Smart Antenna using Switched Multibeam Array

Ms.Priti S.GundPujari[*] , Prof. S.A.Annadate[**]

[*] (Department of Electronics & Telecommunication Engg, ,Dr. B.A.M.University, Aurangabad, Maharashtra, India
Email: preeti.gund@gmail.com)
[**](Department of Electronics & Telecommunication Engg, ,Dr. B.A.M.University, Aurangabad, Maharashtra, India
Email: sureshannadate@yahoo.com)

ABSTRACT

This paper describes the design and realization of a 4×4 Butler Matrix as a beam forming network along with 4 linear antenna arrays to obtain four steerable beams, operating at 2.4 GHz. The simulation results are obtained using HFSS software. Further the concept of multibeam switching is discussed with an idea of suspended feed in between two matrices.

Keywords - **Butler Matrix, Beam forming Network (BFN), Multibeam switching, Microstrip.**

I. INTRODUCTION

Electronic scanning of antennas is used in a variety of applications and can be accomplished using beam forming networks (BFNs). Butler Matrix [1] is an N×N passive microwave network that consists of 'N' input and 'N' output independent ports. It is used as a feed to an array of antennas to generate a set of 'N' orthogonal beams, which scans the array generated beam. Thus a Butler Matrix is considered to be a significant component of a (BFN) beamforming network [2] and widely used in Smart antennas [6]. The matrix is easy to be implemented using micro strip with an advantage of ease in fabrication, compactness and low cost.

In this paper, a 4×4 Butler matrix is designed to form orthogonal beams and the switching is obtained at the end of the array of 4 patch antennas. Basically a 4×4 matrix consists of four 90 degree hybrids, two 0 dB cross-overs and two 45 degree phase shifters. The end four antenna elements are designed for optimum feed position, along with the element spacing, using Method of Moment (MoM), to get a proper VSWR value, maintaining gain characteristics. Individual component fabricated were tested and simulations are carried using HFSS software [16]. With these results, it is proposed to obtain a multibeam switching position using suspended feeding technique.

II.DESIGN AND ANALYSIS

A simple 4×4 Butler matrix is shown in Fig 1.

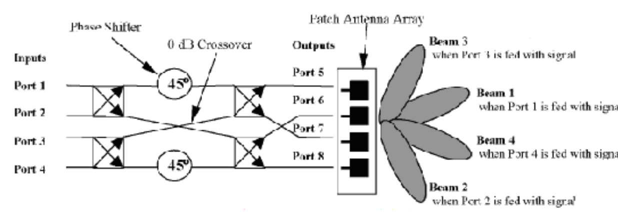

Fig 1 4×4 Butler matrix

For simulation, though the data was considered for a range of 2 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, εr = 4.4, tanδ = 0.0027, with all terminations offered at 50 Ω. The 90 degree hybrid pull out at the port side thickness is 1.141 mm. Along the major width-side arm (thickness 1.932mm), the tapering done at 45 degree gave a proper isolation at port 2.

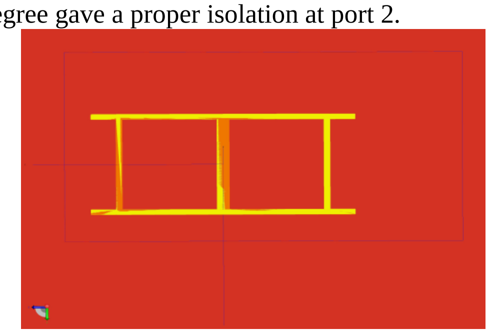

Fig 2 Zero dB cross-over coupler

Crossover coupler shown in Fig 2 was first designed by cascading two hybrids. But the branch increased thickness did not give proper isolation at port 4; as well as zero degree phase was not obtained at port 3. All its arm thickness was then redesigned at 1.414 mm, again with tapering at 45 degree along the port arm side.

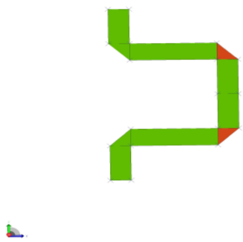

Fig 3 Phase shifter

For the phase shifter [7] shown in fig 3, the phase shift is given by:

$$\phi = (2\pi / \lambda g)\, l, \quad (1)$$

Where, the wavelength is given by:

$$\lambda o / \mathrm{sqrt}\,(\varepsilon eff). \quad (2)$$

Finally the single patch antenna [9] was 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:

$$Leff = L + 2\Delta L \quad (3)$$

where,

$$\Delta L = 0.412h \frac{(\varepsilon reff + 0.3)(W/h + 0.264)}{(\varepsilon reff - 0.258)(W/h + 0.8)} \quad (4)$$

$$Leff = c / 2fo\ \mathrm{sqrt}\,(\varepsilon reff). \quad (5)$$

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

The Butler matrix connected to the patch array [11] shown in Fig 4 also highlights the power distribution. The VSWR graph is shown in Fig 5 is at a value of 1.67 at 2.4 GHz.

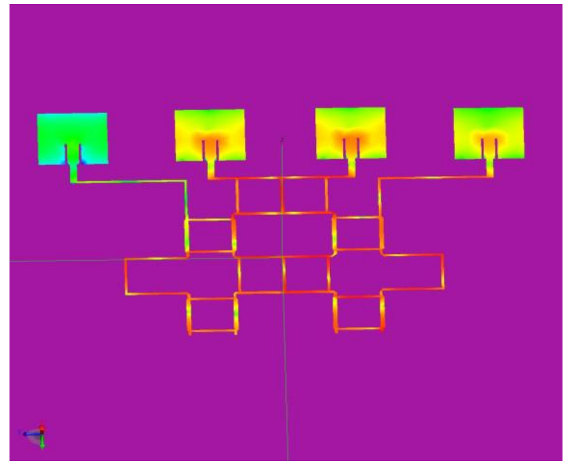

Fig 4 Current distributions in a Butler fed array

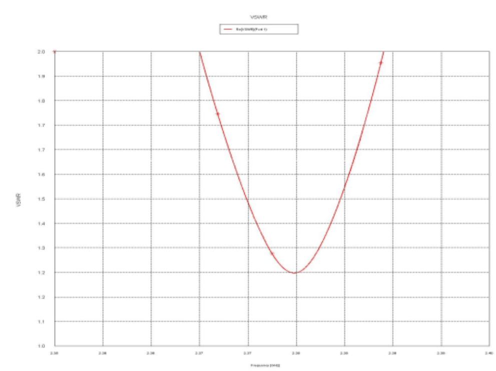

Fig 5 VSWR of Patch antenna

A single beam shift is shown in Fig 6, with a gain of 4.44.

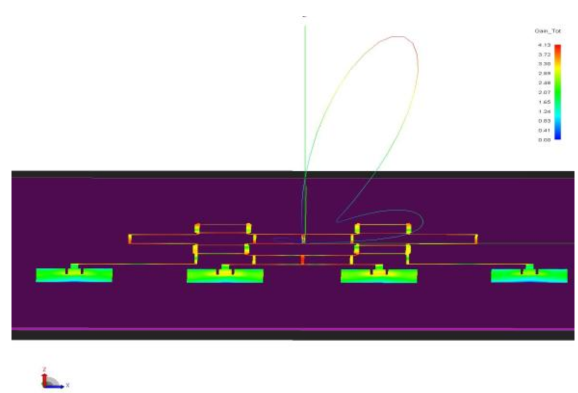

Fig 6 Single switched beam

The total beam steering of the four individual beams is shown in Fig 7. It is observed that the beam has switched at 18degree (shown in different colors). However during the appearance of the forth beam, there is a side lobe formation, due to which its gain has reduced.

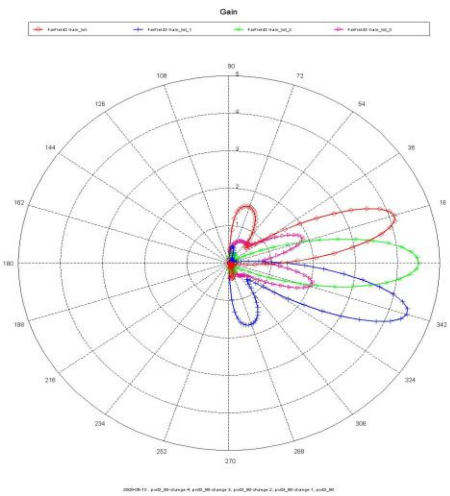

Fig 7 Four beam switching

The beam positions as per the progressive phase shifting at the feed end could be realized. Due to paper size constraints, the figures cannot be discussed at length.

Further to extension of this beam switched part in one plane, it is proposed to switch the beam in multi direction. An experiment was performed by exciting a separate Butler matrix network in a end fire array form, but it is observed that there is a vector addition of the two beams and becomes very difficult to have a 'phased control' switching.

In view of this a bi-layer [10] feed assembly could be a solution. As shown in Fig 8, the Butler matrix structures are placed on two separate substrates sandwiching in between a suspended feed from the connectors spaced at substantially equal distances along the conductor. The spacing is based on the transmitted signal frequency to maintain a substantially constant phase and amplitude to reduce electric field coupling through the support layer [14,15].

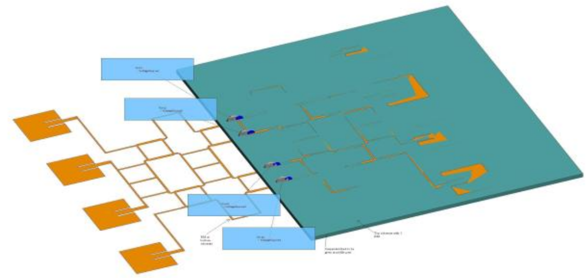

Fig 8 Proposed two layer suspended feed

This feed technique could switch the beam once in XY plane and the second time in YZ plane. The measurement results of this proposition would be presented in the further discussion.

III.CONCLUSION

The Butler matrix works as a perfect passive microwave network and the beam could be switched with a control over its progressive phase change. The basic configuration of a rectangular patch array is observed to give a better performance at the mentioned operating frequency. The effects of the related design parameters are studied and discussed. The isolation at the non-coupling port of the zero dB coupler matches with the measured value. All the simulations were carried over HFSS Software. The proposed multi beam switching technique is under consideration.

REFERENCES

[1] Diu Chang, Shin Hue Jou, The study of Butler Matrix BFN for four beams antenna system, *IEEE A & P Society Symposium,* June 22-27,2003, 176-179.

[2] Phan N. T., Gye Lee, Microstrip antenna array with BFN for WLAN, *A & P Society Symposium,* July 3-8,2005, 299-302.

[3] Tayeb A. Denidni, T. E. Libar, Wideband four port Butler Matrix for switched multibeam antenna array, *14th IEEE International Symposium*, September 7, 2003, 2461-2464.

[4] T. M. Macnamara, Simplified design procedures for Butler Matrix incorporation 90 degree hybrids, *IEEE Proceedings, Microwaves, A & P,* 1987, Vol 134, 50-54.

[5] F. Cladwell, Kenney J. S., Design and implementation of a switched beam Smart antenna, *Radio & Wireless Conference, August* 11-14, 2002, 55-58

[6] S. H. Chu, H.P. Lin, Performance enhancement by using switched beam smart antenna, *Wireless Communications and Applied Computational EM Conference*, April 3-7,2005, 1001-1005.

[7] T. K. Kwang, Gary, 4×4 Butler Matrix beam-forming network using novel reduced size branch line coupler, *IEEE European Microwave Conference*, October 31,2001, 1-4.

[8] S. R. Ahmad, F. C. Seman, Four port Butler Matrix for switched multibeam antenna array, *IEEE Asia Pacific Conference on Applied Eletromagnetics*, December 20-21,2005, 69-73.

[9] Esin Chang, S. A. Long, An experimental investigation of electrically thick rectangular micro strip antenna, *IEEE Transaction A & P, 1986, Vol 34 (6)*, 767.

[10] J. P. Berenger, A perfectly matched layer for the absorption of EM waves, *Journal Computational Physics, , 114*, 1994 1852.

[11 R. B. Waterhouse, s. D. Targonski, Design and performance of small printed antennas, *IEEE Transaction on A & P, November 1998, 46 (11)*, 1629-1633.

[12] M. Sanad, Micro strip antenna on very small ground plane for portable Communication systems, *A& P Society Symposium, , 12*, 1994, 810-813.

[13] I. J. Bahl, P. Bhartia, *Micro strip Antenna* (Artech House, 1980).

[14] C. A. Balanis, *Antenna Theory, analysis and Design (* John Wiley & Sons, 1982).

[15] D. M. Pozar,*Wide Band aperture coupled stacked patch antenna using thick substrates* (Electronic Letters, 1996, Vol 32, No 21, pp 1941-1942) .

[16]HFSS Ansoft Simulation Software.