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Design and implementation of a Planar Array Antenna for L5 band of Indian Regional Navigational Satellite System (IRNSS)

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Abstract - **The Indian regional navigational satellite system (IRNSS) is an autonomous regional satellite navigation system being developed by the Indian Space Research Organization (ISRO) which would be under complete control of the Indian Government. The requirement of such a navigation system is driven by the fact that access to Global Navigation Satellite System, GPS is not guaranteed in hostile situations. Design of IRNSS antenna at user segment is mandatory. The simulated Microstrip patch antenna operates on the frequency of L5 band (1176.45 MHz) which is used for positioning services. Its parameters are enhanced by making 2x8 array with Teflon substrate, increasing gain, directivity, and efficiency to 17.3dB, 18.1dBi and 95.58% respectively. For fabrication purpose substrate FR4 substrate can be used for which 10.1dB gain and 15.4dBi directivity is obtained till 2x8 array. Results of simulation are compared with hardware results using Vector network analyzer for two models of all array.**

Index Terms— **IRNSS, GPS, Microstrip patch antenna and Array antenna**

I. INTRODUCTION

The Global Positioning System (GPS) is a space-based satellite system that provides location and time information in all weather conditions, anywhere on or near the Earth. As it is maintained by the United States government and is freely accessible to anyone with a GPS receiver. The limitation as supposed is if GPS system of US fails then in all over the world system will stop working. The requirement of such a navigation system is driven by the fact that access to foreign government-controlled global navigation satellite systems is not guaranteed in hostile situations, as happened to Indian military depending on American GPS during Kargil War[ii]. India has planned to develop a satellite based navigation systems known as Indian Regional Navigational Satellite System (IRNSS) for positioning applications. The IRNSS is an autonomous regional satellite navigation system being developed by Indian Space Research Organization (ISRO) which would be under the total control of Indian government. The government approved the project in May 2006, with the intention of the system to be completed and implemented by 2015. It will consist of a constellation of 7 navigational satellites. All the 7 satellites will be place in the Geostationary orbit (GEO) to have a larger signal footprint and lower number of satellites to map the region. It is intended to provide an all-weather absolute position accuracy of better than 7.6 meters throughout India and within a region extending approximately 1,500 km around it. A goal of complete Indian control has been stated, with the space segment, ground segment and user receivers all being built in India. The first two satellites IRNSS-1A IRNSS-1B and IRNSS 1-C of the proposed constellation were precisely launched on 1 July 2013 and 4 April 2014 respectively from Satish Dhawan Space Centre. The next satellite IRNSS-1D of the proposed constellation are planned to be launched by end of 2014 and the remaining three satellites IRNSS-1E, IRNSS-1F and IRNSS-1G are planned to be launched by middle of 2015[ii].

II. MOTIVATION

As the next generation of Satellite navigation system, every country wants to be independent for the positioning and other secured services. The whole new Era has taken birth after invention of GPS system. India is densely populated country, need of navigation of Indians is mandatory. For positioning or for military purpose, navigation system like GPS navigation system is required. This requirement gave rise to the birth of IRNSS, constellation of 7 satellite serving 24x7 positioning and secured services.

III. PROBLEM STATEMENT

In Satellite navigation long distant signal exchange is required, so to have healthy communication the signal must be of high frequency. As there will be many losses taking place between satellite and earth station or end user, so high frequency signals are mandatory for it. As the IRNSS will be used for positioning purpose by civilians, the receiving antenna should be such that it can easily adjusted in a mobile, car and other devices. So Patch antenna is the first choice to fulfill the requirement for being receiving antenna of such positioning system i.e. IRNSS. But the gain of the patch antenna is very less compared to the requirement for such antenna. Gain can be increased by increasing the input power but at one level the increasing of power can damage the patch antenna.

IV. OBJECTIVES

The main objectives of this dissertation are as follows:

I. Design and simulate the patch antenna for L5 band and S of the IRNSS
II. Design and simulate an Array patch antenna for the L5 and S band
III. To characterize the antenna parameters in term of radiation pattern and gain for simulation
IV. Compare simulated results with measured results

V. SIMULATION RESULTS

The practical width of the microstrip patch conductor that will produce an effective resonator is given by

$$w = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

However, for widths smaller than those selected according to equation, the radiator efficiency is lower while for larger widths, the efficiency is greater.

However, excessive width is not desirable because the influence of higher order modes becomes significant which may cause field distortion. The ideal width for practical use can be determined from equation, although the value may not correspond to the optimal one. Once W is known, the effective dielectric constant, ε_{reff} is calculated using below equation

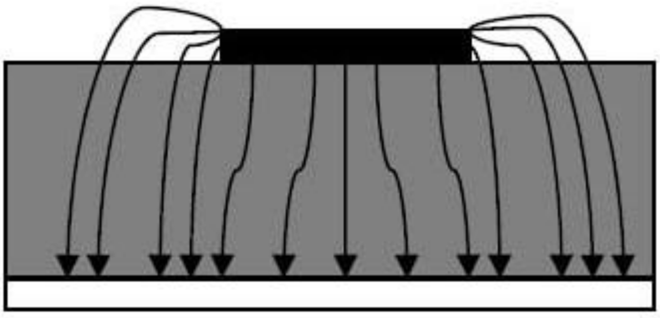


Figure 1 Fringing field

Substitute this value of εeff into equation for the equivalent length of the transmission line extension

$$\Delta l = h(0.412)\frac{(\epsilon_{reff} + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{w}{h} + 0.8)}$$

The length, L of the microstrip resonator slot is then given by

$$L = \frac{v_0}{2fr\sqrt{\epsilon_{reff}}} - 2\Delta L$$

Length is a critical parameter because of the inherent narrow bandwidth of the resonant element, and hence equation should be used to obtain an accurate value of the line length L. Here, 2**Δ**L is the apparent increase in the slot length due to the current flowing around the end of each slot.

Length of Patch (L)	86.2 mm
Width of Patch (W)	102.42 mm
Substrate Height (h)	2.4 mm
Dielectric constant of Teflon (εr)	2.1
Design Frequency	1.176 GHz
Length of strip (Lf)	71.2mm
Width of strip (Wf)	8.4mm

Table 1. Value of Design Parameters

A. II. SIMULATION RESULT

Microstrip patch antennas are to be designed on the computer simulation technology (CST). CST microwave studio is a specialist tool for the 3D EM simulation of high frequency components.

- MSP model for single band(L5)

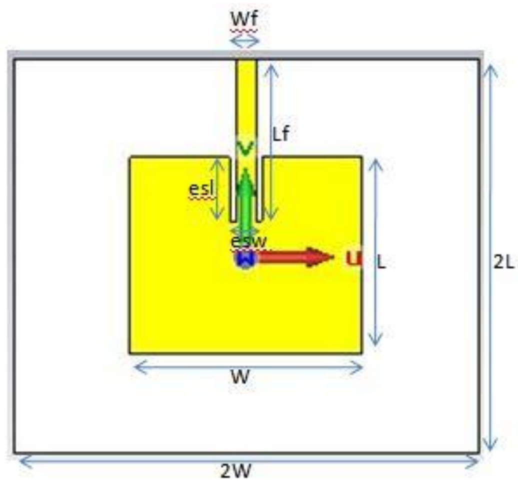


Figure 2 MSP model

This design is the microstrip patch antenna model design. It is design on the CST microwave studio. In that the model consist of four parts which are patch , substrate, ground plane, feeding port. In this design the substrate material is TEFLON and the patch is made up of copper.In this design microstrip feed line is used as a feeding technique. In that the feed line is to be inserted into the microstrip patch.

- Simulation graph for single band

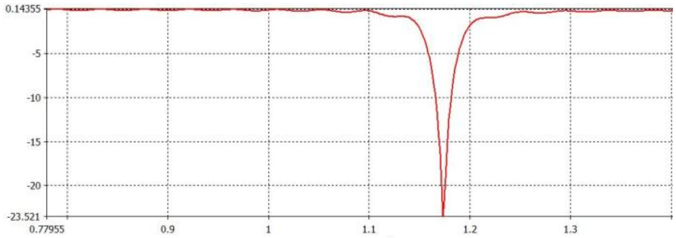


Figure 3 Return loss vs frequency

This graph gives the relationship between Return Loss and Frequency. The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line.

- **Farfield Plot for single band :**

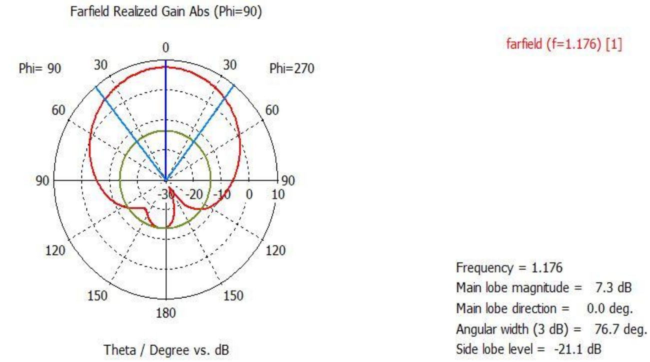


Figure 4 Farfield plot for single band

This figure 4 and 5 gives the gain and directivity of the microstrip patch antenna. And it is the farfield model of the microstrip patch antennas.form this design we can get the gain is around 7.3 dB and directivity 8.2dBi.

- Directivity Vs Angle

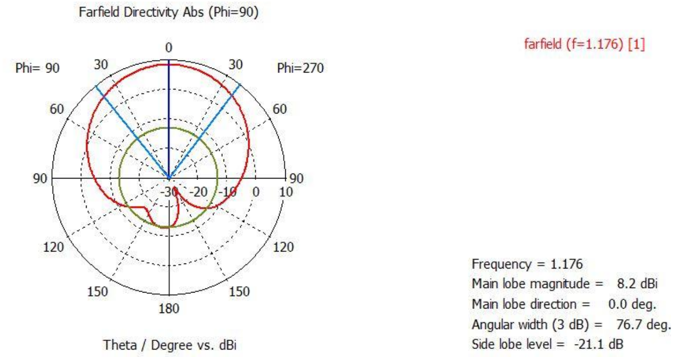
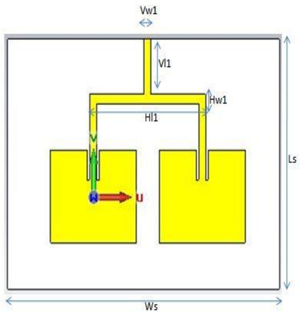


Figure 5 Directivity for single band L5

This design of antenna gives the Gain 7.3 dB and Directivity 8.2 dBi so the effiency obtained is 89.02%

Parameter	**L5 single patch**	**1x2 Array**	**2x2 Array**	**2x4 Array**	**2x8 Array**
S-Parameter (dB)	**-19.2798**	**-9.02087**	**-8.7176**	**-5.0438**	**-9.8041**
Gain (dB)	**7.3**	**8.9**	**11**	**12.4**	**17.3**
Directivity (dBi)	**8.2**	**9.8**	**11.8**	**14.3**	**18.1**
Efficiency %	**89.0243**	**90.8163**	**93.2203**	**86.713**	**95.5801**
Bandwidth (MHz)	**13.4594**	**20.6**	**17.2**	**5.00**	**28.5**

- ARRAY models:



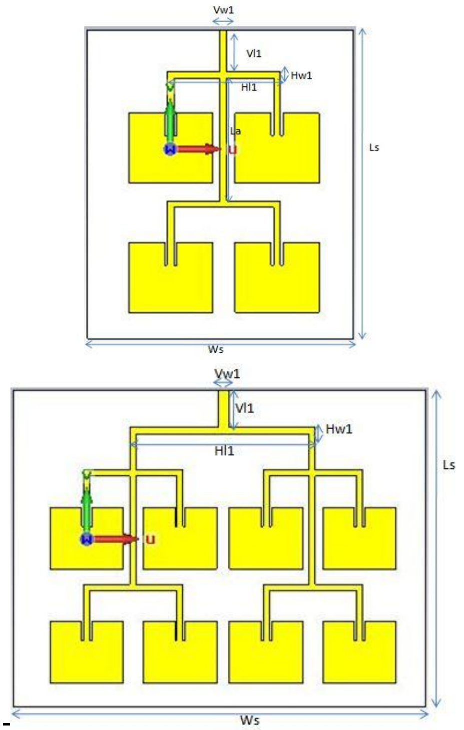


Figure 6 ARRAY models 1x2 2x2 and 2x4

B. For FR4 material

Due to lack of availability of TEFLON substrate in the market we need to fabricate antenna in FR4 material

C. Fabricated ARRAY

Figure 8(a)

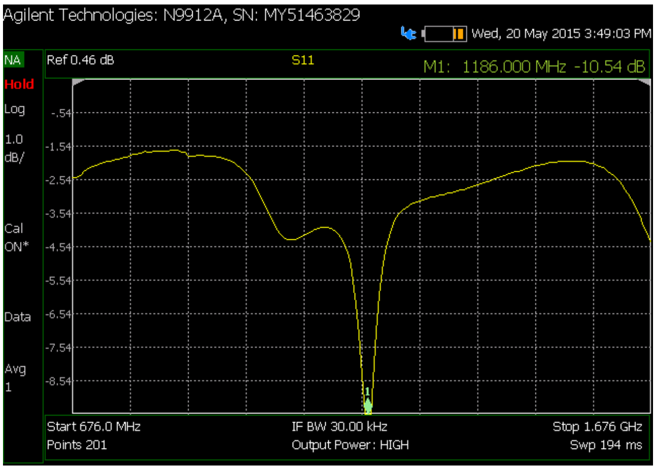


Figure 8(b)

Figure 8 (a) fabricated 1x2 (b)VNA result of 1x2

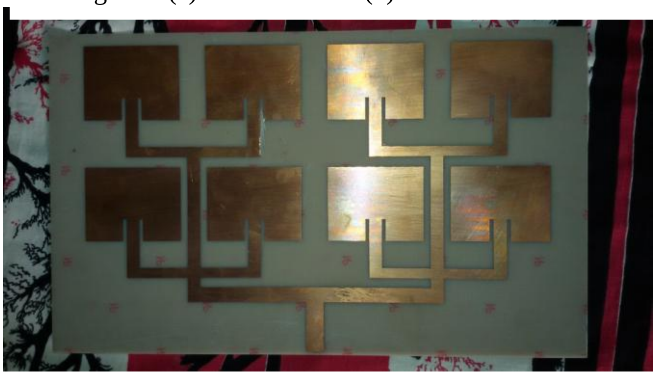


Figure 9(a)

Parameter	L5 single	1x2 Array	2x2 Array	2x4 Array	2x8 Array
S-Parameter	-22.5053	-14.8273	-13.6536	-7.361	-4.836
Gain (dB)	3.1	5.4	7.7	9.4	10.1
Directivity (dBi)	7.1	8.5	10.2	12.8	15.4
Efficiency %	43.6	63.59	75.49	73.43	64.33

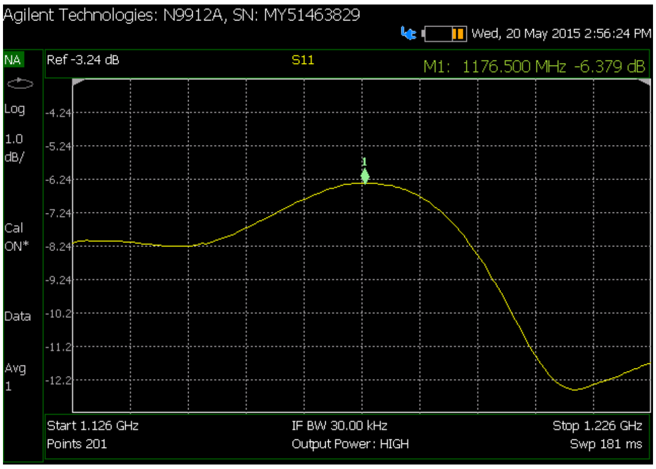


Figure 9(b)

Figure 9 (a) fabricated 2x4 (b)VNA result of2x4

VI. CONCLUSION

The aim of this thesis was to show the design of compact microstrip patch antenna for L5 band and how different parameters are enhanced by making array of that patch with teflon substrate. The gain of L5 single band, 1x2, 2x2, 2x4 and 2x8 array antenna are 7.3, 8.9, 11, 12.4 and 17.3dB respectively and 3.1, 5.4, 7.7, 9.33 and 10.1 respectively for FR4. The simulated results are compared to measurement results for 1x2 and 2x4 arrays.

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