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DESIGN AND IMPLEMENTATION OF A PLANAR ARRAY ANTENNA FOR INDIAN REGIONAL NAVIGATIONAL SATELLITE SYSTEM (IRNSS)

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Abstract: 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 maintained by US government. The limitation as supposed is if GPS system of US fails then in all over the world system will stop working. India is planned to develop a satellite based navigation systems known as Indian Regional Navigational Satellite System (IRNSS) for positioning applications. The design of IRNSS is meant to overcome this limitation as it services in Indian region. The satellites will be placed at a higher geostationary orbit to have a larger signal footprint and lower number of satellites to map the region. IRNSS signals will consist of a Special Positioning Service and a Precision Service. Both will be carried on L5 (1176.45 MHz) and S band (2492.08 MHz). As it will be long range communication we need high frequency signals and high gain receiving antennas are required. So a planar array of patch antennas can be designed to enhance the gain and other parameters of antenna.

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:

- Design and simulate the patch antenna for L5 band and S of the IRNSS
- Design and simulate an Array patch antenna for the L5 and S band
- To characterize the antenna parameters in term of radiation pattern and gain for simulation.

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, εreff is calculated using below equation

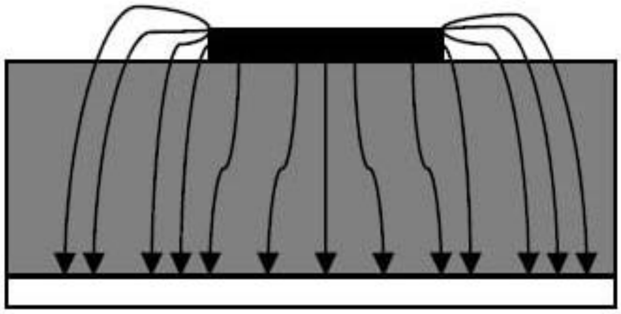


Figure 1 Fringing field

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

$$\Delta l = h(0.412)\frac{(\in \mathrm{reff} + 0.3)(\frac{w}{h} + 0.264)}{(\mathcal{E}\mathrm{reff} - 0.258)(\frac{w}{h} + 0.8)}$$

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

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

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)	60.64 mm
Width of Patch (W)	77.2 mm
Substrate Height (h)	0.035 mm
Dielectric constant of substrate material (εr)	4.1
Design Frequency	1.179 GHz (L5-band) and 2.45 GHz (S-band)
Length of slot	16 mm
Width of slot	10mm

Table 1. Value of Design Parameters

A. 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. CST MWS enables the fast and accurate analysis of high frequency devices such as antennas, filters , couplers, planar and multi-layer structures and SI and EMC effects. CST is broadly applicable for both time domain and frequency domain solver. It also offers further solver modules for specific applications. CST STUDIO SUITE comprises the following modules like cst microwave studio, CST EM STUDIO, CST PARTICLE STUDIO, CST CABLE STUDIO, CST PCB STUDIO. CST MPHYSICS STUDIO, CST DESIGN STUDIO.

- MSP model for single band(L5)

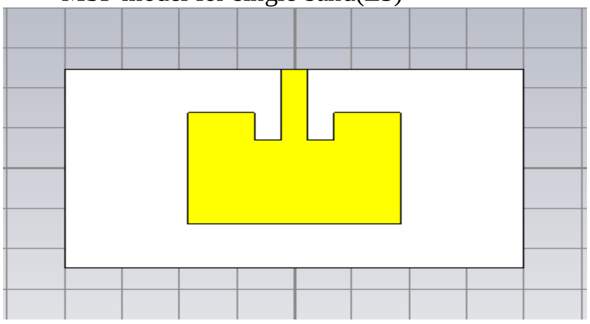


Figure 2 MSP model

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 FR4 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

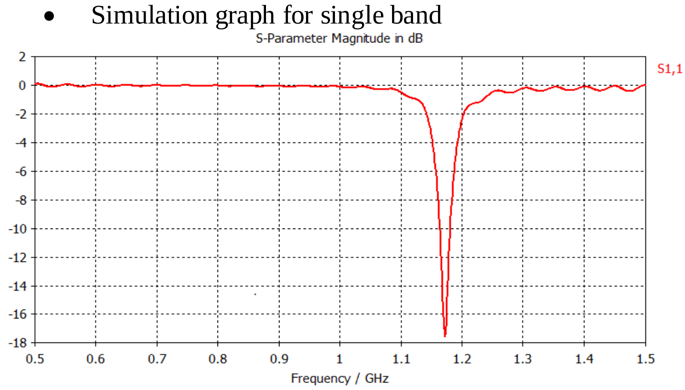


Figure 3 Return loss vs frequency

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.The relationship between SWR and return loss is the following:
Return Loss (in dB) $=20\log_{10}(SWR/SWR-1)$
From this graph the bandwidth is around 30.1 MHz and the s-parameter magnitude around -17.6 dB The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly.The bandwidth can also be described in terms of percentage of the center frequency of the band.
$BW = 100 \times ((F_H - F_L)/F_C)$
where FH is the highest frequency in the band, FL is the lowest frequency in the band, andFC is the center frequency in the band.

- Farfield Plot for single band :

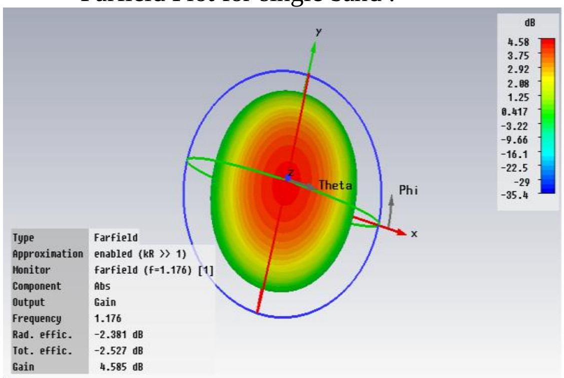


Figure 4 Farfield plot for single band

This graph 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 4.585 dB. In this design, this graph also gives the radiation pattern of the microstrip antennas. And that rediation pattern is designed on the resonance frequency that is 1.176 GHz. Normally microstrip patch antenna gives spherical radiation pattern. We also get spherical radiation pattern from the microstrip patch antenna design.

- Directivity Vs Angle

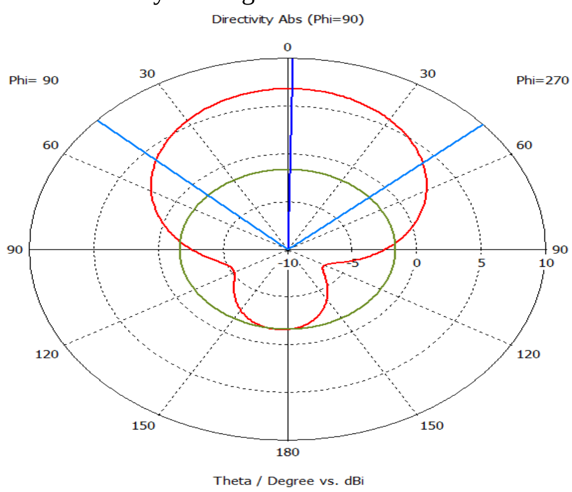


Figure 5 Directivity for single band L5

Frequency	1.176GHz
Main lobe magnitude	6.8 dBi
Main lobe direction	1.0 deg.
Angular width (3 dB)	96.5 deg.
Side lobe level	-8.4 dB

Table 2. Parameter values of single band L5

This design of antenna gives the directivity is around 6.8 db and it gives the main lobe direction of 1 degree. And it gives the angular bandwidth is around 96.5 degree.

B. Simulation of dual band MSP

- MSP model:

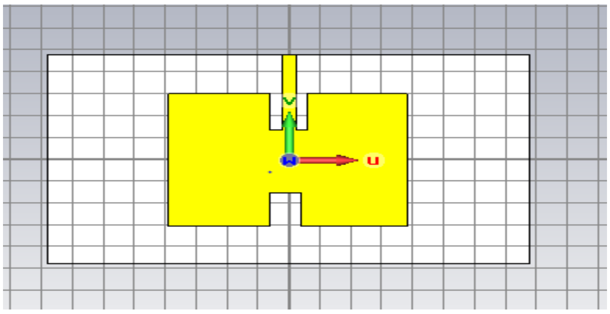
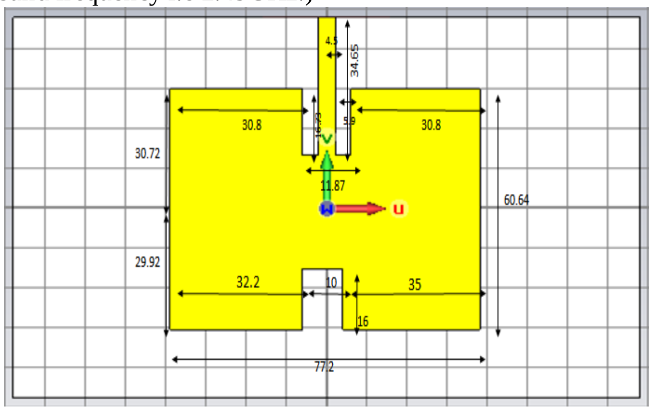
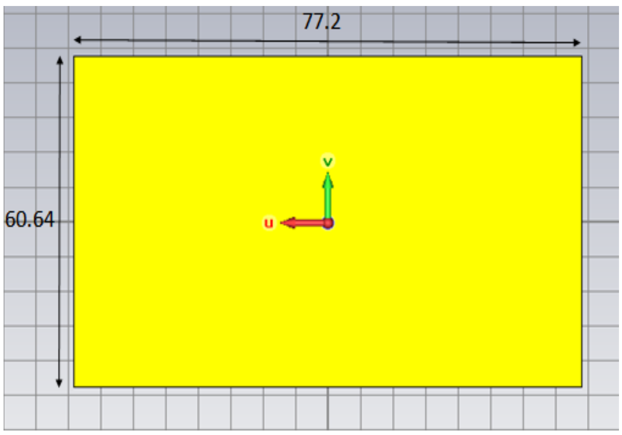


Figure 6 MSP model with slot

(In this model only slot is created in the patch for getting S band frequency i.e 2.49GHz.)



[a]



[b]

Figure 7 Dual band MSP with measurements
[a] Front view [b] Back view

C. Effect of slot

The length of the slot affect the resonance frequency but has only a small effect on the return loss. As the slot length increases, the resonant frequency. Therefore, altering the length of the coupling slot will shift the resonant frequency. The modern trends in wireless communication systems require wide bandwidth antennas, by which the voice, data, and video in- formation can be transmitted. Some of these wireless communication system applications include broadband local multipoint communication services, small mobile units such as cellular phones or other hand held units, laptops and various remote-sensing devices. Most of these applications require miniaturized antennas. The need for increasing the information transfer rate also demands bandwidth enhancement, without scarifying the performance. These requirements, put together, provide a challenging list of specifications that demand innovation in antenna design beyond known conventional techniques. As such, the antenna miniaturization for mobile handsets, PC cards, and wireless Personal Digital Assistants has received much attention. For these applications, a slot antenna is of major importance because of its simple structure. When a microstrip slot antenna is fed using a microstrip line it does not add weight and size to the system and is a suitable design for such applications.

- Simulation graph for dual band

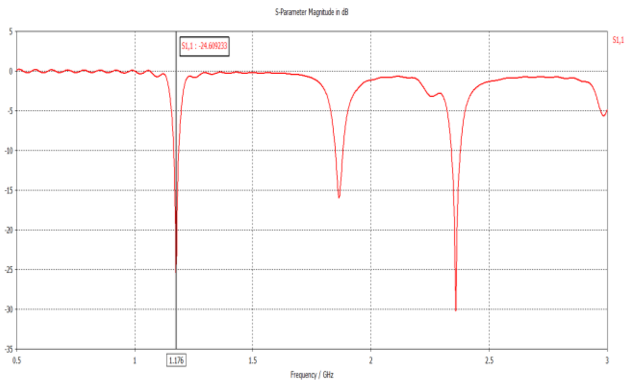


Figure 8 S-parameters for L5 in dual band antenna

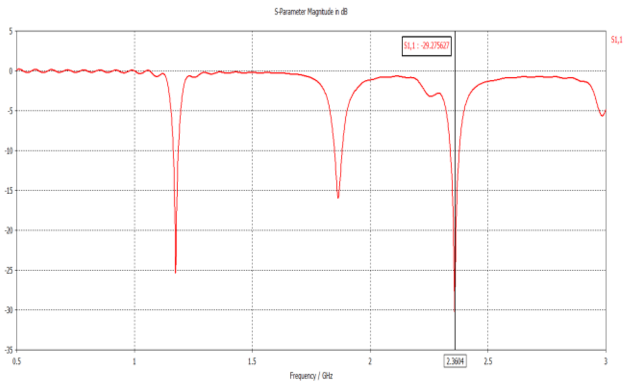


Figure 9 S-parameters for S band in dual band antenna

We have obtained dual band using slot on resonant frequency 1.176 GHZ and 2.3604 GHZ

Simulation Results			
Sr. no.	**Resonating Frequency**	**Gain(dB)**	**Directivit y (dBi)**
MODEL 1 (Fig 2)	L5(1.176GHz)	4.58	6.8dBi
MODEL 2 (Fig 6)	L5(1.176GHz), 1.86GHZ AND 2.36GHz	3.83(L5) 1.77(S*)	6.84 (L5) 5.83(S*)

Table III Summery of two design
(where S* denote approx value of S)

VI. CONCLUSION

The aim of this paper was to design a compact microstrip patch antenna for dual band of IRNSS. Resonant frequencies are 1.176 GHz (L5 band) and 2.36 GHz (approx. to S band) achieved in this paper. Radiation pattern plots have been obtained for the desired antenna orientation. We have obtained 3.83 dB and 1.77dB for L5 and S band respectively in dual band patch antenna.

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