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Wideband Flipped Staired Equilateral Triangular Pyramid DRA

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Abstract: ***In this paper, a flipped staired equilateral triangular pyramid DRA is presented. The proposed antenna is placed on rectangular slot of a ground plane and excited by a microstrip line to give a wide 10-dB impedance bandwidth of 36% between X-band and Ku-band. The antenna has an average gain of 7dbi with a variation of 2dBi across impedance passband. Also, the antenna exhibit broadside radiation pattern as expected. This study was done using CST Microwave studio software.***

Keywords: Dielectric Resonator Antenna (DRA), Computer Simulation Technology (CST)

1. Introduction

Dielectric Resonators (DR) are non-conducting materials just like insulators but their dipoles orientation can be disturbed if the alternating electric field is applied to it. Dielectric Resonator Antennas (DRAs) are unshielded dielectric resonators (DR) that radiate energy into space under proper excitation environment. It consists of a piece of glass or ceramic material of various shapes (i.e. Rectangular, cylindrical, triangular) having high dielectric constant. Since the introduction of this idea in 1939 by Richtinger [1], [2] many kinds of research are continuing on DRA since it poses many benefits compared to the traditional low-gain antenna like dipole and patches. To mention few DRA has wide bandwidth, high radiation efficiency, easy to excite and no conductor loss.

Although it may seem to lack popularity compared to rectangular and cylindrical shape, triangular DRA of the various shape such as equilateral [3], split-triangular [4] and 45°–45°–90° triangular [5] still performs well in antenna design. The advantage of triangular DRA is that for a given resonant frequency and height it will require smaller area compared to rectangular and cylindrical one [2]. This feature attracted research on triangular DRA for array design [6].

Many methods have been developed and researched for bandwidth enhancement of DRA [2] such as air gaps, annular DRA, multiple DRA, hybrid-antennas and modified DRA. In [7] cylindrical and rectangular flipped staired pyramid DRA were investigated for the wideband application. In this paper triangular DRA of the same manner is studied for wideband applications.

2. Theory

Since the proposed flipped staired equilateral triangular pyramid DRA is based single equilateral triangular DRA of different size, placed on top of each other as shown in **Fig.1,** then theoretically resonant frequency can be estimated using transcendental equations discussed in [8]:

$$f_{mn} = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\left(\frac{4\pi}{3a}\right)^2(m^2+mn+n^2)+k_z^2} \tag{1}$$

Where:

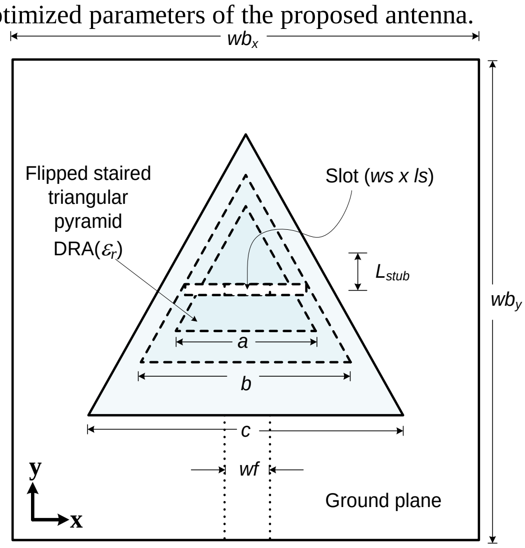
$$k_z = \frac{p\pi}{2h},\ p = 1,2,3...$$

For a very thin DRA (h << a), the resonant frequency of TM10δ mode can be approximated by [9]:

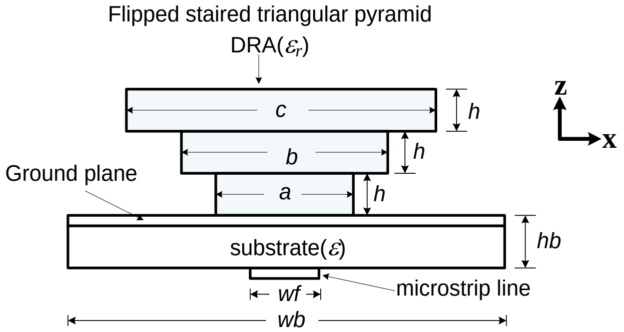
$$f_{10\delta} = \frac{c}{2\sqrt{\varepsilon_r}}\sqrt{\left(\frac{4}{3a}\right)^2+\left(\frac{1}{2h}\right)^2} \tag{2}$$

3. Antenna configuration

The top view and side view of the proposed antenna are shown in section (a) and (b) of **Fig1**. The antenna consists of flipped staired equilateral triangular pyramid DRA with dielectric constant ε_r, side lengths of the top, middle and bottom are *c*, *b*, *a* respectively. The height of each stair is *h*. This antenna is placed at the center of the square rectangular substrate with dielectric constant ε, height *hb*, and side *wb*. The top surface of the substrate has ground plane which has rectangular slot of width *ws* and length *ls* at the center. And the bottom surface of the substrate has microstrip line of width *wf* extending from $(-wb_y/2)$ to L_{stub}. The Table1 shows the optimized parameters of the proposed antenna.



(a)



(b)

Figure 1: The geometry design of the proposed antenna. (a) Top view, (b) Side view

Table 1: The optimized parameters of the antenna

Parameter	Value	Parameter	Value
c	14mm	*wb*	28mm
b	8mm	*hb*	0.8mm
a	6mm	*ws*	5.7mm
h	1.46mm	*ls*	1mm
L_{stub}	4mm	*wf*	1.76mm
ε_r	12	ε	3.38

4. Results and Discussion

The proposed flipped staired equilateral triangular pyramid DRA was designed, simulated and studied with the help of CST Microwave studio. **Fig.2** and **Fig.3** show the return loss $|S_{11}|$ and corresponding VSWR respectively. The antenna have broadband impedance bandwidth ($|S_{11}|$ < -10 dB) of 36% extending from 10.5GHz to 15.2GHz. Also, the figures show that the antenna has two noticeable resonance modes, one at X-band (11.5GHz) and another in Ku-band (14.2GHz).

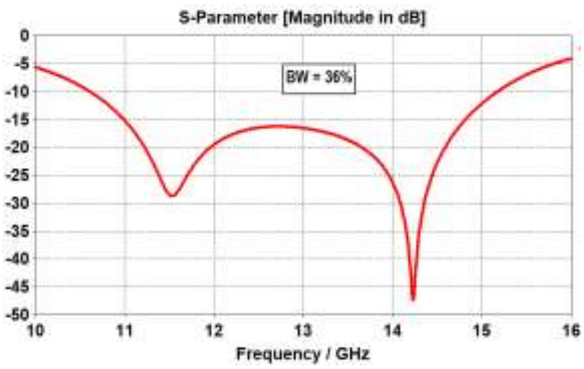


Figure 2: Return loss $|S_{11}|$ plot of the proposed DRA

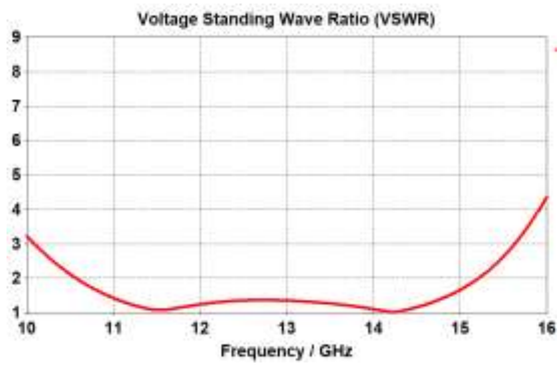


Figure 3: VSWR plot of the proposed DRA

The realized gain of the proposed antenna is depicted in **Fig.4,** where the antenna maintains the average gain of 7dBi across impedance passband ($|S_{11}|$ < -10 dB) between the two strong resonant modes (i.e. 8dBi at 11.5GHz and 6dBi at 14.2GHz).

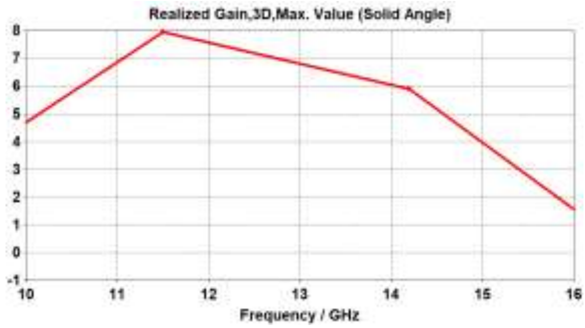
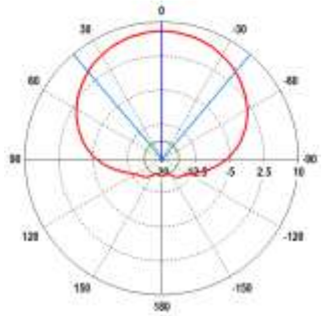
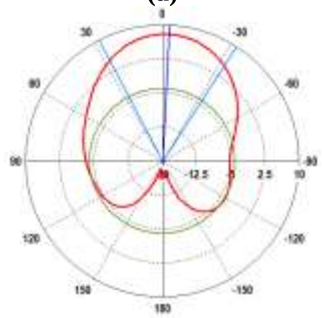


Figure 4: Realized gain plot of the proposed DRA

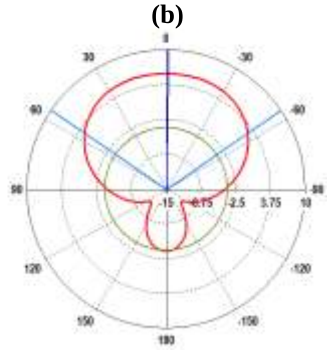
The nature of radiation patterns is depicted in **Fig.5.** The proposed antenna has broadside radiations as expected. (a) and (b) corresponds to E and H-plane at resonant 11.5GHz, where (c) and (d) corresponds to E and H-plane at resonant 14.2GHz respectively. **Fig.6** shows the electric field inside the DRA for $TM_{10\delta}$ at 11.5GHz and $TM_{30\delta}$ at 14.2GHz respectively and symmetrically across Y-Z plane.



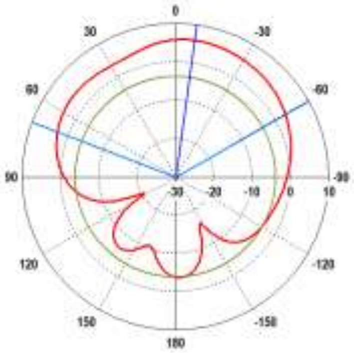
(a)



(b)

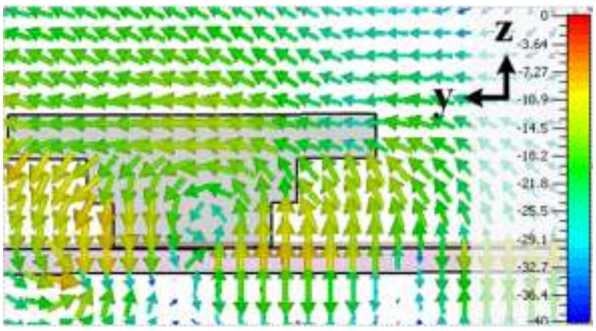


(c)

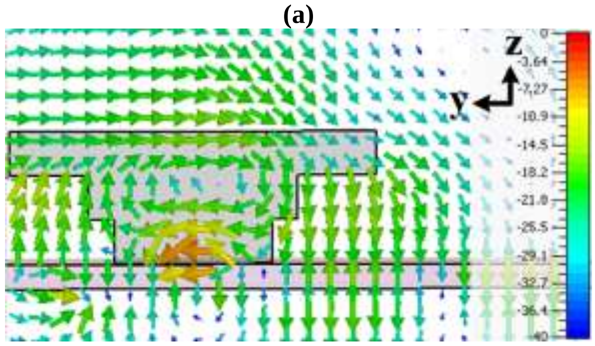


(d)

Figure 5: Radiation pattern of the proposed DRA. (a) E-plane at 11.5GHz, (b) H-plane at 11.5GHz, (c) E-plane at 14.2GHz, (d) H-plane at 14.2GHz.



(a)



(b)

Figure 6: Simulation of E-field inside DRA across Y-Z plane (a) at 11.5GHz ($TM_{10\delta}$), (b) at 14.2GHz ($TM_{30\delta}$).

5. Conclusion

The proposed flipped staired equilateral triangular pyramid DRA was designed and simulated using CST Microwave studio software. The wideband impedance bandwidth ($|S_{11}| < -10$ dB) of 36% have been achieved with the average gain of 7dBi across the passband by merging principal mode 11.5GHz and the immediate higher order mode 14.2GHz. Broadside radiation patterns have been observed. Compared with rectangular and cylindrical design, the triangular shape design offers a small area for a given height and frequency. Generally, due to this, triangular shaped DRAs are also considered to be the good candidate for array and millimeter wave design.

6. Acknowledgment

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Daniel Msilanga received the B.E. in Electronics and communications engineering from St. Joseph University, Tanzania in 2013, then employed to Electrical and Telecommunication Contractor Company called Camusat Tanzania Ltd as field engineer, currently pursuing his master’s degree in Signal and Information processing Engineering at Tianjin University of Technology and Education, P.R China, with research based in Dielectric Resonator Antenna (DRA).