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Analysis of stacked rectangular array antenna by various feedings

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ABSTRACT: Due to various benefits, Microstrip patch antennas are utilized in different applications extensively. Because of the attractive features of ease of fabrication, robustness, light weight, and low profile, microstrip patch antennas have been investigated. However, the significant disadvantage is the narrow bandwidth that is where stacking of antennas is proposed. The stacked antenna is designed to form an array which is used for enhancing bandwidth. The stacked antenna offers many advantages like miniaturization, frequency independent, wideband and multiband capabilities, low volume, smaller dimension and many more. With a rectangular slot, a rectangular microstrip patch antenna is designed in this project and it is replicated based on HFSS tool. A 1*1, 1*2 and 1*3 stacked antenna designs are proposed using line and coaxial feeding techniques. The proposed antennas are intended at a frequency of 2.8 GHz with a substrate of FR-4 EPOXY that has a dielectric constant of 4.4.it has features like enhanced bandwidth which is one of the concerns for this project. For proposed 1*1, 1*2 and 1*3 antennas the feeding techniques used are microstrip line feeding and coaxial feeding. For feeding, inverted T shaped microstrip line feeding was used. Here full ground plane is considered for ground structure. The antennas resonating ate 2.8 GHz frequency meets the desired requirements of VSWR and return loss. The stacked antenna array with a thin slot achieves a better result than single antenna. The HFSS (High Frequency Structured Simulator) tool is utilized to evaluate the performance characteristics of the designed antenna such as Return loss, VSWR, Directivity, Gain and radiation pattern.

Keywords— Ring microstrip antenna, Stacked Array, Gap-coupled, Nearness feeding, and Broadband microstrip antenna.

1. INTRODUCTION

Present day communication system requires radiating patch with superior characteristics, less volume and easy to design to attain its goals diverse methods and designs have been implemented in the previous years by antenna development researchers to enhance bandwidth. The main reason to stack an antenna is to improve bandwidth and double the performance of antenna [1]. Stacking of antenna by 1 increase its bandwidth by one and half and if you stack it by 2 the performance double compared to single antenna.

These antennas are needed sophisticated mounting procedures as they are bulky. In modern wireless communication systems, various types of applications are determined by the microstrip antenna (MSA) owing to the numerous benefits such as ease of integration and low-profile planar configuration with microwave integrated circuits [2, 3]. Based on printed reflect array that has flat surface fed by MSAs or Horn antennas [4-9], antenna gain is also improved rather than using the parabolic reflectors. The aforementioned disadvantages can be overcoming by the printed reflect array which is also combined the both features such as the parabolic reflector and printed array. As the feed antenna is came in the radiation pathway by reflect arrays, the antenna gain is restricted in these reflect array owing to the obstruction effectiveness. Given that the feeding antenna is came into the reflect array's radiating beam [10, 11], the blockage efficiency limitation is eliminated which is due to feed antenna by using the stacked arrays. The detuning of patches dimensions and diagonal and coordinate axis that forming an array in regard to the central and feed path [10, 11] is done in the stacked array for realizing the radiated wave front's equal phase. The stacked array is illuminated by a microstrip patch in stacked array and it governs the antenna BW. Additionally, the appreciated gain is relied on the stacked gap-coupled patches' effective illumination. The lower gain and BW have included in a single microstrip element fed arrays. By cutting the slot inside the path with half wavelength [2, 3], the compact MSA are retrieved. Based on the cutting of slot in the centre of square or rectangular MSA [2, 3], the realization of the rectangular or square ring MSA is done. The lower gain has involved in the compact MSAs owing to the radiation from slotted area.

2. LITERATURESURVEY

The literature survey was initially carried on patch antenna, microstrip antenna and its types, antenna arrays, different antennas arrays, stacking of antennas and types of stacking. The techniques used for improving the bandwidth of an antenna were utilized to enhance the antenna performance. In 1953, G.A. Deschamps was proposed the microstrip antenna primarily but the practical application couldn't be implemented until 1970s. The researchers like Robert E and others were implemented the microstrip antenna further with the use of available low loss soft substrate materials [12]. The frequency is not directly proportional to the microstrip antenna's size [13]. Due to the required size, the microstrip patches don't respond to the frequencies that are lower than microwave. As shown in fig.1

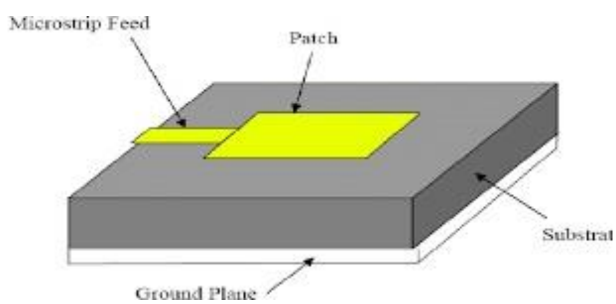

Fig.1: Microstrip patch antenna

A microstrip antenna would be on the order of 1 meter long for making it to obtain FM radio at 100 MHZ. The microstrip patch is available in the football size for AM radio at 1000 KHZ. In the everyday application, microstrip patches are utilized in the satellite radio receivers. In this case, the mounting of an antenna in a vehicle is done in which the angle in the X-Y plane with respect to the satellite that is not fixed. For satellite radio, the circular polarization is incorporated by not considering the angle that the patch is with respect to the satellite. By using the techniques of microstrip on a printed circuit board (PCB), the fabrication of an antenna is usually designed by a microstrip antenna in telecommunication. A patch of various shapes' metal foil on a PCB's surface with a metal foil ground plane on the board's other side [14] is contained in an individual microstrip antenna. In a two-dimensional array, multiple patches are involved in most of the microstrip antennas. Through the transmission lines of foil microstrip, the connection of an antenna to the receiver or transmitter is made usually.

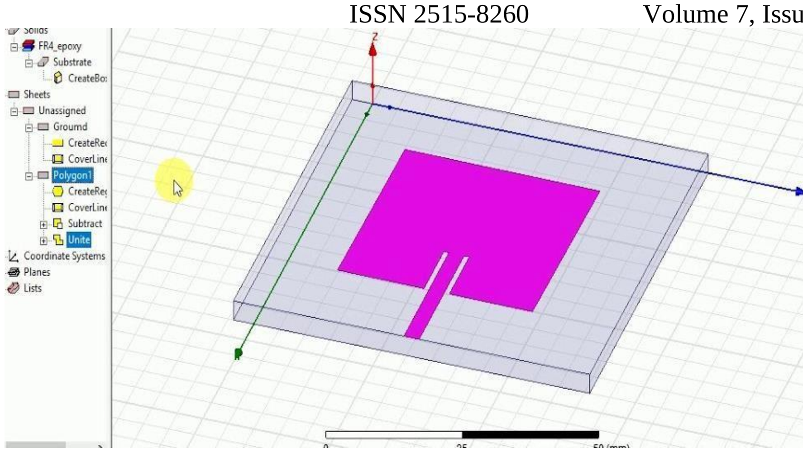

Fig.2: Microstrip antenna design

The examples of antenna limitation are involved the limited gain, loss from leakage at the open boundary, low power handling capabilities, and small radiated power and bandwidth. For improving the performance of microstrip antenna specifically in terms of enhancement of bandwidth, return loss, and the gain, different techniques have been concerned to restrict these limitations. To increase the performance of this type of antenna, various kinds of works have been considered by using the adding of reflector layer air gap, laminated conductor, aperture coupled, parasitic patch, and multiple substrates. Based on the antenna application, the techniques are undergoing various researches and the performance is improved.

Both the impedance bandwidth and radiation pattern will be impacted by the dielectric loading of a microstrip antenna. The bandwidth of an antenna is reduced as the dielectric constant of the substrate is increased. It will lead to the increment of an antenna's Q factor and the impedance bandwidth is decreased. The modern wireless communication and radar application system [15] has focused more attention on the improvement of Reconfigurable Microstrip Antennas (RMAs). As a result of additional convenient for a specific design, it's cost-effective of RMA is to operate with a single antenna instead of multiple antennas. In polarization and multiple frequencies radiation pattern, reconfigurable antennas are having ability to be utilized.

By using either 3 x 3 gap-coupled arrangement of RMSA stack on to nearness fed RMSA or broadband nearness fed rectangular MSA (RMSA), a novel broad design of square ring stacked array fed is proposed in [16]. A design of nearness fed RMSA is demonstrated firstly that provides BW of 1.28 GHz at center frequency of around 4.1 GHz with a peak broadside gain of 7.8 dBi. For stacked array of square ring patches, the nearness fed patch is exploited as feed element further. Different stacked array configurations of ring MSA are proposed such as 3 x 3 stacked array design of square ring patches, shaped gap-coupled square ring MSAs, 1 x 3 and 3 x 1 gap-coupled array of square ring patches, and single ring patch. The distance among the stacked patches and fed patch by different parametric study for dissimilarity is discussed. A peak gain of over 11 dBi with a maximum BW of around 1.4 GHz in 4 GHz range of frequency is obtained in 3 x 3 stacked square ring MSA array. The replacing of fed patch with the stakced arrangement of nearness fed RMSA with 3 x 3 gap-coupled array of rectangular patches is done further for improving the gain and BW. The difference in distance among the space fed MSA and the stacked fed MSAs with the parametric study is demonstrated. To achieve the effective illumination of stacked patches, the configuration of stacked gap-coupled array is used. A peak broadside gain of nearly 16 dBi with the BW of over 2.7 GHz are provided by the 3 x 3 stacked ring MSA array. If the gap coupled stacked RMSA array is considered as a feed element, the realization of increasing in BW and gain is made. By using the software of IE3D with the experimental verifications, the proposed MSAs were assessed primarily in this paper. On glass epoxy substrate with the values $\varepsilon r = 4.3$, $h = 0.16$ cm, $\tan \delta = 0.02$, the fabrication of MSAs was made and they were balanced in air above the ground plan. To support the structure, the foam spacers were utilized. By using ZVH-8, the response of input impedance was computed. Based on RF source (FSC 6), the gain and radiation pattern were measured in the vector network analyzer.

3. DESIGN METHEDOLOGY RECTANGULAR MICROSTRIP PATCHANTENNA:

The Rectangular shape patch has 4 sides. The rectangular sides and its frequency can be determined through mathematical equations. It is capable for radiating circular polarization similar to triangular, square and circular patches.
It exhibits circular polarization because the area of rectangle is equal to area of circle. This result in higher directivity and high gain compared to other configurations. For radiating circular polarization. To design a 1*2 array I need two rectangles with a slot for which line feeding is applied from the bottom in T shape. The measurements of rectangle are given below:
For rectangle
Width = 33.665mm. Length = 42.202mm. FR-4 EPOXY

The rectangular patch is designed to work at 2.8 GHz using the substrate FR4 Glass Epoxy with dielectric constant of 4.4 with microstrip line feed (50Ω impedance). By using the formulae given above, antenna dimensions arecalculated.
Given f_o= 2.8 GHz, h= 1.6mm, ϵ_r=4.4 C = 3*
Width of the patchW=
= 32.602mm;
Effective dielectric constant
=4.;
Extension in length ΔL = 0.7369mm; Effective length L_{eff} =25.5391765mm;
Length of thepatch L 24.0653mm;
Width of the ground W_G= 6(1.6) +32.602 = 42.202mm; Length of the ground L_G = 6(1.6) +24.0653 = 33.665mm. For feed point:
Along x-axis Along y-axis
= 5.736.

= 16.301.

Design of single microstrip antenna

The patch consists of Rectangle with a slot. Microstrip line feeding is used at center of patch. Height of substrate is taken as 1.6mm. This is made to work at 2.8GHz.

Design of 1*3stacked rectangular microstrip patch antenna.

The design of 1*3 antenna array consists of 3 microstrip patch connected to a T shaped feed. It consists of 3 rectangles with a rectangular slot connected to the feed. The rectangle patches are stacked horizontally and the positions of 3 rectangle patches are shown in figure.

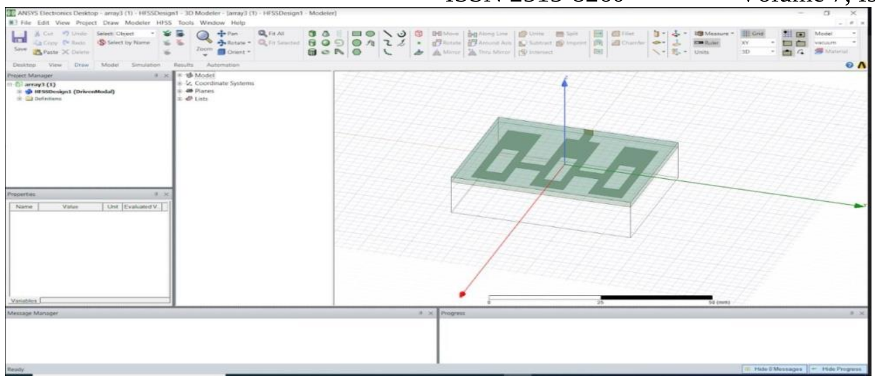

Fig.3: Screenshot of 1*3 stacked antenna

4. RESULT ANDDISCUSSION

4.1 RESULTS of 1*3 stacked antenna array with line feeding

Return loss is also a measure of how fully transmission and receiving devices or transmission lines are well matched. If return loss is high, then it is a good match that leads to less insertion loss and vice versa.

Return loss anywhere Pin is incident power and Pref is replicated loos is Return loss power and reflection coefficient in dB, the returnThe return loss vs VSWR plot of 1*1 microstrip antenna with line feeding are shown below

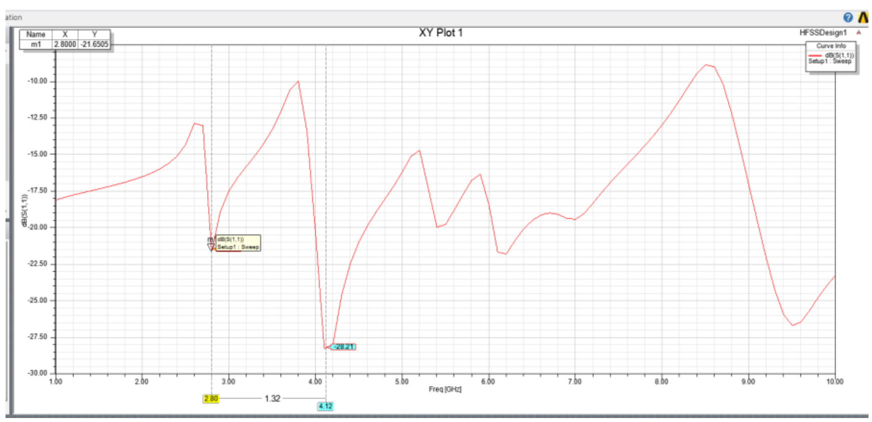

Fig.4: Return loss vs frequency plot for stacked 1*3 rectangular patch antenna

VSWR is also termed as Standing Wave Ration (SWR) that demonstrates how an antenna's good impedance is related to the impedance of connected transmission line. Reflection coefficient is described how much power is reflected from the antenna is relevant with it. It is defined based on reflection coefficient as follows: VSWR

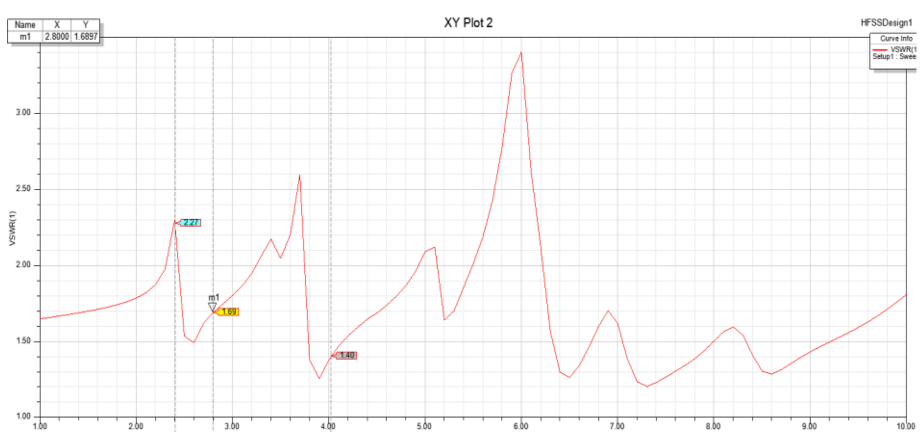

Fig.5: VSWR vs frequency plot for stacked 1*3 rectangular patch antenna

Observations: Return loss and VSWR at the frequency of operation 2.8GHz is -21.6505 dB and 1.6897. With an efficiency of antenna radiation of 0 dB (or 100%), a lossless antenna will be an antenna. When compared to the isotropic antenna, a receiving antenna will receive 5 dB more power with a gain of 5 dB in a particular direction.

Antenna gain = Directivity x Efficiency

Gain of 1*3 stacked rectangular patch antenna using line feeding.

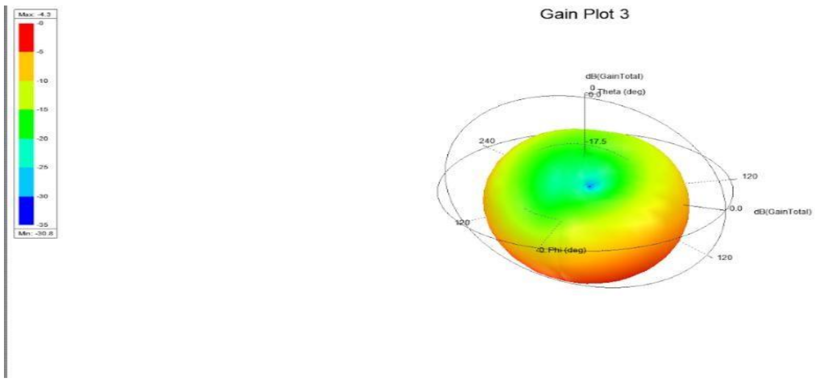

Fig.6: 3D Gain plot for 1*3 antenna array using line feed

Directivity is measured based on how an antenna is directional. Typically, directivity is provided as the main lobe of the radiation pattern of the antenna's peak directivity.

Directivity(D) =

Directivity of 1*3 stacked rectangular patch antenna using line feeding.

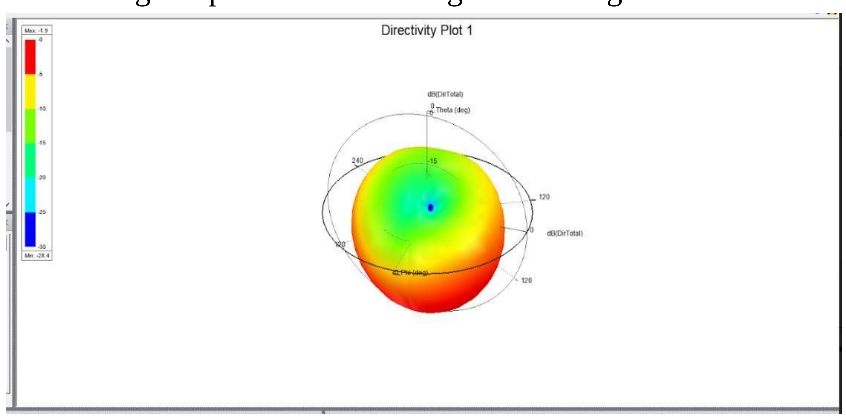

Fig.7: 3D Directivity plot for 1*3 antenna array using line feed Radiation pattern of 1*3 stacked antenna array using line feeding

As the radiation pattern is showed the path the antenna is distributed its energy in space, an antenna's radiation pattern is one of the basic properties. If it is computed far away from the antenna which is not depending on the distance, a number of lobes are included in antenna generally.

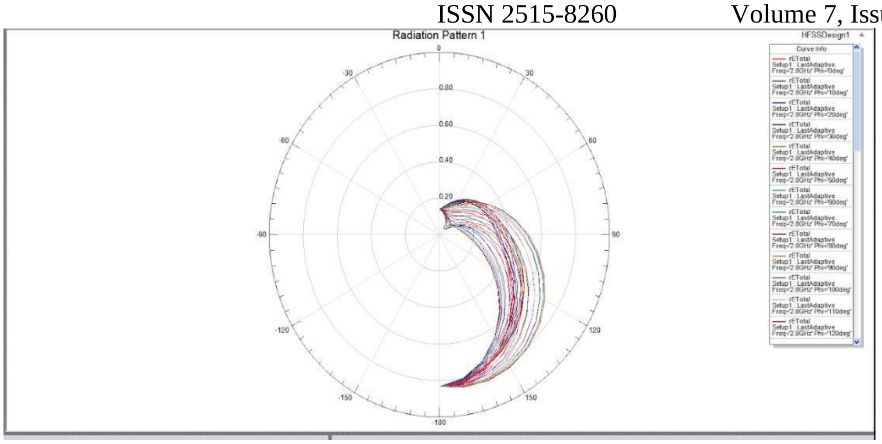

Fig.8: Radiation pattern of stacked1*3 antenna array using line feed

The rectangular microstrip patch antenna's designing is same as that of line feeding the only difference comes when I apply feeding. Here I consider coaxial probe to feed antenna instead of microstrip line. All the microstrip patches are connected to a 100Ω line width of the feeding line is 0.7mm.

At the junction of each pair of 100Ω lines, the equivalent point is 50Ω. The placing of a quarter wave transformer between a 50Ω is done. The resultant impedance of 100Ω line and equivalent point is measured as follows:

Z== *100 = 70.7Ω

- Radius of the patch is17mm.
- Inner element spacing is62.5mm.
- Width of 100Ω feeding is0.7mm.
- With of the 70Ω feeding is1.6mm.
- Width of 50Ω feeding is3mm.

Design of 1*3 stacked antenna

In this the stacking is performed horizontally and it has 3 rectangular patches each with a slot. Where as in coaxial feeding the feeding is connected directly to the ground plane.

In coaxial feeding the position of feeding plays a crucial role where it takes trial and error in order to plot the perfect position.

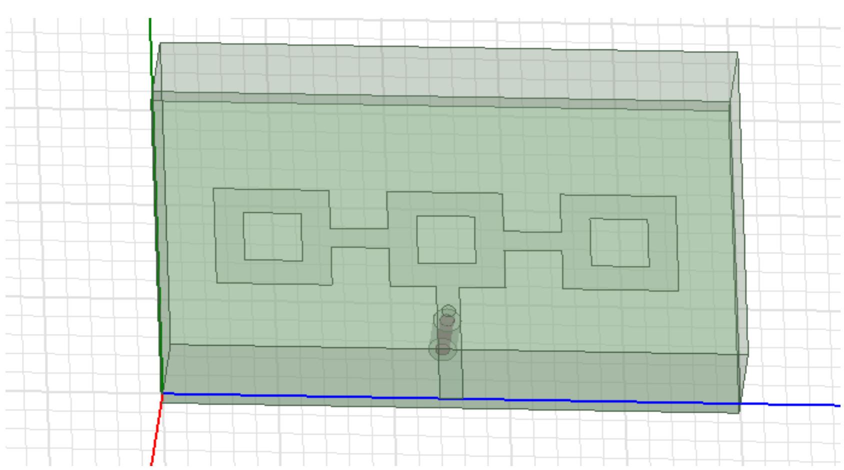

Fig.9: Screenshot of showing design of 1*3 antenna array with coaxial feeding

4.2 RESULTS of 1*3 stacked antenna array with coaxial feeding

The return loss vs VSWR plot of 1*3 microstrip antenna with line feeding are shown below

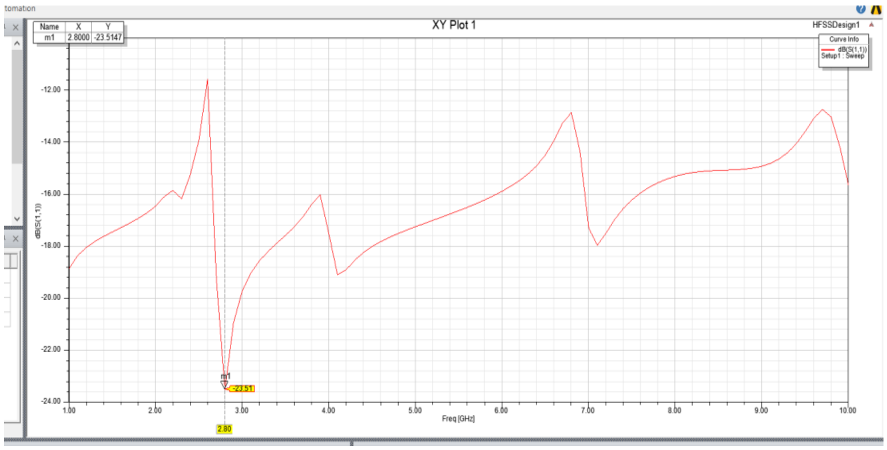

Fig.10: Return loss vs frequency plot for stacked 1*3 rectangular patch antenna

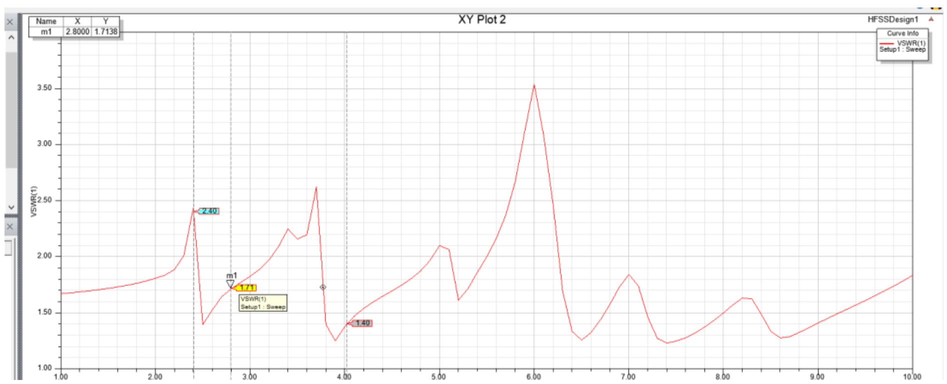

Fig.11: VSWR vs frequency plot for stacked 1*3rectangular patch antenna

Observations: Return loss and VSWR at the frequency of operation 2.8GHz is -235147. dB and 1.7138. Gain of 1*3 stacked rectangular patch antenna using coaxial feeding.

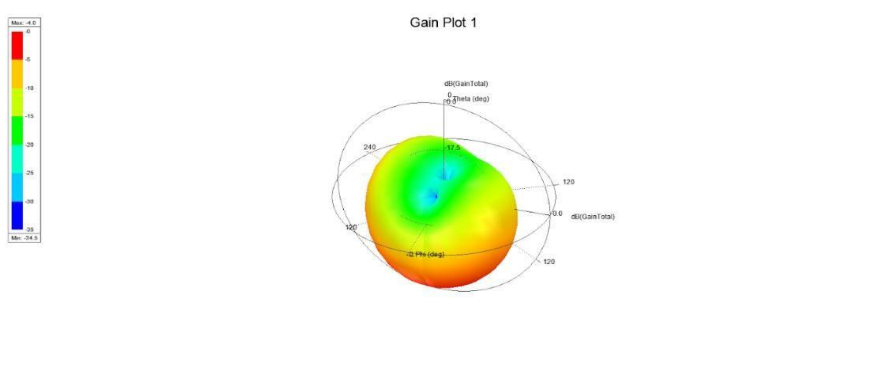

Fig.12: 3D Directivity plot for 1*3 antenna array using coaxial feed

Directivity of 1*3 stacked rectangular patch antenna using line feeding.

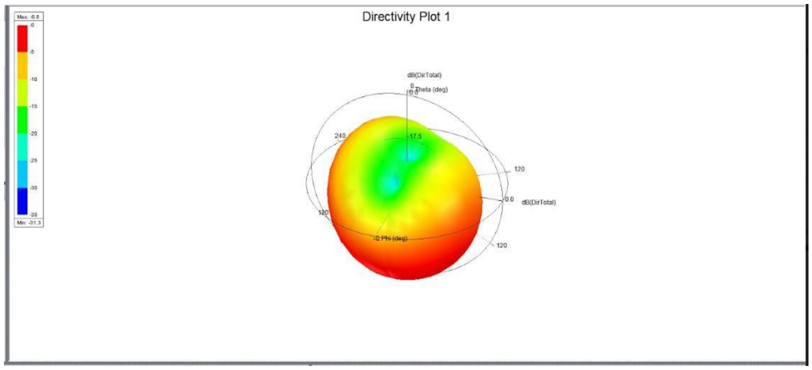

Fig.13: 3D Directivity plot for 1*3 antenna array using coaxial Return loss vs frequency plot for stacked 1*3 rectangular patch antenna

1*3 stacked rectangular patch antenna's radiation pattern is derived using coaxial feeding.

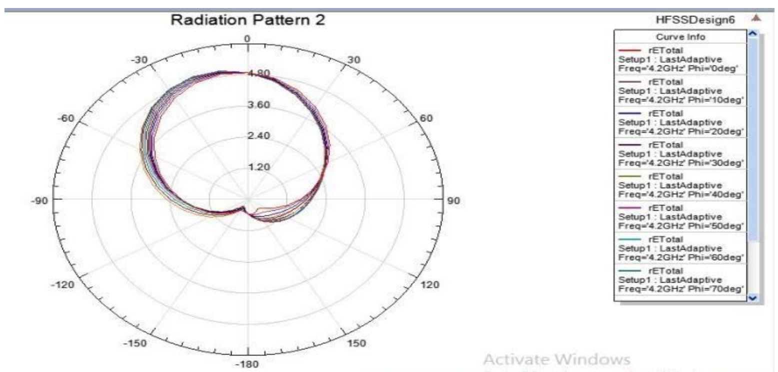

Fig.14: Radiation pattern of stacked1*3 antenna array using coaxial feed Comparison of simulated results

Name	**Parameter**	**Line feeding**	**Coaxial feeding**
1*3 stacked antenna	**Return loss**	-21.6505	1.6897
1*3 stacked antenna	**VSWR**	-23.5214	1.713
	Gain	30.8	34.5
	Directivity	28.8	31.3
	Radiation pattern	Half direction	All directions

CONCLUSION:

A stacked rectangular microstrip antenna is proposed for wideband and wireless applications. In a frequency range of 2.8 GHz, a large bandwidth of 21.8 GHz and the return loss of both the antennas with less than -10dB are provided by the proposed stacked antenna.

The VSWR is less than 2 for both the antennas and covers IEEE standard wireless frequency range. It can be used in 5g applications.

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