COMPARISON BETWEEN THREE DIFFERENT RADIATION PATTERN FOR SWITCH BEAM ANTENNA ARRAY

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Abstract. Butler Matrix is a beamforming network (BFN), functioning as a feeding network of antenna array. It provides multiple values of progressive phase different of excitation current to an antenna array. By integrating Butler Matrix with antenna array, multiple beams on radiation pattern could be created. In this work, three different types of antenna array have been integrated with the same Butler Matrix and the radiation patterns of each configuration have been compared. The chosen antennas types in this project are 4 x 1 square patch antenna array, 4 x (4 x 2) antenna array and 4 x 1 monopole antenna array. They are chosen as each of them has different radiation pattern characteristic. The obtained results show that four independent beams with different angles are generated by individual array where square patch antenna array has Half Power Beamwidth (HPBW) about 30° for each beams and manage to cover 120° of coverage area, 4 x 2 antenna array has HPBW about 7° and cover 30° while dipole antenna produce two kind of beams, broader and narrower beams. The comparison between the measured and computed radiation pattern of each antenna array are presented.

Keywords: Multibeam antenna; 4 x 4 Butler Matrix; microstrip antenna; antenna array; beamforming network

1.0 INTRODUCTION

The topic of multibeam antenna constructed using Butler Matrix as a beamforming network (BFN) has received much attention due to its simplicity and low cost of implementation. It becomes more popular nowadays, as it is capable to reduce co-channel interference and then increase the channel capacity of a system [1]. Co-channel interference could be reduced using multibeam antenna by focusing directional beams to the desired user direction, and be null to undesired user directions. In fact, there are few popular methods of constructing a multibeam antenna such as using digital beamformer [2], Blass Matrix [3] and lens based beamformer [4], but the simplest one is by integrating linear antenna array with Butler Matrix. Butler Matrix is a well known BFN where it has a capability of producing multiple independent beams that directed at different directions. The number of generated beams, the beams angle directions, HPBW of each beams and total coverage angle of multibeam antenna could be varied dependent on the antenna array design configuration itself. The radiation patterns characteristics of the multibeam antenna could be analyzed through pattern multiplication theorem of antenna array.

According to the theory of pattern multiplication theorem, a radiation pattern of an antenna array could be affected by two main factors; the type of antenna array and its feeding network [1]. Since the feeding network in this project is fixed on Butler Matrix, the radiation pattern of the antenna array then could be changed by using different types of antenna. This work is an effort to observe and analyze the performance mainly in terms of radiation patterns characteristics by using different types of antenna array on Butler Matrix. The antenna arrays that have been used in this project are 4 x 1 square patch antenna array, 4 x (4 x 2) antenna array and 4 x 1 monopole antenna array while 4 x 4 Butler Matrix is chosen for its feeding network. These antennas are chosen as each of them has different radiation pattern characteristics which are broader pattern for single square patch antenna, directional pattern for single 4 x 2 antenna array and omnidirectional pattern for single monopole antenna. The numerical analysis of antenna array and Butler Matrix are also presented in this paper.

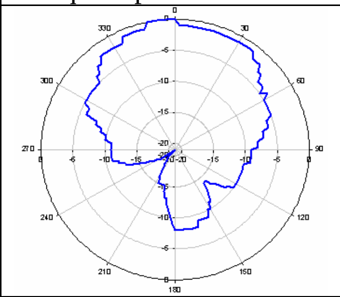
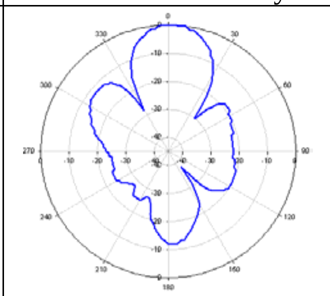
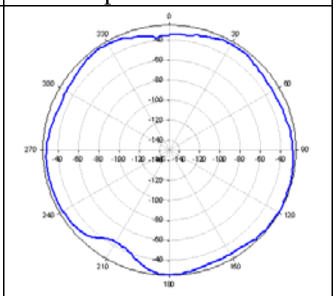
2.0 DESIGN CONSIDERATION

In this project, two major components are needed to be designed which are antenna array and Butler Matrix. The prototypes are designed at 2.4 GHz, implemented by using microstrip transmission line technique and fabricated on FR4 board with dielectric constant (ε_r) of 4.5, thickness (*h*) of 1.6 mm and dissipation factor (*tan* δ) of 0.019. In this project, three different types of antenna array has been developed which are 4 x 1 square patch antenna array, 4 x (4 x 2) antenna array and 4 x 1 monopole antenna array while 4 x 4 Butler Matrix is chosen as its feeding network. All of antenna array elements are arranged in a linear form and spaced at half-wavelength apart. All simulations of antenna design are done using Method of Moments (MoM) in Microwave Office software.

3.0 MEASUREMENT RESULT AND ANALYSIS

The radiation characteristics of the beams are measured using far-field method in the anechoic chamber. At first, the radiation pattern of the single antenna is measured. The obtained radiation pattern of the single antenna can be used later to calculate and predicted radiation pattern of the integrated antenna. The measured radiation pattern of single antenna is shown in Table 1.

Table 1 Measured radiation pattern of single antenna

Antenna Type	Square patch antenna	4 x 2 Antenna Array	Dipole Antenna
Measured Radiation Pattern			
Radiation Pattern Type	Broader beamwidth pattern	Directional pattern	Omnidirectional pattern
HPBW	89°	27°	All directions

By referring to Table 1, it can be seen that the radiation pattern of square patch antenna has a broader HPBW approximately about 89° while 2 x 4 antenna array provide a directional pattern with HPBW approximately about 27°. On the other hand, monopole antenna shows an omnidirectional pattern which receives power almost equal to all direction. The measured radiation patterns of single element results show that three different types of antenna were used when integrating antenna array with 4 x 4 Butler Matrix.

For the measurement of the integrated project, all input ports are fed with the same signal but only one port is activated at instant while the other ports are terminated with 50 Ω.

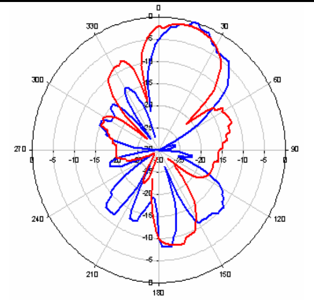
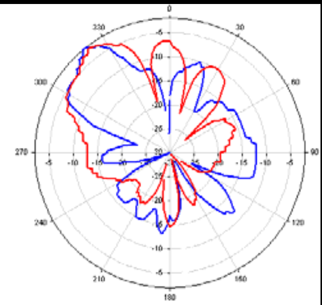
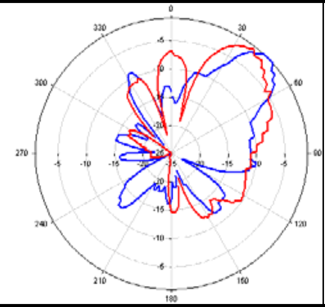
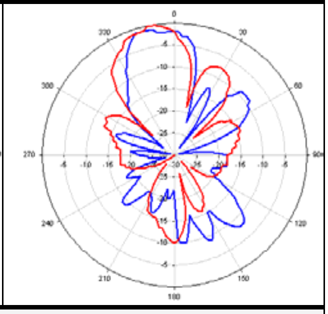
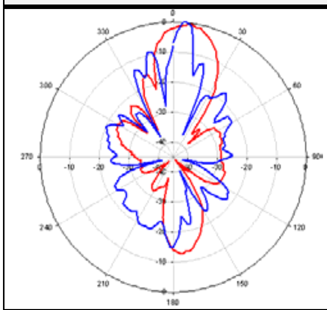
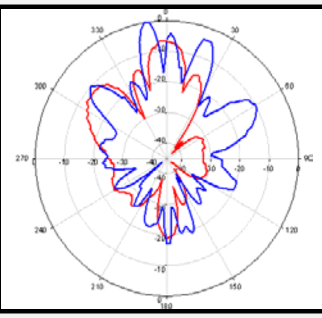
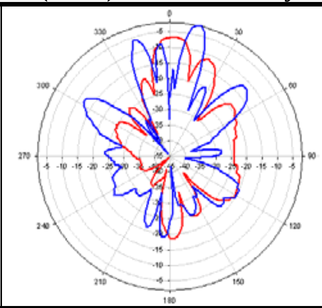
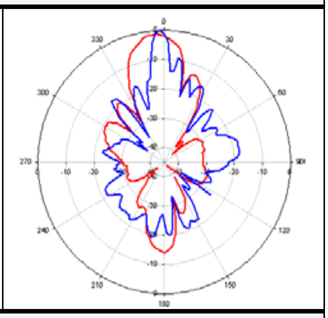
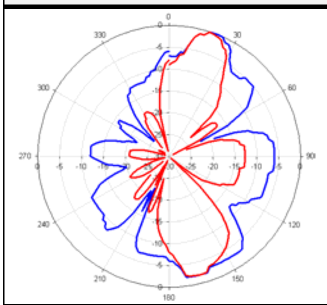
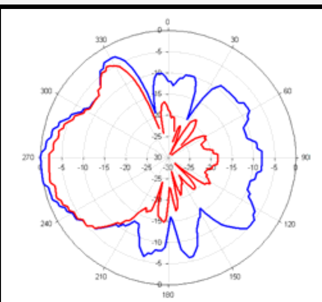
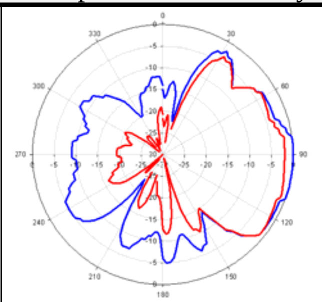
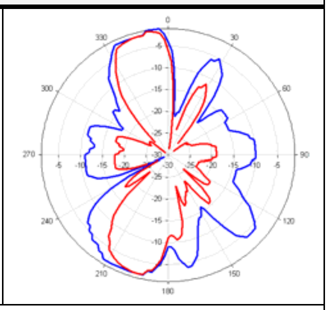
The radiation pattern of the integrated project can be predicted using pattern multiplication theorem. The data of a single array unit pattern is obtained from the measured result of single antenna (Table 1) while the data of the array factors are obtained from the computed results. Table 2 illustrates the comparison between the calculated and measured radiation patterns of each integrated project.

For the case of square patch antenna, it can be observed that the measured radiation has a similar pattern to the computed pattern. This is verified that the experiment is reliable as it has a good agreement with the theoretical calculation.

For the case of 4 x 2 antenna array, it can be observed that the calculated patterns have a bigger beamwidth compared to measured result. The direction of beams of 1R and 1L are similar to the calculated patterns which are directed to 5º and -2º respectively. The main beam of port 2R and 2L are directed to 13º and -9º respectively, which are a little bit different from the computed patterns. Computed patterns show that the main beam appears at the centre of the polar plot with lower magnitude as the beam position of the array factor, 2R and 2L are directed to 48.6º and -48.6º. The measured result shows a narrower beamwidth and more side lobes. This may be due to non-uniform surface of the antenna holder which is then caused the distance between 4 x 2 antenna array is higher than /2. As described in Section 2, side lobes will be appeared when distances between elements increases.

For the case of dipole antenna, it can be observed that the measured radiation has a similar pattern to the computed pattern. The little differences may be due to the misalignment of the rotator inside the chamber. As a conclusion, the entire measured result shows a good agreement with the theoretical calculation.

Table 9 Comparison between computed and measured radiation patterns for each configuration

1R	2L	2R	1L
4 x 4 Butler Matrix with 4 x 1 Square Patch Antenna Array			
			
4 x 4 Butler Matrix with 4 x (4 x 2) Antenna Array			
			
4 x 4 Butler Matrix with 4 x 1 Dipole Antenna Array			
			
Legend Computed Radiation Pattern Measured Radiation Pattern			

4.0 CONCLUSION

Three different radiation patterns constructed by integrating three different antenna arrays with 4 x 4 Butler Matrix have been presented. Three types of antenna array that have been used in this project are square patch antenna, 4 x 2 planar antenna array and monopole antenna. They have been proved that through measurement each of them produces different kind of radiation patterns which are broader beamwidth for square patch antenna, directional beam for 4 x 2 antenna array and omnidirectional pattern for dipole antenna. With the existence of Butler Matrix, it has been proved that four different independent beams with four different directions have been generated. The obtained result shows that square patch antenna array has HPBW about 30° for each beams and manage to cover 120° of coverage area, 4 x 2 antenna array has HPBW about 7° and cover 30° while dipole antenna produce two kind of beams, broader and narrower beams. Further more, the radiation characteristics are compared between the theoretical and measured result, and they correlate well.

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