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A Planar Multislot Antenna with Backplane for Search and Rescue Applications

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***Abstract* - This study focuses on the development of a low-profile planar multislot antenna with backplane that was built specifically for the requirements of search and rescue operations. The antenna presented here serve as the primary focus of this investigation. The planar multislot antenna with backplane antenna that are being considered are planned to be constructed on a substrate that is made of polydimethylsiloxane (PDMS). PDMS is selected because of its desired features, which include its durability, flexibility, resistance to water, and adaptability for deployment in demanding environmental circumstances. The usage of the search and rescue application necessitates the operation at a relatively lower frequency of 406 MHz, which in turn necessitates the utilization of antennas that have a longer electrical length. As a consequence of this, these antennas have a propensity to have larger physical dimensions. In order to circumvent the problem, it is possible to make use of RT/duroid® 6010.2LM laminates substrate, which will result in a smaller dimension due to increase in the relative permittivity constant. This was proved by the results of the simulation, which showed that the antenna functioned at a central frequency of 406 MHz, displaying bandwidth of 228.8 MHz. Concerning the antenna, the bandwidth is equivalent to a fractional bandwidth percentage of 58.28%, when evaluated at -10 dB of the reflection coefficient.**

Keywords: wearable antennas; flexible antennas; compact antennas; search and rescue; Cospas-Sarsat.

I. INTRODUCTION

The COSPAS-SARSAT system is a worldwide satellite-based radiolocation framework aimed at improving the identification and geolocation of distress signals in search and rescue (SAR) operations. This global program assists aviation, maritime, and terrestrial users during emergencies by utilizing a network of satellites and ground infrastructure to transmit essential data to rescue coordinating authorities. The system's architecture consists of two fundamental components: COSPAS (an acronym from the Russian "Cosmicheskaya Systyema Poiska Aariynyich Sudov," meaning "Space System for the Search of Vessels in Distress") and SARSAT (Search and Rescue Satellite-Aided Tracking System), which together establish a cohesive network for the detection, processing, and response to emergency signals.

SARSAT was established in the late 1970s through a collaborative effort among France, Canada, and the United States, motivated by the necessity to enhance search and rescue capabilities for aviation and maritime emergencies. Simultaneously, the Soviet Union established COSPAS as an auxiliary system. In acknowledgment of the strategic advantages of interoperability, the four nations formalized a cooperative agreement in 1979, creating the COSPAS-SARSAT program as a humanitarian initiative under the auspices of the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). The collaboration currently comprises 45 member governments, bolstered by a hybrid satellite constellation of 62 active spacecraft distributed across low-Earth orbit (LEOSAR), geostationary orbit (GEOSAR), and medium-Earth orbit (MEOSAR) platforms. These satellites identify and triangulate signals from emergency beacons, including Emergency Position-Indicating Radio Beacons (EPIRBs), Personal Locator Beacons (PLBs), and Emergency Locator Transmitters (ELTs), which operate at the internationally standardized frequency of 406 MHz.

Upon activation of the beacon, the system utilizes Doppler shift techniques to ascertain the distress position, attaining an accuracy of around 2–5 km for LEOSAR and providing near-instantaneous alerts using GEOSAR. MEOSAR satellites, launched in 2018, improve accuracy to less than 100 meters through sophisticated GNSS (Global Navigation Satellite System) integration. Distress signals are transmitted to Local User Terminals (LUTs) for decoding and verification, following which Mission Control Centers (MCCs) distribute confirmed alerts to Rescue Coordination Centers (RCCs) in the impacted area. This comprehensive process generally transpires within 10 to 15 minutes, facilitating the swift deployment of SAR units.

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The system's effectiveness is highlighted by its contribution to saving more than 54,000 lives since 1982, according to the COSPAS-SARSAT Secretariat. Its non-discriminatory service provision guarantees accessible to all nations, regardless of their program participation. Data-sharing procedures, standardized under the International Cospas-Sarsat Programme Agreement, promote interoperability among member governments while upholding rigorous cybersecurity precautions to avert false warnings. Recent developments encompass the incorporation of second-generation beacons featuring GNSS self-location capabilities and the enhancement of MEOSAR coverage, which diminishes latency and augment's reliability in polar and isolated areas. The system's architecture conforms to the United Nations' Global Maritime Distress and Safety System (GMDSS), solidifying its position as a fundamental element of international humanitarian search and rescue efforts. Current partnerships with organizations like the European Galileo and U.S. GPS systems seek to enhance coverage, guaranteeing that the network adapts to the changing technological and operational requirements of the 21st century[1]–[5].

Research that focuses on the construction of antennas that are designed specifically for different applications has been provided by researchers from a wide variety of academic institutions, which has resulted in substantial contributions to the subject matter. In this research, the vital necessity of keeping the antennas' robustness under extreme environmental conditions has been taken into mind. This has been accomplished by utilizing a variety of materials that are constructed to persist for an extended period of time. In [6], An analysis has been carried out, and the focus of the investigation has been on the presentation of two distinct designs of meandering dipole antennas that operate at a frequency of 406 MHz. Among the two materials that are being evaluated for usage in the textile industry, one of the materials that is being considered is a non-conductive textile material. With a permittivity (ε_r) of 1.44 and a loss tangent (tanδ) of 0.044, the first textile material demonstrates its characteristics. A thickness of three millimeters can be found in it. Another sort of textile material is referred to as the shield, and it is the second type of textile material. In the design of the antennas that have been proposed, there are components that are conductive that are included. The conductivity of the layer is determined to be 1.18 x 10^5 S/m, while the thickness of the layer is measured to be 0.17 millimeters. The antenna being considered has a fractional bandwidth of 10.05%. The recommended antenna has dimensions of 200 x 75 x 3 mm^3, which may alternatively be represented as $0.271\lambda_0 \times 0.102\lambda_0 \times 0.0041\lambda_0$. The antenna mentioned in reference [3] is a patch antenna of the type that functions at a frequency of 406 MHz [4], [7] . The substrate of this product is made of a low-loss foam substance, while the conductive components are created using an inkjet-printing technology. The antenna has dimensions of 283 x 65 x 17.5 mm^3 $(0.383\lambda_0 \times 0.088\lambda_0 \times 0.024\lambda_0)$ when it operates at a frequency of 406 MHz. The antenna was aligned parallel to the human body model, and the distance between the antenna and the model was systematically varied between 0 and 200 mm. An experiment was conducted to examine the effect of water on the return loss of an antenna. This was done by varying the gap distance between the water and the antenna, ranging from 0 to 120 mm. In a recent study, researchers presented a unique device comprising of two antennas that may be worn on a life vest [8]. One antenna is attached to the buoyant elements in the chest area, while the other is connected to the buoyant elements in the neck area. In the realm of life-saving apparatus, a conventional life vest is employed, with the antenna affixed to both the chest and neck regions of the buoyant component of the vest, serving their designated purposes. The antennas analyzed in this study are meandering dipole antennas that are folded and utilize a Rohacell substrate. The antennas exhibit resonance at a frequency of 406 MHz. The antenna has dimensions of 300 × 150 × 1 mm^3 $(0.406\lambda_0 \times 0.203\lambda_0 \times 0.0014\lambda_0)$ and operates at a frequency of 406 MHz. A fractional bandwidth of 4% is demonstrated by the suggested antenna. When the antenna was positioned on the chest, the experiment produced a simulated rise of 7 dB; however, when the antenna was relocated to the head position, this value decreased to 1 dB.

This article presents a dual substrate antenna for use in search and rescue missions. A backplane is included in the antenna, which is a planar multislot antenna. With a resonance frequency of 406 MHz, the antenna that is being presented has a maximum gain when it is positioned at an elevation of 0 degrees (pointing up at the sky). In this paper, we propose alternatives to the sorts of antennas that are already in use that share these properties. Based on the findings of the simulation, it was determined that the antenna functioned at a central frequency of 406 MHz, displaying a bandwidth of 228.8 MHz. It was demonstrated by the fact that the antenna operated at a fundamental frequency of 406 MHz, which was the operating frequency. When the reflection coefficient is given a value of -10 dB, this bandwidth is equivalent to a fractional bandwidth percentage, and it equates to 58.8 percent of the total bandwidth.

II. ANTENNA DESIGN

2.1 Materials

Two distinct kinds of materials will be utilized in the construction of the antenna for the purpose of the investigation. Two different types of dielectrics, denoted by

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the symbol (ε_r) are utilized in this context. The top substrate has a relative permittivity of 10.2; RT/duroid6010.2LM laminates, whereas the bottom substrate has a permittivity of 2.7.Copper clad coating features a thickness of 0.035 millimeters and is utilized in both the radiating structure of the antenna and the reflective ground plane. The material possesses a thickness of 0.17 millimeters and possesses an electrical conductivity of 1.18 x 10^5 S/m. Polydimethylsiloxane (PDMS) substrates, which are employed in this experiment, have a permittivity (ε_r) of 2.7, a loss tangent (tanδ) of 0.02, and a thickness of 3 millimeters. These characteristics are like those of SAR antennas. Both ShieldIt Super and PDMS have been applied for developing antennas for satellite communications, as well as polarizing converter surfaces, which have been demonstrated by Hidayath *et al* and Hossain *et al*[9]–[11].

2.2 Planar multislot antenna with backplane topology

When it comes to the microwave frequency range, microstrip antennas, also known as patch antennas, have grown in popularity due to the technology's inherent simplicity and ease of integration with printed circuit board processes. In the capacity of a microstrip antenna, the pin-fed rectangular patch is utilized extensively in a wide range of applications.

Patch antennas are characterized by a relatively narrow bandwidth, which is one of the most significant restrictions associated with them. There are a variety of approaches that can be followed in order to achieve the goal of increasing bandwidth. There are several techniques that can be utilized, such as increasing the patch height, decreasing the relative permittivity, utilizing layered patches, employing a coplanar parasitic subarray, adding shorting pins, or integrating slots.

The Multislot Antenna with Screening Backplane (MSA-BP) incorporates a reflective metallic backplane designed to minimize backward radiation. The structure was developed utilizing a desensitization technique to mitigate the impact of the human body on overall performance. The assembly comprises two distinct layers: the first layer features a slot that is etched into the groundplane of the upper substrate, while the second layer incorporates an additional substrate designed to position the backplane at a precisely defined distance from the slot[12].

The antenna receives its power via a CPW line that is tapered, which allows for wideband matching.

2.3 Operation Mechanism

The odd mode of the coupled slot line, which is also referred to as the CPW mode, is the mode in which the coplanar waveguide is excited. During this mode, the equivalent magnetic currents on both CPW slots radiate almost out of phase, which makes a negligible contribution to the cross-polar component of the radiation pattern. When it comes to the design of antenna arrays, this characteristic of CPW feed is beneficial since it reduces the amount of reciprocal coupling that occurs between neighboring lines. The electric field that is present in the two CPW apertures activates the primary slot arms of the antenna in their respective positions. To enhance the impedance matching across the operating band, the two parasitic slots serve the purpose of improving the impedance matching. It is possible to obtain a good impedance match in the lower section of the frequency band with the assistance of a pair of tapered slots. On the other hand, the upper tapered slots are dedicated to matching the middle frequency band.

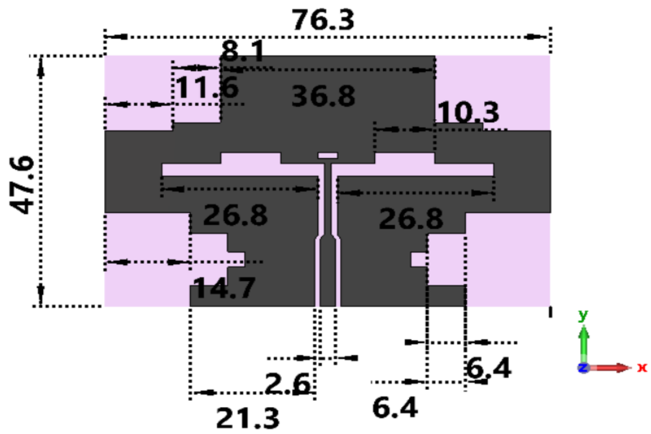

Figure 1(a): Antenna with slotted patch front view (in cm)

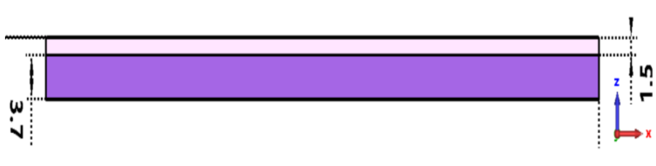

Figure 1(b): Slotted patch antenna side view (in cm)

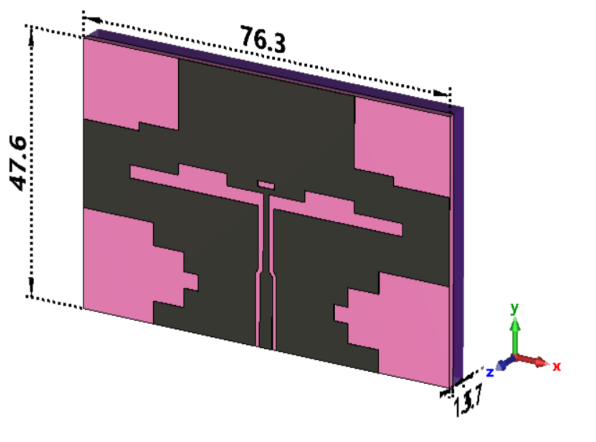

Figure 1(c): Front View and, side view of Slotted Patch antenna in CST

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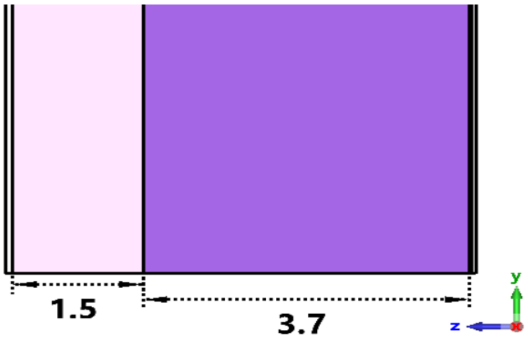

Figure 1(d): Side view of Slotted Patch antenna in CST (in cm)

2.4 Principles of Design

The dependencies of various parameters have been elucidated by Wei et al., specifically noting that the location of the primary slot exerts a considerable influence across the entire operating band. The length of the feedline predominantly influences the upper section of the band, while the spacing between the upper edge of the substrate and the slot primarily governs the lower band, which can be adjusted by modifying the overall width of the backplane. The spatial relationship between the slot and the backplane necessitates meticulous adjustment due to its influence on the input impedance. The role of the parasitic slots is to enhance impedance matching across the entire frequency range; notably, their width significantly affects the matching in the upper band.

- Enhancements in impedance matching within the lower band could be achieved by reducing the lengths of matching elements 1 and 2, whereas the influence of these parameters on high frequencies remains minimal. • The tapered slots are specifically designed to facilitate matching within the central frequency band.

III. RESULTS AND DISCUSSIONS

The antenna that is being presented is a planar multislotted patch antenna. The reflection coefficients of the antenna are shown in Figure 3 (a), the impedance with real and imaginary with regard to frequency is shown in Figure 3 (b), and the voltage standing wave ratio at 406 MHz represents 1.5 value at 406 MHz, respectively. Figures like this illustrate the results of the investigation into the fundamental parameter of the antenna. With the help of the image, it is clear that the frequency at which antennas exhibit resonance is 406 MHz. This is equivalent to 58.28% when compared to a bandwidth of 228.8 MHz with a -10dB level. Upon further investigation, it has been discovered that the antenna exhibits impedance matching that is optimal for the frequency that is meant to be utilized.

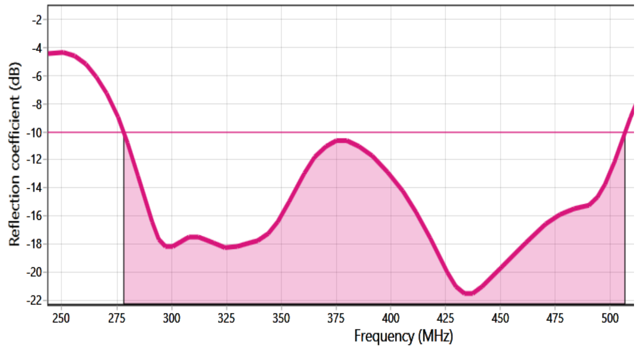

Figure 3(a): Reflection coefficient slotted patch antenna with a -10 dB performance

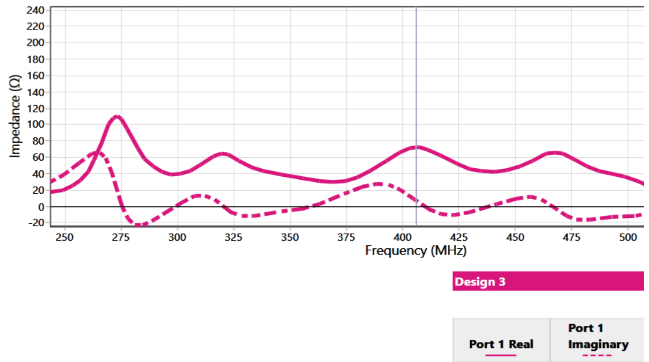

Figure 3(b): Impedance of the antenna with respect to frequency

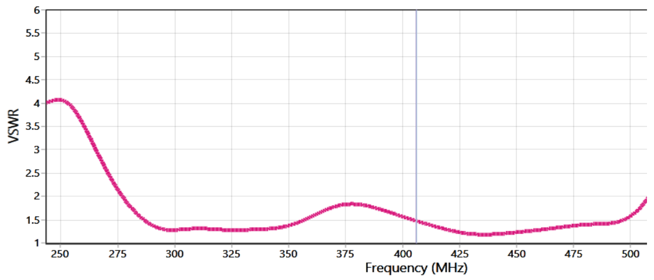

Figure 3(c): Voltage standing wave ratio at 406 MHz

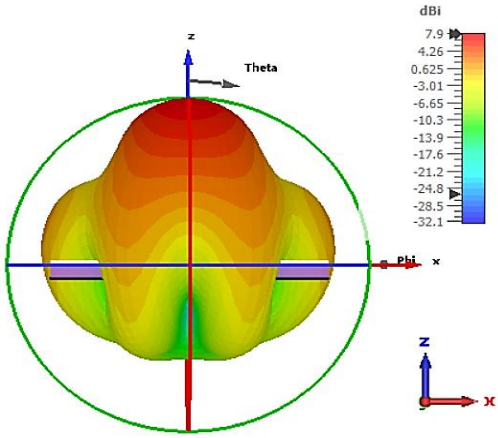

Figure 4(a): 3D radiation pattern with slotted patch antenna in middle

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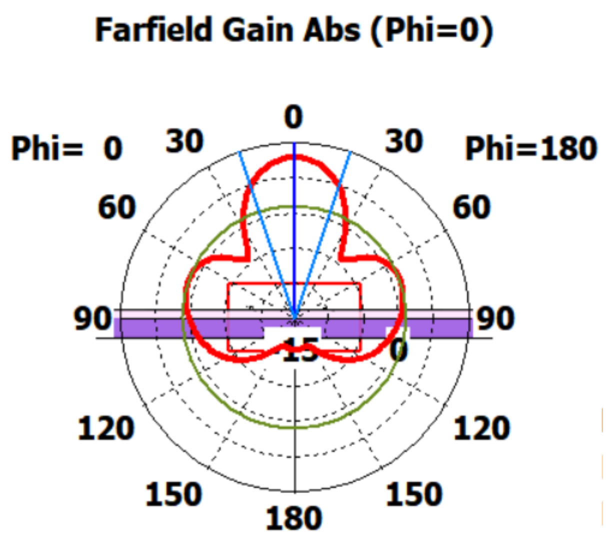
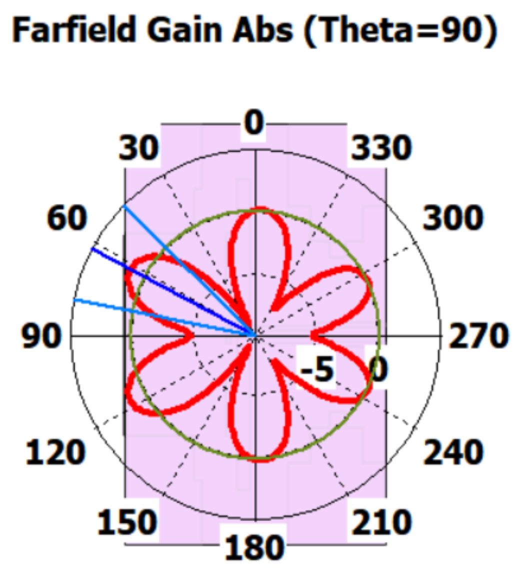
It has been demonstrated that the antenna has attained gain 3D radiation patterns, which can be seen in Figure 4(a). Because the antenna will be positioned or placed on the beacon, and it will be facing upwards toward the sky, this attribute is extremely significant because the antenna will be placed on the beacon. The maximum gain of the antenna, as measured by the IEEE, can be seen to be in the z-direction, and it is nearly 8dBi. This is easy to see and confirm. Therefore, in the event that the antenna possesses a null at 0 degrees or in the z-direction. In the event that this is the situation, the antenna will be unable to transmit a signal to the satellite on its own.



(a)



(b)

Figure 5: Simulations of Planar Multislot Antenna with Backplane radiation in free space: (a) Eφ (φ =0^0), and (b) E_θ (θ=90^0)

The Fig. 5 (a), (b) and Fig. 6(a), (b) presents the magnitude of gain in form of radiation patterns for

φ =0^0 and θ=90^0.It can be observed that the antenna does not have nulls at 0^0 when **Eφ (φ =0^0), and (b) E_θ (θ=90^0).**

IV. CONCLUSION

Current investigations center on developing a unique, flexible COSPAS-SARSAT beacon antenna. For the time being, this study is being carried out. The frequency at which the system operates is 406 MHz, and it was developed with the express purpose of being utilized in the Mission Control Centers of COSPAS-SARSAT. Through the following means, the antenna that has been illustrated here is able to successfully accomplish the two most important goals: The first function's primary objective is to maximize gain at an angle of 0 degrees, which is almost 8dBi, whereas the second function's primary objective is to optimize impedance matching at a frequency of 406 MHz. The two functions in question are incompatible with one another. The Shield It Super conducting element is used in the overall design of the structure, and the RT/duroid® 6010.2LM laminates substrate and PDMS are used for the substrate. The foundation that was used in the construction of the entire building is one that allows for complete flexible construction. The investigation of the antenna indicated that the Planar Multislot Antenna with Backplane under planar conditions had an estimated -10dB fractional bandwidth of 228.8 MHz. This was the case when the antenna was subjected to normal conditions.

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