Stack of Four Elements Triangular Dielectric Resonator Antenna Excited by Coaxial Probe

Fizza Khatoon¹, Amit Kumar², Nidhi Vats³

¹,² M. Tech, ²Assistant Professor, SEECE Department, Galgotias University, Noida, India

Abstract—A triangular dielectric resonator antenna is examined, the structure is a stack of array of four equilateral triangles placed over a ground plane, with different dielectric constants of all layers and excitation is provided by co-axial probe to provide a broadband radiation pattern. The structure will provide wideband low profile monopole like structure. Results are verified using CST Microwave Studio Suite 10.

Keywords— Dielectric resonator (DR), triangular resonator antenna (TRA), S11-parameter, perfect conductor (PEC), VSWR, CST Microwave Studio Suite 10.

I. INTRODUCTION

After investigating the different materials, it is found that dielectric resonators are efficient radiator and energy storing element. Some of the features of dielectric which attract antenna designers are mechanical simplicity, small size, high radiation efficiency, which is due to low inherent conductor losses, wide bandwidth and simple coupling scheme to nearly all transmission line [1]. Different shapes of dielectric resonators are investigated and after comparing results it is concluded that some geometries are giving better bandwidth and linear polarization characteristic than other [2]. Triangular shapes give the smaller shape as compared to other shape for the same height and resonance frequency. Various feeding methods can be used for exciting the antenna, like microstrip feeding [3], disk feeding, slot line method [4] here we are using coaxial feeding [5] because it provides better matching. In this paper the simulation of a stack of four elements triangular shaped DRA excited by coaxial probe is shown.

II. THEORY

As the dielectric constant of the material increases the Q-factor increases and as a result of it the bandwidth also increases. So, in order to have an antenna of high bandwidth the dielectric constant must be kept low [6]. Now a day the main concern about the antenna design is bandwidth enhancement[7].The bandwidth can be improved by working on different parameters like changing aspect ratio of the DRA, by implementing the stack or multisegement DRA, or by changing the dielectric constant of the DRA [8-9]. If we compare the DRA with other antennas like microstrip antenna, we find that it has better efficiency and wider bandwidth, which is due to absence of surface wave [7-12].

The transcendental equation derived from waveguide model can be used for calculating the resonance frequency for TMllm modes of an equilateral triangular DRA (where l=m=n=0) [13]. The resonance frequency can be calculated in terms of wave number by the following expression:

\[ f_{mn} = \frac{c}{2\pi \sqrt{\varepsilon_r}} \left( \frac{4\pi}{3L_d} \right)^2 (m^2 + mn + n^2) + k_z^2 \right]^{1/2} \]

Where \( c \) is the speed of light, \( \varepsilon_r \) is the dielectric constant, \( L_d \) is the length of the equal side of the equilateral triangular element. Here, we used the resonance frequency index \( mn \) instead of \( mnl \) because the third index \( l=m+n \) is dependent on the values of \( m \) and \( n \).

III. ANTENNA STRUCTURE

The structure is a stack of three layers of four element triangular DRA, which is described below. An array of four elements equilateral triangular DRA is taken and two layers of same array and of same dimensional triangles is placed on it to make a stack of DRA. Central feeding is used to excite the antenna, a coaxial probe is of 50Ω is used for this purpose. The height of the probe is \( h_p=10 \)mm. It is taken from \( Z_{min}=3 \) to \( Z_{max}=10 \). Different materials are used in different layers. Arlon AR 1000(loss free) is used in base layer having the dielectric constant of \( \varepsilon_1=10 \), and thermal conductivity of 0.645 K/W/m. Gallium Arsenide (loss free) is used in middle layer which has dielectric constant of \( \varepsilon_2=12.94 \), thermal conductivity of 54 K/W/m, Young’s modulus of 85(KN/mm^2) and poison ratio of 0.31. The top most layer has the dielectric constant of \( \varepsilon_3=16 \).Height of all layer are same i.e. \( h=4mm \).A probe is inserted centrally through the ground plane.. A cylindrical structure of Teflon (PTFE) (lossy) material is used as an outer cylinder of the probe. This is used for insulating the ground plane from probe, so that no current can go through the ground plane. The Teflon has the value of Epsilon=2.1, thermal conductivity=0.2 W/K/m, Young’s modulus=0.5 KN/mm^2, poison’s ratio=0.4,Mue=1. Ground plane is used in the structure ,the significance of which is to provide a monopole like structure i.e. to restrict the electromagnetic waves going towards \( Z_{min} \) direction i.e. in downwards direction. The dimensions of the ground plane is taken as: \( X_{min}=-20, X_{max}=20, Y_{min}=-20, Y_{max}=20 \) \( Z_{min}=3 \) and \( Z_{max}=0 \) i.e. 40mmx40mm. The ground plane is a square of perfect
conductors (PEC). The feeding provided for this system is coaxial probe feeding. Coaxial probe feeding is used because it provides proper matching between antennas and feeding probe than any other type of feeding.

Below are shown different views of the antenna. Measurements are also mentioned after every structure and result.

![Figure: (a)](image)

Figure: (a)

![Figure: (b)](image)

Figure: (b)

![Figure: (c)](image)

Figure: (c)

Figure 1: Geometry of four element antenna structure is shown in figure (a) Top view (b) Bottom view (c) perspective view. \( h_g=3, l_g=40, w_g=40, h_d=4, h_{probe}=10 \) all dimensions are in mm.

Where \( h_g \) is the height of the ground, \( l_g \) is the length of the ground, \( w_g \) is the width of the ground, \( h_d \) is the height of the DRA, which is equal for all elements of all layers of structure, \( h_p \) is the height of the probe.

IV. RESULTS

After simulation of the structure results are shown below. In figure 2, the S-parameter is shown. We have achieved antenna ranging from 6.74GHz-9.74GHz i.e. a bandwidth of 3 GHz (where S11<-10 db), which is much sufficient for an antenna to radiate in wide range. The resonance frequency is 9.095.

The return loss i.e. \( S_{11} \) is -21.50 db, which is very good because for an antenna to radiate efficiently, it must have as low loss as possible, lesser the loss better will be the antenna.

![Figure 2: S11 parameter showing bandwidth of approximately 3GHz and very low return loss of -21.50 db. \( h_g=3, l_g=40, w_g=40, h_d=4, h_{probe}=10 \) all dimensions are in mm.](image)

Figure 2: S11 parameter showing bandwidth of approximately 3GHz and very low return loss of -21.50 db. \( h_g=3, l_g=40, w_g=40, h_d=4, h_{probe}=10 \) all dimensions are in mm.

VSWR is shown in below figure, it is clear from figure that the value of VSWR lies between 1 and 2 for the frequency range from 6.74GHz-9.74GHz i.e. for S11 (<-10 db).

![Figure 3: VSWR \( h_g=3, l_g=40, w_g=40, h_d=4, h_{probe}=13 \) all dimensions are in mm.](image)

Figure 3: VSWR \( h_g=3, l_g=40, w_g=40, h_d=4, h_{probe}=13 \) all dimensions are in mm.

VSWR can be calculated using the following formula as:

\[
\Gamma = \frac{Z_1 - Z_0}{Z_1 + Z_0}
\]

\[
VSWR = \frac{1 + \Gamma}{1 - \Gamma}
\]

Where \( Z_1 \) is the antenna impedance, \( Z_0 \) is the impedance of feed line and \( \Gamma \) is the reflection coefficient.

The farfield radiation pattern at the resonance frequency of 9.10GHz is shown in the figure below, the gain is 5.046dbi, radiation efficiency of 99.31% and
efficiency of 91.26% which is much sufficient for an antenna to perform efficiently.

Figure 4: Farfield radiation pattern of the antenna showing gain at resonance frequency of 9.10 GHz. [h_g=3, l_g=40, w_g=40, h_d=4, h_probe=10] all dimensions are in mm.

Figure 5: E-Field distributions, [h_g=3, l_g=40, w_g=40, h_d=4, h_probe=10] all dimensions are in mm

Figure 6: H-Field distribution. [ h_z=3, l_z=40, w_z=40, h_d=4, h_probe=10] all dimensions are in mm

Figure below shows the S_{11} parameter variation for different height of DRA, some selected curves are shown out of various results. All curves shows the different values of h i.e. height of DRA. The best results are shown at H=h_1=h_2=h_3=4.

From above table it is clear that bandwidth is maximum when height of the DRA is 4, in this case impedance bandwidth is also maximum than any other case. The impedance bandwidth of DRA can be estimated by the following formula:

\[ \text{Impedance Bandwidth (I.BW)} = \left( \frac{F_H - F_L}{F_C} \right), \]

Where \( F_H \) is the higher cut off frequency and \( F_L \) is the lower cut off frequency at -10db return loss, and \( F_C \) is the resonance frequency.

The figure below shows the variation of S_{11} parameter for different values of dielectric constant, some selected curves are shown out of various curves. The result is achieved at \( \varepsilon_1=10, \varepsilon_2=12.94 \text{ and } \varepsilon_3=16. \)
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REFERENCES


Figure 8: Variation of S11 parameter for different values of dielectric constant. h1=3, l1=40, w1=40 h2=4, hreso=10] all dimensions are in mm

Table: II Variation of impedance bandwidth with different values of dielectric constant. [h1=3, l1=40, w1=40 h2=4, hreso=10] all dimensions are in mm.

<table>
<thead>
<tr>
<th>Dielectric constant (ε)</th>
<th>Range</th>
<th>Resonance frequency</th>
<th>BW</th>
<th>Impedance bandwidth%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ε1=11</td>
<td></td>
<td>6.74-9.56</td>
<td>9.16</td>
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<tr>
<td>ε2=13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ε3=15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ε1=11</td>
<td></td>
<td>6.76-9.54</td>
<td>8.94</td>
<td>2.78</td>
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<tr>
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<tr>
<td>ε3=17</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>ε1=11</td>
<td></td>
<td>6.51-9.18</td>
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<tr>
<td>ε2=15</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ε3=17</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ε1=10</td>
<td></td>
<td>6.74-9.74</td>
<td>9.1068</td>
<td>3.0</td>
</tr>
<tr>
<td>ε2=12.94</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>ε3=16</td>
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</tbody>
</table>

From above table it is clear that the maximum bandwidth and impedance bandwidth is achieved at the values of dielectric of ε1=10, ε2=12.94 and ε3=16.

V. CONCLUSIONS

In this paper a stack of triangular DRA is examined numerically using CST Microsoft studio suit 10, and a wideband antenna is simulated with the following specifications. Bandwidth of 3GHz ranging from 6.74GHz-9.74GHz (<-10 db S11). Impedance bandwidth of 33%, Radiation efficiency of 99.31% and total efficiency of 91.26% and gain of 5.064 dbi is achieved.