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Research Article

The Effects of Planar Microstrip Patch Antennas on Cross Polarised X-Ray Radiations

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Abstract: An MPA, or microstrip patch antenna, is an antenna made out of a metal patch mounted on a grounded base. The shape of the metallic patch is flexible and may be a rectangle, a circle, a triangle, etc. For decades, microstrip patch antennas have played a crucial role in wireless communication systems. The Mobile Phone Industry has come to rely heavily on the MPA in recent years. The primary goals of this study are to minimise XP radiation, suppress a higher-order mode that isn't desired (a spurious mode), shrink the size of planar RMPA, and increase its gain for use at lower frequencies (S-band, 2–4 GHz). A pair of symmetrical metallic stubs loaded between the ground and the patch, a pair of symmetrical linear slots etched in the ground plane as DGS(Defected Microstrip Surface) (DMS), and the incorporation of a rectangular slot etched in the radiating patch as DMS(Defected Ground Structure) near the non-radiating edge all contribute to this goal. The HFSS simulator was used to conduct analyses of the investigated parameters, including return loss, gain, radiation pattern, etc.

Keywords: Microstrip patch antenna (MPA), Defected Microstrip Surface, Defected Ground Structure, non-radiating edge, radiation pattern

Introduction

Wireless communication systems' significance in today's environment is paramount. In 1844, with the use of only one cable, Samuel Morse invented wireless communication. In a similar line, wireless communication was pioneered by an experiment conducted by German scientist Heinrich Hertz in 1888 [1,8]. Since then, advances in both wired and wireless communications have allowed them to mature to the point that they can satisfy the needs of their users. Without wireless internet, modern life just wouldn't be possible. The many possible means of communication may be roughly classified into two major categories: narrowband and wideband systems. Communication systems that use both broadband and ultrawideband (UWB) spectrums fall under the umbrella term "wideband" [2,10]. They differ primarily in the frequency range where their impedance is most variable. Systems having a bandwidth of impedance of 10% or less are considered narrowband. More than 10% and less than 25% is considered a broadband impedance system [3-6]. The term "ultra-wideband" (UWB) refers to systems having a bandwidth over twenty-five percent. . Wireless networking's many advantages have attracted a large number of young researchers. These advantages include the technology's ease of use, the support it provides for end-user mobility, the ability to connect in remote locations, and its relatively cheap cost. In wireless communication systems, the antenna is a crucial component that works in tandem with the other electronic circuits.

Antennas are used in transmitters and receivers in wireless communication systems. The receiving antenna converts space's electromagnetic (EM) signal into electricity. A transmitter's antenna converts electrical impulses into electromagnetic waves. "A metallic device for radiating or receiving radio waves" is how Webster's Dictionary describes an antenna [2]. IEEE standard says that an antenna is "a structure between a free-space device and a guided device that can send or receive radio waves" [2]. Antennas provide wireless communication networks, which enable modern technology. Radio communication antennas were improved by researchers., this work proposes a range of structural design configurations for microstrip patch antennas to

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enhance radiation characteristics using the probe-fed approach. By suppressing cross-polarized radiations and removing the neighbouring higher-order mode, this is achieved.

Microstrip Patch Antenna (MPA)

Modern wireless communication systems need MPAs. G. A. Deschamps invented the microstrip patch antenna in 1953. Robert E. Munson and John Q. Howell invented the first functioning antenna [11, 12]. In the 1970s, spacecraft used microstrip patch antennas [1-3]. Figure 1 shows microstrip patch antennas. Dielectric substrates, ground planes, and metallic patches make MPAs. The patch and ground plane are excellent conductors, generally copper, and dielectric substrates with dielectric constants (r) between 2.2 and 12. FR4, RT-duriod, Rogers, etc. are popular dielectric substrates. This work employed rectangular patch antenna. The ideal rectangular patch antenna has a length (L) of 0/3 to 0/2, a height (h) of 0.003 to 0.05, and a thickness (t) of 0 [2-4].

Since microstrip patch antennas (MPAs) are inexpensive, small, and can be easily fabricated using Printed Circuit Board (PCB) techniques, they have quickly become the standard in all wireless communication applications. Additionally, MPAs can be seamlessly integrated with other circuit elements in an electronic system. Microstrip patch antennas are constructed by bonding metallic patches of varying shapes to a dielectric substrate. Several various feeding methods, including microstrip line feed, coaxial feed, aperture coupled, and proximity coupled, are used to excite the radiating patch. Many types of communication systems rely on the microstrip antenna, including broadcasting, cellular phones, portable devices, radar, satellite communications, Bluetooth-enabled devices, etc.

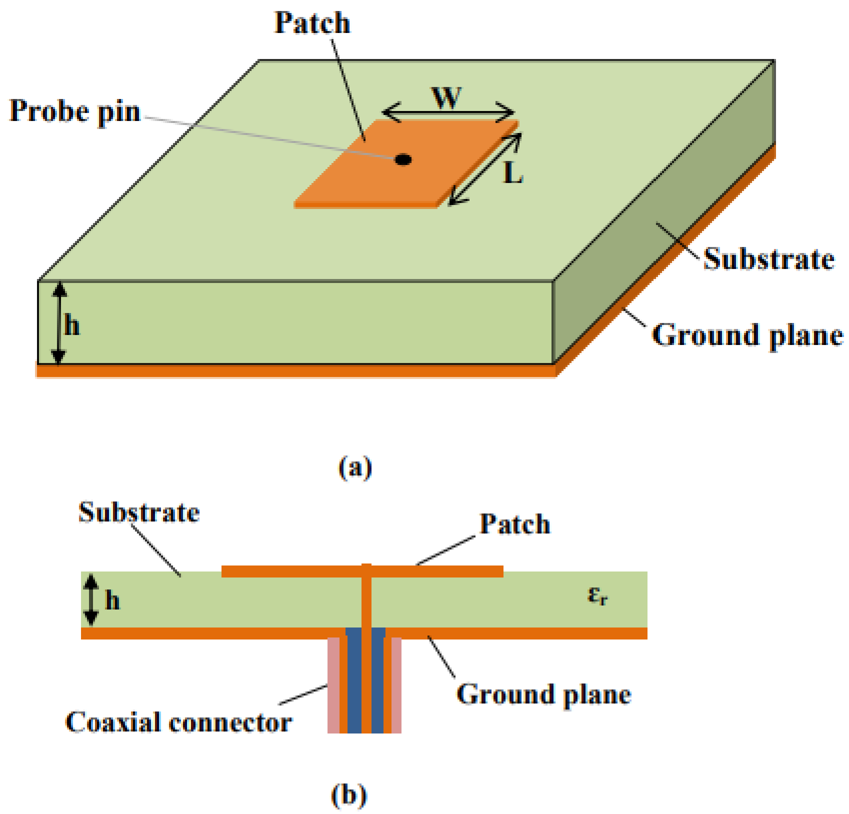

Figure 1. (a) Isometric view of conventional MPA, (b) Side view of coaxial fed conventional MPA

The Electronics Engineering communication system is a cutting-edge tool contributing to humanity's progress in the current era. In wireless communication, the antenna plays a crucial role. In wireless communication systems, antenna devices that are as small as possible are favoured. A lot of labs are trying to figure out how to make antennas smaller and more robust so that they can function in any setting. The microstrip patch antenna's versatility in wireless communication stems from its simplicity of construction. Since the microstrip patch antenna may function over several frequencies, it can be used for a wide variety of purposes beyond only wireless local area networks (WLANs), including satellite communications, mobile communications, global positioning system (GPS) communications, and radar communications. To improve the performance of a standard microstrip patch antenna, slots may be placed onto either the ground plane or the radiating patch, or both. Microstrip patch antennas' radiation properties may be enhanced by using a metal bar or pin, a slot-loaded substrate, or several substrate layers. These antennas have a complicated layout, making them problematic for use in any state-of-the-art wireless network. They focused only on the dominant mode to improve RMPA's defining features. In order to reduce complexity and expense, it is suggested that rectangular microstrip patch antennas be employed for S-band applications. In this study, we focus on suppressing the undesirable higher-order mode to achieve more isolation, which is known as cross-polarization (XP) suppression. The approach comprises suppressing cross-polarization (XP) using three techniques: defective ground structure (DGS), defected microstrip surface (DMS), and metal stub insertion between the ground and the patch.

Problem Statement and Objective

Probe radiations, orthogonal radiation components, radiation owing to a non-radiating edge, and radiation from a corner all contribute to a high level of cross-polarized (XP) radiations in the H-plane for a planar probe-fed MPA. The RMPA's co-pole and cross-pole isolation is reduced since these unwanted radiations are anti-phase with regard to radiation from the emitting edge. The primary focus of this thesis is on suppressing cross-polarized (XP) radiations in coaxial probe fed RMPA and taming undesired higher-order modes.

Placement of a pair of metallic stubs, one on either side of the non-radiating edge, between the ground and the radiating patch. By moving the resonant frequency to the lower side, the suggested arrangement creates a compact MPA. The elimination of higher-order undesirable modes and cross-polarized radiations is an added bonus.

Two ground-plane linear slots with mirror-image symmetry serve as DGS. By decreasing crosspolarized radiations, the suggested RMPA arrangement increases isolation between co-pole and cross-pole radiations. For cutting-edge wireless sensor applications, its exceptional isolation is necessary.

DMS consisting of a rectangular slit cut into the non-radiating edge of the radiating patch is used. Higher isolation between co-pole and cross-pole radiations is achieved, and the cross-polarized (XP) radiation is decreased thanks to the suggested RMPA configuration's suppression of higher order undesirable mode.

Miniaturised Microstrip Patch Antenna with Better Cross-Polarized Radiation

The antenna's XP value was improved by increasing the amount of damping applied to its higher-order DRA modes [8]. But in order to get this effect, we have to mess with the DRA, which is the element that does the radiating. There are several other types of defective ground structures (DGSs) that have been shown, such as an arc-shaped DGS [7], an L-shaped DGS [3], an H-shaped DGS [5], and an asymmetric L-shaped DGS [8]. However, because to the poor backradiation properties, its application is restricted. A shorting pin may be used to regulate the field perturbation in MPA, which can be found in references [7–9]. It was shown that modified circuits had enhanced frequency tuning [38], decreased size [39], higher gain and bandwidth, and suppressed XP. It was shown in reference number 9 that completely shorting the borders of the patch that did not radiate had a considerable suppressive effect on the XP level. However, the resonance frequency of the antenna needs to be adjusted such that it operates in the higher-order TM11 mode. Since higher-order mode designs need a larger antenna, they are less practical than lower-order mode designs.

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Design of Proposed Antenna

Figure 2 depicts the planned antenna design from above and to the side. The suggested antenna is accomplished by partly shorting the non-radiating edges of the antenna-2 with two symmetric metallic stubs. Good outcomes have been achieved by optimising the metal stub length ls. Length (ls) and width (ws) of metal stubs are best set at 10 and 2 millimetres, respectively.

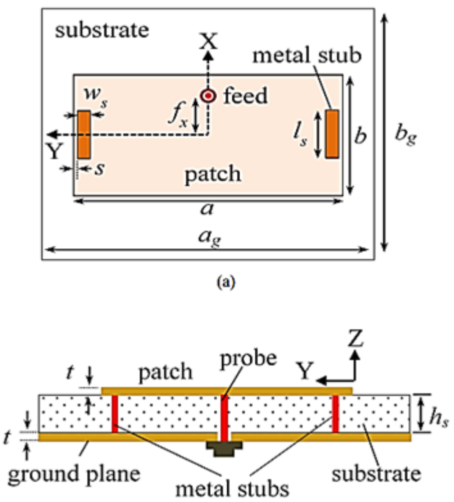

Figure 2 Schematic diagram of the proposed RMPA (a) top view and (b) side view

The effect of stub length on the antenna's resonance frequency, impedance matching, peak gain, and cross-polarization

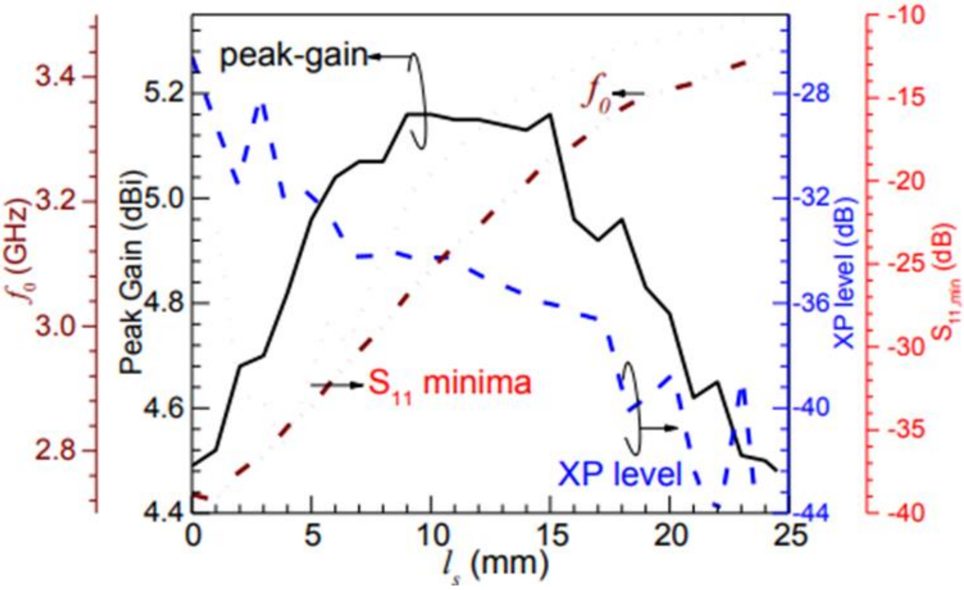

Figure 3. The influence of stub length on the proposed antenna's cross-polarization purity, peak gain, resonance frequency, and impedance matching

Figure 3 displays scatter plots that compare the resonant frequency (f0), S11 minima, peak gain, and XP level versus the stub length (ls). According to [20], the greatest amount of XP suppression may be accomplished using a non-radiating edge that is completely shorted. However, because to the higher-order TM11 mode, the corresponding f0 value is too high for a design that is intended to be miniaturised. The f0 and XP characteristics in Figure 3 provide more evidence of this..

Furthermore, the impedance matching performance is really low. Impedance matching is enhanced with a lower f0 when ls is small, however this comes at the expense of XP performance. The TM01 mode excitation is detected using a standard patch and ls=0 resonance characteristics.

Figure 3 illustrates the use of a versatile design guideline to determine an appropriate ls value for meeting functional criteria. The antenna has been tuned to resonant at 3.09 GHz with significant reduction in XP radiation by using a metal stub length of ls=10 mm. In doing so, the highest possible advantage is achieved. Over the entire usable frequency range, the XP level is kept below 35 dB..

A comparison of the levels of cross-pollution (XP) between the existing MPA and the new one that is being proposed

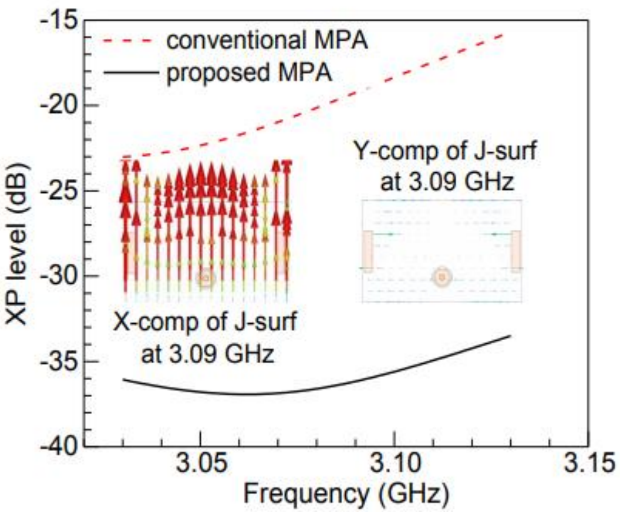

Figure 4 presents a comparison of the cross-polarized (XP) level comparing the reference and the recommended MPA over the operational frequency range.

In Figure 4, we see a comparison between the typical MPA and the proposed MPA in terms of the amount of cross-polarization (XP) throughout the 3.09 GHz operational frequency range. Cross-pol (XP) is kept below -35 dB over the entire usable spectrum. This verifies an increase of almost 16 dB in XP level relative to the baseline antenna. The subset of Figure 4 depicting surface current components provides supporting evidence for the same.

Study of the 3D Radiation Pattern of the Proposed Antenna

The 3D gain pattern of the antenna at 3.09 GHz is shown in Figure 5 as the sum of the gain-theta and gain-phi components. The 3D gain pattern, shown in Figure 5, depicts the side-to-side radiation pattern of the antenna. The E-plane (XZ-plane) with gain phi and the H-plane (YZ-plane) with gain theta are shown to be the only two possible configurations with minimum XP in Figures 5(b) and 5(c). radiation.

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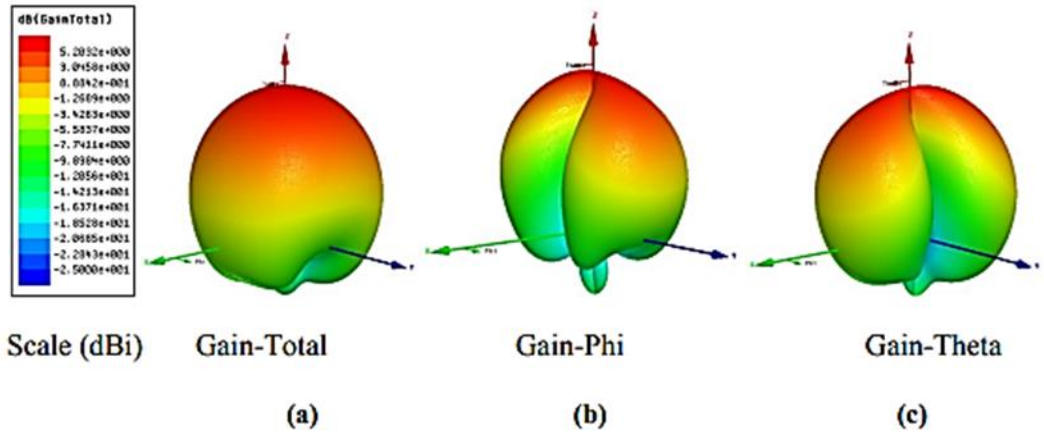

Radiation pattern of the proposed antenna in three dimensions at 3.09 GHz is shown in Figure 5. Total Gain (a), Gain (b), and Gain (c): Phi (b) and Theta (c) Components

Comparison of Experimental and Simulation Results

Return loss characteristics (S11) are shown for both the current RMPA systems and the proposed designs in Figure 6. The experimental results corroborate the simulated behaviour. The resonance frequency may shift somewhat if the stubs are not soldered correctly. Designs for RMPAs have been proposed that effectively reduce higher-order modes.

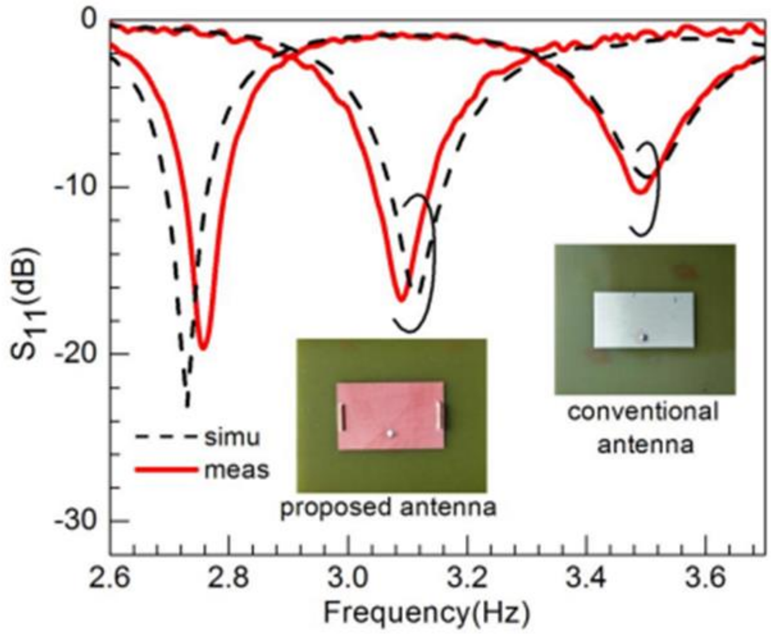

Figure 6. S11 features of the prototype antennas compared with measurements and simulations

The principal-plane radiation patterns of the prototype antennas are shown in Figures 7 and 8. The simulation findings of both the standard and proposed antennas are compared with the experimental results. There is a really high degree of agreement between the findings and the simulated data. No obvious change in E-plane patterns can be found in the measured data, as shown in Figure 7. The degree of cross-polarization in the H-plane has increased noticeably.

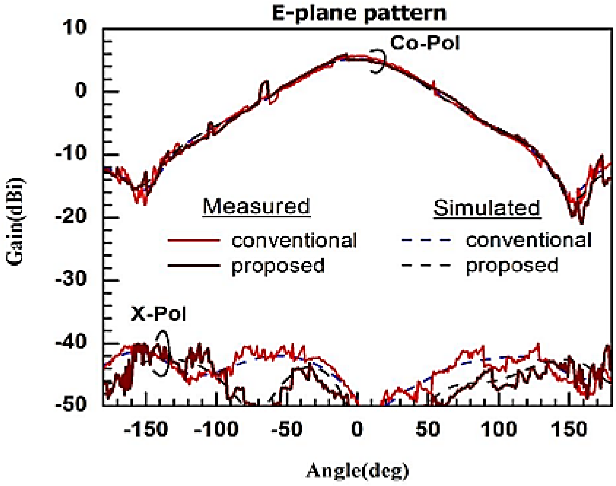

Figure 7 Analysis of conventional and suggested RMPA radiations in the E-plane, comparing simulated and measured findings.

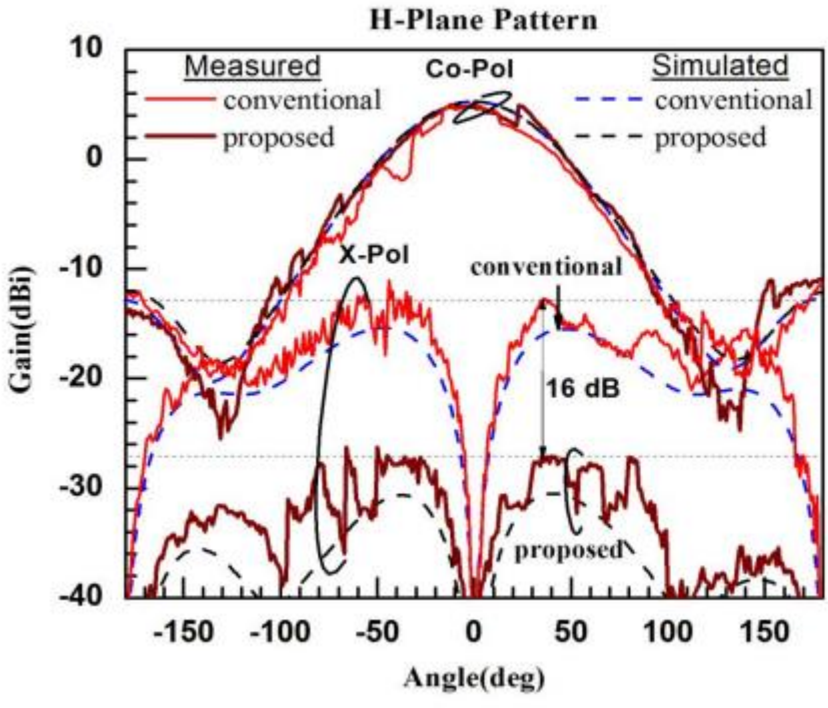

Figure 8 Radiation in the H-plane: experimental and computational findings for conventional and suggested RMPA

Conclusion

Rectangular microstrip patch antennas with considerable improvements to cross-polarization (XP) have been presented, using a simple approach and miniaturised design. With this kind of design, it's considerably easier to fine-tune the antenna's resonance frequency for maximum efficiency. It has been determined that XP radiation originates from a higher-order spurious mode that is orthogonal to the co-polarized fields, and measures are being taken to mitigate its effects. There was no change to the antenna's ground plane or radiating patch when the planned arrangement was implemented. Any standard patch may have its cross-polarization level lowered in practical use by using this method. A coaxial probe is supplied into a rectangle patch, which serves as the primary radiating element. An HFSS simulator is used to model the planned antenna. When compared to a standard antenna setup, the suggested arrangement achieves cross polarised (XP) suppression of about 16 dB. The suggested antenna achieves overall isolation of about 26 dB to 48 dB and an XP level of -35 dB symmetric along 800 with a broadside. The suggested antenna will be useful for the antenna community and may have some uses in the S-band..

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