Design, Simulation and Development of 2x2 Microstrip Patch Array Antenna for Ranging Transponder in IRNSS

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Abstract— Indian Regional Navigation Satellite System (IRNSS) is an independent regional navigation satellite system being developed by India. All the satellite in the constellation is placed in Geo-stationary or Geo-synchronous orbit. All the satellites are visible from the user's location unlike the G.P.S. system. Hence the receive antenna need not be omnidirectional instead of only need of higher directivity and higher gain for the fixed object. By the array antenna we can reduce the beam width of antenna, and this will enhance gain for the antenna and signal strength will be more. Thus receiver system will work more efficiently. The aim of this Dissertation is to design and simulate 2x2 Microstrip patch array antenna for ranging transponder at 3.4 GHz to the receiver side.

Key words: Microstrip patch, 3.4 Ghz, IRNSS, Rogers Duroid RT 5880,ADS

I. Introduction

IRNSS Refers to Indian Regional Navigation Satellite System. IRNSS is an independent Navigation Satellite System providing services in the Indian Region.

IRNSS is being implemented by the Indian Space Research Organization. The project is being managed by the lead centre viz., ISRO Satellite Centre, Bangalore with support from the other work centres viz., Space Application Centre, Ahmedabad, ISTRAC, Bangalore, MCF, Hassan, VSSC, Thiruvananthapuram. IRNSS provides fairly good accuracy and the whole constellation is seen all the time. There are plans to send integrity and ionospheric correction messages to the user. A variety of applications taking the benefit of above will be catered by IRNSS.

Microstrip patch array used in IRNSS (Indian Regional Navigational Satellite System) and within short period of time it will replace the GPS(Global Positing System).

There are two types of transponder is used in IRNSS:

1) Navigation transponder
2) Ranging transponder.

II. Introduction to Patch

Microstrip antenna: it consists of a dielectric substrate present in between a ground plane and a patch. Patch antennas are low profile, simple, easy to fabricate. Within these advantages it has disadvantages of low fain and directivity. So Patch antennas are not only used as single element antenna but as arrays also. The dictionary defines array as an orderly arrangement of things. Therefore, proper arrangement of multiple antenna elements results in an array. Arrays are considered to be very versatile and are used to synthesize a required pattern that is difficult to obtain using a single patch. The results also show that patch array help in increasing the directivity, gain and power. The most important parameter for the design of a patch antenna is the operating frequency. In this paper designs of single element operating at 3.4GHz, known as resonant frequency is shown

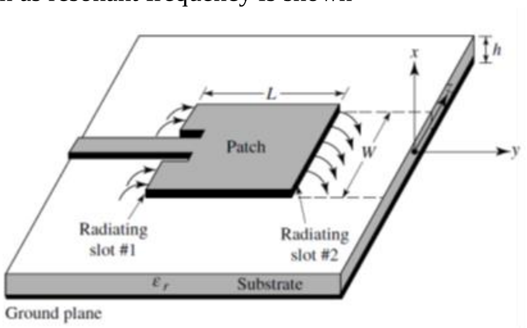

Fig. 1: Single Microstrip patch

A. Introduction To Antenna Factor:

- In array antenna, performance is controlled by array factor. Array factor is a function of the number of elements, their geometrical arrangement, their relative magnitudes, their relative phases, and their spacing.
- Array factor for N elements is given by

$$(\mathrm{AF})_n = \frac{1}{N}\left[\frac{\sin\left(\frac{N}{2}\psi\right)}{\sin\left(\frac{1}{2}\psi\right)}\right]$$

- Broadside Array
- In many applications it is desirable to have the maximum radiation of an array directed normal to the axis of the array.
- Directivity for broadside array is given by,

$$D_0 = 2N\left(\frac{d}{\lambda}\right)$$

- Ordinary End-Fire Array
- Instead of having the maximum radiation broadside to the axis of the array, it may be desirable to direct it along the axis of the array (end-fire) accordingly application.
- Directivity is given by,

$$D_0 = 4N\left(\frac{d}{\lambda}\right)$$

- Planar array
- Individual radiators can be positioned along a rectangular grid to form a rectangular or planar array. Planar array can be used to scan the main beam of antenna toward any point in space accordingly application including communication, tracking radar, search radar,etc.

$$AF = \left\{ \frac{1}{M} \frac{\sin\left(\frac{M}{2}\Psi_x\right)}{\sin\left(\frac{\Psi_x}{2}\right)} \right\} \left\{ \frac{1}{N} \frac{\sin\left(\frac{N}{2}\Psi_y\right)}{\sin\left(\frac{\Psi_y}{2}\right)} \right\}$$

- Equation indicates that the pattern of a rectangular array is the product of the array factors of the arrays in the x- and y-directions.
- Directivity for planar array is

$$D_0 = \frac{32,400}{\Theta_{1d}\Theta_{2d}}$$

- Θ_{1d}=half power beam width in one plane (rad)
- Θ_{2d} =half power beam width in a plane at a right angle to the other (rad)

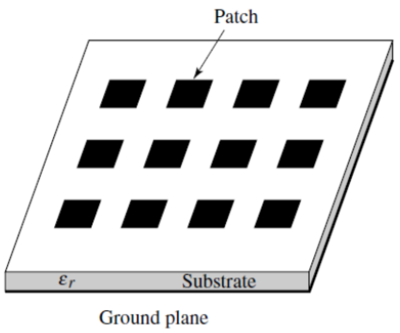

Fig. 2: Microstrip patch array

III. ANTENNA DESIGN

The goal of designing a microstrip antenna at 3.4GHz is to improve gain and directivity for the Ranging Transponder in IRNSS. There are various important steps in designing microstrip antennas. we will design single patch, 2x1, 2x2 array and will analyzing results such as directivity, gain, return loss at center frequency 3.4 GHz. Selection of a proper substrate is an important parameter in the design process. In this design, dielectric constant is taken as 2.2 and thickness (h) as 1.574mm.

Centre frequency	3.4Ghz
Dielectric constant	2.2
Substrate height	1.574mm
Copper thickness	0.035mm
Loss tangent	0.0009

Table 1: Design specification

A. *Geometry Of Single Patch:*

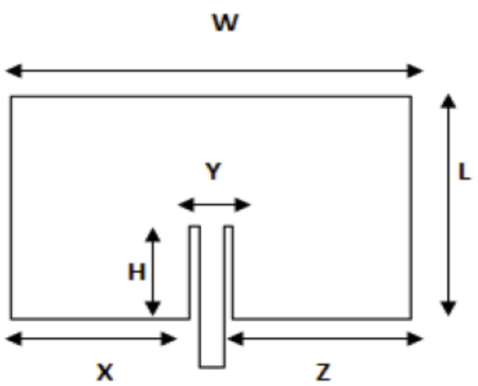

Fig. 3: Geometry of patch

B. *Design Equation:*

Patch width is given by,

$$W = \frac{1}{2f_r\sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r+1}} \text{...(1)}$$

Effective parameters is given by,

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \text{.................(2)}$$

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \text{........................(3)}$$

Patch length is given by,

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0 \epsilon_0}} - 2\Delta L \quad \text{....................(4)}$$

The depth of the feed line in to the patch is given by,

H=0.822*L/2……………………………………………(5)

The other dimensions are,

Y=W/5……………………………………………….(6)

X = Z = 2W/5……………………………………….(7)

The Agilent Advanced Design System (ADS) is the software used to Design and simulate the patch antenna. Using equation calculated width and length and all the dimensions for single patch. It shown in Table II.

W	35mm
L	29.95mm
H	5.95mm
Y	14.8mm
X=Z	10.1mm

Table 2:

1) *Design of single patch:*

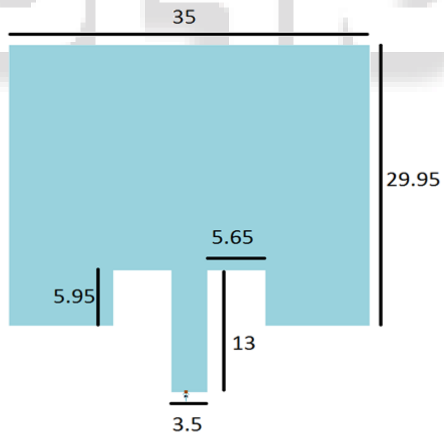

Fig. 4: Patch Dimension

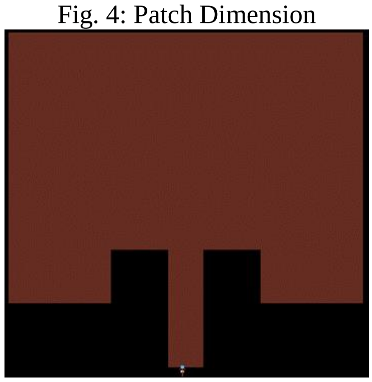

Fig. 5: Patch layout

Simulation Results

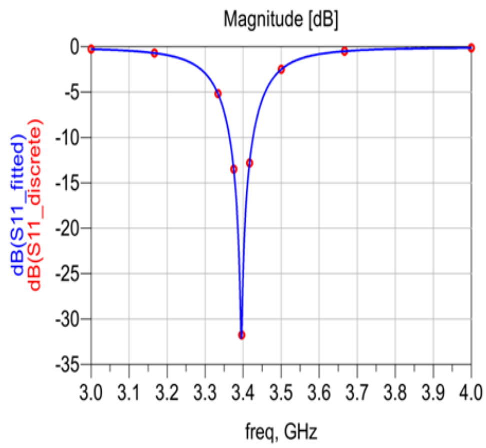

Fig. 6: RL curve of antenna

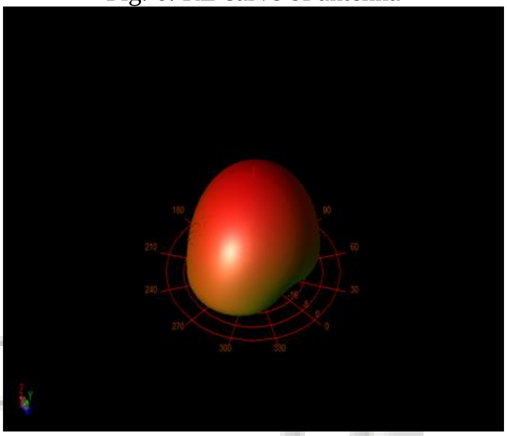
Fig. 7: Radiation pattern

2) *Design OF 2X1 ARRAY:*

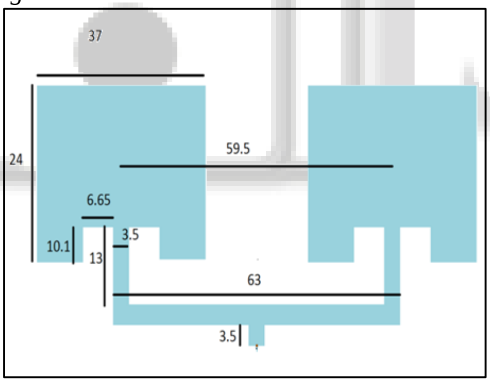

Fig. 8: 2x1 array Dimension

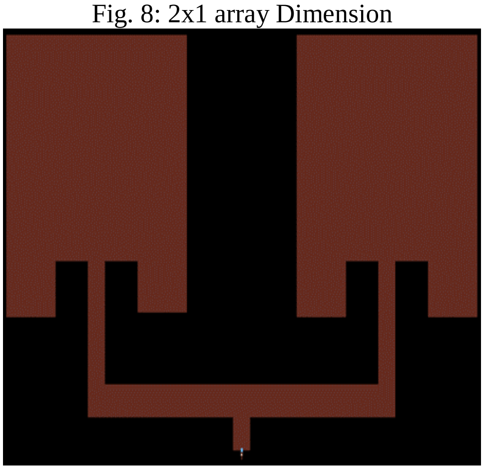
Fig. 9: 2x1 layout

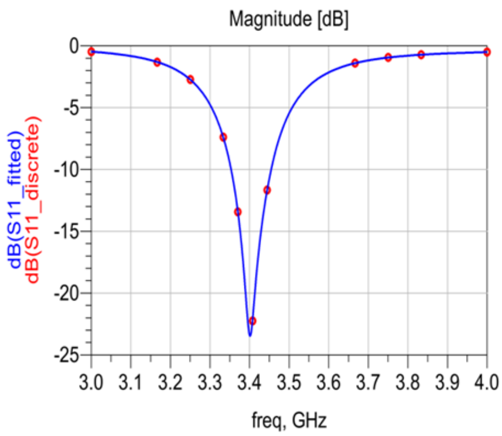

Fig. 10: RL curve

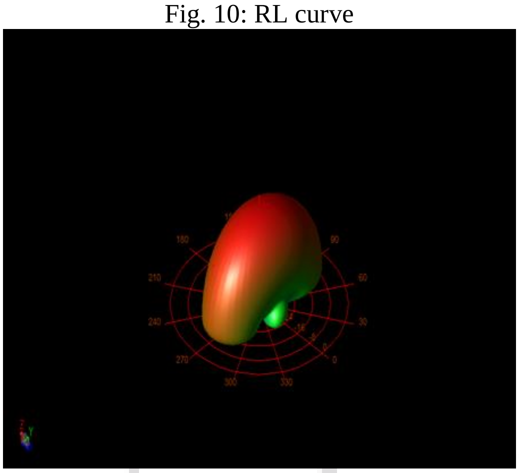
Fig. 11: Radiation pattern

3) *Design Of 2x2 Array:*

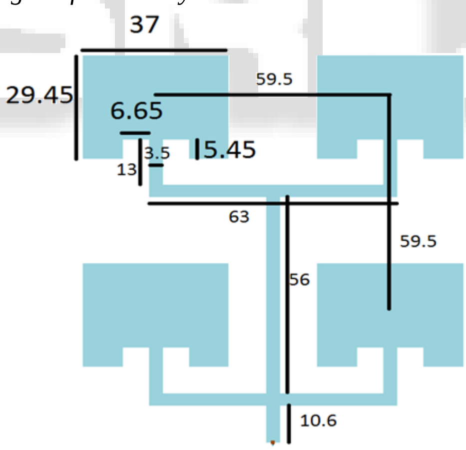

Fig. 12: 2x2 Dimension

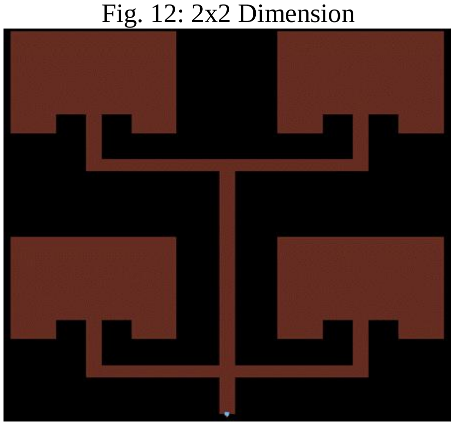
Fig. 13: 2x2 layout

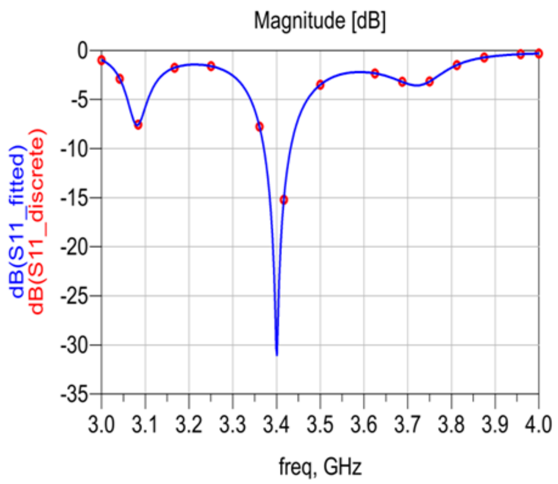

Fig. 14: RL Curve

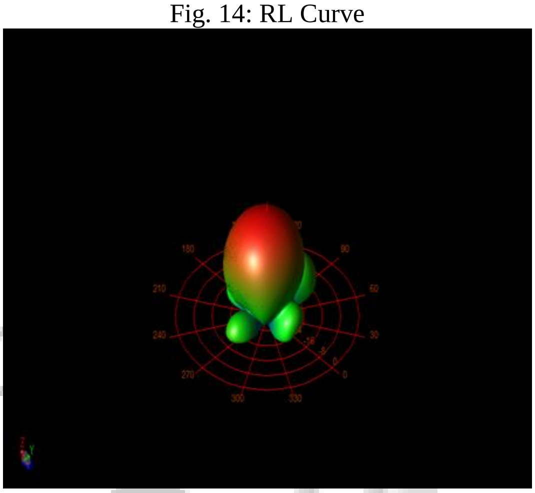
Fig. 15: Radiation pattern

	Gain	Directivity	Efficiency
Single patch	7.44	7.68	96%
2x1 array	9.56	10.25	93%
2x2 array	13.25	13.76	96%

Table 3:

IV. Conclusion

I have designed and simulated single patch, 2x1 and 2x2 array for 3.4 Ghz frequency, And as per the results we can say that as increasing number of patch, we can increase gain as well as directivity.

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