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Designing a Switchable Stacked Patch Antenna for GPS Application

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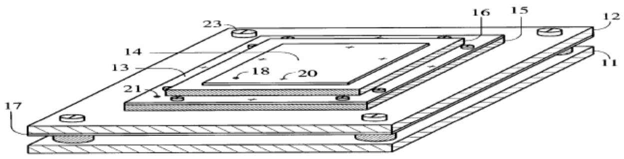
Abstract: *GPS receivers are used for civilian and defence applications extensively. The signals received from GPS satellites are very weak and susceptible to interference. The principle objective of the proposed project work is mitigation of intentional and unintentional jamming signals in the L5 frequency band. By employing an antenna having two patch antenna elements with similar azimuth radiation patterns but distinct elevation radiation patterns. The two antenna elements may be operated independently of each other by selectively disabling one or the other of the two elements.*
Index terms*: Stacked Microstrip Patch Antenna.*

I. INTRODUCTION

Method for mitigation of intentional and unintentional jamming signals using a dual element patch antenna. The antenna possesses two antenna elements having distinct radiation patterns. Either element may be independently selected using DC bias voltage. Diodes connected to the elements serve to disable one element when the other is selected.

This combination of features is packaged in a single antenna unit that can be a direct replacement for the existing antennas. The dual element antenna has a low vertical profile and is suitable for mounting on high speed vehicles.This paper concentrates only on the design of the antenna which is used for mitigation of jamming signals. In this my work is to design the stacked patch antenna. Here we have a stacked patch antenna showing two rectangular patches placed one above the other which in turn placed over a ground plane, with single feed.

II. PROPOSED ANTENNA MODEL



10- Patch Antenna, 11- Support Plate,12 - Conducting Ground Plane, 13 & 14 - Antenna Elements, 15 & 16 – Dielectric Substrates, 17 - Printed Circuit Board,18- Feed, 19- Output Connector, 20- PIN Diodes

Figure 1: Geometry of the proposed stacked patch antenna having single coaxial feed.

III. ANTENNA DESCRIPTION

This paper describes the design of a stacked patch antenna showing two rectangular microstrip patches stacked one over the other with substrates interposed between them which in turn placed over the ground plane. The two patch elements are fed by a common feed. In this configuration both the upper and lower patch elements will be circularly polarized. In addition the patches are electrically in series with each other. The upper patch operates in the nominal or general purpose mode. When active, the upper patch and the lower patch form a resonant cavity at the frequency of interest, using the upper substrate as the cavity dielectric material. The lower patch operates in the RFI resistant mode, using the lower substrate as the cavity dielectric material and the ground plane as the other resonant cavity wall. The upper and lower substrates are open to free space on all four sides. These open surfaces define the radiating apertures for the upper and lower patches.

The planar antenna elements are switched ON and OFF by DC bias voltage levels applied to PIN diodes, which are connected between each patch element and its respective resonant cavity wall. By altering the bias control voltage level, the antenna can be switched between two modes, one mode where the upper patch is enabled and the lower patch is disabled, and another mode where the lower patch is enabled and the upper patch is disabled.In one selected mode, a nominal radiation pattern provides a broad, hemispherical shaped sensitivity that is designed for acquiring and tracking all navigation satellites above the horizon. The second selectable radiation pattern of the dual element antenna has comparatively higher gain toward zenith, lower gain at and below the horizon to mitigate interference.

The upper dielectric substrate preferably has a high dielectric constant so that the size of the upper patch is minimized. The lower dielectric substrate preferably has a very low dielectric constant so that the size of the upper patch is comparatively large as that of the upper patch.Both the patches are fed by a common feed. The common feed is connected only to the upper patch element. The patches are electrically in series with each other. And the feed is selected so as to match to 50 ohms impedance. The patch elements are switched ON and OFF using DC control bias voltage levels in conjunction with two sets of pin diodes, which are connected between the upper and lower patch elements and their respective lower cavity walls. When a particular set of diodes is reverse biased, they possess large capacitive reactance, and are essentially out of circuit. This allows operation of the particular patch cavity that they bridge, enabling the associated antenna element. When the diodes are forward biased, they possess a low resistance and inductive reactance.

IV. Design Equations

Calculation of the Width (*W*): The width of the Micro strip patch antenna is given by

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Where c = 3×10^8 m/s (free space velocity)
f_o = resonant frequency
ε_r = Dielectric constant of the substrate.

Calculation of Effective dielectric constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Calculation of effective length (L_{eff}):

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

Calculation of length extension (ΔL):

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

Calculation of actual length (L):

$$L = L_{eff} - 2\Delta L$$

V. IMPEDANCE

The input impedance of the antenna can be matched by using either a coaxial feed or an edge feed with a quarter wave transformer. The approximate input edge impedance of a microstrip element is given as Rin=60 λo/W, where W is the width of the slot. The input impedance in the embodiment is matched to 50Ω impedance by using a coaxial feed. The 50 Ω point for the feed is obtained by varying the distance between the feed location and the edge of the element. Each candidate feed position for 50Ω impedance is calculated for material properties and roughly located for the element. These values are used as starting points, but exact dimensions are adjusted empirically. Fabrication accuracy, materials consistency and mutual coupling result in small variations over a group of units. This antenna uses a coaxial approach for circular polarization.

VI. DIMENSION ANALYSIS

The exact dimensions of each element and the feed-point locations are defined empirically using an iterative process. The process consists of building the elements of the design equations for a rectangular microstrip element.

The resonant frequency and impedance are measured; usually differing slightly from theoretical predictions because of the combined effects of: dielectric constant variation, impedance variation for non-resonant coupling elements, feed-probe inductance and mutual coupling. Adjustments to the microstrip element sizes and feed-point locations are made to correct the resonant frequency and feed impedance respectively.

Multiple iterations may be required. Once optimized, microstrip dimensions and feed-probe locations will be consistent based on materials uniformity and fabrication variance.

VII. FEED POINT LOCATION

Feed points are located using the 1-D current distribution of the element at the resonant frequency. The feed input impedance of the antenna varies proportionally with patch current and location. Resonant frequency and pattern of the microstrip element are essentially independent of feed position. The rectangular patch's dimensions are mechanically tuned to resonate at the L1 frequency.

VIII. DESIGN PARAMETERS

Resonant frequency (L5) = 1.17645GHz
Relative Permittivity (ε_r) = 1& 4.4
Substrate used is FR4 glass epoxy substrate and air medium substrate.

Antenna Dimensions:

Thickness =5 mm & 0.8 mm
Width of the patch= 121.5 mm & 80 mm
Length of the patch = 120.5 mm & 65 mm
Width of the substrate = 132.3 mm
Length of the substrate = 131.15mm

Layout of the Antenna

The 3D view of the proposed antenna is given below:

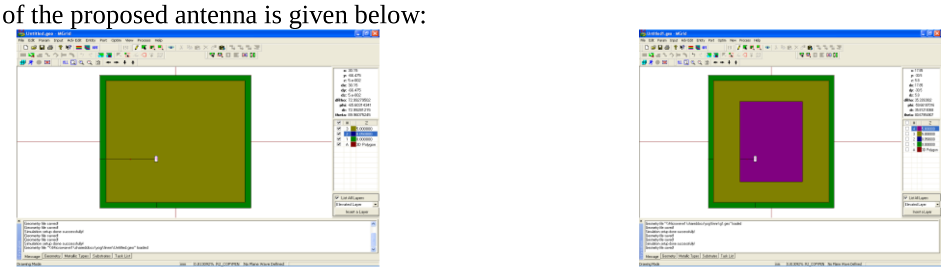


Figure 2. (a) 3D View of the Proposed Antenna before stacking (b) 3D View of the Proposed Antenna after stacking

IX. PROPOSED FABRICATED ANTENNA

The proposed work of the fabricated antenna using FR4 (Epoxy/Glass) as a dielectric substrate is shown. A thin layer of Copper is Photo etched above the dielectric which radiates the fringing field. The Radiating element is excited using coaxial connector at the Feed point in rectangular patch which is clearly shown.

(a)

(b)

Figure 3(a) Test Setup of proposed fabricated antenna before stacking (b) Test Setup of proposed fabricated antenna after stacking

X. DESIGN OF ANTENNA

10.1.ANTENNA RADIATION PATTERN

An antenna radiation pattern is a 3D plot of its radiation far from the source. It usually takes two forms, the elevation pattern and the azimuth pattern. The elevation pattern is a graph of the energy radiated from the antenna looking at it from the side. The azimuth pattern is a graph of the energy radiated from the antenna as if you were looking at it from directly above the antenna.

10.2.RETURN LOSS

Return loss is the ratio, at the junction of a transmission line and terminating impedance or other discontinuity, of the amplitude of the reflected wave to the amplitude of the incident wave. It describes the reduction in the amplitude of the reflected energy, as compared to the forward energy.

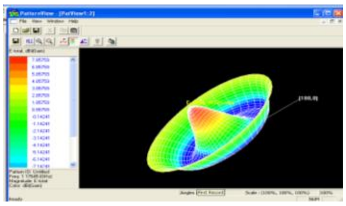
10.3.STANDING WAVE RATIO (SWR)

Standing wave ratio (SWR) is the ratio of the amplitude of a partial standing wave at an antinode (maximum) to the amplitude at an adjacent node (minimum), in an electrical transmission line.

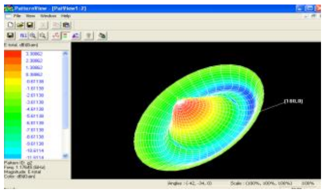
XI. IE3D RESULTS

11.1. RADIATION PATTERN

The antenna resonates at 1.17645 GHz with linear polarization. The radiation pattern is shown below.



(a)

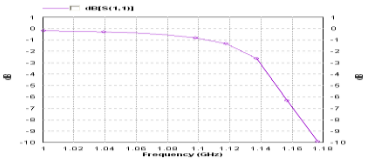


(b)

Figure 4. (a) Proposed antenna gain at 1.17645 GHz before stacking (b) Proposed antenna gain at 1.17645 GHz after stacking

11.2. RETURN LOSS

The antenna resonates at 1.17645GHz and shows -10dB and -7.8dB respectively which satisfy the requirement of achieving a value less than -6dB which states that the matching between the source and the load is acceptable.



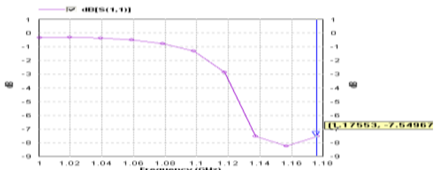
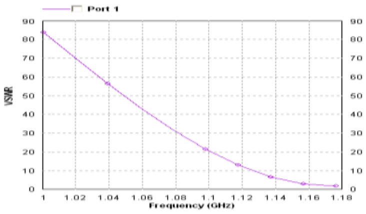


Figure 5 (a) Return Loss of the proposed antenna before stacking (b) Return Loss of the proposed antenna after stacking

11.3 VSWR

The simulated result of VSWR also satisfies the condition <2.5 .



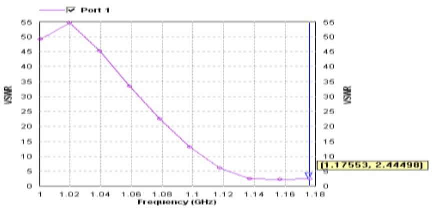
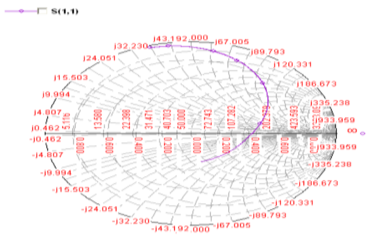


Figure 6 (a) Voltage Standing Wave Ratio of the proposed antenna before stacking (b) Return Loss of the proposed antenna after stacking

11.4 SMITH CHART

The simulated result obtained shows 50 ohm impedance matching.



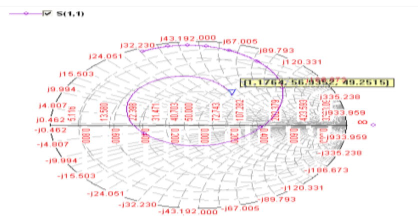


Figure 7. (a) Smith Chart of the proposed antenna before stacking (b) Return Loss of the proposed antenna after stacking

XII. Simulated Result

The software has yielded results to us as below:
VSWR is < 2.5 at port
Gain of the antenna = 7.85 dB and 3.38dB(1.17645GHZ)

MEASURED RESULTS OF THE PROPOSED ANTENNA WITH A NETWORK ANALYZER

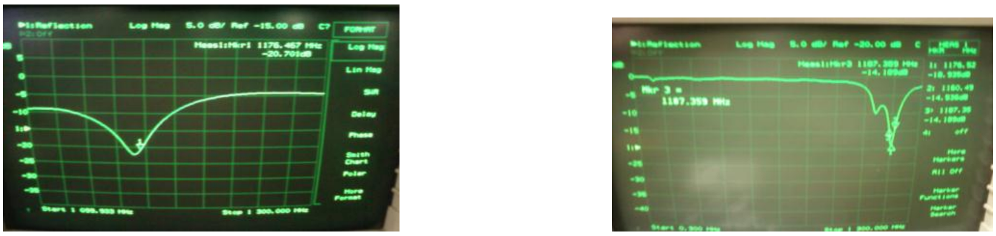


Figure 8 (a) Return loss of the proposed antenna before stacking (b) Return Loss of the proposed antenna before stacking

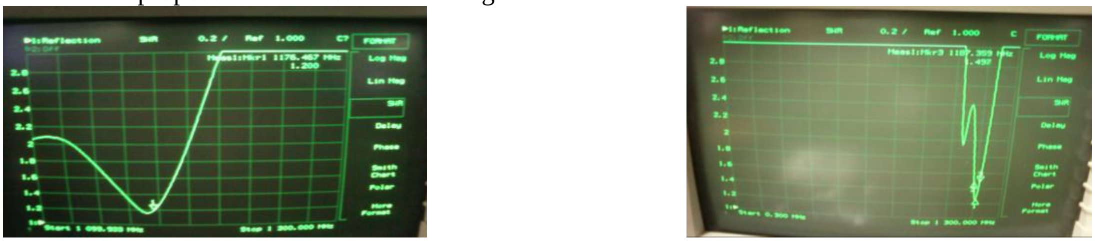


Figure 9 (a) VSWR of the proposed antenna before stacking (b) VSWR of the proposed antenna before stacking

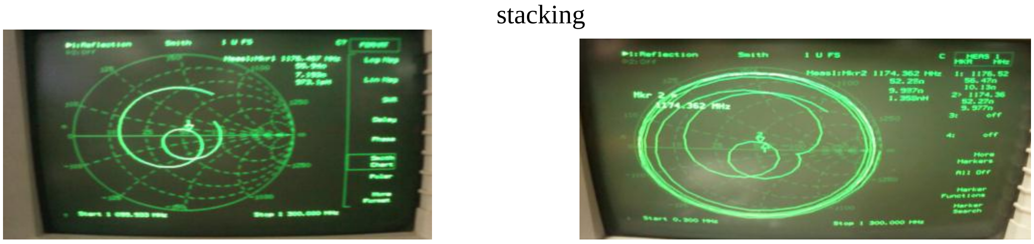


Figure 10 (a) Smith chart of the proposed antenna before stacking (b) Smith chart of the proposed antenna before stacking

XIII. CONCLUSION

Thus a stacked patch antenna is designed using this procedure and it is fabricated using FR4 substrate and is analysed using a network analyser. It is proposed to design the antenna with a gain of about 5 dB and VSWR < 2.

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