These elements are basically the vector addition of the fields and determine the total array field with an assumption that each element and the remote element produce the same current. To convey the directive shapes, it is necessary to interfere constructively the field components whereas the rest interfere destructively. In this design, eight identical elements (parasitic patches) are used to form the antenna array. The excitation amplitude, phase and relative pattern of the individual components are considered as the geometrical structure of the array. Furthermore the comparative dislocation between the elements plays an important role.

2.2. Effect of parasitic patches

The resonance frequency of the antenna is less affected by the change in the width of the patch. But the performance characteristics of the antenna such as gain, directivity, bandwidth and efficiency increases with the change in the width of the parasitic patch as well as the side lobe level. The beam width of the E plane decreases keeping the H plane unaffected. The square patch has the maximum impedance bandwidth.

2.3. Design formulation

For rectangular patch antenna, the patch length is L , dielectric constant is $\in_r$, Light speed is c ,Resonant frequency is f_r Wavelength is λ , The rectangular patch width W_o and the dielectric thickness H_o

Then,

$$W_O = \frac{c}{2f_1} = \left(\frac{\in_r + 1}{2}\right)^{-1/2} \qquad (1)$$

$$L = \frac{C}{2\sqrt{\in_r} + f_r} \qquad (2)$$

The effect of dielectric is given by [26]

When $\left(\frac{W_O}{H_O}\right) \le 1$

$$\in_r = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[\left(1 + 12\left(\frac{H_0}{W_0}\right)\right)^{-1/2} + 0.04\left(1 - \left(\frac{W_0}{H_0}\right)\right)^2\right] \qquad (3)$$

When $\left(\frac{W_0}{H_0}\right) \ge 1$

$$\in_e = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left(1 + 12\left(\frac{H_0}{W_0}\right)\right)^{-1/2} \qquad (4)$$

The proposed gap coupled antenna is displayed in Figure.1and Figure.2. The ground is considered to be a square one where the microstrip patch antenna which was probe fed is located at the centre of the antenna and gap fixed with the other patches. The centre patch was cut diagonally at the two corners. The other parasitic patches are square of different dimension in the given design. The feed point position is nearer to the upper cut of the patch. In the proposed work a 3X3 antenna array is designed having dimension of array to be 30X30(mm). The central patch of the array is of dimension of 11X11(mm). The patch is gap coupled with the other square patches of the array. The parasitic square patches are of different dimension. The dimension of the patches is generally represented as having dimension of dXd. The design of the antenna is realized with ANSOFT HFSS.

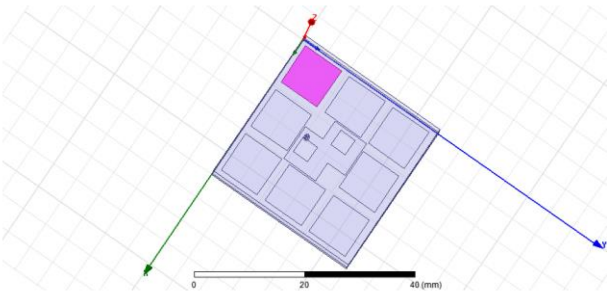

Fig. 1: Geometry of Unoptimized 3X3 Array.

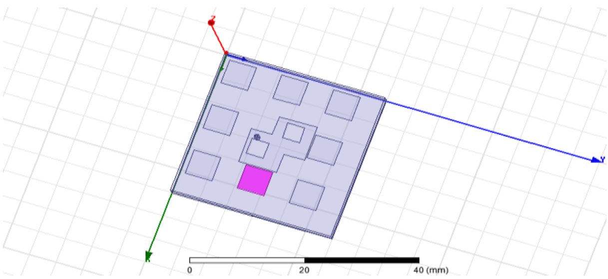

Fig. 2: Geometry of Uptimized 3X3 Array.

3. Optimization using GA

In this paper the dimension of the single patch has been optimized using EA. The patch is repeated in the antenna array of 3X3. The parasitic patch dimension is optimized using the Evolutionary Algorithm which is considered as genetic algorithm based optimization. The GA is very accurate and fast as compared to other techniques because here optimization is done with the en-coded parameters generated by the GA. The Genetic Algorithm is based on the theory of evolution strong ones survive but weak species face the extinction and bypass their genes to the next generation. But for the strong species to survive it is highly required to have random addition of genes. GA is mainly implemented using MATLAB. The step by step procedure of generating the software program is shown below [12]:

Step 1: A fixed number of binary digit are assigned to each variable as a result the final solution contain the required accuracy of the variable

Step 2: All the variables in their binary form are grouped into a sequence known as chromosome.

Step 3: The current generation is based on the selection of a fixed number of random chromosomes known as a population out of all possible number of chromosome present by using the Mat lab software..

Step 4: The objective function(O) and the relative fitness of each chromosome(C_i) is evaluated by converting the digital value of each variable in a chromosome to an analogue value,. This relative fitness is defined as

$$O = \sum eval[C_i] \qquad (5)$$

Step 5: For the production of new off spring cross over is applied for random chromosomes between the parent and next generation

Step 6: the mutation of the population is done by considering the value of genes with least significant bit with highest probability of mutation and the most significant as the lowest probability. As a result the next generation becomes the parent one. This process is repeated until the genetic variation of the population fall below a certain threshold value. The cross over rate and the mutation rate are gradually decreases with increase in the number of generation.

The genetic algorithm contain the solution to a given optimization problem for a population of encoded candidate. The antenna parameter design based on the optimization technique is given as follows [2, 12]:

Step-1

The center frequency, dielectric constant and height of substrate(substrate thickness) are used initially.

Step-2

The width(W) and the length(L) of the patch calculated is used for design of parasitic patch of the array .

Step-3

The performance of the patch antenna designed is analysed in terms of return loss.

Step-4

The proposed antenna is optimized for a return loss more than -20dB. Otherwise go to Step-3.

4. Result discussion

The results of the proposed design are given in the following figures. The Fig3, Fig.6 represents the VSWR of the antennas. The Fig.4, Fig.7, represent the Impedance bandwidth of the antennas. The Fig.5, Fig.8 represents the radiation pattern of the antennas.

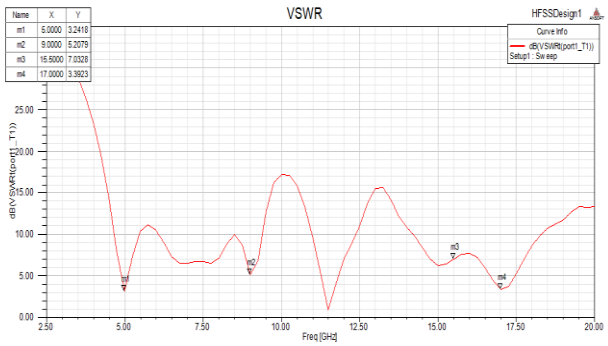

Fig.3: VSWR Plot of Unoptimized 3X3 Array.

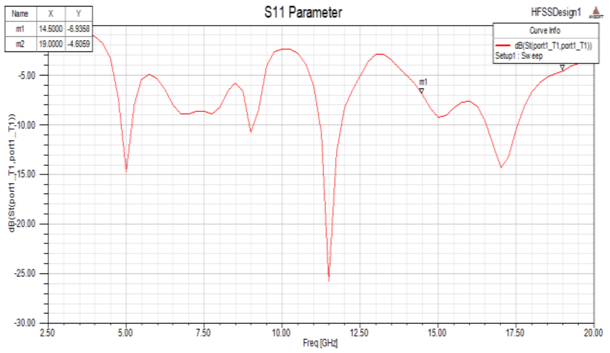

Fig. 4: Impedence Bandwidth Plot of Unoptimized 3X3 Array.

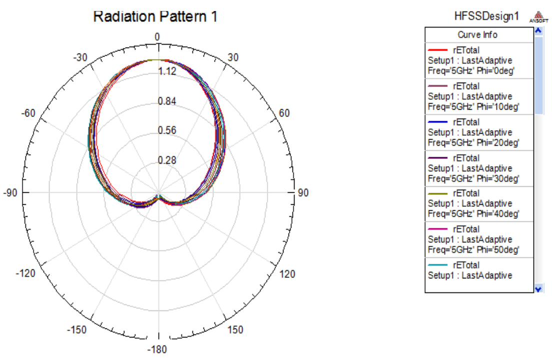

Fig. 5: Radiation Pattern of Unoptimized 3X3 Array.

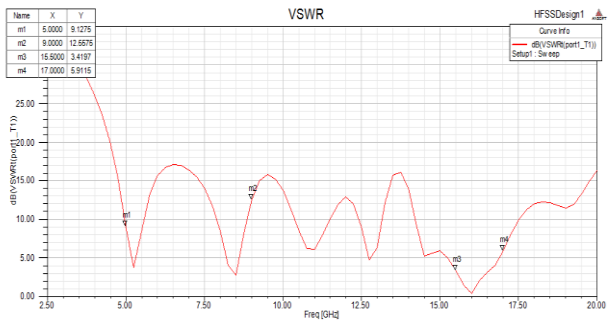

Fig. 6: VSWR Plot of Optimized 3X3 Array.

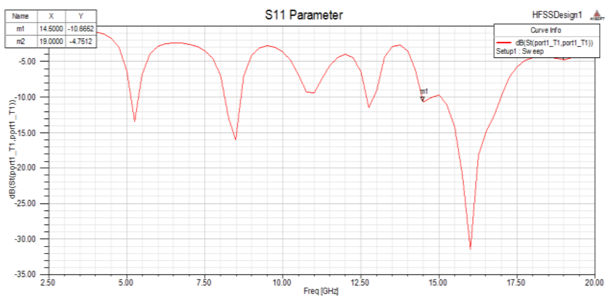

Fig. 7: Impedence Bandwidth Plot of Optimized 3X3 Array.

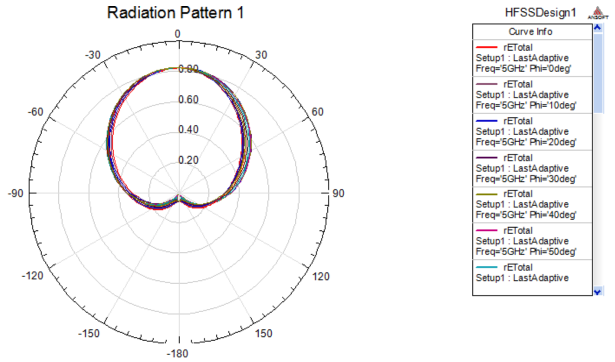

Fig. 8: Radiation Pattern of Optimized 3X3 Array.

The VSWR of an antenna must be in the range of 1-2. Fig. 3, Fig.6 represent the VSWR of the antenna designs. The antennas converges at different frequencies but it result in a better VSWR value in the 15GHz to 17.5 GHZ range.When we compare the differnt designs in the respective range,the design having parasitic patch of dimension 5X5(mm) has impedence bandwith of of 2GHz as compare to the other different design .The return loss of the proposed antenna is calculated as 31dB. The antenna is suitable for operating in the higher frequency range.

Table 1: Optimized Dimension of Parasitic Patch Parameter

P Parameters	Non-Optimized Results	Optimized Results
Substrate Material	Fr4 Epoxy(Dielectric Constant=4.4)	Fr4 Epoxy(Dielectric Constant=4.4)
Loss Tangent	0.02	0.02
Substrate Length	30mm	30mm
Substrate Width	30mm	30mm
Substrate Thickness	1.6mm	1.6mm
Length Of Centre Patch	11mm	11mm
Width Of Patch	11mm	11mm
Length Of Parasitic Patch	8mm	5mm
Feed Type	Coaxial Feed	Coaxial Feed

Table 2: Performance Analysis

	Return loss (dB)	Bandwidth (GHz)
Un optimized	-14	1
Optimized	-31	2

5. Conclusion

The simulation of the rectangular microstrip patch antennas arrays are analyzed and observed. A 3X3 array antenna is designed considering the parasitic patches to be rectangular patches of different dimensions. The rectangular parasitic patches are compared with each other to get a better performance. Though we compare the rectangular patches the patch having parasitic patch of dimension 5X5 (mm) has a return loss of 31dB and bandwidth of 2GHz. The outcome specify that the proposed antenna with small dimension will perform better in the desired frequency range as compare to the other antennas in the same design process.

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