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Design and Analysis of Frequency Reconfigurable Log Periodic Microstrip Dipole Antenna Array with Different Substrates for wideband Applications

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ABSTRACT:-*The concept of reconfigurable antenna is widely used as an additional feature of reconfigurable ability [9] for future wireless communication systems especially for cognitive radio applications, radar system and multi-frequency communications. There are various configurations of reconfigurable antenna such as monopole, dipole and log-periodic wideband antenna. This paper describes the design and simulation of frequency reconfigurable log periodic array (FRLPA) using dipole patch elements with different substrate materials namely Duroid 5880, FR4 and Arlon AD250. Radio frequency (RF) switches are used to integrate the reconfigurable antennas for switching ability [4-8]. To achieve the diversity in frequency, fifteen PIN diodes are connected at every transmission line using coaxial feed line technique to perform a wideband frequency (4-18 GHz) operation. In this paper, three different substrate materials are used to design and simulate three different frequency reconfigurable LPMDAs and the corresponding parameters are evaluated and compared. It is compact in size and useful to support on board radar and many wireless applications.*

Key words: *reconfigurable, log periodic antenna, microstrip , substrate, diversity.*

1. INTRODUCTION

Design of the modern microwave communication systems and on board radar equipment for air craft and war ships EW/ECM needs a proper technical solution for small size broadband antennas .The structure of this antenna for frequency diversity can be achieved by controlling of the PIN diode switches at the transmission line of patch .The required frequency band could be achieved for three sub bands by controlling a group of switches as shown in table 2. For this purpose, reconfigurable log periodic microstrip dipole array is used for broad operating bandwidth of 14GHz. Here ANSYS HFSS 13.0 v is used to carry out the simulation process. In this work, three different substrates namely Duroid 5880 (ϵ_r = 2.2), FR4 (ϵ_r = 4.4) and Arlon AD250 (ϵ_r = 2.5) are used with thickness of h = 0.51mm. These antennas are analyzed based on several parameters such as return loss, gain, VSWR and radiation patterns and these are low cost multiband printed circuit board (PCB) antennas.

2. ANTENNA DESIGN

The standard approach for the design of LPDAs proposed by carrel [1] can be used with suitable modifications. The geometrical structure of the proposed frequency reconfigurable log periodic microstrip dipole array antenna [2] is shown in Figure.1 with fifteen dipole patches which are developed on three different substrate materials with thickness of 0.51mm and dimensions of 70×40 mm .The design principle of log periodic microstrip dipole array antenna requires scaling of dimensions from period to period so that the performance is periodic with logarithm of frequency. Scaling of dimensions of patch dipole elements from one dipole element to another is given by scaling factor 'τ' which determines the antenna apex angle 'α'. spacing factor 'σ ' which is also known as " Relative Spacing constant " . Patch length (L_n), width (W_n) and distance between elements ($d_{n,n+1}$) are calculated [3, 10] and they are presented in table 1.

For this design f_h = 18 GHz, f_l = 4 GHz.

STEP 1: The Scale Factor τ = 0.850 and
Spacing Factor σ = 0.14

STEP 2: The apex angle can be obtained as,

$$\tan(\alpha) = \frac{(1-\tau)}{4\sigma}$$

$$\alpha = 15^0$$

STEP 3: The number of elements in an array is given by

$$N = 1 + \frac{\log B_s}{\log\left(\frac{1}{\tau}\right)}$$

$$B_S = \frac{\text{Length of the largest dipole}}{\text{Length of the smallest dipole}}$$

$\tau = 0.850$ Number of elements $N = 15$

STEP 4: Calculation of lengths of dipole the length of last dipole is

$$L_{15} = \frac{c}{2\times f_l\sqrt{\epsilon_e}} = 29.33 \text{ mm}$$

Where, $c = 3\times10^8$ and $\epsilon_e = 1.634$ (ϵ_e-Effective dielectric constant),distance between dipole elements is given by

$$d_{n,n+1} = \frac{L_{n+1} - L_n}{2\tan(\alpha)}$$

The length and distance between elements of other dipoles is computed as

$$\frac{L_n}{L_{n+1}} = \frac{d_{n-1,n}}{d_{n,n+1}} = \tau$$

STEP 5: The width of the largest dipoles is computed as $W_n = \pi\, a_n$

$$Z_n = \frac{\eta}{\pi}\left[\ln\frac{L_{n/2}}{a_n} - 2.5\right]$$

For Zn to be 50Ω, we calculate corresponding a_n ,where a_n is the radius of cylindrical dipole and 'η' is the characteristic impedance of substrate. Then, $W_n = \pi\, a_n$ For longest dipole $L_n = 29.33$ mm $W_{15} = 1.95$ mm ,Width of the 50Ω transmission line is 1.91 mm.

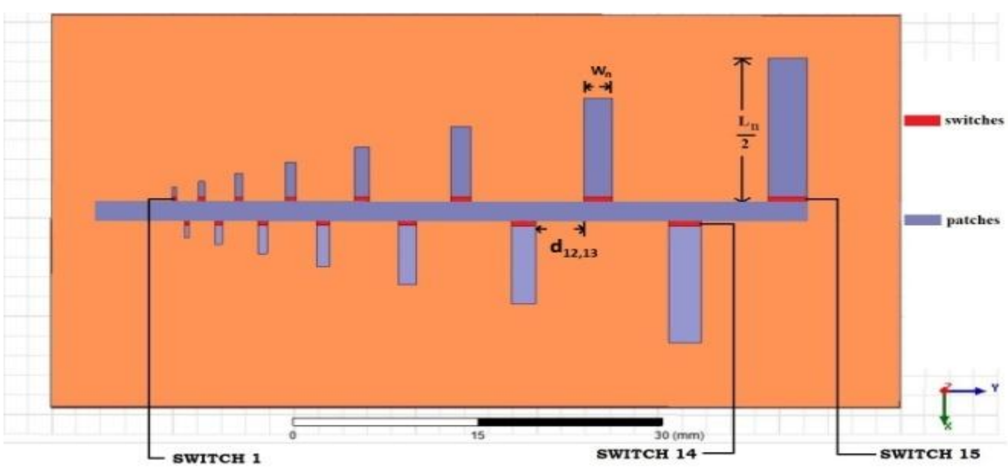


Figure.1 Proposed Antenna Top View

Dipole	Ln [mm]	Wn[mm]	$d_{n,n+1}$ [mm]
1	3.01	0.20	
2	3.54	0.23	0.99
3	4.17	0.27	1.16
4	4.90	0.32	1.37
5	5.77	0.38	1.61
6	6.79	0.45	1.90
7	7.99	0.53	2.23
8	9.40	0.62	2.63
9	11.06	0.73	3.09
10	13.01	0.86	3.64
11	15.31	1.02	4.28
12	18.01	1.20	5.04
13	21.19	1.41	5.93
14	24.93	1.66	6.97
15	29.33	1.95	8.21

Table 1: Geometry of the designed printed FRLPMDA.

Here coaxial feeding technique is used. Outer conductor of the coaxial cable is connected to bottom layer of the antenna and the inner conductor is connected to the top layer of the antenna via a hole inside the substrate material. We have selected the characteristic impedance Z_n of the feeding line equals to 50 ohm so as to obtain an easy matching with the coaxial cable. Here the Ku band operation is achieved by switching ON the first five PIN diodes and remaining all are OFF. While X band is attained when only 6-10 switches are ON and C band operation can be possible if switches 11-15 are ON and remaining OFF. In this simulation process the ohmic losses assumed to be zero by using ideal substrate and perfect electric conductor (PEC) for patch as well as PEC pad representation shown in Figure.2. PEC pad is a small metal strip, ON state is represented by the metal strip and absence of the metal strip represents OFF state. Wide band operation is achieved when all switches are ON.

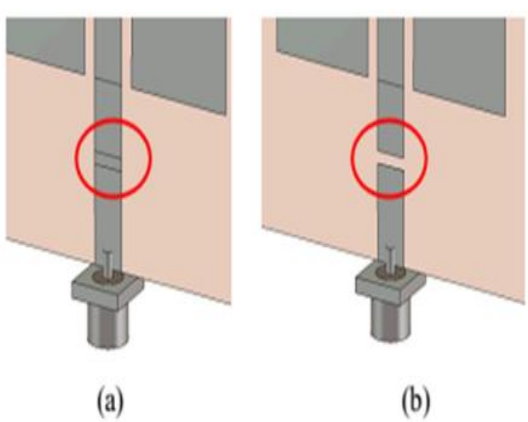


Figure.2 (a) PIN diode ON state (b) PIN diode OFF state

PIN diodes ON	PIN diodes OFF	Band of operation
1-5	6-15	Ku
6-10	1-5 and 11-15	X
11-15	1-10	C
1-15	----	Ultra wide band

Table 2: Switching Combinations

3. SIMULATION RESULTS

The proposed frequency reconfigurable log periodic microstrip dipole antenna array is simulated using ANSYS HFSS 13.0 v to analyze the performance characteristics like VSWR, Return Loss and Gain of the antennas. The plotted characteristics shown below (Figs. 3a,3b,3c,4a,4b,4c and 5a,5b,5c) are representing with three different colors namely violet color for Duroid 5880, red color for Arlon AD250 and green color for FR4 substrate materials. Figure.3 (a), (b) , (c) shows the VSWR , return loss and radiation patterns of Ku band for three different substrates , Figure.4 (a), (b) , (c) shows the VSWR , return loss and radiation patterns of X band for three different substrates , Figure.5 (a), (b) , (c) shows the VSWR , return loss and radiation patterns of C band for three different substrates. The corresponding performance characteristics are evaluated and they are tabulated in table 3 for Ku band, table 4 for X band and table 5 for C band respectively.

Comparison of FRLPMDA parameters with different substrate materials for Ku Band

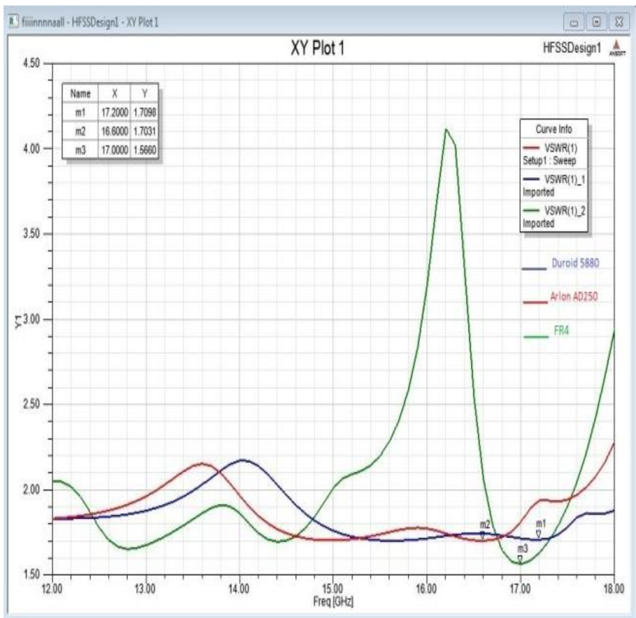


Figure.3 (a): VSWR for Ku Band

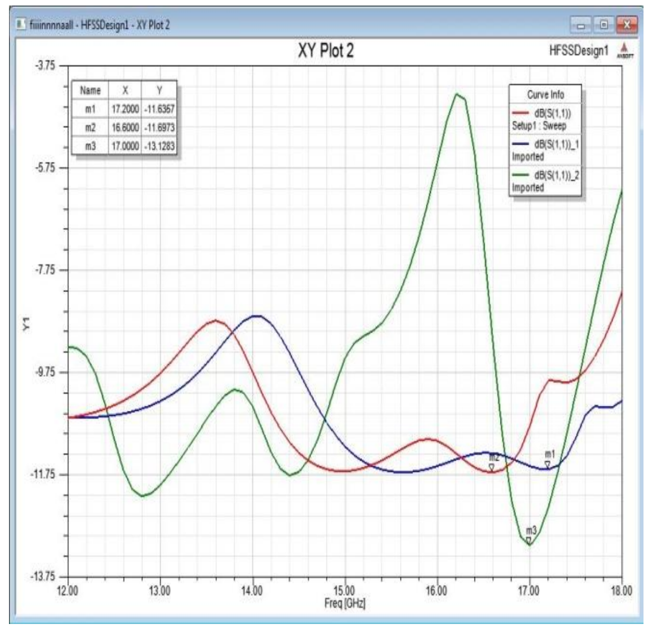


Figure.3 (b): Return loss for Ku Band

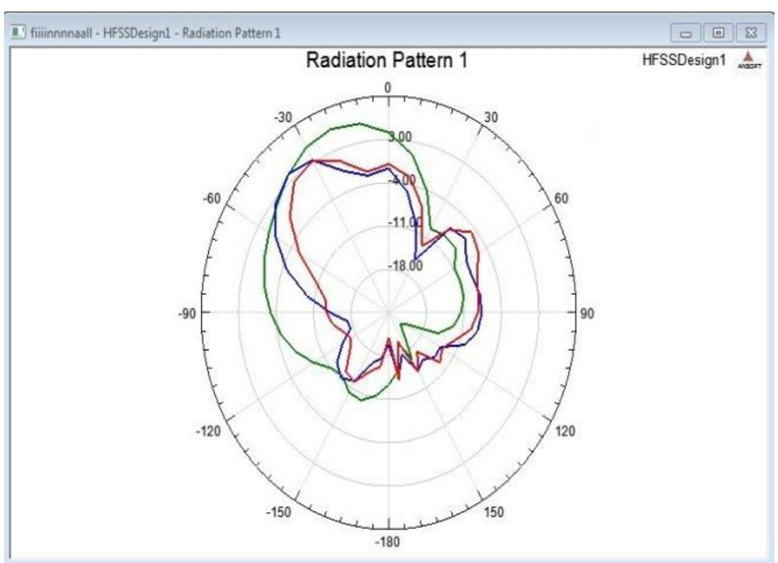
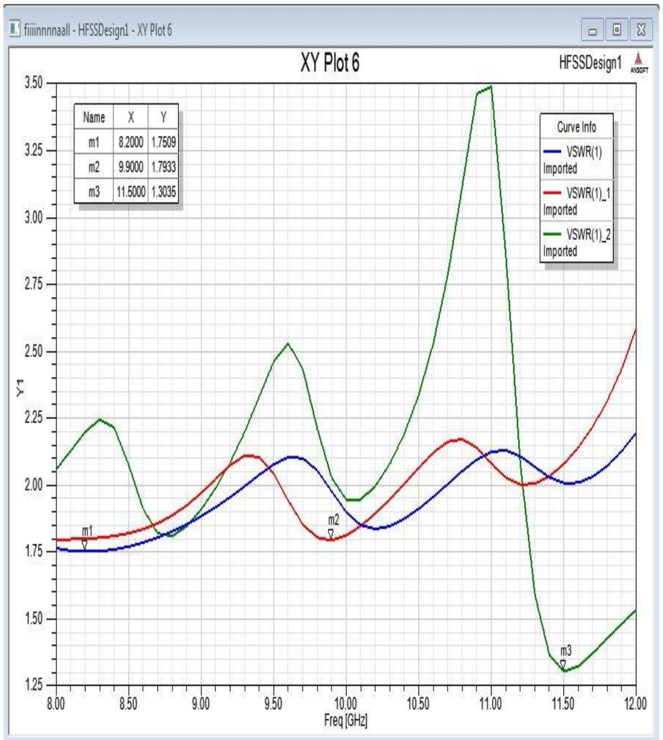


Figure.3 (c): Radiation pattern for Ku Band

Comparison of FRLPMDA parameters with different substrate materials for X Band



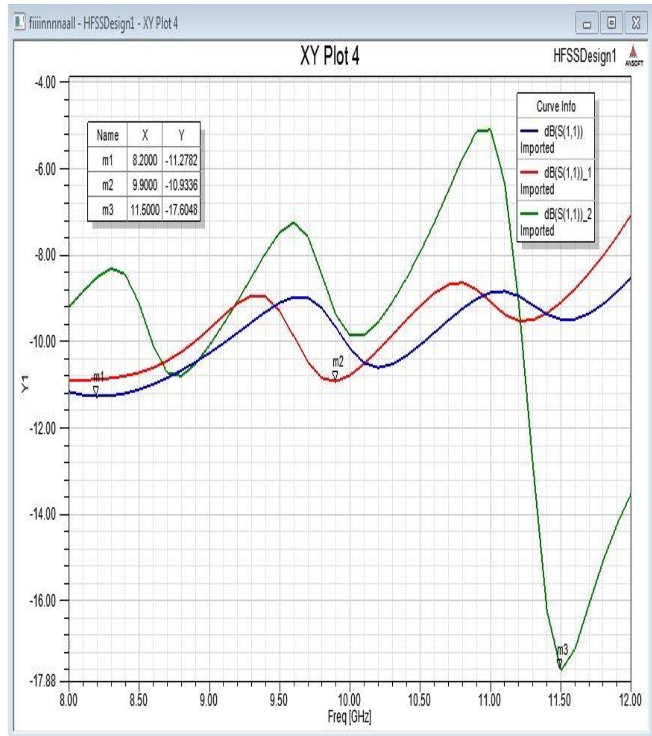


Figure.4 (a): VSWR for X Band

Figure.4 (b): Return loss for X Band

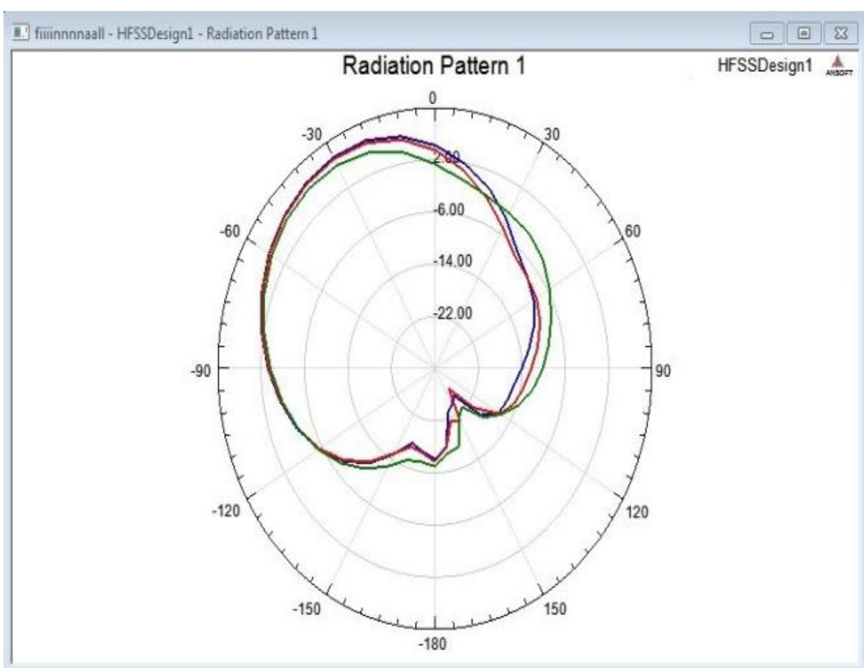


Figure.4 (c): Radiation pattern for X Band

Comparison of FRLPMDA parameters with different substrate materials for C Band

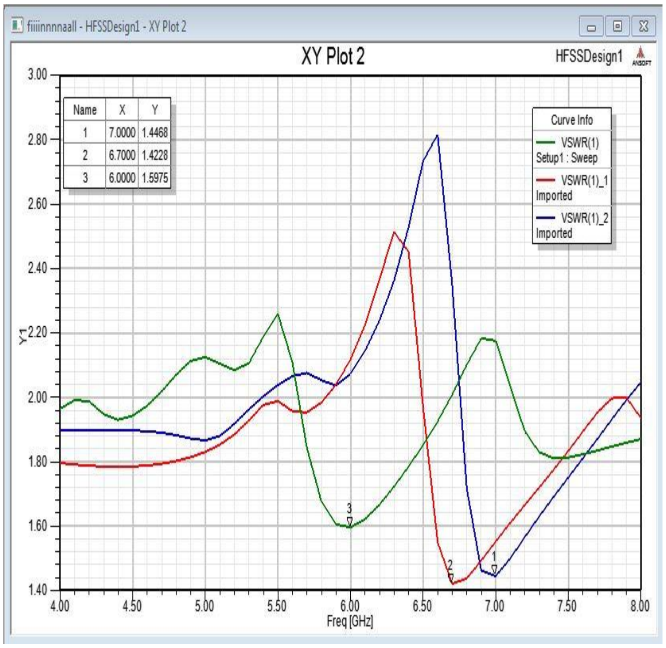


Figure.5 (a): VSWR for C Band

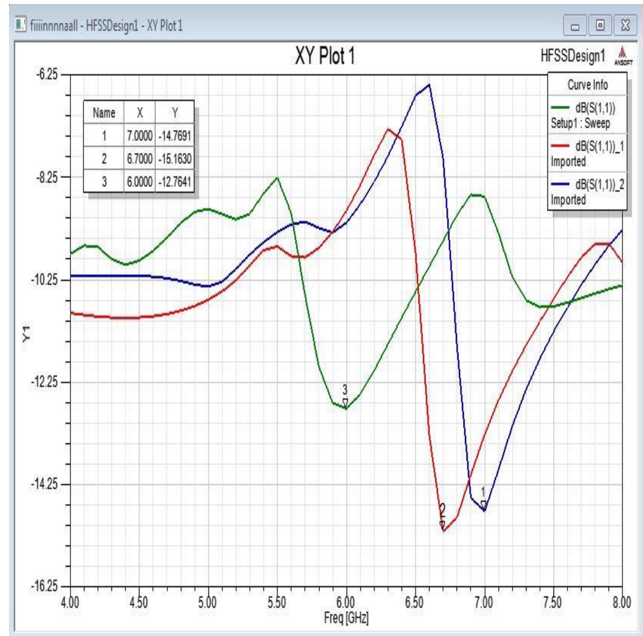


Figure.5 (b): Return loss for C Band

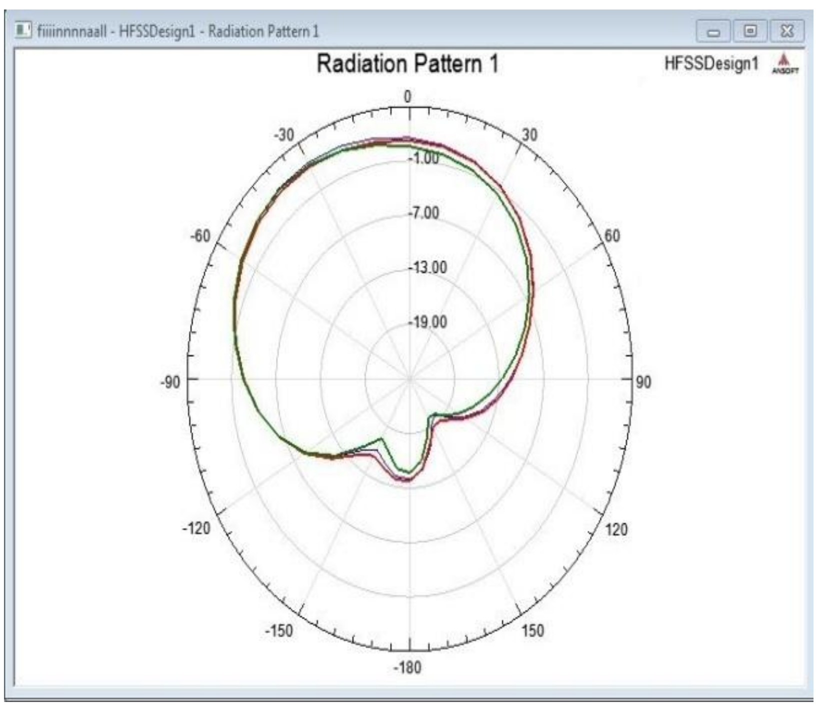


Figure.5 (c): Radiation pattern for C Band

Comparison tables of FRLPMDA parameters with different substrate materials for Ku, X and C Bands

Parameter	Arlon AD250	Duroid 5880	FR4
VSWR	1.7031	1.7098	1.566
Return Loss (dB)	-11.69	-11.63	-13.12
Gain (dB)	3.79	3.22	4.06
Resonant Frequency(GHz)	16.6	17.2	17.0

Table 3: Performance Characteristics for Ku Band

Parameter	Arlon AD250	Duroid 5880	FR4
VSWR	1.79	1.75	1.30
Return Loss (dB)	-10.93	-11.27	-17.60
Gain (dB)	7.14	7.43	6.05
Resonant Frequency(GHz)	9.9	8.2	11.5

Table 4: Performance Characteristics for X band

Parameter	Arlon AD250	Duroid 5880	FR4
VSWR	1.42	1.44	1.59
Return Loss (dB)	-15.16	-14.76	-12.76
Gain (dB)	1.98	2.48	2.28
Resonant Frequency(GHz)	6.7	7.0	6.0

Table 5: Performance Characteristics for C Band

4. CONCLUSION

The frequency reconfigurable log periodic microstrip dipole array operated over C,X and Ku bands by using three different substrate materials have been designed and simulated by ANSYS HFSS 13.0v .The simulation results shows that the proposed antenna arrays can be successfully used for three sub bands with three different substrate materials. It is observed from the results that FR4 substrate is the best material for Ku band. For X band, Duroid 5880 and FR4 substrate materials are showing the better performance characteristics. It is also observed from the results Duroid and Arlon substrate materials are showing good performance characteristics for C band. In this proposed design of Log periodic dipole array, the frequency switchability can be easily achieved for different sub bands as shown in table 2.

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