Analyze a various specifications of Microstrip Patch Array Antenna Using Beamforming Method for ISM Band Applications

E.Praveen Kumar[1], G.sakana [2], S.Mohan Raj [3], S.Thiyagarajan[4], R.Lavanya[5]

[1,2,3,4,5] *Assistant Professor, Department of ECE,*
[1,2,4,5] *Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Avadi.*
[3]*Cheran College of Engineering.*

Abstract— *In this paper, the design of 4x4 smart antenna array antenna along with the butler matrix network which can be used for beamforming (pointing an antenna array). Unlike the conventional schemes where an array of microstrip patch antennas are used, the radiation becomes omnidirectional and therefore the power losses are more. In the proposed design, the designed antenna is operating at the frequency of ISM Band 2.4 to 2.48 GHz. The smart antenna array consists of microstrip patch antenna with the inclusion of Butler matrix and the performance of the antenna is improved from the obtained simulation results in Advanced design System (ADS).*

Index Terms— *ADS, Beamforming, Butler matrix, Microstrip patch*

INTRODUCTION

There is an high demand on mobile service providers to provide voice and high-speed data services. At the same time, these operators want to support more users per base station to reduce overall network costs and make the services affordable to subscribers [1-4]. As a result, wireless systems that enable higher data rates and higher capacities are a pressing need. Mitigation of interference can be obtained through the implementing the smart antennas. This smart antenna system can enhance the frequency only at the desired direction and it suppresses the unwanted frequencies. The systems can be classified as either switched beam array or adaptive array. Depending on which of N inputs is accessed, the antenna beam is turned in a particular direction The popularity of Butler matrix as a beamformer in a switched multiple beam smart antenna is due to many advantages. First, it can be implemented easily using hybrids and phase shifters. Second, the generated beams are orthogonal of the Woodward-Lawson type and have narrow beamwidth and high directivity. Third, it has minimum path length and number of components compared to other uniform excitation beamforming net-works. Fourth, it has a high and almost constant beam crossover level that does not change with frequency. The primary characteristics of the Butler matrix areN inputs and N outputs, with N usually 4,

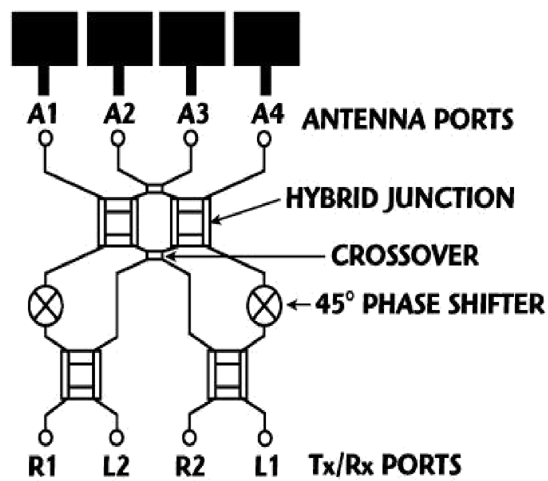

Figure 1: **4x4Butler matrix network**

I. BEAMFORMING IN SMART ANTENNA:

Smart antenna technology offers a significantly improved solution to reduce interference levels and improve the system reliability. In this technology each user's signal is transmitted and received by the base station only in the direction of that particular user. This reduces the system interference in the whole. A smart antenna system consists of an array of antennas that together direct different transmission and reception signals to each user. This method is called beamforming. The Butler matrix is a type of beam-forming network. Depending on which of N inputs is used, the antenna beam is receives the signal only in the desired direction [5]. It performs a similar function to a Rotman lens, or a phased array antenna system.

The passive reciprocal network works the same when it transmits energy as when it receives energy, but in our analysis we will assume that it is employed as a transmitter. It is comprised of four beams that is used for forming a box, with the vertical elements at impedance equal to Z0, and the horizontal elements at Z0/[sqrt(2)]. Two 45 degree fixed phase shifters are needed here. these are series lines sized to provide 45 degrees in length. The butler matrix used ib this paper consist of four hybrid couplers, two cross couplers and two phase shifters For beamforming network, N inputs and N outputs are used, where N= 4,8 and 16. The inputs are isolated with each other. The phase increments between outputs are depending upon the input that is selected. For the input impedance and dielectric constant the width and height is calculated as (7).

II. THE HYBRID COUPLER

The hybrid couplers are the special case of a four port directional coupler that is designed for 3dB power split. Hybrids come in two types, 90 degree or quadrature hybrid and 180 degree hybrids [6-9]. Hybrid couplers are often used in creating reflection phase shifters the hybrid couplers has the characteristics of dividing the input power equally amongst to the two output ports. The hybrid couplers are used in many circuits and system applications such as test and measurement, RF amplifiers, transmitters and receivers. The main line of the coupler is coupled to a secondary line by two quarter wavelength long sections spaced over one quarter wavelength.

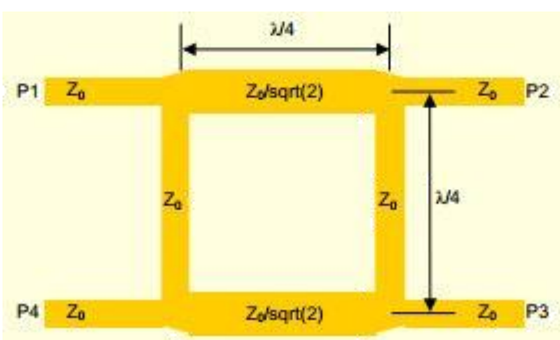

Figure 3: **Hybrid coupler**

The basic properties of the quadrature hybrid can be obtained from the scattering matrix which is given by [7]

$$\frac{-1}{\sqrt{2}}\begin{bmatrix} 0 & J & 1 & 0 \\ J & 0 & 0 & 1 \\ 1 & 0 & 0 & J \\ 0 & 1 & J & 0 \end{bmatrix}$$

The length of the can be calculated as

$$L=\frac{c}{4 f_r \sqrt{\varepsilon_{reff}}}$$ Where f_r represented as design frequency and ε_{reff} is effective dielectric constant, hence it is represented as

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}-\frac{1}{\sqrt{1+12h/w}}$$

III. THE CROSS OVER COUPLPER

Cross over coupler is also called as null cable the applications includes hub less connection of two Ethernet devices, connection of two hubs that lack on uplink or connection of a cable modem to the hub that lacks the uplink port..The cross over cable is not expensive. The benefit of using a cross over coupler is that we can replace it with a hub in a future without changing any of the cables. The cross directional couplers are the special type of directional couplers. An waveguide couplers is a reciprocal four port which is also a ideally loss free.

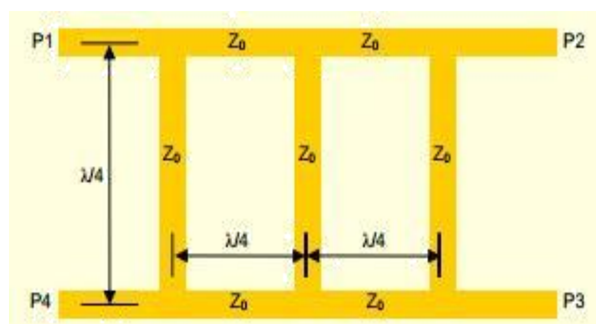

Figure 4: **cross over couple**

The perfect design of the cross over coupler is accomplished if every adjacent ports are isolated such that if port 1 is fed, the output of port 2and 4 should be equal to 0and if port 4 is fed, the output of ports 1 and 3 should be 0. The passive reciprocal network works the same when it transmits energy as when it receives energy. The passive reciprocal network works the same when it transmits energy as when it receives energy, but in our analysis we will assume that it is employed as a transmitter. It is comprised of four beams that is used for forming a box, with the vertical elements at impedance equal to Z0, and the horizontal elements at Z0/[sqrt(2)]. Two 45 degree fixed phase shifters are needed here. these are series lines sized to provide 45 degrees in length. The butler matrix used ib this paper consist of four hybrid couplers, two cross couplers and two phase shifters The matrix will be in following form of the matrix [7]

$$\begin{matrix} 0 \\ \frac{\pi}{2} 1 \\ 1 \\ 0 \end{matrix} \begin{bmatrix} -1 & -1 & 1 \\ -1 & 1 & 0 \\ 1 & -1 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

IV. SIMULATION AND RESULTS OF THE ANTENNA

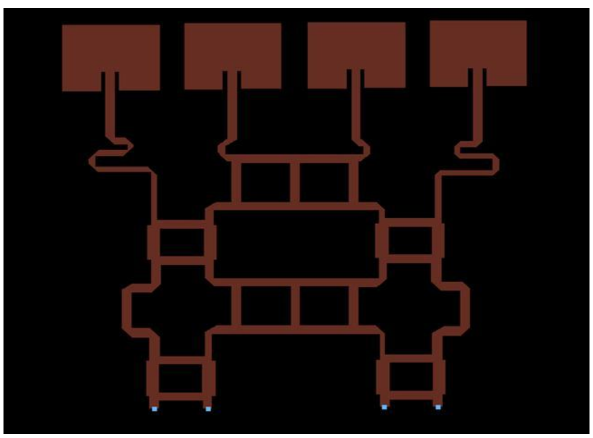

***Figure 5*: Simulated Antenna with Butler matrix**

In this section, a multiple-beam forming network using Butler matrix is designed and realized with microstrip technology to feed the antenna array of the previous section at frequency 2.4 to 2.48 GHz. A 4 x 4 butler matrix creates a set of 4 orthogonal beams in space by processing the signal from the 4 antenna elements of an equi-spaced linear array [10]. The Butler matrix is realized using four directional couplers, two 0 dB cross couplers, and phase shifters. Its components are designed and fabricated separately. This smart antenna is built on the RT Duroid 5880 substrate. The thickness of the substrate is 1.6mm

Specifications	Bandwidth (GHz)	Efficiency	Directivity	Gain(dB)
Required specification	2.4-2.48	>85	>11	>10
Obtained in patch	2.45	87	7.54	7.04
Obtained in array	2.4 – 2.5	91.5	12.464	12.065

***Table 1*: Compared specifications.**

Furthermore, smart antenna efficiency and directivity are improved, while minimizing its size to cope with the required constraints. This comparison proves that this work enhances many parameters which shows an outstanding performance of the proposed antenna due to design and optimization efforts. The width and length of the rectangular patch that is used for the butler matrix is 45mm and 35mm respectively. Hence it can be calculated by following expressions for normal length and width (7)

$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{reff} + 0.3)\frac{w}{h} + 0{,}264}{(\varepsilon_{reff} - 0.258)\frac{W}{h} + 0.8}$$

$$W = \frac{V_O}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}}$$

Hence the original length can be calculated by

$$L = \frac{V_O}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L$$

The position of the feed that is given to patch, where the impedance is given as 50Ω. Hence it can be calculated using the following expression

$$R_\alpha(y = y_o) = R_m(y = 0)\cos^2(\pi/L \, y_0)$$

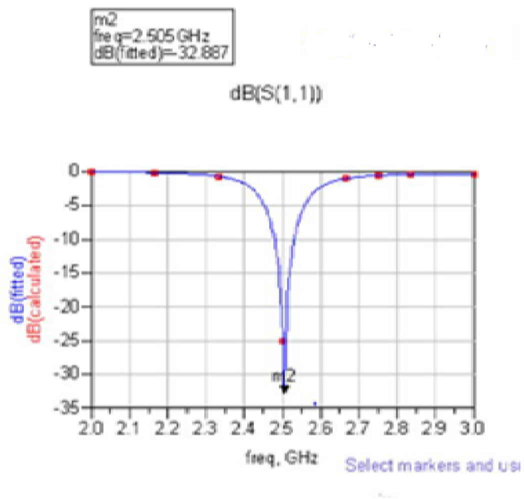

Figure 6: **Obtained result**

The gain and directivity of the smart antenna with butler matrix beamforming network is obtained as following radiation pattern for 2.48 GHz ISM band

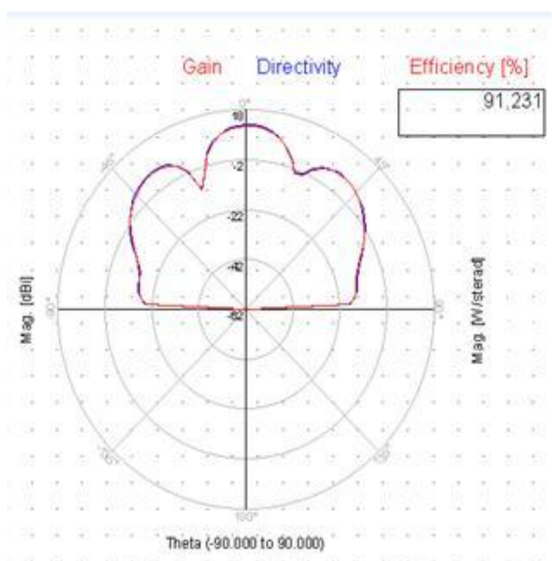

Figure 7**: Radiation pattern**

V. CONCLUSION

The 4x4 butler matrix is designed and simulated by using the beamforming network to suppress the undesired frequencies. Hence the obtained efficiency of the smart antenna is 91%. The components of butler matrix are given in detail which is used to operate under ISM band from 2.4 – 2.48 GHz. The obtained results as consolidated in the Table 1 shows a great improvement in factors like gain, directivity, bandwidth and efficiency. Future work may incorporate the use of different beamforming techniques with enhancement of the factor like power radiation and gain.

VI. REFERENCES

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