International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 7, July - 2014

Design & Simulation of Switched-Beam Antenna using Butler Matrix Feed Network

Mr. Amit N. Kshirsagar
P.G. Student Electronics Department
Walchand Institute of Technology,Solapur. India

Mr. Prashant S. Malge
AssistantProfessor Electronics Department
Walchand Institute of Technology,Solapur. India

***Abstract*—Thispaper concentrates on development of Switched beam smart antenna system for 2.45GHz ISM band. A smart antenna system hasthe ability to direct the beam in desired direction thereby reducing the problem of multipath fading, delay, interference. Basically there are two types of smart antenna systems; one is Switched beam system and another Adaptive array system. This paper presents optimum designof a switched beam smart antenna using 4x4 planar Butler matrix array. The beamforming network is formed using micro strip antenna and buttler matrix (hybrid couplers, cross-coupler, phase shifter). All the individual components of buttler matrix as well as the microstrip patch antenna is designed and simulated. Finally thearchitecture of beamforming network simulated using HFSS softwareand made analysis of coupling effect between different fundamental elements of network.**

***Keywords*—Butlermatrix, microstrip antenna, beam forming network.**

I. INTRODUCTION

In the recent years topic of multi-beam smart antenna has been receiving much attention.A smart antenna system combines multiple antenna elements with a signal processing capability to optimize its radiation transmission and reception pattern adaptively in response to the available signal environment.Smart antenna system have been introduced to improve wireless performance and to increase the capacity by spatial filtering, which can separate spectrally and temporally overlapping signals from multiple users.

Multiple beam smart antenna has wide range of applications. Different multi-beam antenna prototypes are implemented for the applications in base stations [1], [2] to improve the quality of transmission and enhance the cellular capacity, range, and coverage [3] because the antenna array is capable of pointing to desired targets automatically in real time. Moreover, the multipath fading and interferences phenomenon in communications systems can be solved using switched beam antenna array for rejecting interference signals and increasing desired signal level [1]. The system can produce multiple narrow beams in different directions and select the strongest signal among all of the available ones. The system can distinguish the users that stand at different positions, and as a result, expand the capacity [3]. Smart antennas can be characterized into two main categories: adaptive antenna array and switched beam system [1]. Compared with adaptive antenna arrays switched beam systems have advantages inimplementation because of its simplicity in the design [1].Over the last few years there is huge growth in the number ofusers for different wireless services. This fact introduces amajor technological challenge to the design engineer: that is to increase the overall performance and efficiency of the wireless system with an increased number of users under the constraints of spectrum efficiency, power usage and cost.

Recently developed smart antenna technology may be the solution to satisfying the requirements of next generation wireless networks. The smart antenna or adaptive array allows the system to manipulate received signal not only in the time and frequency dimensions but in the spatial domain as well to achieveOptimized system goals. The unique ability of the smart antenna to perform spatial filtering on both the received and transmit signals is the major benefit of smart antennas over existing conventional transceiver techniques. With the exponentially increasing demand for wireless communications the capacity of current system will soon become incapable of handling the growing traffic. Since radio frequencies are diminishing natural resources, there seems to be a fundamental barrier to further capacity increase. The solution can be found in smart antenna system.

II. LITERATURE REVIEW

In the paper of Nhi T. Pham1, Gye-An Lee2 [1] stated that beam forming network with a multi-narrow-beam antenna array for WLAN applications is presented. The antenna array has four inputs and is excited by the Butler matrix feeding network to electronically steer the beams in desired directions. The architecture of the Butler matrix beamforming network is analyzed with the considerations of coupling effects between fundamental elements of the network and the antenna array.

An ISM-band smart antenna system of 4-element microstrip linear array antenna with Butler matrix beam forming network is designed [12][2], analyzed and implemented using microstrip technology in completely planar structure without suffering from power losses or poor antenna pattern characteristics. The performance of this smart antenna system is analyzed and the beam forming features are monitored as function of geometrical antenna and Butler matrix parameters in the ISM-band at frequency from 2.4 to 2.48 GHz. Smart antenna efficiency and directivity are improved and its side lobe level is enhanced which make it very promising.

An Overview of Adaptive Antenna Technologies for Wireless Communication" [3] Smart antenna systems are rapidly emerging as one of the key technologies that can enhance overall wireless communications system performance.By making use of the spatial dimension, and dynamically generating adaptive receive and transmit antenna patterns, a smart antenna can greatly reduce interference, increase the system capacity, increase power efficiency as well as reduce overall infrastructure costs. In this paper the concept of the smart antenna is reviewed.

The topic of multi-beam smart antenna array has been receiving much attention due to its wide range of applications. Different multi-beam antenna prototypes are implemented for the applications in base stations [5], [6] to improve the quality of transmission and enhance the cellular capacity, range, and coverage [7] because the antenna array is capable of pointing to desired targets automatically in real time. Moreover, the multipath fading and interferences phenomenon in communications systems can be solved using switched beam antenna array for rejecting interference signals and increasing desired signal level [5]. The system can produce multiple narrow beams in different directions and select the strongest signal among all of the available ones. The system can distinguish the users that stand at different positions, and as a result, expand the capacity [7]. Smart antennas can be characterized into two main categories: adaptive antenna array and switched beam system [3]. Compared with adaptive antenna arrays, switched beam systems have advantages in implementation because of its simplicity in the design.

As Jean-SébastienNéron and Gilles-Y.Delisle stated in the paper [4] Scientific studies based on indoor channel measurement campaigns have shown that highly directive antennas used at both the transmitter and receiver of a communication system can reduce considerably the delay spread of the signal reaching the receiver while at the same time improve the signal gain. Electronically-steered phased arrays are well known for their ability to generate a directive beam according to a given control signal and may be a possible multipath mitigation solution. One way to implement this electronic scanning is by using electronically controlled phase shifters [8]. Another approach would be to generate a set of predefined beams and select among them the beam with satisfying properties [9]. A subset of these beams (or all of them) with proper weighting can also be combined in such a way that a desired array response is obtained. The latter alternative requires a beamforming network that transforms the signal from the N antenna elements to a predefined set of M beams.

III. DESIGN AND SIMULATION

The structure of beamforming network [10] with array elements is as shown in figure 1. This matrix generates a set of N orthogonal beams from the N antenna elements of an equispaced linear array. For simulation, though the data was considered for a range of 1.5 to 3 GHz frequency, but the individual component designs were done at 2.4 GHz. The final design was done on FR4 board, with substrate height of 1.6mm, $\varepsilon r = 4.4$, $\tan\delta = 0.0027$.

In this we simulate the Butler Matrix. The N × N Butler matrix creates a set of N orthogonal beams in space by processing the signal from the N antenna elements of an equispaced linear array. These beams are pointing in direction θ governed by the following equation [4]:

$$\sin \theta_{\mathbf{i}} = \pm (i\lambda / 2Nd) \quad (1)$$

Where i = 1, 2, 3… (N-1). The corresponding inter element phase shift with spacing d=λ/2 is

$$\alpha_{\mathbf{i}} = \beta d \sin\theta_{\mathbf{i}} = i(\pi / N) \quad (2)$$

Where $\beta = 2\pi/\lambda$, is the wave number. The optimum design of 4x4 planar Butler matrix array which consist of phase shifters. Butler matrix has four in-puts 1R, 2L, 2R, 1L and four outputs. These four outputs are used as inputs to antenna elements to produce four beams. The input ports of the Butler matrix are named according to their beam position.

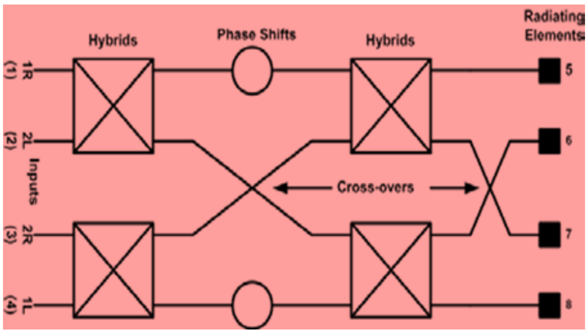

Fig.1.Structure of Butlermatrix fed array

A. *Microstrip antenna*

The main radiating element in this proposed work is rectangular patch antenna. The microstrip antenna is implemented FR4 substrate with on planer substrate. The single patch antenna is designed, with an inset feed at a length of 33.33 % of the total length.However when the array of four patches was placed together, it is observed that maximum radiated field obtained at normal to the structure surface.Hence to take care of this new problem of the fringing fields along the width, the patch length is extended on both sides by additional length given by,

$$L_{eff} = L + 2\Delta L \quad (3)$$

where,

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)(W/h + 0.264)}{(\varepsilon_{reff} - 0.258)(W/h + 0.8)}$$

$$L_{eff} = c / 2f_0 \text{sqrt}(\varepsilon_{reff}).$$

However the element spacing was kept constant throughout the four patch antennas [12].

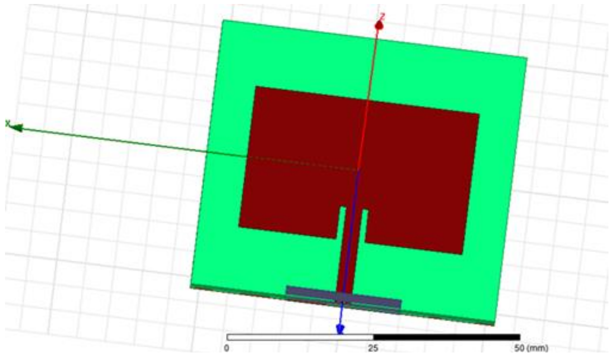

Fig.2.Microstip antenna simulated in HFSS

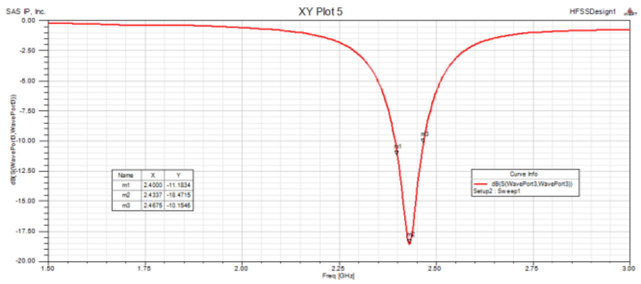

Fig. 3.Return loss for microstrip patch antenna.

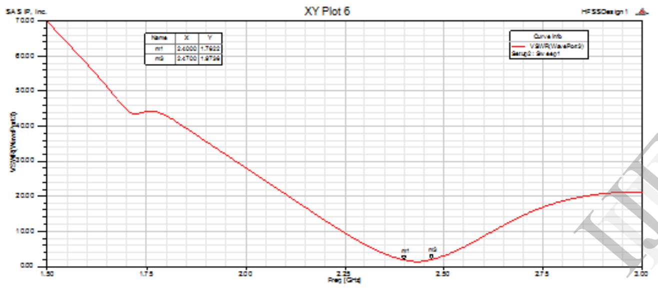

Fig. 4. VSWR for microstrip patch antenna.

B. *Buttler Matrix*

The Buttler matrix if formed using four 90^0 hybrid, two zero dB crossover and 45^0phase shifter. In this process a zero dB cross over coupler (Ref.Fig.3) and phase shifter are needed to complete fabrication of microstrip antenna.The Butler matrix connected to the patch arrayas in Fig. 5.

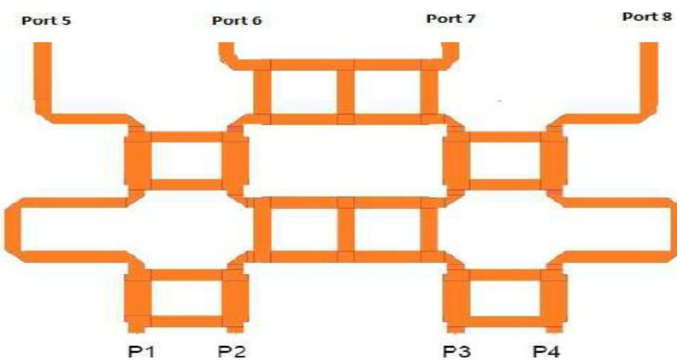

Fig. 5.Structure of Buttler matrix.

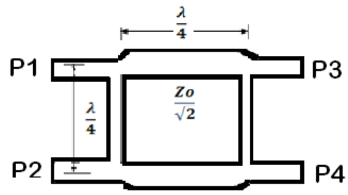

Fig. 5. Structure of 90^0hybrid

The 90^0 hybrid is simulated and S parameters are analyzed. The result ensures the requiredphase shift.Crossover coupler shown in Fig 9. It has been designed by cascading two hybrids.

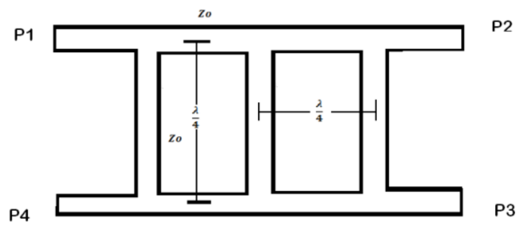

Fig.7. Zero dB cross-over coupler [11]

The phase shifter [4] is implemented using microstrip transmission line. The length of the line corresponding to 45^0phase shift is given by the formula

$$\Phi = (2\pi /\lambda)L \qquad (4)$$

Where L is in meters, φ is in radians. λ is the wavelength in the microstrip line. The wavelength in the microstrip transmission line is given by

$$\lambda = \lambda o /(\epsilon_{reff})^{0.5} \qquad (5)$$

Where λ_0 is the free space wavelength and ϵ_{reff} is the effective dielectric constant of the microstrip line. Since the phase shift is implemented using simple transmission line therefore it is linearly frequency dependent.

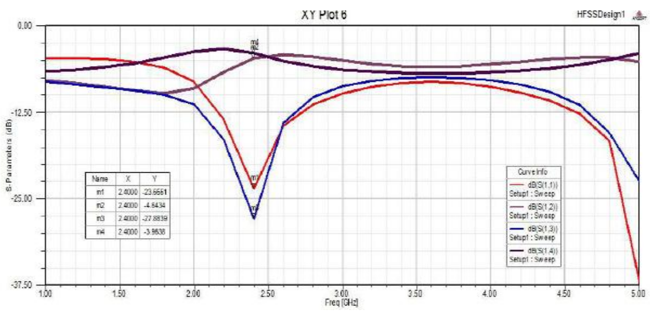

Fig.8.S-Parameters for 90 degree hybrid.

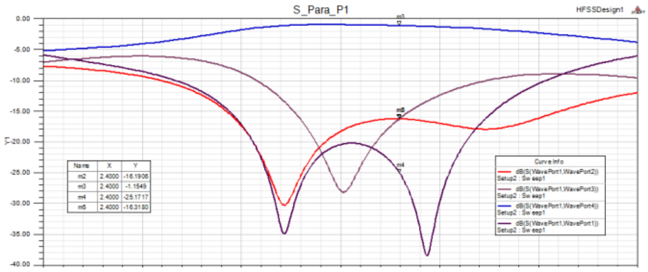

Fig.9. S-Parameters of Zero dB cross-over coupler.

TABLE I. SUMMARY OF RESULTS FOR 90 DEGREE HYBRID AND CROSSOVER SECTION

Parameters	**90^0Hybrid**	**Zero dB Crossover**
Return Loss (S_{11})	-18.35 dB	-25.17 dB
Isolation (S_{12})	-6.25 dB	-16.31 dB
Isolation (S_{13})	-3.08 dB	-16.19 dB
Isolation (S_{14})	-14.15 dB	-1.15 dB
VSWR	1.2905 dB	1.11 dB

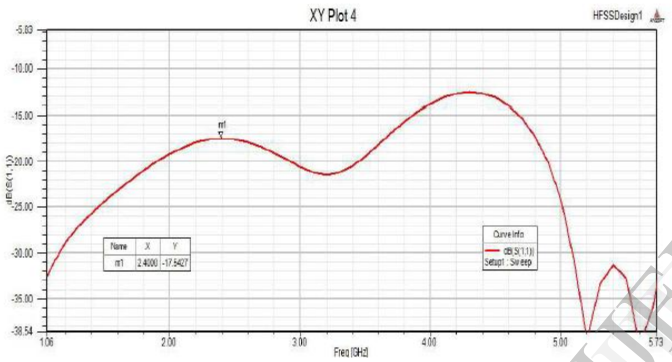

Fig.10.Return loss for phase shifter

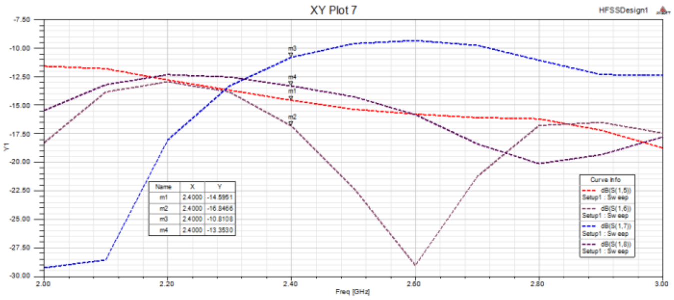

Fig.11.Transmission coefficient for port 1 of Butler Matrix.

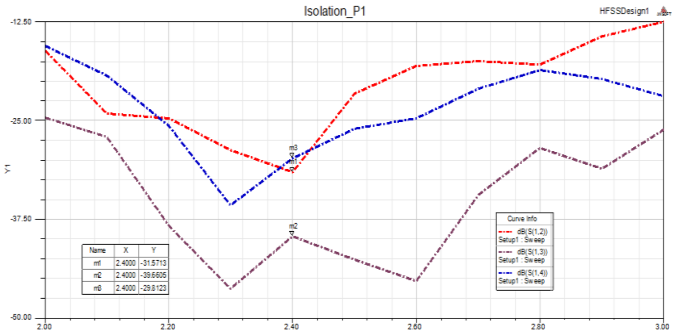

Fig.12.Isolation parameters for port 1 of Butler matrix

CONCLUSION

This paper presents design and simulation of a smart antenna system using microstrip antenna array with Butler matrix beamforming network for wireless applications in the required ISM-band.The basic configuration of a rectangular patch antenna array is observed to give a better performance at the mentioned operating frequency.The Butler matrix works as a perfect passive beamformingmicrowave network. The optimized design of 90^0 hybrid and phase shifter has been achieved. The reflection, coupling, isolation effects of the individual design are studied and discussed. The isolation at the non-coupling port of the zero dB coupler is effectively achieved. The beam can be switched with a control over its progressive phase change.

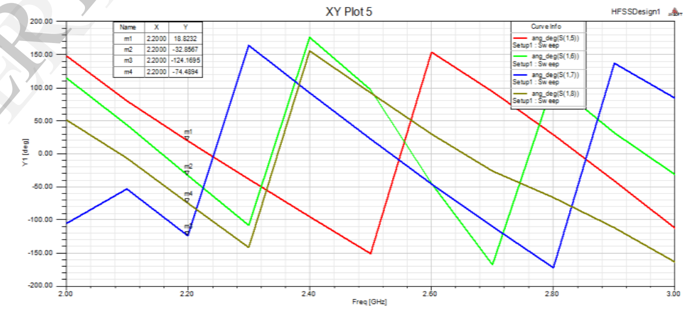

Fig.13. Simulated S-Parameter in degree when port 1of ButlerMatrix is excited.

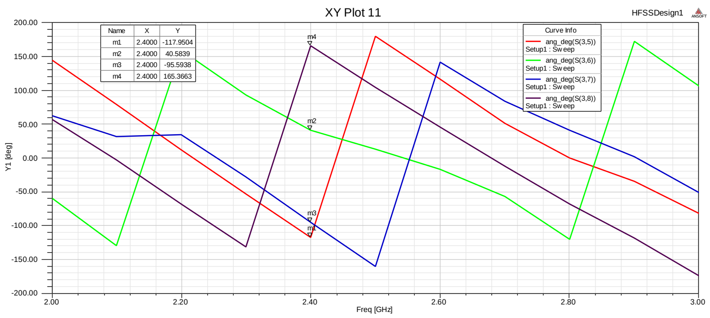

Fig.14. Simulated S-Parameter in degree when port 3 of Butler Matrix is excited

TABLE II. SUMMARY OF RESULTS FOR BUTTLER MATRIX

Parameters	Simulated Results
Return Loss (S_{11})	-7.98 dB
Isolation (S_{12})	-31.57 dB
Isolation (S_{13})	-39.66 dB
Isolation (S_{14})	-29.81 dB
Coupling (S_{15})	-14.59 dB
Coupling (S_{16})	-16.84 dB
Coupling (S_{17})	-10.81 dB
Coupling (S_{18})	-13.35 dB
Return Loss (S_{22})	-7.22 dB
Return Loss (S_{33})	-7.17 dB
Return Loss (S_{44})	-8.14 dB
VSWR for port 1	1.70

REFERENCES

[1] Microstrip Antenna Array with Beamforming Network for WLAN Applications Nhi T. Pham1, Gye-An Lee2, and Franco De Flaviis1 Department of Electrical Engineering and Computer Science.

[2] M. El-Tager and M. A. Eleiwa Electronics Department, M. T. C., Cairo, Egypt Design and Implementation of a Smart Antenna Using Butler Matrix for ISM-band Progress In Electromagnetic Research Symposium, Beijing, China, March 23{27, 2009}

[3] CNSRC3, SESSION A3 Chris Loadman ,Dr.ZhizhangChen,DylanJorgenssen,"An Over view of Antenna Technologies For Wireless Communication"

[4] Jean-SébastienNéron and Gilles-Y. DelisleETRIMicrostrip EHF Butler Matrix Design and Realization Jean-SébastienNéron and Gilles-Y. DelisleETRI Journal, Volume 27, Number 6, December 2005.

[5] Tayeb. A. Denidni and Taro Eric Libar, "Wide Band Four-Port Butler Matrix for Switched Multibeam Antenna Arrays," The 14th IEEE 2003 International Symposium on Personal, Indoor and Mobile Radio Communication Proceedings, pp.2461-2464, 2003.

[6] E. Siachalou, E. Vafiadis, Sotorios S, Goudos, T. Samaras, C. S. Koukourlis, and Stavros Panas, "On the Design of Switched-Beam Wideband Base Stations", IEEE Antennas and Propagation Magazine, Vol. 46, No. 1, pp. 158–167, February 2004.

[7] R. Comitangelo, D. Minervini, B. Piovano, "Beam Forming Networks of Optimum Size and Compactness for Multibeam Antennas at 900 MHz", IEEE Antenna and Propagation International Symposium, Vol. 4, pp. 2127-2130, July, 1997.

[8] M. J. Gans, R. A. Valenzuela, J. H. Winters, and M. J. Carloni, "High Data Rate Indoor Wireless Communications Using Antenna Arrays," Sixth IEEE Int'l Symp. Personal, Indoor and Mobile Radio Communications, Toronto, Canada, 1995, pp. 1040–1046

[9] P. F. Driessen, "Gigabit/s Indoor Wireless Systems with Directional Antennas," IEEE Transactions on Communications, vol. 44, Aug.1996, pp. 1034–1043.

[10] J. L. Butler, "Digital, Matrix and Intermediate-Frequency Scanning," Microwave Scanning Antennas, R. Hansen, ed., Academic press, New York, vol. 3, 1966, pp. 217–288.

[11] Planar Implementation of Butler Matrix feed network for a switched Author: Ajay P. Thakare, MIEEE, FIETE, FIE (I), MISTE.

[12] WriddhiBhowmik and ShwetaSrivastava, "Optimum Design of a 4x4 Planar Butler Matrix Array for WLAN Application", Journal Telecommunication Volume 2 Page-68-74,Volume-April-2010.

[13] Progress In Electromagnetic Research, PIER 74, 131–140, 2007 WIDEBAND X-BAND MICROSTRIP BUTLER MATRIX J. He, B.-Z. Wang, Q.-Q. He, Y.-X. Xing, andZ.-L. Yin.