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Design and Analysis of Frequency Reconfigurable Microstrip Dipole Array with Roger RO Substrate for wideband Applications

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Abstract

Reconfigurable concept is widely used in antenna array design as an additional feature of reconfigurable ability for wireless communication systems especially for cognitive radio applications, radar system and multi-frequency communications. There are different configurations of reconfigurable arrays such as monopole array, dipole array and log-periodic wideband arrays which can be designed with different substrate materials. This paper mainly describes the design and analysis of frequency reconfigurable dipole array (FRDA) using dipole patch elements with Rogers RO4350B as substrate material for a wideband frequency range. The radio frequency (RF) switches are integrated to perform the switchable [3-6] ability of the designed antenna array. The Frequency reconfigurable dipole array has been designed to perform a frequency operations in Ku , X and C bands by connecting fifteen dipole antennas using edge feed technique. Then, the frequency mélange is attained by switching ON and OFF of the PIN diodes which are kept at each transmission line. The antenna size is small which can be used in radar and wireless applications.

Keywords:

Switchable,microstrip, wideband,substrate,reconfigurable, Rogers RO Substrate..

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1. Introduction

In the design of the broad band antennas for radar equipment for warships, aircrafts and microwave communication systems, we should show proper technical answer for small size broadband antenna arrays. The aim of designing this antenna array is to get diversity in frequency. A single antenna array can be used to operate over three different sub bands like Ku, X and C bands. We can use a single antenna which can shift the present operating frequency band without changing the design. This can be done by controlling of the PIN diode switches which are place at each transmission line of patch. By controlling different switches, we can change the frequency band as shown in table 2. For changing the frequency band of operation, a frequency reconfigurable log periodic microstrip dipole antenna array is used for broadband operation. In this paper ANSYS HFSS 13.0 v is used to carry out the simulation process and the results of the antenna array are analyzed based on antenna parameters such as VSWR, Gain, radiation Pattern and Return loss. The antenna can be fabricated on Rogers RO4350B substrate with Relative Dielectric Constant $\epsilon r = 3.66$ and thickness h = 0.51mm which is a less cost multiband printed circuit board (PCB) antenna array.

2. ANTENNA DESIGN:

In the design of log periodic dipole antenna arrays which are proposed by carrel [1] can be used with some changes in it. The geometrical shape of the proposed antenna array is shown in Figure.1 with fifteen dipole patches which are developed on Rogers RO4350B substrate with thickness of 0.51mm and dimensions of 70×40 mm .The log periodic microstrip dipole antenna array requires scaling of dimensions time to time so that performance of the antenna is periodic with logarithm of frequency. The Scaling factor 'τ', which is used

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to find the apex angle of the antenna array and Relative Spacing constants 'σ '. Length of the Patch (L_n), width of the patch (W_n) and the separation between the elements ($d_{n,n+1}$) are calculated [2] and they are presented as shown in table 1.

In this paper, for the design of antenna array, we assumed 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,
$\tan(\alpha) = \frac{(1-\tau)}{4\sigma}$ α = 150
STEP 3: The number of elements in an array is computed by

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

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

τ = 0.850 Number of elements N = 15
STEP 4: Dipole Lengths can be obtained as follows.
The length of last dipole,

$$L15 = \frac{c}{2\times f_l\sqrt{\epsilon_e}} = 29.33 \text{ mm}$$

Where, c = 3x108 and ϵ_e-Effective dielectric constant ϵe = = 1.634
Separation between dipole elements is given by

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

The length and separation 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 calculated as
$W_n = \pi a_n$

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

Let the Z_n 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 and W_{15} = 1.95 mm
Then the Width of the 50Ω transmission line is 1.91 mm.

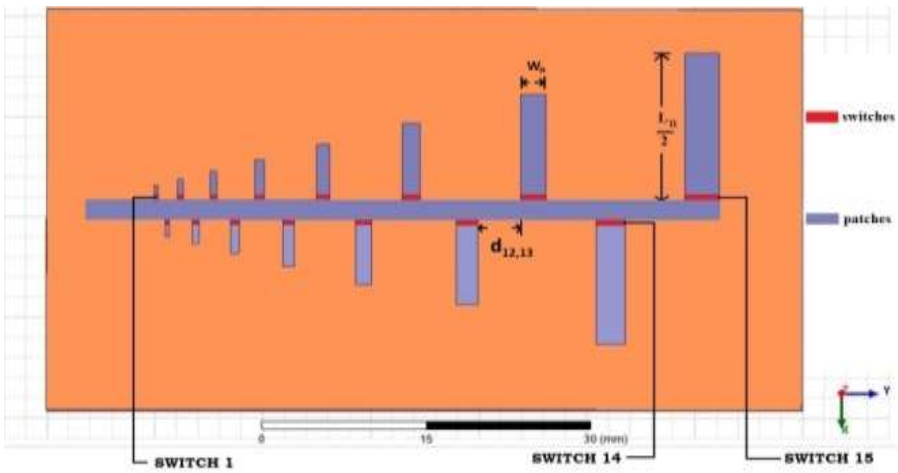

Figure.1 Proposed Antenna Top View

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 edge feeding technique is used. Here, we use Rogers RO substrate material where the Outer conductor of the coaxial cable is connected to bottom layer of the antenna array and the inner conductor is connected to the top layer of the antenna array via a hole inside it. The characteristic impedance Zn of the feeding line equals to 50 ohm so as to obtain an easy matching with the coaxial cable. We have selected the characteristic impedance Zn 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.

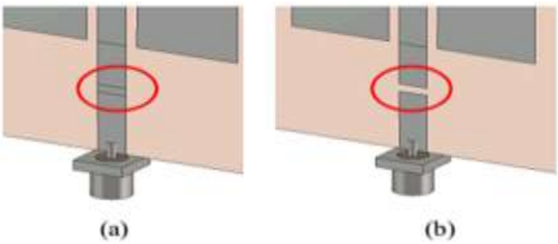

Figure.2 (a) PIN diode ON state (b) PIN diode OFF state

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:

In this paper, the proposed frequency reconfigurable antenna array is simulated using ANSYS HFSS 13.0 v to analyze the performance characteristics like VSWR, Return Loss and Gain of the antenna. Figure.3 (a), (b) , (c) shows the VSWR of Ku , X, C bands of operation while Figure.4 (a), (b) , (c) shows Return loss for Ku, X and C bands respectively . Figure.5 (a), (b) and (c) shows 2D Radiation patterns for different sub bands. Figure.6 (a), (b) and (c) shows that simulated Gain and 3D radiation patterns for Ku, X and C bands of frequencies. The corresponding performance characteristics are evaluated and they are tabulated in table 3.

VSWR:

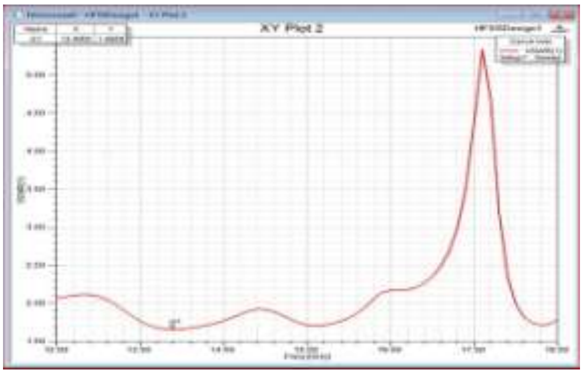

Figure.3 (a): for Ku Band

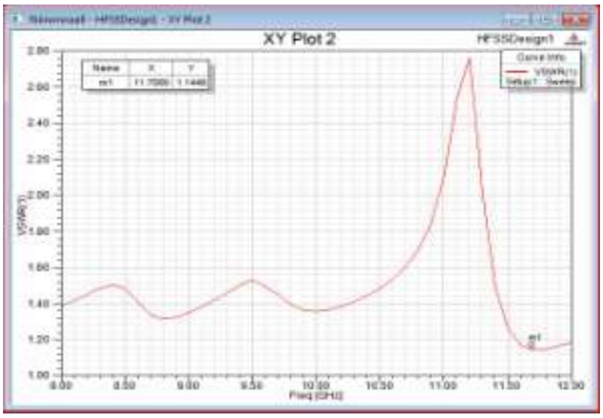

Figure.3 (b) : for X Band

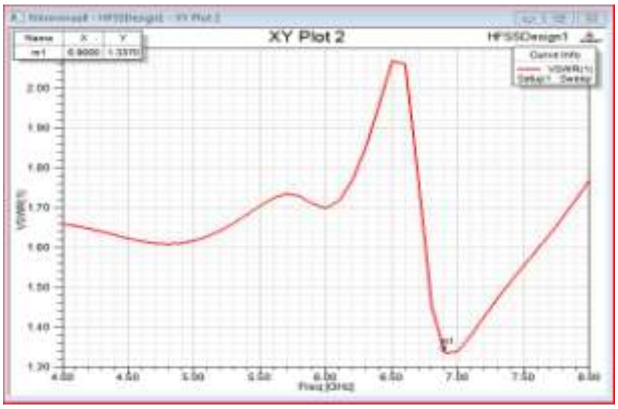

Figure.3 (c) : for C Band

Return loss:

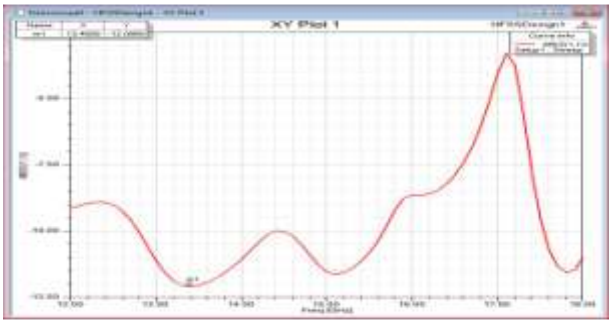

Figure.4 (a) : for Ku Band

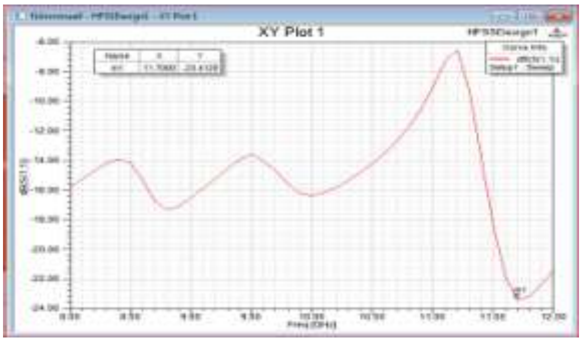

Figure.4 (b): for X Band

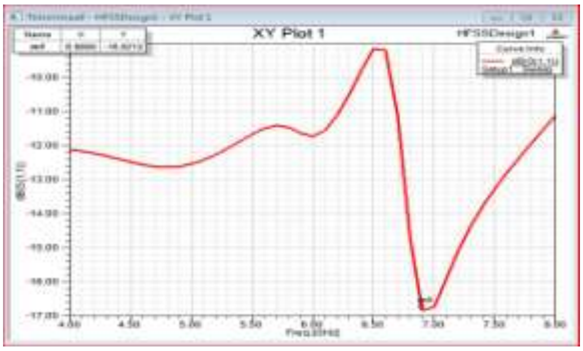

Figure.4 (c) : for C Band

2D Radiation pattern :

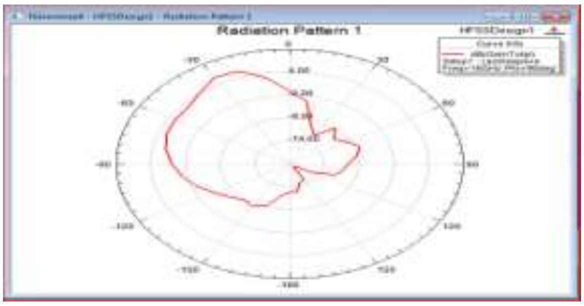

Figure.5 (a) : for Ku Band

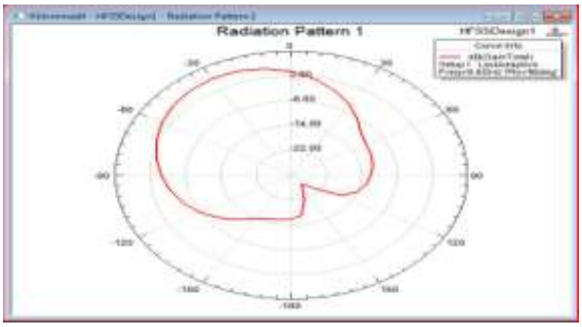

Figure.5 (b) : for X Band

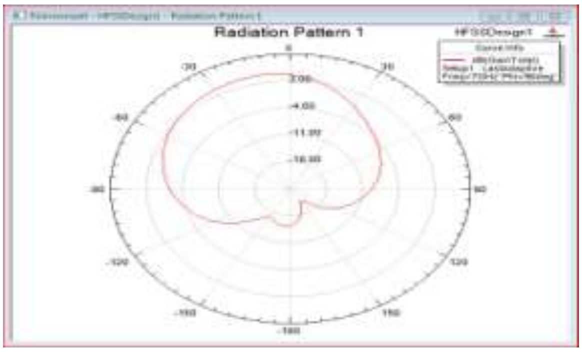

Figure.5 (c) : for C Band

Gain and 3D Radiation pattern:

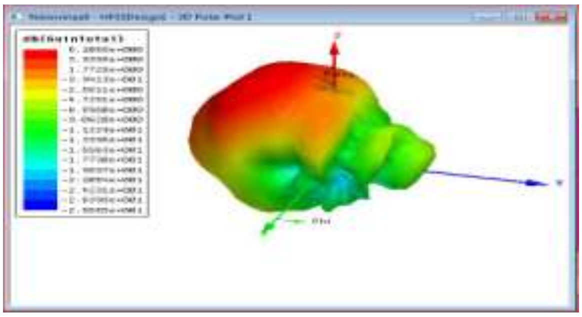

Figure.6 (a) : for Ku Band

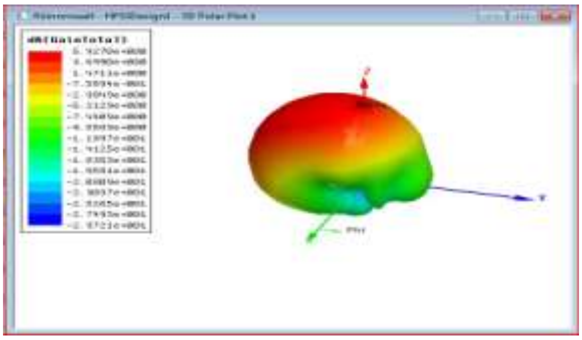

Figure.6 (b) : for X Band

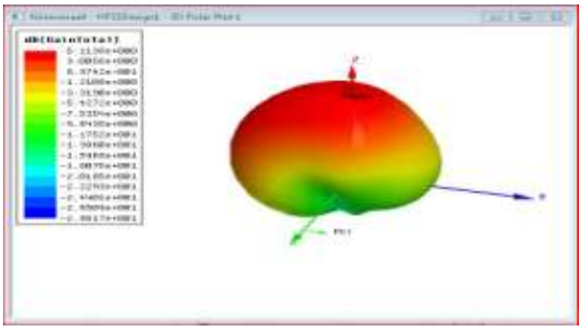

Figure.6 (c) : for C Band

Operating band	VSWR	Return Loss (dB)	Max Gain (dB)	Resonant frequency (GHz)
Ku	1.66	-12.09	6.10	13.4
X	1.14	-23.41	5.92	11.7
C	1.33	-16.82	5.11	6.9

Table 3: Performance Characteristics of FRLPMDA

4. CONCLUSION:

The frequency reconfigurable log periodic microstrip dipole array with Roger RO Substrate can be operated over C,X and Ku bands has been designed and simulated by ANSYS HFSS 13.0v .The simulation results shows that the proposed antenna array with Roger RO Substrate can be used as wide band antenna over frequency range from 4 GHz to 14 GHz. In terms of gain and VSWR, this antenna array shows it's best performance in the X band .It also shows better performance in terms of VSWR and Return loss in X band frequency range. Also, it shows that good performance in Ku band in gain and wide operating range aspects. Here the required frequency band can be easily selected by choosing various switching combinations as shown in table 2.

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