DESIGN OF RECTANGULAR PATCH ANTENNA ARRAY USING ADVANCED DESIGN METHODOLOGY

[1]Abishek S, [2]Kaushik Ram S
Department of Electronics and Communication,
PSNA College of Engineering and Technology, Dindigul, INDIA

Abstract

Array antennas are used extensively in remote sensing applications, where a highly directive beam is needed to scan a particular area of interest on the surface of the earth. The study focuses on the design of two different microstrip patch antenna arrays to be used in environmental sensing applications in the ISM frequency bands. Arrays of microstrip patches are easily printed on substrates using photolithography techniques and can be mass produced at cheap costs. In this project we have implemented two types of array model using rectangular patch. Specifically, 1X2 and 2X2. This study includes design of feedback network, impedance matching, and return loss calculation. The substrate used is FR4 with dielectric constant of 4.6 and thickness about 1.6mm. The feed network is designed and optimized using ADS 2013 and then integrated with the array.

Keywords: Feedback network, Quarter wave Transformer, Radiation Pattern, Return loss.

1. Introduction

A microstrip or patch antenna is a low- profile antenna that has a number of advantages over other antenna. It is lightweight, inexpensive, and easy to integrate with accompanying electronics. There are different kind of shapes to construct a single patch antenna. Among them, the shape which adopt the needs can be separable. We choose rectangular patch model. In order to build an array structure, single element is designed with at most care. The application software Advanced Design system has sufficient required simulation techniques to check the antenna parameters. The same result can be compared with the testing equipment, vector network analyzer of Agilent.

2. Single element design issues

A microstrip antenna element can be used alone or in combination with other like elements as part of an array. In either case, the designer should have a step-by-step element design procedure. Usually, the overall goal of a design is to achieve specific performance at a stipulated operating frequency. If a microstrip antenna configuration can achieve these overall goals, then the first decision is to select suitable antenna geometry.

3. Single patch dimension

Selecting an appropriate substrate of thickness (h) and dielectric constant (ε_r) for the design of the patch antenna. In present case, we shall use following Dielectric for design: Height: 1.6 mm. Metal Thickness: 1.4 mil (Copper i.e. 35um), Er: 4.6, TanD: 0.001, Conductivity: 5.8E7 S/m. Calculating the physical parameters of the patch antenna as shown in the geometry in Figure 1 using the given formula.

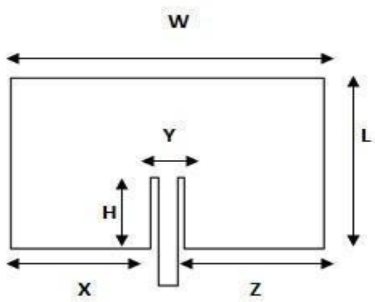

Figure 1. Geometry of the Square patch antenna

The width and length of the radiation surface is given by, $W=L=(c/\ (2f\sqrt{\varepsilon_r})) = 29.2$mm. Where, velocity of light, c = 3*10^8 m/s, frequency f =2.4 GHz, relative permittivity, $\varepsilon_r = 4.6$.

The depth of the feed line in to the patch is given by, H = 0.822*L/2 = 12mm. Other dimensions are, Y =W/5 = 5.8mm, X = Z = 2W/5 = 11.7mm

3.1. Antenna simulation

Connect a pin at the feed point of the antenna at the required point and go to the EM setup window and click on Substrate then, click on New to accept the 25 mil Alumina template.

Define the substrate as below, modify the default substrate height, Er, TanD and conductor height and define it as Copper (Select it from Add from Database list). Changing name of the dielectric is optional as it has no bearing on the simulation [2].

Click on Cond and check as intrude into the substrate. Set the Simulation Frequency range as 2.1GHz – 2.7GHz (adaptive sweep) and Add a new Single Point of 2.4GHz. Click on Simulate and observe the simulation results which has a S11 depth at single point frequency.

4. Design of an array antenna

This part includes the basic step necessary for the design of an array antenna in ADS simulation software. Place Patch Antenna feed point at (0, 0) coordinate to make job easier for creation of our patch array. Place a Pin for simulation at the centre of feed line [2,3]. This step will ensure that all copied instances will also have simulation pins else we will need to keep it manually. Copy/Paste antenna element using Insert->Coordinate Entry and enter required coordinates. Click Apply between every coordinate entry. Press Esc button to cancel the command. Select this entire row and then select Insert->Coordinate Entry and enter coordinates.

For Patch Array design, separation between elements are usually kept as 0.7*lamda – 0.8*lamda. In our case 93.75mm is 0.75*lamda at 2.4 GHz on 1.6mm FR4 substrate. Controversy, In case of calculation characteristic impedance for the feedback networks (not for the matching transformer) the length of the transmission line doesn't depend on the impedance. The only factor depends on the impedance is width of the transmission line.

5. Important parameters

5.1 Return loss

S-parameters describe the input-output relationship between ports (or terminals) in an electrical system. In practice, the most commonly quoted parameter in regards to antennas is S11. S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient. If S11=0 dB, then all the power is reflected from the antenna and nothing is radiated. If S11= -10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power. The remainder of the power was "accepted by" or delivered to the antenna. This accepted power is either radiated or absorbed as losses within the antenna. Since antennas are typically designed to be low loss, ideally the majority of the power delivered to the antenna is radiated.

5.2 VSWR

When a transmission line (a feeder cable, for example) is connected to a load (say an antenna) a reflection may occur if both impedances are not matched. The superposition of waves traveling forward and backward on the same cable forms a standing wave.

The reflection coefficient ρ which represent the amplitude of the reflection. The return loss (RL) which represent the reflection coefficient converted in dB. The voltage standing wave ratio (VSWR) which represents the ratio between the maximum and minimum amplitude of the standing wave.

5.3 Impedance matching

The impedance matching, or Smith* chart was created to enable graphical solutions of transmission line problems. It maps complex load impedances into the Γ plane of complex reflection coefficients.

The quarter-wave transformer is simply a transmission line with characteristic impedance Z_o and length $l = \lambda/4$ (i.e., a quarter wave line). It is often written as λ/4 impedance transformer, is a component used in electrical engineering consisting of a length of transmission line or waveguide exactly one-quarter of a wavelength (λ) long and terminated in some known impedance. The device presents at its input the dual of the impedance with which it is terminated.

It is a similar concept to a stub, whereas a stub is terminated in a short (or open) circuit and the length designed to produce the required impedance, the λ/4 transformer is the other way around. It is a predetermined length and the termination is designed to produce the required impedance. The relationship between the characteristic impedance, Z_0, input Impedance, Z_{in} and load impedance, Z_{out} is given by
$Z_0 = \sqrt{(Z_{in} Z_{out})}$

6. Linear 1x4 array

In order to make fair comparison, the same substrate used in single element (Er= 4.6 and thickness h=1.6 mm), is used in the 1x2 array. The configuration of 1x2 linear rectangular patch antenna array. To obtain 50 Ohms input impedance, feeding line with width W_1=4.85 mm is used. This line is split into two 100 Ohms lines, with width W_o =1.41 mm. The configuration of 1x2 linear rectangular patch antenna array is shown below

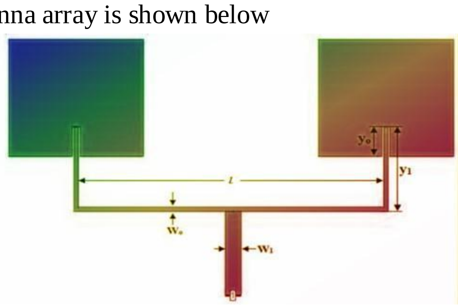

Figure 2. Configuration of 2x1 linear rectangular patch antenna array

In an attempt to design 4x1 array, for both rectangular and triangular, quarter wave transformer is used to feed the elements. Figure 3 shows the configuration of 4x1 rectangular patch antenna array. The dimensions of quarter wave transformer are based on Transmission line calculation in the ADS software [1]. It can be seen the design resonate approximately at 2.4 GHz.

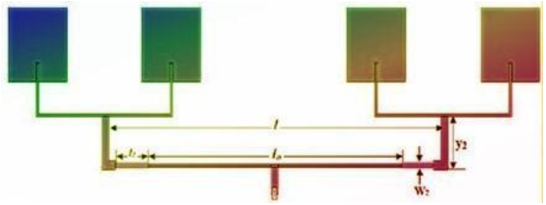

Figure 3. Design of 1x4 rectangular patch array

7. Linear 2x2 array

The design of 2x2 array antenna will follow after the design of single patch antenna. To design an array we need a feed network which will connect all the four elements [2]. In order to have a matched impedance feed network, we need to start from the input impedance of the patch. The single element is fed by a 100Ω. So the starting point of the feed will be 100 Ω. The scheme of the feed network is as shown in the figure 4.

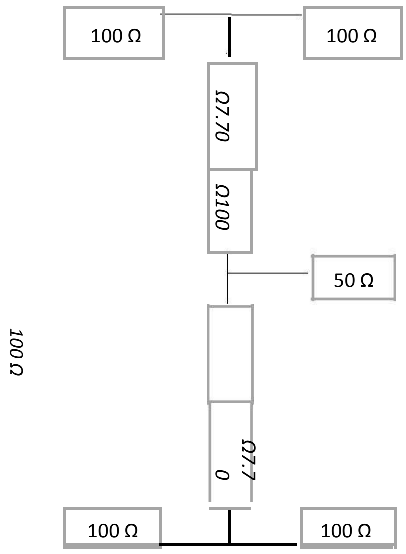

Figure 4. Block diagram for 2x2

8. Simulated Results

The Return loss graph and Smith chart at the depth of the frequency about 2.4GHz is shown below for 1x4 and 2x2 array antennas. In all the simulated outputs, the S11 value lies at the negative deep at the operating frequency, while the impedance of the antenna at operating frequency stays near to the midpoint for the exact matching to radiate efficient.

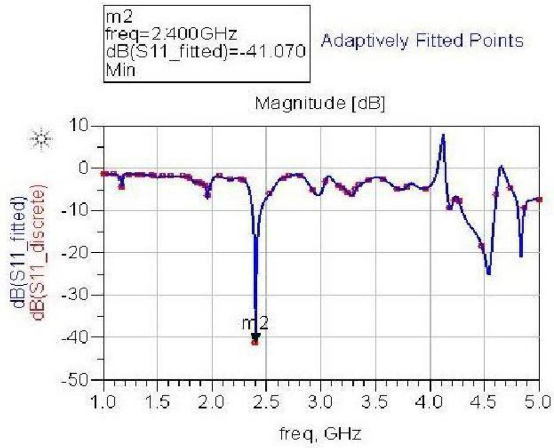

Figure 5. Return loss of 1x4 array

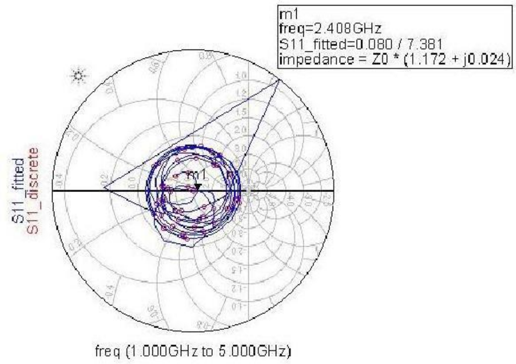

Figure 6. Smith chart for 1x2 array

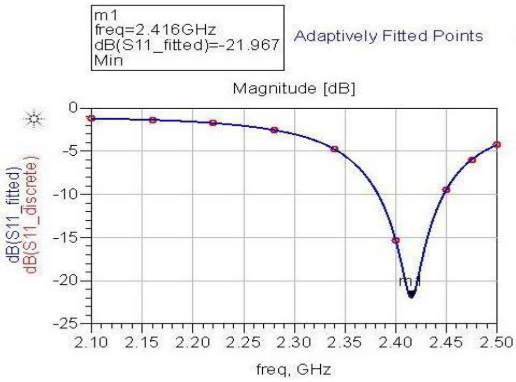

Figure 7. Return loss for 2x2 array

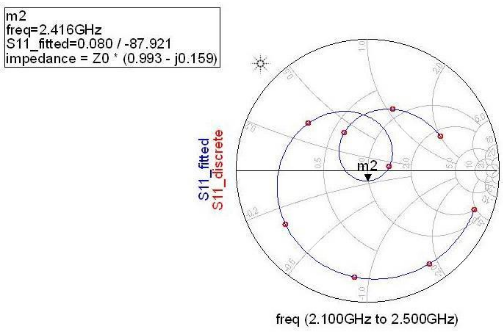

Figure 8. Smith chart for 2x2 array

Radiation pattern is one of the important characteristic of an antenna as tells the spatial relative distribution of the electromagnetic wave generated by the antenna. Since the radiation pattern is supposed to provide relative distribution of the fields, the absolute size of the 3-D surface does not have any significance. In practice therefore the maximum amplitude is normalized to unity.

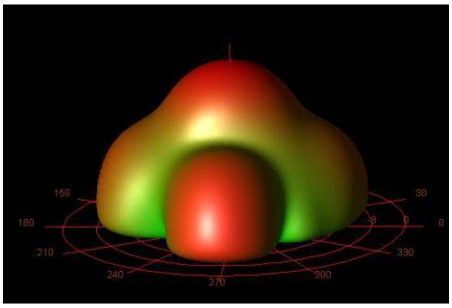

Figure 9. Side view of radiation pattern for 2x2

9. Conclusion

In the present work, arrays of Microstrip patch antenna with different types are modelled using finite element method and simulated in ADS 2013.

The results are compared with conventional rectangular patch array for 1x4 and 2x2. By analysing the results we inferred that the HPBW and BWFN decrease as spacing between the array elements increases. The gain and directivity increases with the increase in spacing. The beam gets narrow if the number of the elements in an array increases.

Considering the area of the element, Rectangular shaped patch gave better gain and directivity at different array models. The proposed antenna array is suitable in designing the environmental scanning antenna and Phased array Antenna. The simulation work carried out by us can be made use for the design of any shapes of Microstrip patch antenna.

10. References

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