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COMPARATIVE ANALYSIS OF APERTURE COUPLED SAPPHIRE HEAPED AND THERMOSET MICROWAVE MATERIAL (TMM13I) HEAPED RECTANGULAR DIELECTRIC RESONATOR ANTENNA

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ABSTRACT

This paper presents a comparative analysis between two different stacked rectangular dielectric resonator antenna design structures. Two separate stacked Structure has been designed using sapphire and thermoset microwave material TMM13i respectively. Both the antenna design structures are aperture coupled. Due to advantage of aperture coupled feed mechanism such as good isolation between antennas and feed networks it has been employed. The simulation results obtained indicates that sapphire stacked rectangular dielectric resonator antenna design has better performance as compared to the thermoset microwave material TMM13i stacked rectangular dielectric resonator antenna design. The sapphire stacked antenna design exhibits two frequency bands from 7.41GHz to 8.21 GHz and 9.11GHz to 12.65GHz whereas TMM13i stacked antenna shows only one frequency band from 8.62 GHz to 10. 6GHz.The radiation efficiency of sapphire stacked antenna is far more superior than TMM13i stacked antenna. Hence Sapphire stacked rectangular dielectric resonator antenna has proven to be the good material for designing antennas in future and thus can be used for C-band applications as well as X-Band applications.

Keywords: sapphire heaped rectangular dielectric resonator antenna (RDRA), thermoset microwave material TMM13i heaped rectangular dielectric resonator antenna (RDRA), X band applications, C-band applications.

INTRODUCTION

There has been revolutionary growth in the world of wireless communications system. Since its inception wireless technology has undergone many stages of development. Antennas form the most integral part of any wireless communication systems. In order to the keep pace with fast changing requirements of wireless communication market, the fast and efficient antennas are in great demand. Besides it is desired that antennas should be of that type which can be scaled up in frequency. There are two types of antennas which have been able to match up these needs namely micro strip antenna and dielectric resonator antenna. Initially micro strip patch antennas were best suited for it but from last few decades' dielectric resonator antennas have totally replaced it [1-3]. Since DRAs have an edge over micro strip antennas because of its many attributes namely ease of fabrication, flexibility in feed mechanism, low profile, high radiation efficiency and wide frequency range to name a few. Moreover, DRA is a 3-D structure whereas micro strip antenna is a 2-D structure. In addition, DRA's are well suited for low-loss applications for the reason that there is no conductor loss in them.

In 1939, Rich Myer proved that dielectric resonator antenna radiate energy [4]. However, the investigation done by him were theoretical. Thus practical applications did not occur till 1960's. It was S.A Long *et at* [5] who for the first time conducted a proper study and experimentally investigated properties. Also he measured the radiation pattern, the input impedance for structures of many geometrical aspect ratios, permittivity and sizes of co-axial fed probes. This study on dielectric resonator antenna gave a suitable substitute over traditionally used low gain antenna elements. After carrying out investigation of cylindrical DRA, Long and his members carried out research on other DRA shapes such rectangular and hemispherical [6-9].

The type of design flexibility DRAs offer that make them the first choice of antenna designers. Though world-wide DRA has given base for many research activities which have resulted in design of many efficient and novel DRAs. However, there are many unexplored areas too such as using new material for designing DRA. Therefore, because of sapphire's lot of merits namely robustness, light transmission, thermal insulation. Sapphire can be used to design an antenna [10].

The literature review [11-21] reveals that possible materials used for DRAs so far are Roger TMM 3, TMM 4, TMM 6, TMM 13i these thermoset microwave material is a ceramic thermoset polymer. In microwave region losses in the ceramic material increases because of interaction among the applied field and the phonons which leads to the damping of the optical lattice vibrations in turn causing a dielectric loss. Thus, there is need for a material to replace the ceramic material.

Sapphire material dielectric resonator antenna overcome ceramic material drawbacks and thus has better performance when compared to the ceramic material dielectric resonator antenna. It is the potential prospect for future smart phones and mobile communication. Hence in this paper a comparison has been presented between Sapphire stacked rectangular dielectric resonator antenna design and thermoset microwave material TMM13i stacked rectangular dielectric resonator antenna design.

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The effective way of enhancing the gain of any antenna is to deploy stacked structure design instead of single structure design [22-24]. Number of shapes of DRAs are available but the rectangular shaped DRA have been put in use as this is the only shape that gives more fabrication flexibility as compared to other geometries. Also, because this shape achieves better radiation as well as impedance in the design [25].

There are multiple ways or methods to excite an antenna such as micro strip transmission line, coaxial probe fed, coplanar waveguide line, aperture coupled feed to name a few. Out of all, aperture coupled feed mechanism is mostly employed. The objective behind using aperture coupled feed is that it avoids the spurious modes because it keeps feeding networks below the ground plane [26 -28]. The five sections of the paper are organized as follows: section I is covering the introduction section II shows antenna design calculation, section III gives antenna design configuration and design. Section IV explains simulated results and discussion whereas section V is the conclusion.

ANTENNA DESIGN METHODOLOGY

Dielectric waveguide model has been utilized for finding out the resonant frequency and initial dimensions of rectangular dielectric resonator antenna. By the magnetic wall boundary condition and solving the following transcendental equation the resonator frequency for dominant modes (TE to Z mode) are obtained:

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_0^2$$

$$f_o = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{k_x^2 + k_y^2 + k_z^2}$$

$$k_x = \frac{\pi}{a} \quad ; \quad k_y = \frac{\pi}{b}$$

$$k_z \left(\tan\frac{k_z d}{2}\right) = \sqrt{(\varepsilon_r - 1)k_0^2 - k_z^2}$$

Where ε_r denotes dielectric constant of dielectric resonator antenna, c is the velocity of light, and k_0, k_x ,k_y and k_z are wave numbers along x ,y and z directions.

As shown in Figure-1 aperture coupling has been used as method of excitation so following equation have been utilized as the initial point for designing slot dimensions.

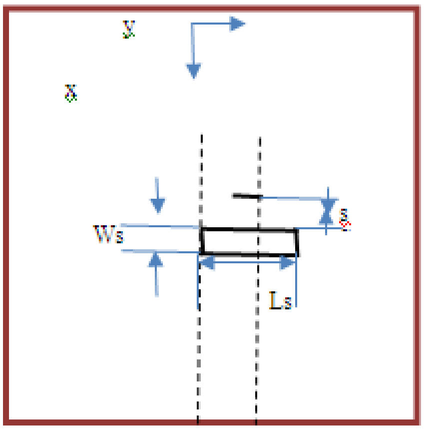

Figure-1. Aperture coupled Feed.

Slot length,

$$L_S = \frac{0.4\lambda_o}{\sqrt{\varepsilon_e}}$$

Where λ_o is the wavelength and the effective permittivity is defined as:

$$\varepsilon_e = \frac{\varepsilon_r + \varepsilon_s}{2}$$

Where $\varepsilon_r$and ε_s are the dielectric constant of the rectangular dielectric resonator and substrate respectively.

Slot width,

$$W_s = 0.2L_s$$

Stub length,

$$s = \frac{\lambda_g}{4}$$

Where λ_g is the guided wave in the substrate.

ANTENNA CONFIGURATION AND DESIGN

Both the design structures have been created on FR4 substrate possessing dielectric constant 4.4 and dimensions 50 x 50 mm^2 with the loss tangent 0.002. The first antenna design consists of two sapphire of same permittivity =10 and same height= 2.5 mm but different dimensions piled over each other as shown in Figure-2. The second antenna design consist of two different sized TMM13i piled over one another, both TMM13i having same permittivity and height of 12.8 and 2.5mm respectively as shown Figure-3.

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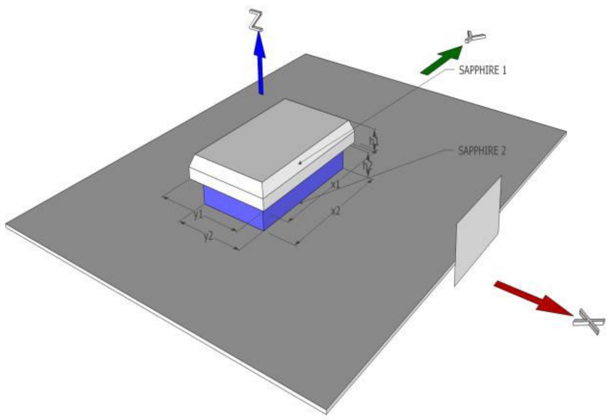

Figure-2. Geometry of the Sapphire Stacked Antenna x_1=13mm, y_1=10 mm, h_1=2.5mm, x_2= 12mm, y_2= 8mm and h_2=2.5mm.

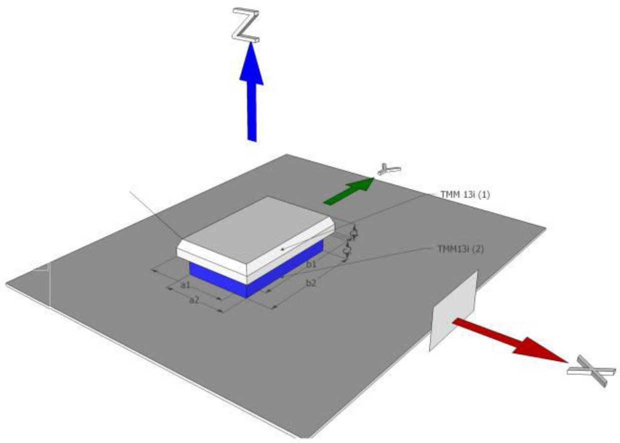

Figure-3. Geometry of the TMM13i Stacked Antenna b_1=13mm, a_1=10 mm, c_1=2.5mm, b_2= 12mm, a_2=8 mm and c_2=2.5mm

In order to provide feeding mechanism through aperture coupled method a feed line of L=30.5mm and W= 1.2mm and a slot of dimension Ls=9mm and Ws=1.5mm has been etched from the ground plan to create the aperture coupling excitation mechanism shown in Figure-4.

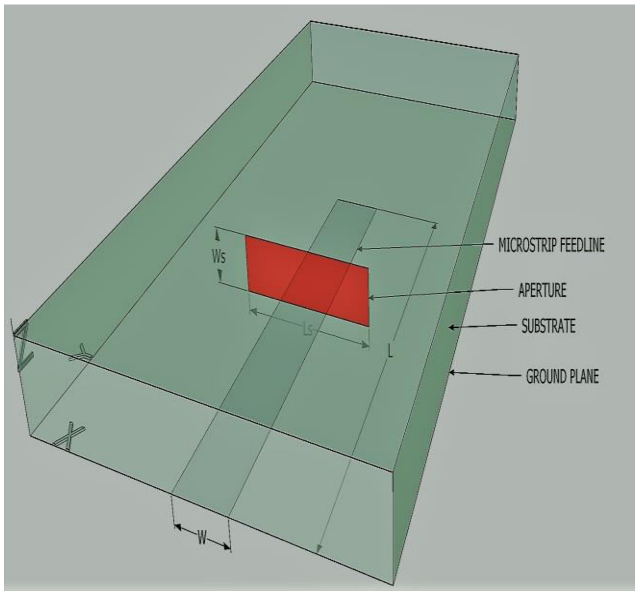

Figure-4. Aperture coupled Feed.

SIMULATED RESULTS AND DISCUSSIONS

Anasoft HFSS has been employed to simulate both stacked structures. The return loss versus frequency response of the both the design structures are displayed in Figure-5 and Figure-6. For sapphire stacked antenna design it is noticeable that antenna is showing reflection over two frequency bands from 7.41GHz to 8.21 GHz and 9.11GHz to 12.65GHz. However, TMM13i piled antenna exhibits reflection over only one frequency band from 8.62 GHz to 10. 6GHz.The S_{11} outputs shows that sapphire stacked antenna provides a wide band as well as two bands even though band 1 has more return loss but it is usable where as TMM13i antenna design provides single and narrow band.

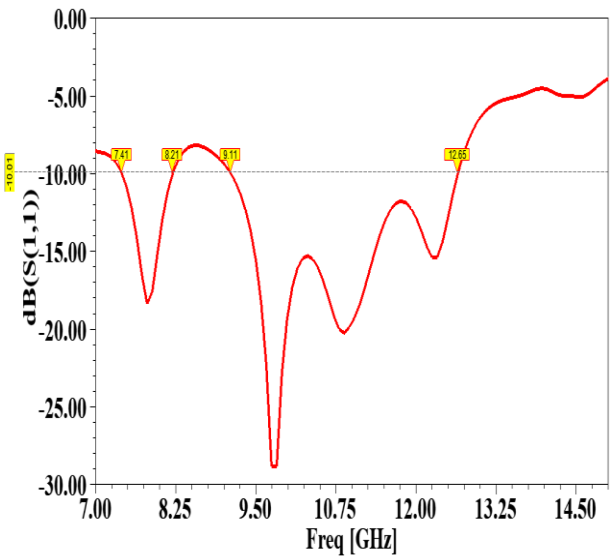

Figure-5. $|S_{11}|$ Return Losses Vs Frequency plot for Sapphire Antenna design.

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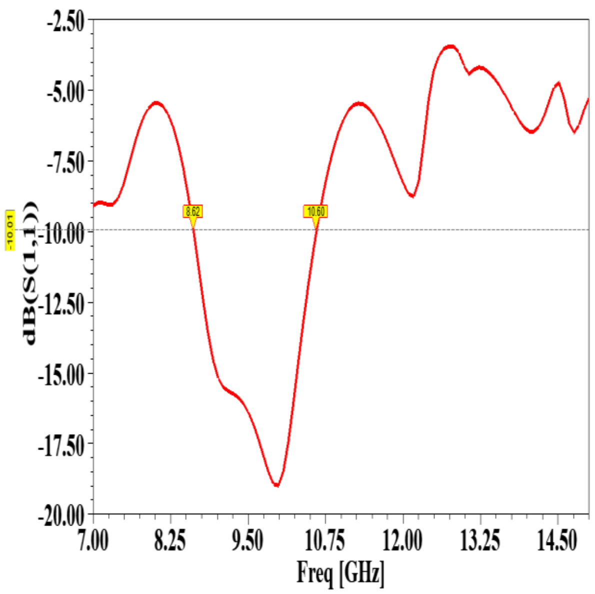

Figure-6. $|S_{11}|$ Return Losses Vs Frequency plot for TMM13i Antenna design.

Figure-7 gives a comparative analysis between S_{11} outputs of both antenna design structures. It shows that Sapphire stacked antenna provides a wide band as compared to TMM13i stacked antenna design which is providing a narrow band.

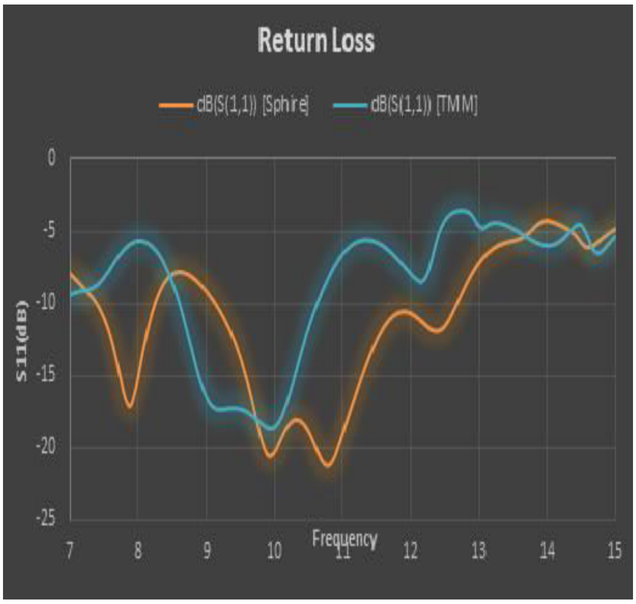

Figure-7. $|S_{11}|$ outputs of both antenna design structures.

In Figure-8 the radiation efficiency of both sapphire stacked antenna and TMM 13i stacked antenna can be seen. It's clearly visible that the radiation efficiency of sapphire stacked antenna is throughout constant for both frequency bands while for other design antenna it is not the case. Hence, the radiation efficiency of sapphire stacked antenna is far better.

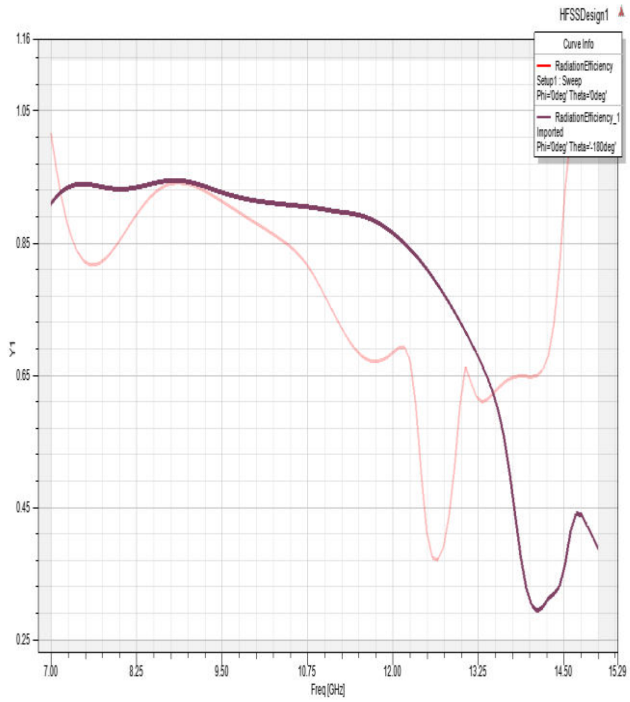

Figure-8. Radiation Efficiency of both antenna design structures.

CONCLUSIONS

A comparison between two separate heaped rectangular dielectric resonator antenna designs using sapphire and thermoset microwave material TMM13i respectively has been conducted. The parametric study clearly shows that the sapphire stacked antenna design has achieved two usable frequency bands 7.41GHz to 8.21 GHz and 9.11GHz to 12.65GHz so it can be utilized for C-band and X-band applications whereas TMM13i stacked antenna exhibits only one frequency band from 8.62 GHz to 10. 6GHz therefore its usage is only limited to C-band applications. Also radiation efficiency of sapphire stacked antenna is far better than TMM13i stacked antenna. Thus, Sapphire stacked rectangular dielectric resonator antenna has proven to be the good material choice for designing antennas in future.

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