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Simulation of Frequency Reconfigurable Square Log Periodic Microstrip Antenna Array

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Abstract **-This paper describes the design and analysis of a frequency reconfigurable square microstrip patch antenna using the log periodic technique. The three square patches are fed by inset feed line technique and 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 at the transmission line, two different sub-band frequencies are configured by switching ON and OFF the PIN Diode. Simulation results of return loss, realized gain, directivity for every sub bands also presented and discussed along with the antenna design.**

Keywords **- log-periodic antenna, reconfigurable frequency, PIN diode, wideband, microstrip**

1.INTRODUCTION

Reconfiguraable antennas have received much attention than the passive antennas as they can provide diversity functions in operating frequency, polarization, and radiation pattern to wireless The reconfiguration can be implemented through the PIN diode switches[2], MEMS [5] or varactor diodes. However, electronic tunability using PIN diode is more frequently used because of its efficiency and reliability especially in dynamic bandwidth allocation. There has been a dramatic increase in the awareness of reconfigurable antenna for applications in future wireless communications such as cognitive radio [8], RFID applications, ground pentrating radar applications and multi-frequency communication.The advantage of frequency reconfigurable antenna is that it can be reconfigured into any frequency in wideband range and can change dynamically, either transmitting or receiving on a single antenna instead of using multiple antennas as usual.

Microstrip patches are often used as single element antennas in certain applications, but in case of conventional microwave antennas, characteristics such as high gain, beam scanning, or steering capability are possible only when discrete microstrip patches are combined to form arrays[10,11]. The frequency independent behavior of an antenna is very useful as it increases its area of application

In [3],Yang and RahmatSamii presented a more practical way to construct a frequency-reconfigurable patch antenna by introducing a switchable slot. A vertical slot is cut in the patch antenna with a diode switch placed across the slot in the middle. When the switch is on, the horizontal main current of the patch's first resonance is only slightly disturbed as compared to the case with no slots. But when the switch is turned off, the horizontal current is forced to detour around the slot and travels a longer path; as a result, the patch antenna resonates at a lower frequency.

In this paper, a log-periodic antenna with the feature of reconfigurability is developed to meet the requirements in terms of the return loss, radiation pattern, gain, and ease of integration with switching circuitry. The proposed antennais 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, when compared with other wide band antennas. The 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 structure of the proposed three element logperiodic microstrip antenna with reconfigurability is as shown in figure 1. The concept of frequency reconfigurability is investigated based on changing the position of the switches to ON or OFF. This antenna can perform in frequency range from 2.9 GHz until 3.4 GHz with two different sub bands. There are three circular 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 structure is 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 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 diameter (d) and the inset feed distance (I) are related to the scaling factor (τ) by equation as shown below.

$$\tau = \frac{d_{m+1}}{d_m} = \frac{I_{m+1}}{I_m} \qquad (1)$$

The first patch (lower frequency) diameter is 13.81 mm with resonant frequency at 3 GHz and it is scaled by a factor of 1.05 to obtain the second patch dimension of 13.15 mm which has a resonant frequency at 3.15 GHz. Second patch diameter is once again scaled by a factor of 1.05 to obtain the third patch diameter of 12.52 mm with a resonant frequency at 3.3 GHz. The space between each patch (Dm) is a half wavelength apart thus giving a forward fire radiation pattern and reducing mutual coupling effect. The reconfi-gurabilty is achieved when the RF PIN diodes were integrated with the feeding line to act as a switch and to control the ON/OFF mode. For the purpose of simulation, the PIN diode is modeled as shown when it is in ON condition and it is incorporated in to the structure. The metal cut stripe of 3mm x 1mm have been used to represent a switch when it is in OFF state . The PIN diode equivalent circuit is as shownin Figure 1. For simulation purpose the circuit is modeled as shown in the Figure 4 and it is simulated. 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 paper, two sub-band are achieved by controlling a group of switches as tabulated. 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. The sub bands operations are shown in Table 1. For simulation process, the model for implementing the three element circular LPA with incorporated PIN diode structures is as shown in Figure 3. By using MODUA tool in IE3D, the simulation model for reconfigurable LPA for various switching combinations is as shown in the Figure 4 . When the PIN diode is ON state, it is modelled by the PIN diode equivalent circuit model and the absence of the metal strip of 3.078 mm X 1 mm is representing the OFF state.

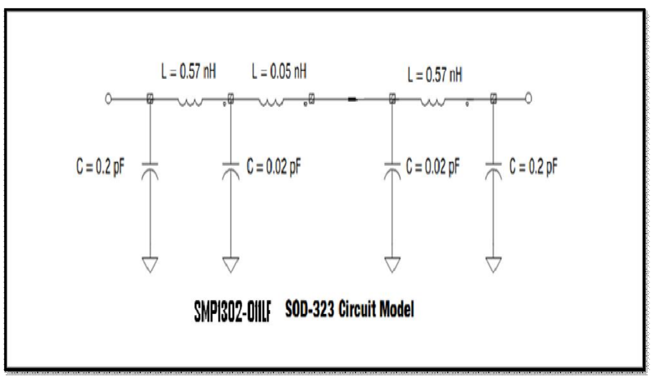

Figure1. Pin diode equivalent circuit model.

Table 1. Switching Conditions

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

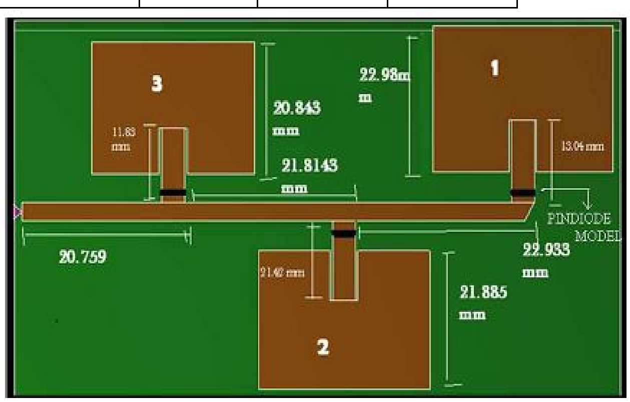

Figure 2. Top view of Proposed Three Element Square Logperiodic Antenna Array

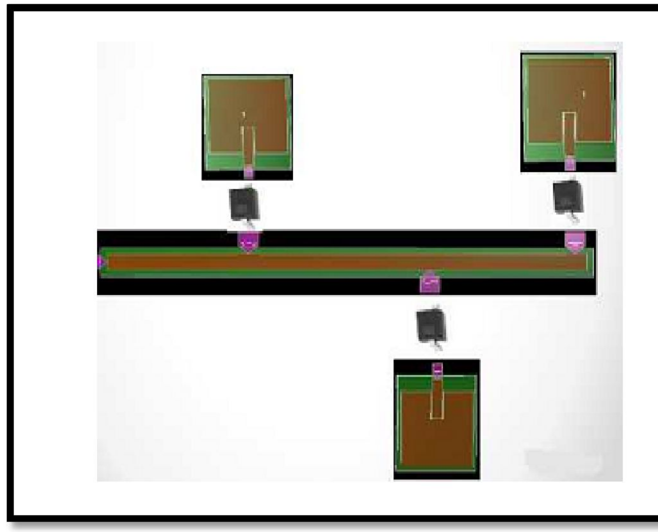

Figure 3. Model for implementing three element reconfigurable square LPA.

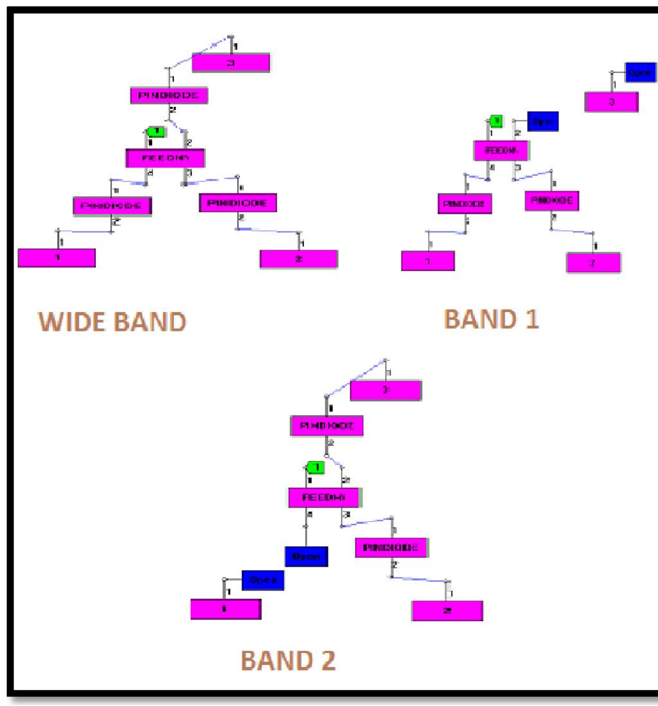

Figure 4. Square LPA with modeled PIN diodes incorporated in to the antenna structure for various switching combinations.

3.SIMULATION RESULTS

The proposed log-periodic microstrip antenna has been simulated using zealand's IE3D software to carry out the results of the antenna performances. Figure 5(a) shows the return loss of the wideband operation when all the pin diodes are in ON state, while Figure 5(b) shows the return loss for two different sub bands. The log-periodic microstrip antenna operates from 2.9 GHz until 3.4 GHz or over 15.31 % bandwidth. The different sub bands bandwidth for each band are as shown in table 2. Figure 6(a) shows the simulated gain for wideband operations while the simulated gain for sub bands is represented by figure 6(b).

Comparison of gain, directivity for each band at centre frequency is given by Table 3.

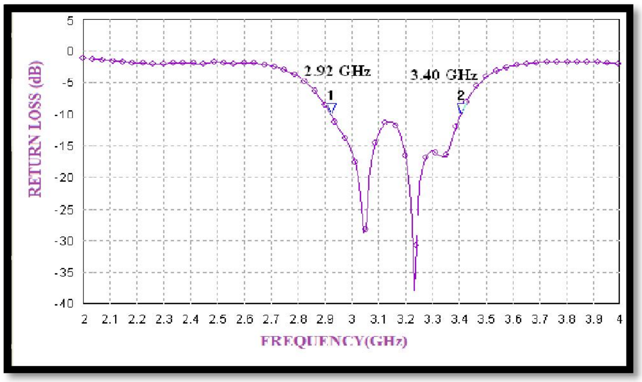

Figure 5(a). Simulated Return Loss characteristics for wideband operation

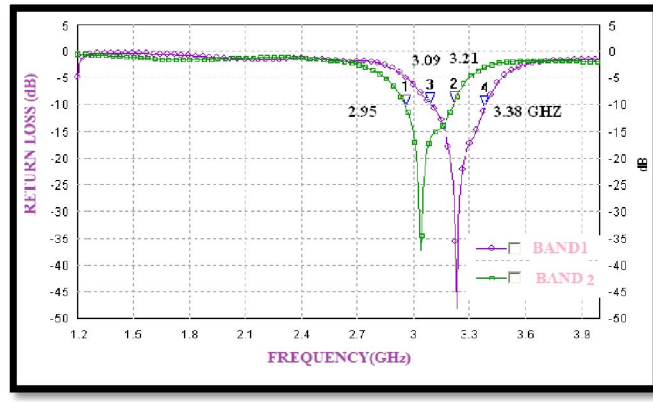

Figure 5(b). Simulated Return Loss characteristics for various Bands

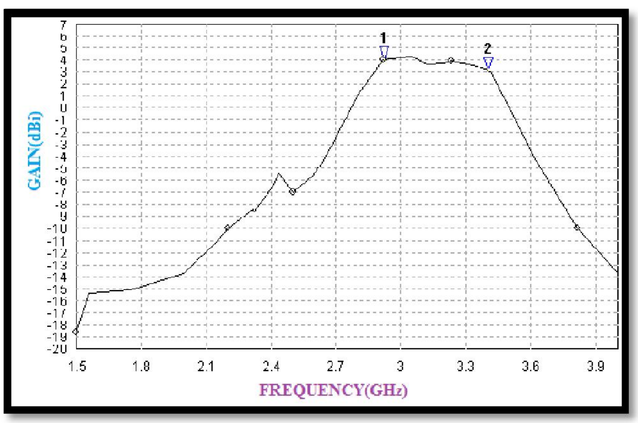

Figure 6(a). Gain vs Frequency Response for Wide band operation of LPA

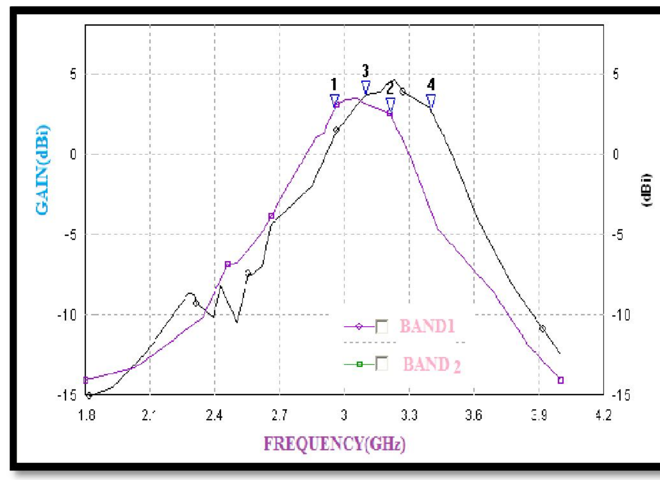

Figure 6(b). Gain vs Frequency response for different sub-band operations of LPA

Table II. Comparision of return loss for each band

BAND	F(L) GHz	F(C) GHz	F(H) GHz	BAND WIDTH (%)	BAND WIDTH (MHz)
WIDE	2.92	3.16	3.40	15.31	484
BAND 1	2.95	3.08	3.21	8.63	266
BAND 2	3.09	3.23	3.38	9.04	292

TABLE III. COMPARISION OF GAIN AND DIRECTIVITY FOR EACH SUBBANDS.

BAND	FREQUENCY F(C) GHz	Max. Gain (dBi)	Max. Directivity (dBi)
WIDE	3.16	3.69	8.69
BAND 1	3.08	3.20	8.31
BAND 2	3.23	4.53	9.37

The realized gain at all frequency bands are about 3.2 dB to 5 dB and the directivity of the antenna is about 8 dB for various subbands as tabulated above.

4. CONCLUSION

The proposed "Frequency Reconfigurable Log-periodic Antenna" has been design and simulated. It operates from 2.9 GHz to 3.4 GHz with realised gain of 3 dBi to 6 dBi for directivity of 8 dBi to 10.5dBi It has been demonstrated that the required frequency band could be achieved by choosing various switching combinations. Two sub-bands in which two groups of patches were selected from a wideband frequency are obtained. For different group patches selection, others sub-band could be achieved. For each frequency band, a good return loss, gain and radiation pattern have been obtained. Therefore, the proposed antenna with more elements with further wide bandwidth could be used for cognitive radio, which requires sensing over a wideband of frequency and dynamically switching over the band that is being sensed.

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