International Journal of Electronics Engineering, 4 (1), 2012, pp. 39–42

Microstrip Linear Phased Array for Smart Antenna Applications

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Abstract: In this paper, we have proposed microstrip phase antenna arrays for smart antenna applications designed at 2.7GHz frequency. The antenna array simulations are carried out by using IE3D software. The simulated antennas are fabricated using glass epoxy substrate with dielectric constant 4.4. The fabricated arrays are tested practically for the return losses, radiation patterns and gain measurements. Both the simulation and practical results are compared and found that they are in good agreement. Details of the antenna array design are presented and experimental results are discussed. Phased antenna arrays are useful for many types of applications such as traffic control and collision avoidance radars, smart base station antennas for WLAN and cellular communication.

Keywords: Microstrip phased arrays, beam steering, transmission line phase shifter**.**

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1. INTRODUCTION

Many antenna system applications for wireless communication require that the direction of the main beam lobe be changed with time. This can be achieved by phase array antennas which can sweep the direction of the beam by varying electronically the phase of the radiating elements, thereby producing moving a pattern electronically with high effectiveness managing to get minimum side lobe levels and narrow beam widths. Schematic illustration of a phased array antenna is shown in Figure 1. It consists of power distribution network, phase shifters and antenna elements. Wire antenna, microstrip patches, horn antenna and wave guides are various types of antennas that are used. A large number of antenna elements were needed to construct the array to achieve a narrow beam width or considerable scanning range with high angle resolution. Phase shifters are classified as mechanical phase shifters, ferrite phase shifters, semiconductor device phase shifters and transmission line phase shifters. Power dividers are used for splitting microwave signals to feed the radiating elements [1].

In this paper, the investigation on amount of beamsteering of main beam by changing the length of transmission line is presented. We found practically that there is an increase in gain by factor 2 with the increase in array elements and also demonstrated 5° beamsteering of a main beam towards right with the L/6 length of transmission line from first element (5L/6 from second element). Similarly, there is a 5° beamsteering towards left with a reverse condition.

Phased array antenna can be used for beamsteering applications in smart antennas, submarine communication and air borne mobile communication. Higher data rates up to and beyond 1Mbps and over long distances (around the globe) is possible with INSAT series having S-band mobile communication pay load for submarines. Considerable research has been conducted by several organizations and individuals because of advances in phased array antennas and its underlying signal processing algorithms theoretically [2][3].

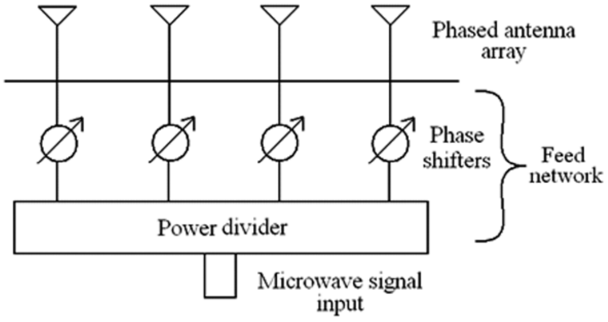

Figure 1: **Phased Array Antenna**

2. DESIGN OF MICROSTRIP ARRAY ANTENNA

Microstrip patch antennas are important as single radiating elements but their major advantages are realized in application requiring moderate size arrays. The primary radiator microstrip antenna is designed with frequency f = 2.7GHz which gives single element microstrip antenna (SEMA) as shown in Figure 2. The dimensions of the patch are calculated using formulae found in [4]. Single patch is extended to two element microstrip array (TEMA) shown in Figure 3 and extended to four element microstrip array

(FEMA) shown in Figure 4. The impedance is matched to 50 ohms at all the ports with quarter wave transformer and impedance transformer. Further, to achieve beamsteering towards right, feed line is shifted to left slightly by L/6 from first element which gives TEMA1. Similarly to have beamsteering towards left feed line is shifted to right slightly by 5L/6 from first element which gives TEMA2 as shown in Figure 5. As said above, from four element microstrip array (FEMA), FEMA1 and FEMA2 are designed by changing the length of transmission line as shown in Figure 6. The above antennas are simulated and optimized using IE3D software.

The art work of the proposed antennas are sketched using AutoCAD 2004 and are fabricated on low cost glass epoxy substrate material of thickness h = 0.16 cm and permittivity $\varepsilon_r = 4.4$. Microstrip line feeding is used to feed the antenna and antenna arrays. The various antenna parameters shown in Figure 2 to Figure 6 are shown in Table 1.

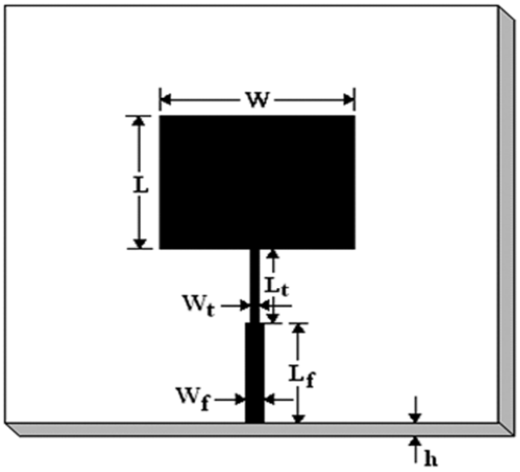

Figure 2: Geometry of SEMA

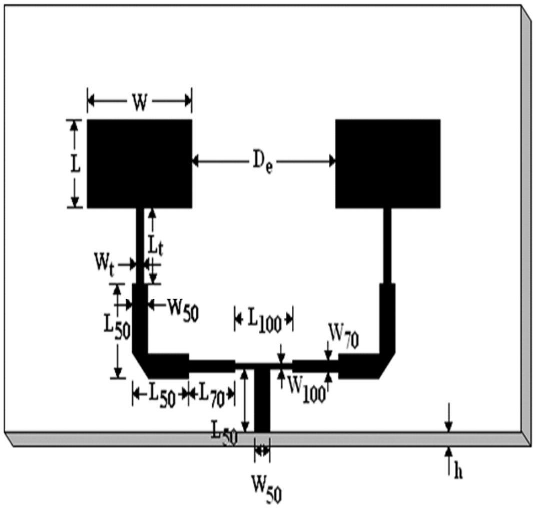

Figure 3: Geometry of TEMA

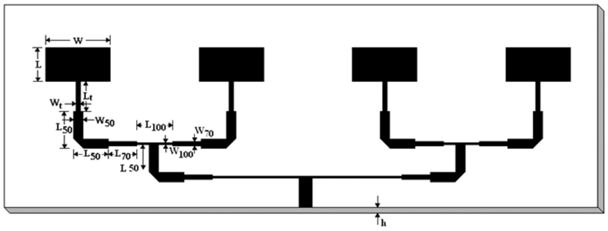

Figure 4: Geometry of FEMA

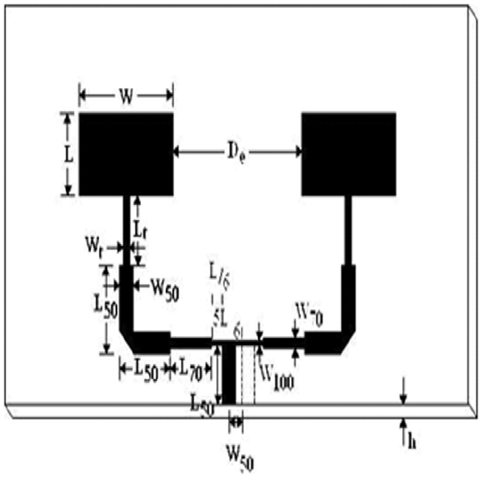

Figure 5: Geometries of TEMA1 and TEMA2

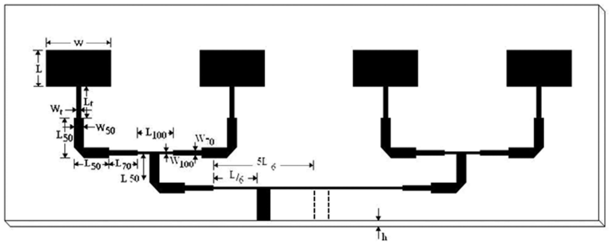

Figure 6: Geometries of FEMA1 and FEMA2

Table 1
Design Parameters of Proposed Antennas

Antenna Parameters	*Dimensions in mm*	*Antenna Parameters*	*Dimensions in mm*
h	1.6	L_{50}	14.77
L	26.105	W_{50}	3.06
w	33.81	L_{70}	14.80
L_f	14.77	W_{70}	1.028
W_f	3.06	L_{100}	14.82
L_t	14.83	W_{100}	0.709
W_t	0.525	D_e	43

3. RESULTS AND DISCUSSIONS

All the proposed antennas have been simulated using Mentor Graphics IE3D software and the results are shown in Table 2. The characteristics such as return losses, radiation patterns and gain measurements of all proposed configurations have been obtained through simulation and also verified experimentally by using Vector Network Analyzer (Rohde & Schwarz, Germany make ZVK model 1127.8651). The simulated and measured results are in good agreement.

The simulated and practical return loss characteristics of antenna are shown in Figure 7 and Figure 8. From these figures it is seen that, all the antennas are resonating for the desired frequency. The gains of the proposed antennas are also measured and results are shown in Table 2. The measured radiation pattern of single element microstrip antenna (SEMA) in elevation plane is shown in Figure 9. Figure 10 and Figure 11 shows radiation patterns of two element microstrip array (TEMA) and four element microstrip array (FEMA) respectively. It has seen that there is an increase in the gain and directivity by factor 2 with the increase in antenna elements. The main beam of the array is scanned electronically by changing the length of transmission line. We have demonstrated beamsteering towards right with the L/6 length of transmission line from first element (5L/6 from second element). Similarly, beamsteering towards left with a reverse condition.

Phase Shift is determined by the equation given by

$$\beta = \sqrt{\varepsilon_{eff}}\, K \Delta L$$

Where $k = 2\pi f/c$ and ΔL = physical length

$$\beta = \frac{2\pi\, \Delta\, L f\, \sqrt{\varepsilon_{eff}}}{c}$$

where c is the speed of light, f is the operating frequency and ε_{eff} is effective dielectric constant.

For $\Delta L = L/6$ then = 0.26, therefore $\theta = \beta LX180/\pi = 4.7^{\circ}$.

Similarly, for $\Delta L = 5L/6 = -L/6$ then $\beta = -0.26$ therefore $\theta = -4.7^{\circ}$.

By using IE3D we have obtained the beamsteering and also we have practically obtained beamsteering of 5° towards right and left with reduced sidelobes and increased directivity with the increase in array elements.

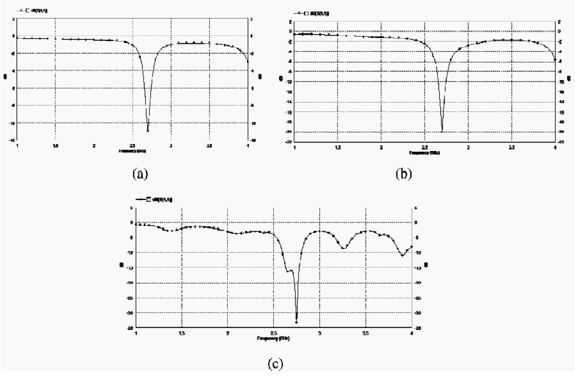

Figure 7: Simulated Variation of Retun Losses of (a) SEMA, (b)TEMA and (c) FEMA

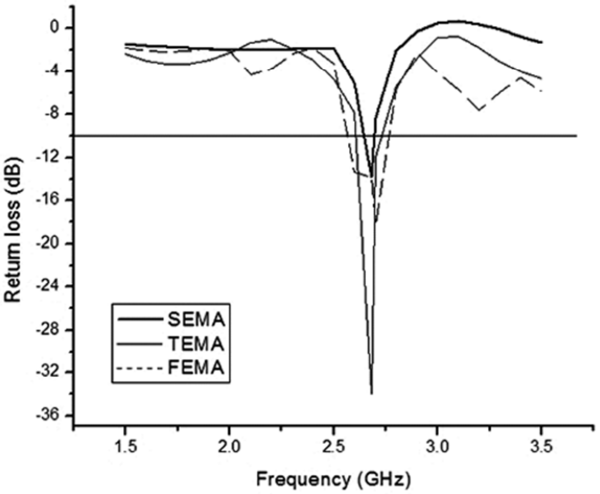

Figure 8: Variation of Return Losses of SEMA, TEMA and FEMA versus Frequency

Table 2
Performance of Proposed Antennas

	Resonant frequency (GHz)		*Return loss (dB)*		*Gain (dB)*	
Types of Antennas	*Simulated*	*Measured*	*Simulated*	*Measured*	*Simulated*	*Measured*
SEMA	2.69	2.68	-10.83	-13.84	1.73	1.92
TEMA	2.69	2.68	-19.84	-33.9	3.04	2.35
FEMA	2.75	2.71	-32.66	-18.2	5.77	3.85

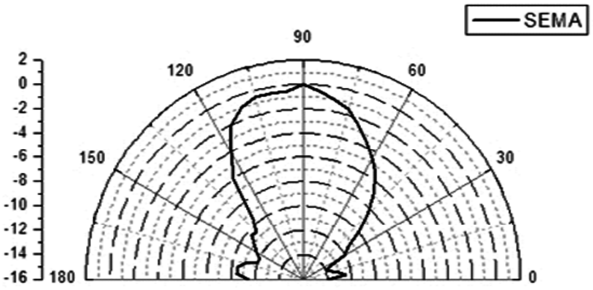

Figure 9: Radiation Pattern of SEMA

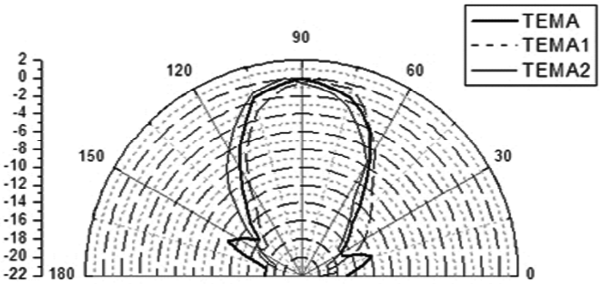

Figure 10: Radiation Patterns of TEMA, TEMA1 and TEMA2

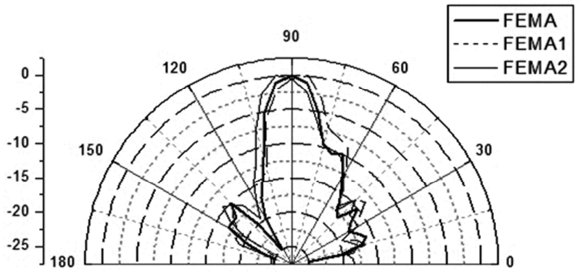

Figure 11: Radiation Patterns of FEMA, FEMA1 and FEMA2

4. CONCLUSION

In this paper we demonstrated a phased array concept by varying the length of the transmission line. The results obtained through simulation and experiments of microstrip arrays are discussed. All the proposed antennas are fabricated and tested practically. Both the results are good in agreements. Theoretical and practical beamsteering angle are also good in agreement. The designed antenna can be used for phased array applications in S-band i.e. at 2.7GHz. The integrating phased array antenna with digital signal processing (DSP) algorithms may find application in the smart antenna systems.

ACKNOWLEDGMENTS

The authors acknowledge their thanks to UGC, New Delhi for sanctioning the IE3D software under Major research project which is most useful and reliable for designing microstrip antennas. The authors also thank the authorities of Department of Science and Technology (DST), Govt. of India, New Delhi, for sanctioning the Network Analyzer under the FIST project to the Department of Applied Electronics, Gulbarga University, Gulbarga.

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