Design of Beam Steering Antenna for Localization Applications

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***Abstract* – A 2.4 GHz beam steering antenna array is presented and tested in this paper. This antenna uses the 4x4 planar Butler matrix as a key component of phase-shifter which exhibits ±135° and ±45° phase shifts corresponding with four position of main beam. The proposed design is fully described, from the element blocks (antenna element, butler matrix) to the full integrated beam steering antenna array. The proposed antenna has the 20°-27° of beam-width in vertical and 240° of beam-width in horizontal. The main beam of this antenna can steer from -37°, -12°, 12° to +36° in vertical. Simulation results will be presented and compared with experimentation data.**

***Index Terms* — Beam steering antenna, 4x4 Butler matrix array, dipole antenna.**

1. Introduction

Beam steering antenna have been a critically important component in the modern wireless communication system with applications in radar, satellite, localization technologies [1]. Phased array is common technique to be used to steer the main beam of antenna array by shifting the phase of excitation to each element. The Butler matrix is useful phase-shifter in advanced antenna design and has advantages in term of manufacturing, integration, cost… . Several antenna can steer at some fixed direction using Butler matrix for phase-shifter, they are available in the literatures [2-3][5] This paper will present the design of an array of four dipole antennas integrated with 4x4 planar Butler matrix. The main beam of this microstrip antenna array can steer to four positions in vertical plan. Therefore, this beam steering antenna helps to improve the locating error of localization system. The smaller beam-width this antenna is, the minimum locating error of localization system is.

2. Butler Matrix Design

As shown in Fig. 1, a 4x4 Butler matrix includes four 90° couplers, two 45° phase shifters, two 180° phase shifters and two crossovers. By selecting one of the inputs while the other are matched to 50 Ω, four different beams can be generated respectively. The 4×4 Butler matrix in Computer Simulation Technology (CST) is shown in Fig. 1. The S11 of four input ports are shown in Fig. 3, S11 of each port are all lower than −10dB from 2.2 GHz-2.7 GHz:

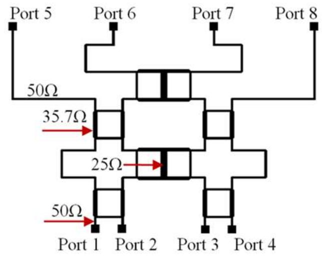

Fig. 1. Model of the 4x4 Butler matrix in CST

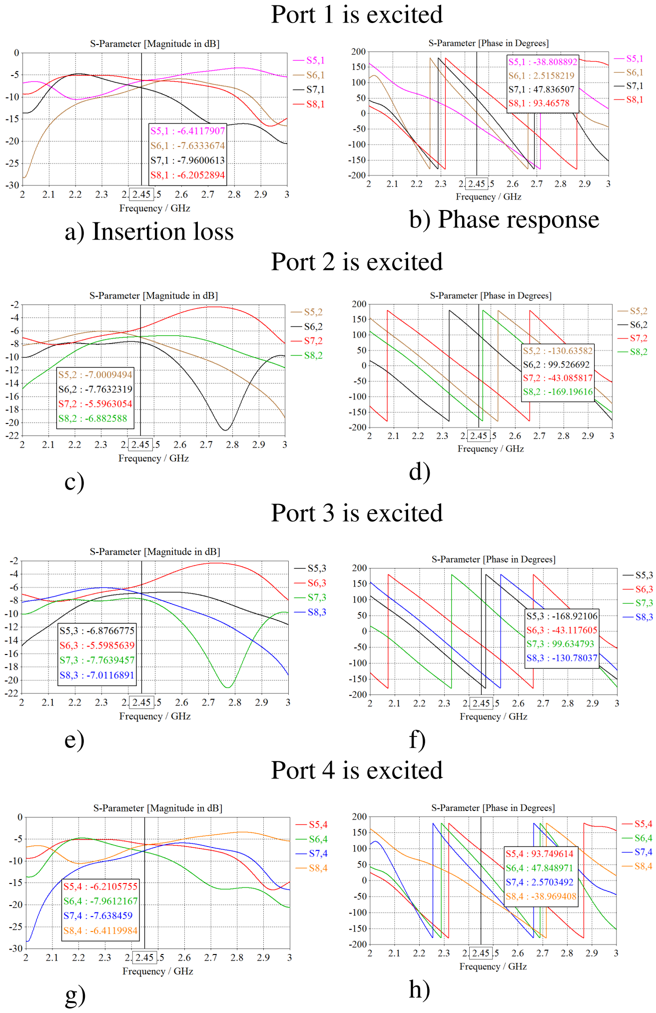

Fig. 2. Simulation results of insertion loss and phase response of the Butler matrix

3. Design of Beam Steering Antenna

An array of 1x4 dipole antennas (with $0.7\lambda_0$ spacing) integrated with 4x4 Butler matrix is shown in Fig. 3. The

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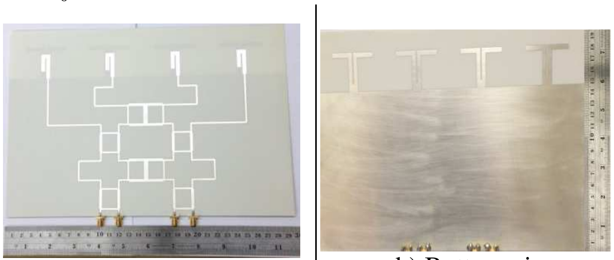
total antenna size is 200 mm x294 mm, equivalent with $1.6\lambda_0$ x $2.4\ \lambda_0$:



a) Top view b) Bottom view

Fig. 3. Fabricated microstrip antenna array with 4x 4 Butler matrix

Fig. 4 shows the simulated and measured return loss plot of beam steering antenna array. The bandwidth of proposed antenna is from 2.3 GHz to 2.7 GHz, covering the LTE band as well as 2.4 GHz ISM band. The radiation pattern of antenna is presented in Fig. 5 and Fig.6 with 8dBi of peak gain and efficiency is greater than 70%.

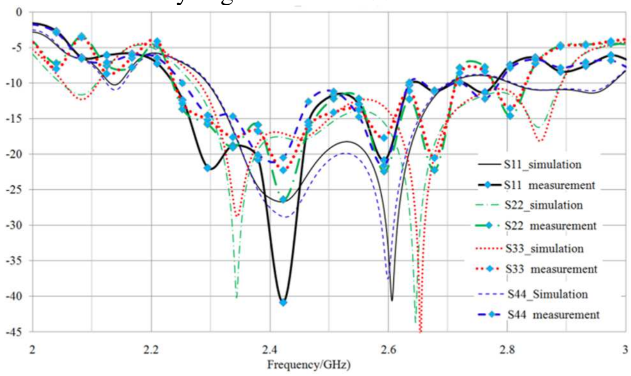


Fig. 4. The simulated and measured results of return loss at input ports of aray antenna

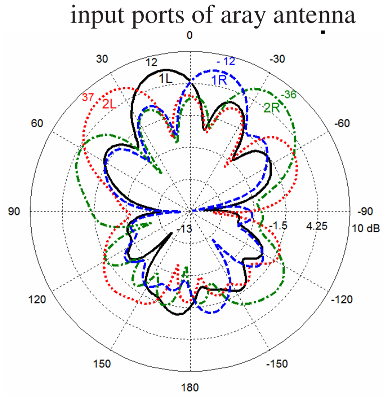


Fig. 5. Radiation pattern 2D in vertical beam steering antenna

Antenna can steer in 1-direction, For port 1 excitation the beam is formed in the direction of 12°(**1L**), for port 2, port 3 and port 4 excitation, it is at −36°(**2R**), 37°(**2L**) and -12°(**1R**), respectively, with the beam-width of 20.7° ÷ 27°:

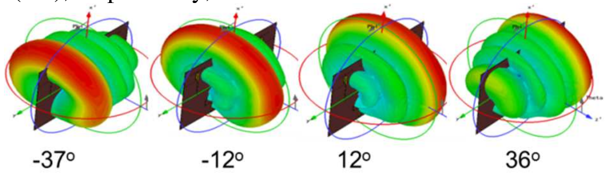


Fig. 6. Radiation pattern 3D of beam steering antenna

Our antenna is compared with related works [3-5] in term of the beam direction, gain, beam-width and side lobe level (SLL) (see Table I). It is clear to see that this proposed antenna is: smaller beam-width in vertical (20°), wider beam-width in horizontal (240°) and higher gain.:

TABLE I: The comparison of the antenna performance

Beam	**Ref**	**Beam angle** (°)	**Gain** (dB)	**BW** (3dB)	**SLL** (dB)
1L	[3]	12	11.8	34.9	-16
	[4]	15	~11	28	-9.5
	[5]	12	6.4	30	-9
	This work	12	**8.16**	**20.7**	**-9.3**
2R	[3]	-39	7.4	60.6	-11.9
	[4]	-45	~11	30	-8
	[5]	-42	6.4	33	-2
	This work	-36	**8.15**	**27**	**-8.1**
2L	[3]	40	7.1	34.9	-3.7
	[4]	45	~11	30	-5.5
	[5]	45	6.4	33	-8
	This work	37	**7.925**	**26.3**	**-5.5**
1R	[3]	-12	6.6	55.7	-3.1
	[4]	-15	~11	28	-9
	[5]	-15	6.4	30	-7.5
	This work	-12	**7.95**	**21.3**	**-9.0**

4. Conclusion

The design of a beam steering antenna using 4x4 Butler matrix is presented and tested. This antenna has advantages of high gain, low-profile, small beam-width in steering direction (vertical) while 240° beam-width in the other direction helps localization system can work at different higher-level compared with ground.

Acknowledgment

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