Design and Analysis of Microstrip Antenna using Reduced Butler Matrix for 2.4GHz Frequency Band

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***Abstract*—In this paper the array of rectangular patch antenna is connected to the reduced size butler matrix network. Butler matrix network is used for beam switching. This design is realized on a low cost substrate FR4 with dielectric constant $\mathcal{E}_r$ =4.4 and height of substrate is 1.6mm.Here antenna is operated at 2.4GHz frequency. The simulation result is obtained using HFSS.**

Keywords- Butler Matrix, Beam forming Network (BFN), Micro-strip Antenna, VSWR, Return Losses

I.INTRODUCTION

In recent years, wireless technology has rapid growth in creating new and improved services at lower costs. In wireless communication it is very important to separate desired signal from unwanted signal. Thus to overcome this problem smart antenna system is developed. There are main two types of smart antenna systems. One is Switched beam system and another is Adaptive array system. Here smart antenna is form by using butler matrix network. In switched beam system manual switching of beam is possible but on other hand in adaptive array system we can use different type of algorithms for switching the beam.

In this paper the microstrip patch array is use as a radiating element and butler matrix is use for beam switching. Here 2x2 butler matrix network is use. There are number of advantages of using this network the advantages are low profile, easy fabrication and low cost. The diagram shows the reduced size butler matrix network it consist of hybrid coupler, phase shifter and crossover. There are number of advantages of using microstrip antenna as a radiating element. The main advantages of microstrip antenna is low profile, simple and inexpensive to manufacture using modern printed circuit technology, possible to have dual or triple frequency operations. The figure1 below shows 2x2 butler matrix

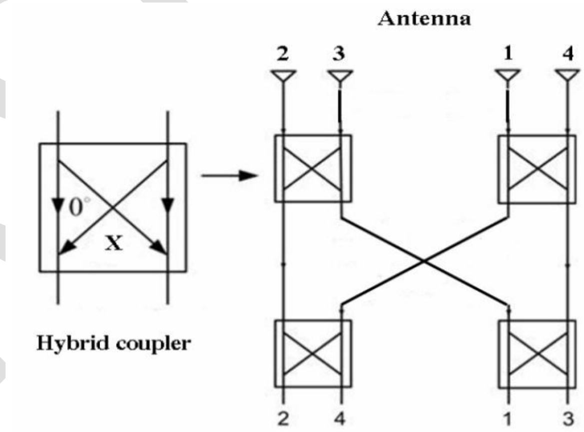

Figure1. Butler Matrix

II. DESIGN AND ANALYSIS

A. Rectangular Patch antenna(Microstrip Antenna)

To design microstrp antenna we must know the length and width of patch. The width and length of antenna is calculated by formula

$$W = \frac{C}{2f} \times \sqrt{\frac{2}{\mathcal{E}_r + 1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{(-0.5)} \text{ ...... (2)}$$

$$\Delta L = 0.412 \times h \frac{(\epsilon_{reff}+0.3)\times(\frac{w}{h}+0.264)}{(\epsilon_{reff}-0.258)\times(\frac{w}{h}+0.8)} \text{ .... (3)}$$

$$L=\frac{\lambda}{2}-2\times\Delta L \text{ .... (4)}$$

The figure2 shows the antenna created in HFSS software. This antenna is designed for 2.4GHz range of frequency.

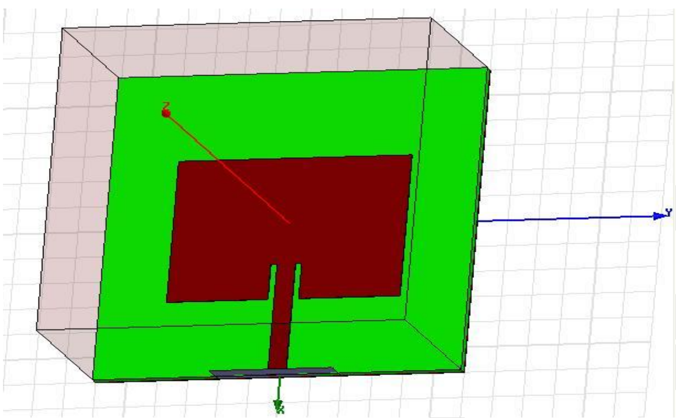

Figure2. Design of Patch Antenna at 2.4GHz

Figure no 3,4,5 shows the simulation result of designed antenna in HFSS softewar at 2.4GHz frequency.Here return loss and VSWR of antenna is minimum for 2.4GHz rang of frequency.

Calculated value of patch antenna

Antenna Width	38mm
Antenna Length	29mm
Substrate Height	1.6mm

VSWR- For the proper working of antenna the VSWR of antenna is less than 2db.Here for 2.43GHz to 2.47GHz range of frequency VSWR of antenna is less than 2db,so antenna can work properly for that band of frequency. This is shown in figure 5.

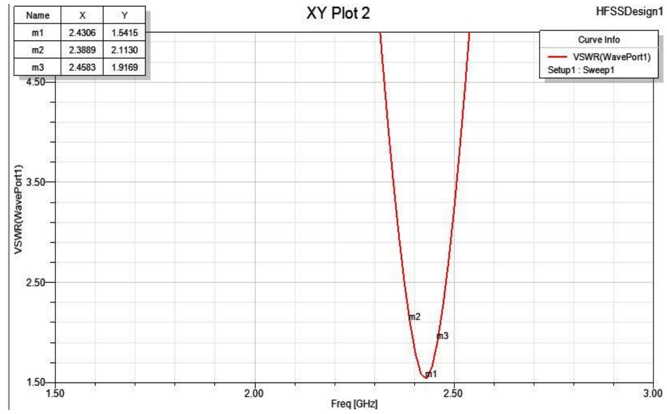

Figure5. VSWR

Return loss- For proper working of the antenna return loss must be less than -10db. Here for 2.47 to 2.43 GHz range of frequncy return loss is less than -10db.

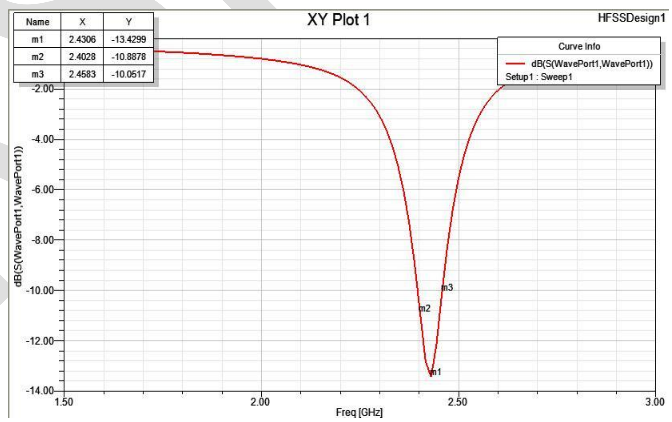

Figure3. Return Loss

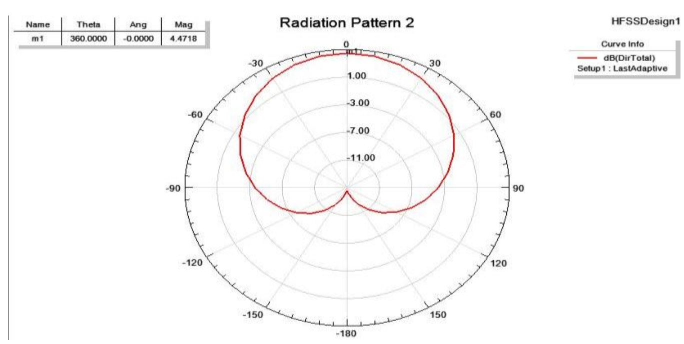

Figure4. Radiation Pattern

B. Design of 4x4 Matrix Array

The butler matrix is a NxN network consisting of N input ports and N output ports. The NxN Butler matrix creates a set of n orthogonal beams is space by processing the signal from N antenna elements.

The components of Butler Matrix are

1. 90° Hybrid
2. Crossover
3. Phase Shifter

1. 90° Hybrid:-

The design of hybrid can be calculated by following formulae.

a. $\lambda = \frac{c}{f}$ ………………… (5)

b. $\lambda/4$ ………………… (6)

c. feed length = $\frac{\lambda}{4\sqrt{\varepsilon_r}}$ …… (7)

d. width of hybrid is given by

$$Z_{50} = \frac{377}{\sqrt{\varepsilon_r}\left(\frac{W}{h}+2\right)} \quad \ldots\ldots\ . \ (8)$$

Where

Z_{50} is the impedance of 50ohm line

W is the required width

h is the height of substrate

Obtained results are as follows

a. $\lambda/4$ = 30mm

b. feed length = $\frac{\lambda}{4\sqrt{\varepsilon_r}}$ = 15mm

c. Width of hybrid = 3mm

d. L = 4.8 mm

Figure shows the hybrid coupler created in HFSS software.

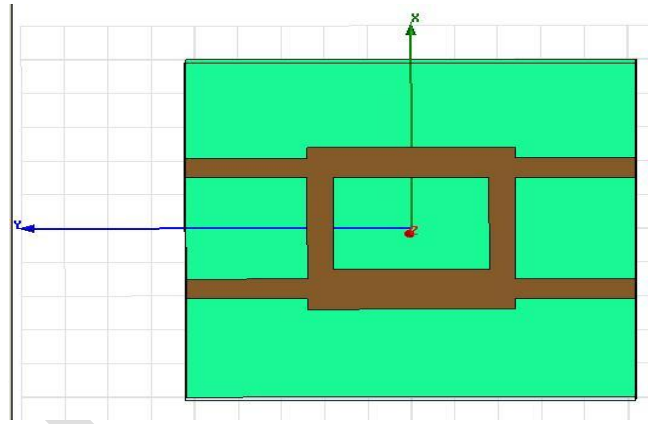

Figure6.Hybride coupler

In hybride coupler has 4 ports, 2 input and 2 output ports , when signal is fed to one of the input ports ,then output we get at one output port is in phase with input signal, and output at other is -90 degree out of phase with respect to input.

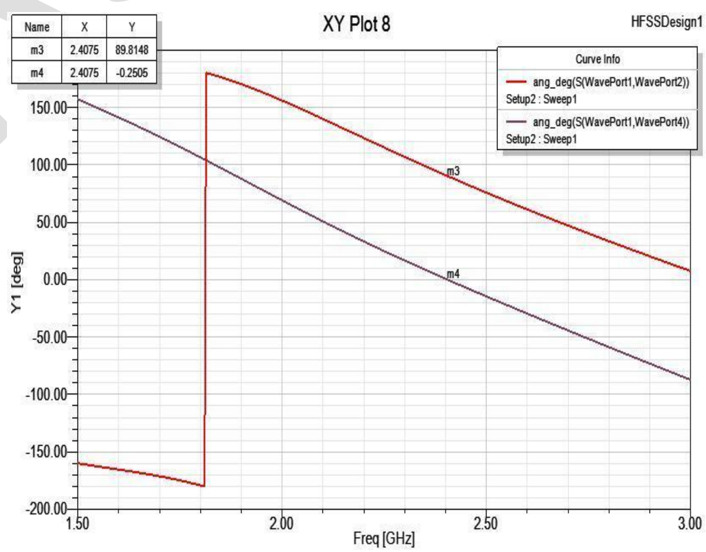

Figure7.simulation result of hybrid coupler

Here graph shows that when we feed signal to the port 1 then at output of port2 and port4 there is phase shift of 90 degree

2. Crossover-

Crossover is use to transmit information from one hybrid coupler to another without loss of information .The formula for design of cross over is similar to that of the crossover. It is used to avoid interference of electromagnetic signal when two electromagnetic signal travelling close from each other.

3. Phase shifter-

Phase shifter is use to provide phase shift to the signal. Here phase shifter is provided 45degree phase shift. The length of phase shifter is given by formula

$$\phi = \frac{2\pi}{\lambda} \times L \text{ .... } (9)$$

$$\lambda = \frac{\lambda_0}{(\varepsilon_{reff})^{0.5}} \text{ .... } (10)$$

Table.1 Phase Excitation at Output with respects to input

Port No.	Antenna Element			
	2	3	1	4
2	0^0	x^0	x^0	$2\,x^0$
4	x^0	$2\,x^0$	0^0	x^0
1	x^0	0^0	$2\,x^0$	x^0
3	$2\,x^0$	x^0	x^0	0^0

Consider each hybrid coupler gives x degree phase shifted signal that is there is x degree phase shift between its two output ports. When we feed signal to the port 2 then at the output port of 2 we get 0degree phase shifted signal. If we feed signal to the port2 then at port4 we get x degree phase shifted signal and at output of port3 we can get 2xdegree phase shifted signal. According to this phase shift signal is radiated towards the desired user. Here the butler matrix is reduced from 4x4 to2x2.That is in 4x4 hybrid coupler we required the 2 crossover, on the other hand in 2x2 butler matrix we required only 1 crossover so size and coast of hybrid coupler is reduced here. This is the advantage of using 2x2 butler matrix. Working of 2x2 butler network is shown in table1.

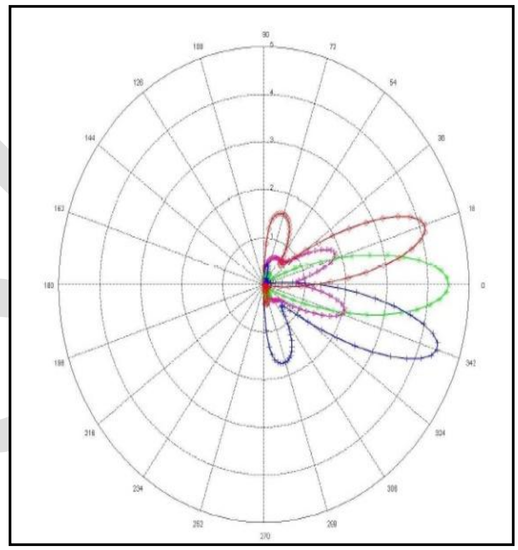

Figure9. Expected Results

When we can combine all the component of butler matrix which is individually designed in HFSS software then we can get sharp switched beam these expected result are shown in figure9.

III CONCLUSION

This paper represents optimum design of 2x2 planer butler matrix for ISM band application. Here because of 2x2 butler network cost of implementation is reduced. The formulae for designing antenna are mentioned in paper. The results are simulated in HFSS. For larger area coverage design can be extended to 8x8 matrix.

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