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A Comparitive Study of Four Different Shaped Frequency Reconfigurable Log Periodic Microstrip Antenna Arrays

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ABSTRACT

This paper describes the design and simulation of four frequency reconfigurable three element log-periodic microstrip antenna arrays. A comparative study is presented using rectangular, square, triangular and circular patch elements .The three patches fed by inset feed line technique are connected with a single transmission line by a log-periodic array formation to form a wideband frequency from 2.9 to 3.4 GHz. By applying three PIN diodes modules at the transmission line, two different sub-band frequencies are configured by switching ON and OFF the switches.The frequency responses of these arrays are analysed using the Zealands IE3D commercial software that implements the method of moments. After the simulations were completed, different shaped Log PeriodicAntennas(LPA) were compared in terms of return loss, realized gain and directivity.

Key words: log-periodic antenna, microstrip, reconfigurable, wideband.

1. INTRODUCTION

Reconfigurable antennas[1] are becoming more widely used due to the increasing number of wireless communications and new functionalities of these systems than the passive antennas as they can provide diversity functions in operating frequency[2]-[4], polarization[5], and radiation pattern by altering the current flow on an antenna, using mechanically movable parts, phase shifters, attenuators, diodes, tunable materials, or active materials. Moreover, multiple antennas supporting different wireless bands are not a suitable solution, because of the higher demand of compact size, efficiency, low power consumption and low cost. There has been a dramatic increase in the awareness of reconfigurable antenna for applications in future wireless communications such as cognitive radio, ground pentrating radar applications and RFID applications.

Frequency reconfigurable antennas are useful to support many wireless applications, where they can reduce the size of the front end circuitry and also allow some additional receiver pre-filtering. The reconfiguration can be implemented through the PIN diode switches[6], MEMS[7] or varactor diodes. However, electronic tunability using PIN diode is more frequently used because of its efficiency and reliability especially in dynamic bandwidth allocation.

In [8], a novel both pattern and frequency reconfigurable annular slot antenna is presented. The antenna has three different frequencies by controlling the matching stubs, which are fabricated on the opposite side of the board. And it also has a reconfigurable radiation pattern, which is controlled by the dc voltage of the PIN diodes on the slot

In [9], a low-cost multiband printed-circuit-board(PCB) antenna that employs Koch fractal geometry and it has tunability over the bands of several applications including 3G, WiFi, WiMAX as well as a portion of the UWB range.

In this paper, four different shaped microstrip log-periodic antennas with the feature of reconfigurability[10] were designed to meet the requirements in terms of the return loss, gain, and directivity. The proposed antennas are designed from the combination of three elements by using the logperiodic technique with the scaling factor of 1.05. As each element radiates at different frequency bands, the logperiodic antennas are easy to select required band from wideband. The commercial zealand's IE3D software is used to carry out the simulation for the reconfigurable log periodic antenna. The antenna is analyzed based on several parameters such as return loss, radiation pattern, gain, directivity and bandwidth.

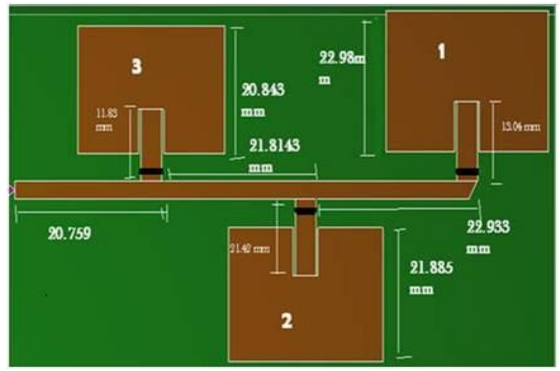
2. ANTENNA DESIGN

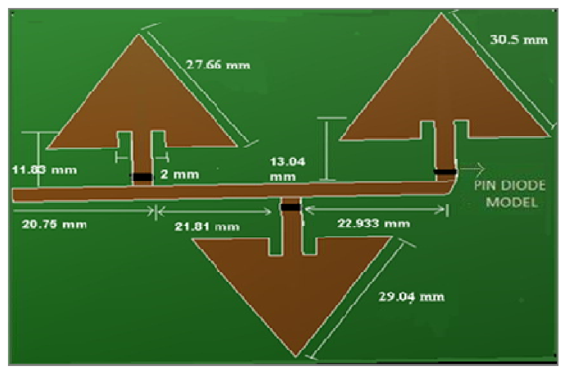
The geometrical structures of the three element logperiodic microstrip antennas are as shown in figure 1. The concept of frequency reconfi-gurability is investigated based on changing the position of the switches to ON or OFF. These antennas can perform in frequency range from 2.9 GHz until 3.4 GHz with two different sub bands. There are different shaped patches with inset fed lines, which are connected with a log-periodic array formation to a 50 Ω microstrip transmission line on a top layer of substrate. The antenna structures are developed on a FR-4 substrate which has relative permittivity of 4.5, with a thickness of 1.6 mm and loss tangent of 0.019.

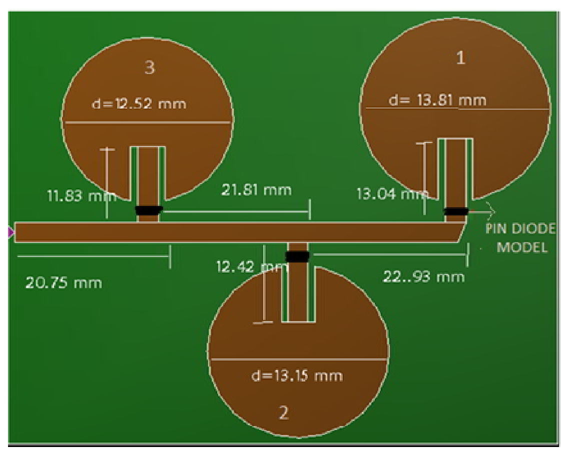
The log periodic microstrip antenna[11] is a more conventional approach for the implementation of a broadband antenna. The basis of this design is the linear array of coplanar patch antennas with the size and spacing of the patches increasing in a log periodic manner. The design principle for log-periodic wideband microstrip antenna requires scaling of dimensions from period to period so that the performance is periodic with the logarithm of frequency. The patch lengt(L), width(W), side length(S) and diameter(d) are related to the scaling factor (τ) by equation as shown below.

$$\tau = \frac{L_{m+1}}{L_m} = \frac{W_{m+1}}{W_m} = \frac{S_{m+1}}{S_m} = \frac{d_{m+1}}{d_m} \qquad (1)$$

The first patch (lower frequency) is designed with resonant frequency at 3 GHz and it is scaled by a factor of 1.05 to obtain the second patch dimensions. Second patch diameter is once again scaled by a factor of 1.05 to obtain the third patch dimensions. The space between each patch (Dm) is a half wavelength apart thus giving a forward fire radiation pattern and reducing mutual coupling effect. The reconfigurabilty is achieved when the RF PIN diodes are integrated with the feeding line to act as a switch and to control the ON/OFF mode. For the purpose of simulation, the switch in RF systems is represented by a open and short of the transmission line[3],[12]. Therefore, metal stripes 3mm x 1mm have been used to represent the PIN diode and located at the transmission line. The wideband operation is achieved when all switches are in ON state. By controlling the switch at the transmission line of patch, the required frequency band could be achieved. For this design, two sub-band are achieved by controlling a group of switches as in table 2. The band one operation is achieved by switching ON the first two diodes while the third is OFF state. While second band operation is attained when first pindiode is in OFF state while the remaining two PIN diodes are in ON state. In simulation process, the ohmic losses are assumed to be zero by using the ideal substrate and perfect electric conductor of patch. Hence, the ON state is representing by that metal stripe and the absence of the metal stripe is representing the OFF state.







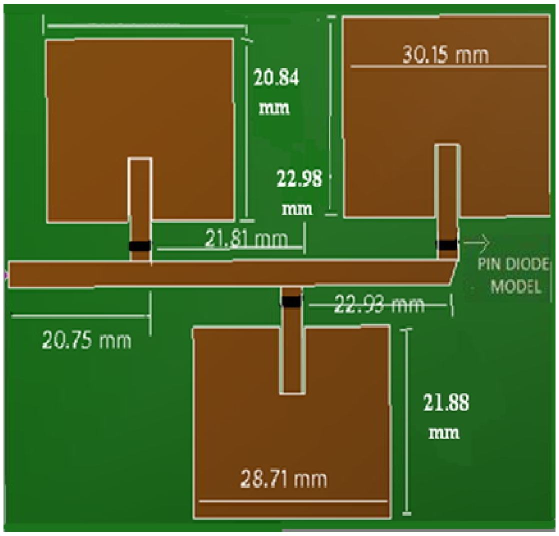


Figure 1: Top view of Proposed Three Element Square, Triangle, Rectangle, Circular shaped Log periodic Antenna Array

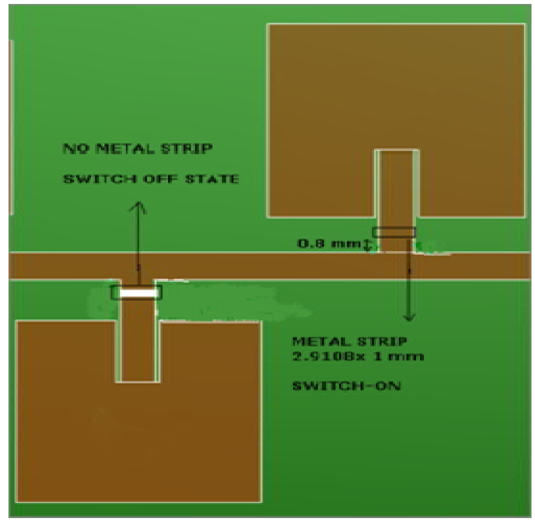


Figure 2: Switch Modelling in simulation to consider reconfigurability feature.

Table1: Design dimension of different shaped LPA

PATCH SHAPE	PARA METER	PATCH 1	PATCH 2	PATCH 3
SQUARE	LENGTH = WIDTH	22.98	21.88	20.84
TRIAN-GLE	SIDE	30.50	29.04	27.66
RECTAN-GLE	LENGTH	30.15	28.71	27.34
	WIDTH	23.17	22.06	21.01
CIRCLE	DIA-METER	13.81	13.15	12.52

Table 2: Switching Combination

No. of the PIN diode	WIDE BAND	SUB BAND 1	SUB BAND 2
1	ON	ON	OFF
2	ON	ON	ON
3	ON	OFF	ON

3. SIMULATION RESULTS

The proposed log-periodic microstrip antennas have been simulated using zealand's IE3D software to carry out the results of the antenna performances. Figure 2(a) shows the return loss of the wideband operation when all the pin diodes are in ON state, while Figure 2(b), 2(c) shows the return loss for different subband operations of various shaped patches. The –10 dB return loss bandwidth for wide band operation and for different sub bands of different shaped patches are as shown in table 3, 5 and 6. Figure 3(a) shows the simulated gain for wideband operations of different shaped patches, while the simulated gain for sub bands is represented by figure 3(b), 3(c). Figure 4(a) shows the simulated directivity for wideband operations of different shaped patches, while the simulated directivity for sub bands is represented by figure 4(b), 4(c). Comparison of gain, directivity for each band at centre frequency is given by Table 4 and 7.

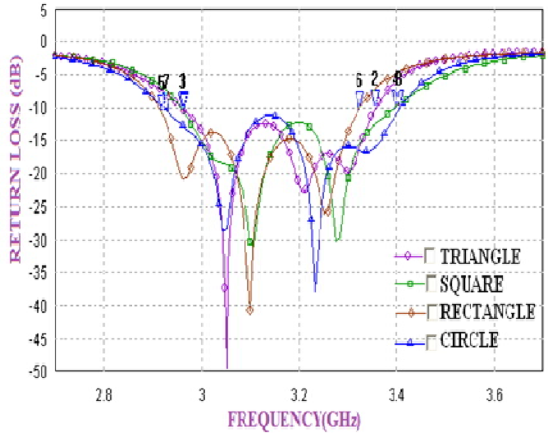


Figure 2(a): Simulated Return Loss characteristics for wideband operation

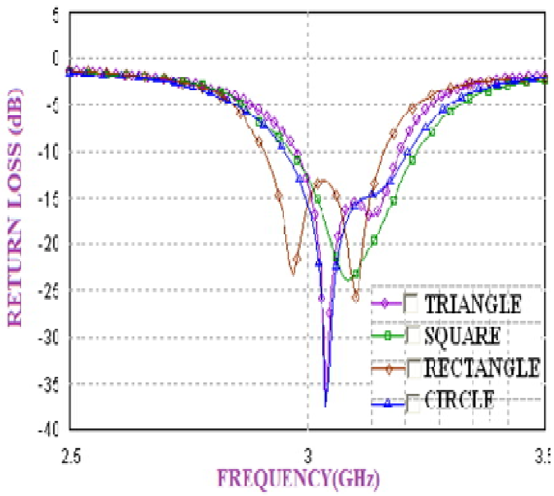


Figure 2(b): Simulated Return Loss characteristics for subband1 of different shaped LPA.

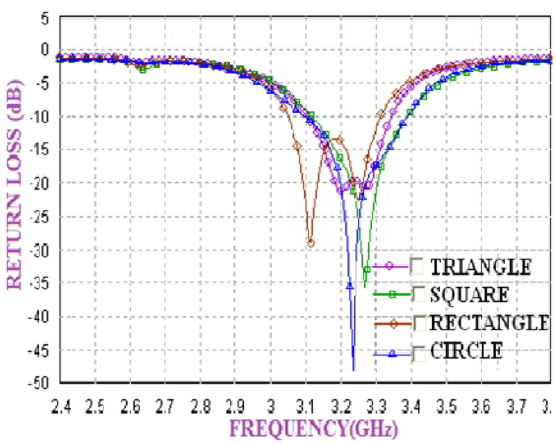


Figure 2(c): Simulated Return Loss characteristics for subband2 of different shaped LPA.

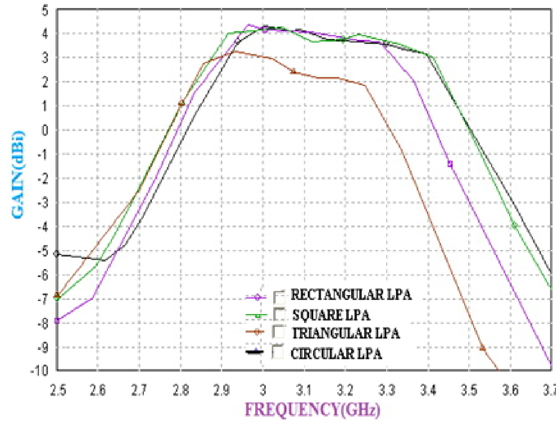


Figure 3(a): Gain vs Frequency Response for wide band operation of different shaped LPA

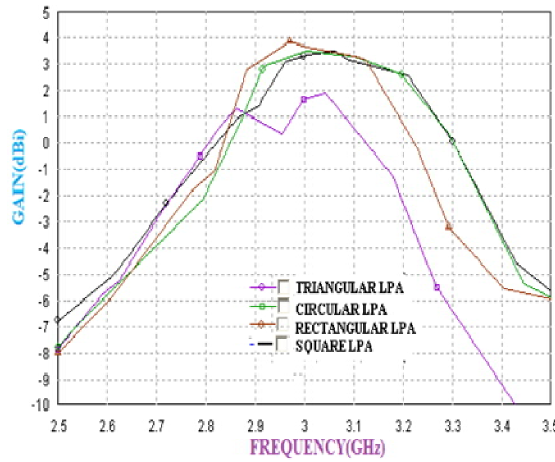


Figure 3(b): Gain vs Frequency response for subband1 of different shaped LPA.

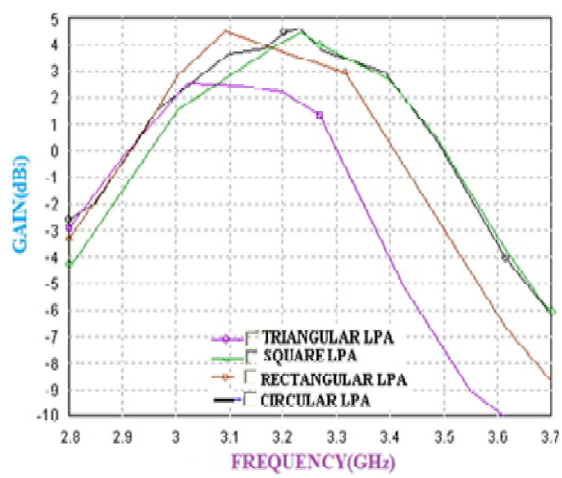


Figure 3(c): Gain vs Frequency response for subband2 of different shaped LPA

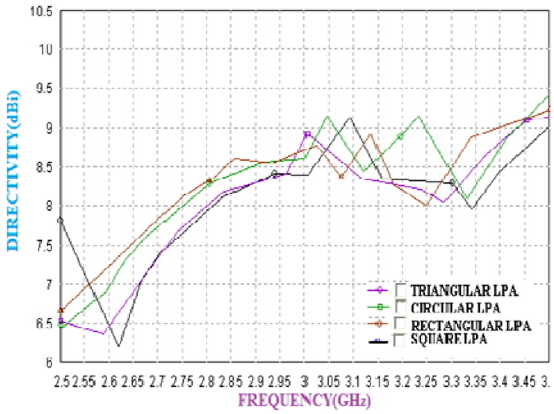


Figure 4(a): Directivity vs Frequency response for wide band operations of different shaped LPA.

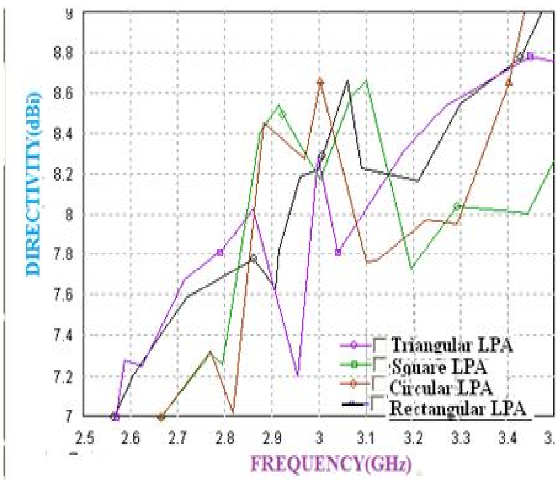


Figure 4(b): Directivity vs Frequency response for sub band1 of different shaped LPA.

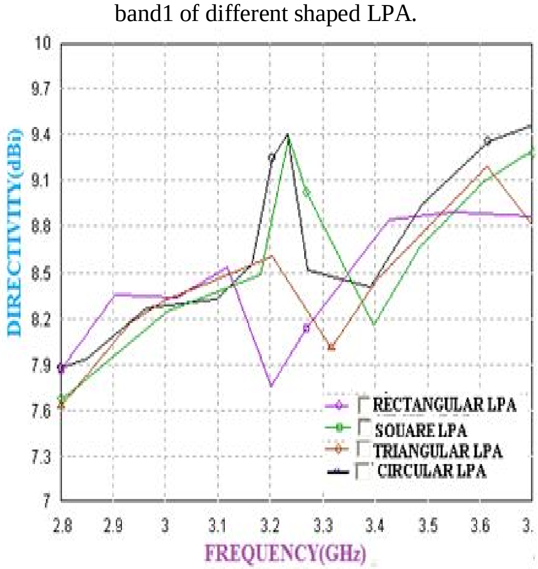


Figure 4(c): Directivity vs Frequency response for sub band2 of different shaped LPA

Table 3: Comparision of bandwidth for wide band

PATCH SHAPE	F(L) GHz	F(H) GHz	BAND WIDTH MHz	BAND WIDTH (%)
SQUARE	2.96	3.39	438	13.79
TRIAN-GLE	2.96	3.36	400	12.65
RECTAN-GLE	2.91	3.32	411	13.21
CIRCLE	2.92	3.40	484	15.31

Table 4: Comparision of gain & directivity for wideband

PATCH SHAPE	Gain. (Min) dBi	Gain (Max) dBi	DIREC-TIVITY (Min) dBi	DIREC-TIVITY (Max) dBi
SQUARE	3.05	3.92	7.99	9.09
TRIAN-GLE	1.58	3.04	8.49	8.95
RECTAN-GLE	2.65	4.24	8.05	8.86
CIRCLE	3.12	4.15	8.48	9.11

Table 5: Comparision of bandwidth for band one

PATCH SHAPE	F(L) GHz	F(H) GHz	BAND WIDTH MHZ	BAND WIDTH (%)
SQUARE	2.96	3.22	259	8.36 %
TRIAN-GLE	2.97	3.19	217	7.14 %
RECTA-NGLE	2.91	3.16	250	8.25 %
CIRCLE	2.95	3.21	266	8.63 %

Table 6: Comparision of bandwidth second band.

PATCH SHAPE	F(L) GHz	F(H) GHz	BAND WIDTH MHZ	Band width (%)
SQUARE	3.11	3.38	275	8.46%
TRIANGLE	3.10	3.34	237	7.14 %
RECTANGLE	3.05	3.31	250	8.33 %
CIRCLE	3.09	3.38	292	9.04 %

Table 7: Comparision of gain & directivity for subbands

PATCH SHAPE	BAND 1		BAND 2	
	Gain (Max) dBi	DIREC-TIVITY (Max) dBi	Gain (Max) dBi	DIREC-TIVITY (Max) dBi
SQUARE	3.45	8.62	4.29	9.34
TRIAN-GLE	1.77	8.26	2.46	8.58
RECTAN-GLE	3.76	8.61	4.49	8.53
CIRCLE	3.38	8.64	4.44	9.37

5. CONCLUSION

A comparative study of different shaped log-periodic microstrip antenna arrays using rectangular, square, circular and triangular electromagnetically coupled patch elements was accomplished in this paper. After the done study, was verified that the lower cut off frequency of the antenna arrays depended on the choice of the patch geometries. Thereafter, in terms of –10 dB return loss bandwidth, the circular patch presented the best performance, followed by the square, rectangle and triangle patch shapes, respectively. In terms of the gain, the rectangular patch has more gain followed by circular, square and triangle. In terms of directivity, the circular patch presents the best performance followed by square, triangle and rectangle. However, it was also verified that any of these patch geometries can be used for the design of wideband log-periodic microstrip antennas and it has been demonstrated that the required frequency band could be achieved by choosing various switching combinations.

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