Design and Analysis of Arrow Shaped Antenna for Satellite Communication

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ABSTRACT- The recent trends in satellite communication antennas reflect a notable shift towards advanced technologies and innovative designs. Antenna miniaturization and integration have become prominent, enabling the development of compact and lightweight solutions. Phased array antennas have gained widespread attention for their ability to electronically steer beams, enhancing communication flexibility. This paper presents a comprehensive analysis and comparison of arrow-shaped antennas designed for satellite communication applications within the frequency range 0-60 GHz. The study explores multiple designs, including those with one-side spokes, double-side spokes, and lower strips. Additionally, the behavior of the antenna is examined using various substrate materials such as Air, FR_4, and silicon-di-oxide($S0_2$). Furthermore, the paper investigates the impact of exposure to different conductors, specifically indium and copper (Cu), on the antenna's performance. The findings contribute valuable insights into optimizing the antenna's effectiveness under diverse design parameters and material considerations for practical applications in satellite communication.

keywords: Arrow antenna, satellite communication, copper ,indium ,FR_4, Air, silicon-di-oxide, substrate analysis, design analysis.

I. INTRODUCTION

The growing focus on the implementation of advanced materials and manufacturing techniques is to improve antenna performance and durability. Additionally, the advent of software-defined antennas allows for dynamic reconfiguration and adaptability to changing communication needs. These trends collectively signify a transformative phase in satellite communication antenna technology, characterized by increased efficiency, versatility, and reliability.

When it comes to space-to-ground communications, the use of frequency spectrum has often moved up from the lowest bands that can allow propagation via space to the greater bands, which have required technological improvement and research to execute[1]. Radio waves may carry information across great distances and The distribution of radio-frequency spectrum to different services is a necessary component of high-quality satellite communications. Since Earth-space radio communications are only allotted a small portion of these spectra, it is imperative that the bandwidth that is available be utilized as efficiently as possible. The effective application of RF spectrum for satellite messaging and navigation involves numerous technical components[2]. Bluetooth communication in satellites are fully meet societal objectives in both indoor and outdoor applications, high data rate components are necessary. High bandwidth and reliable connectivity are necessary for these applications[3].An arrow antenna is a type of directional antenna commonly used for amateur radio and satellite communication .It is designed to be lightweight, portable and easy to handle. [4]when setting up an arrow antenna the positioning is crucial to ensure its optimal performance due to its Directionality, Gain, Compact and Portable Design, Ease of Tracking, Dual-Band Capability, Suitability for Handheld Operations, Amateur Radio Satellite Communication ,Polarization Adjustability, Educational and Recreational Use, Real-time Communication Experiences.

II. ANTENNA DESIGN:

In view of the large frequency range involved, designing an antenna for satellite applications that spans the range of 0 to 60 MHz is a challenging undertaking. In general, Yagi-Uda antennas are simpler than the antennas used for satellite communication in this frequency range. A common variety utilized for this objective is the Log-Periodic Antenna.[3]-[6]

However, precise calculations and simulation tools are needed to create a specific design for a log-periodic antenna.

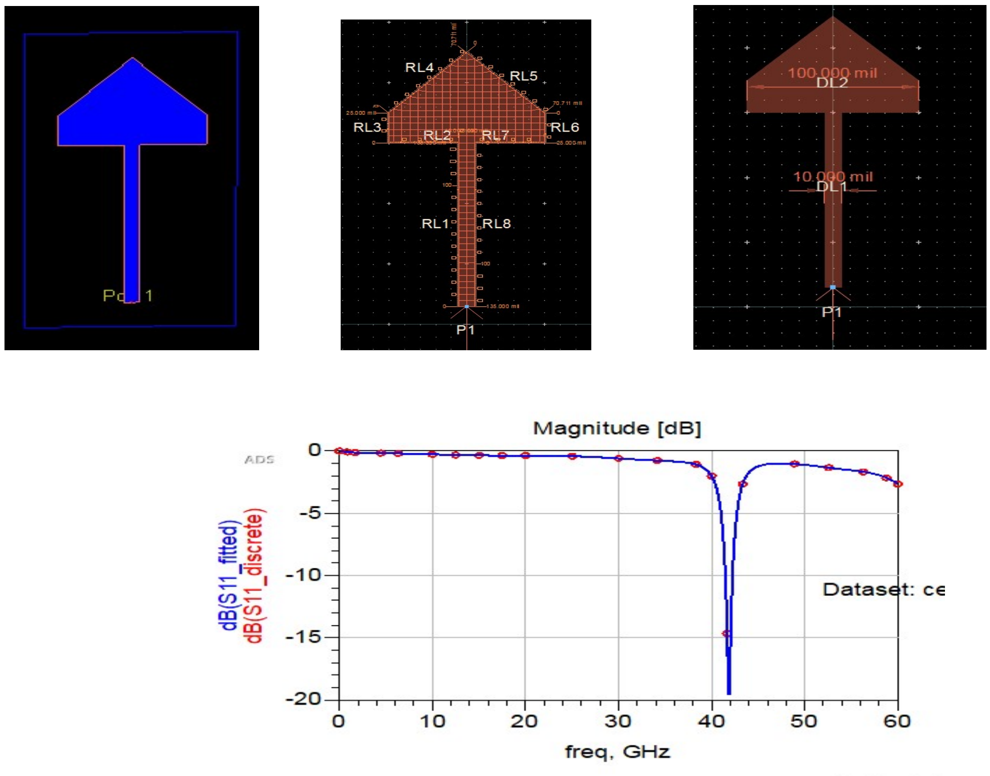
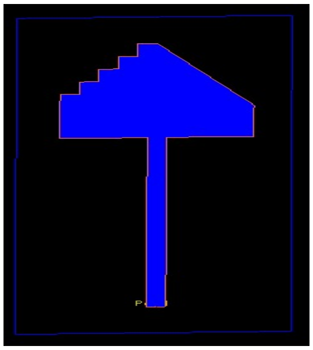


Fig. 1 Design and Result of proposed antenna

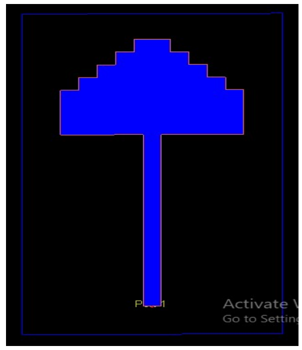
This arrow-shaped antenna is crafted with the copper conductor and FR_4 substrate and the following dimensions: RL1 and RL8 are 135.000mm, RL2 and RL7 are 45.000mm, RL3 and RL6 are 25.000mm, and RL4 and RL5 are 707.110mm. It has a width of DL1 measuring 10.000mm and DL2 measuring 100.000mm. The material used has a relative permittivity of 4.600000e+000 and a relative permeability of 1.000000e+000 as shown in the fig(a).and the gain obtained near 41.8 GHZ with the magnitude of -20 dB as shown in the Fig(1).

The design of an arrow-shaped antenna plays a pivotal role in shaping its performance and functionality. The distinctive arrow configuration, characterized by a tapered structure resembling an arrowhead, is meticulously crafted to optimize key parameters.[8] The dimensions of the arrow's arms, the spacing between elements, and the overall geometry are carefully determined to achieve specific goals such as enhanced gain, directional characteristics, and frequency response. The design process involves intricate calculations and simulations, considering factors like impedance matching, radiation pattern, and material properties. Engineers aim to strike a balance between size, weight, and performance, particularly in portable applications. Additionally, innovations such as incorporating spikes or other modifications can further refine the antenna's capabilities.[6]-[9] A well-executed design ensures that the arrow-shaped antenna delivers optimal signal reception and transmission, making it a valuable component in applications ranging from satellite communication to portable radio setups. By incorporating a spike-shaped structure on one side of the arrow peak, [7]illustrated in Fig(b), we observe a gain at the frequency of 40.1 MHz, depicted in Fig(2), with a magnitude of -19 dB and By incorporating a spike-shaped structure on double side of the arrow peak Fig(c)it is observed at a gain at the frequency of 38.95 with the magnitude of -14.6 dB as Fig(3),Additionally, the subsequent analysis will involve modifying the antenna design by exciting rectangular strips in its lower section

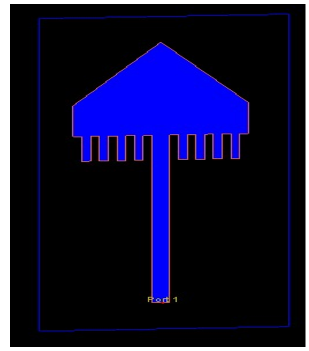
-(Fig d),The resulting graph indicates a return loss of -15 dB at a frequency of 36.1 GHz Fig(3).



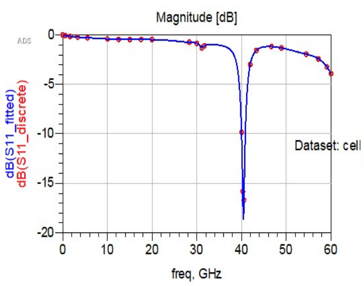
Fig(b)



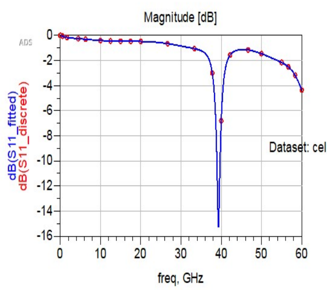
Fig(c)



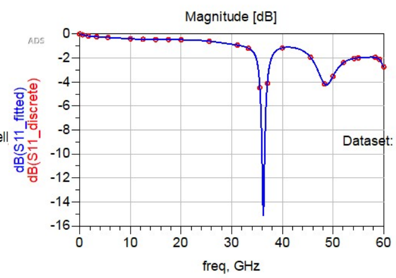
Fig(d)



Fig(2)

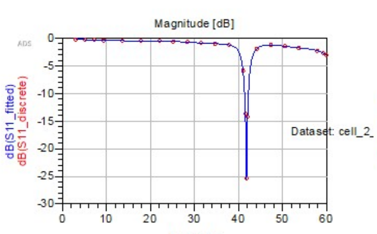


Fig(3)

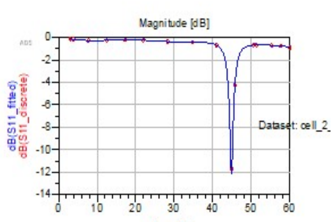


Fig(4)

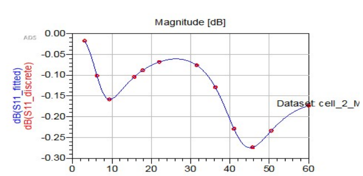
The effectiveness of indium as a conductor depends on the specific application and requirements[8]. Indium is known for its good electrical conductivity, making it suitable for certain electronic and electrical applications. It is often used in the production of indium tin oxide (ITO), a transparent and conductive material used in technologies such as touchscreens, flat-panel displays, and solar cells. Indium also finds application in various electronic soldering alloys due to its low melting point. [9]However, its effectiveness may vary depending on factors such as the intended use, environmental conditions, and specific conductivity requirements. For detailed information on the effectiveness of indium in a particular context, it is recommended to consult relevant literature or experts in the field.[8]-[11] hence, after changing the antenna's conductor into indium we have infer this result as the gain is observed to be -26 DB at 46GHZ frequency as shown as Fig(5), its comparatively higher than using copper conductor.



Fig(5)
Conductor -Indium



Fig(6)
silicon dioxide (SiO_2)

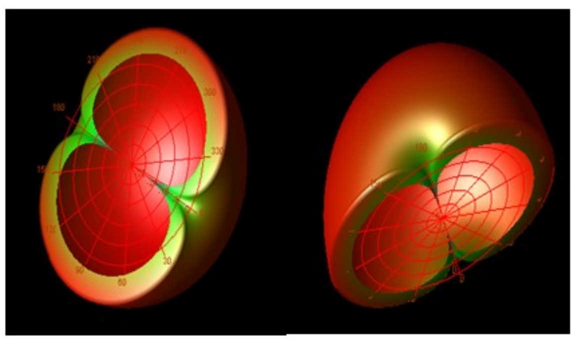


Fig(7)
Substrate-Air

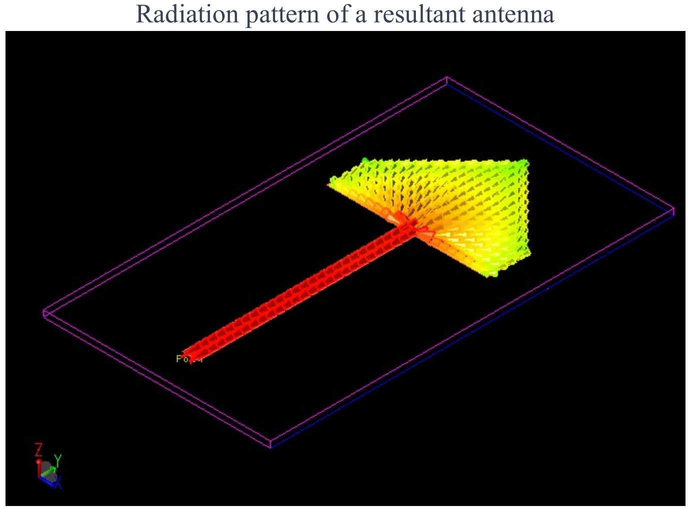
The effectiveness of using silicon dioxide (SiO2) as a substrate in antenna designing depends on the specific requirements and goals of the antenna design. [10]Silicon dioxide is a dielectric material with properties that can influence the performance of an antenna in various ways such as high dielectric constant, low loss tangent , high thermal stability and the thickness of the silicon dioxide substrate can influence the antenna's radiation pattern, impedance matching, and overall performance[11]. The substrate thickness is often a critical parameter in antenna design. Silicon dioxide can be effective as a substrate in antenna design, especially in applications where its dielectric properties align with the desired characteristics of the antenna[8] However, the specific requirements of the antenna, such as frequency range, bandwidth, and environmental conditions, should be carefully considered to determine the suitability of silicon dioxide or other substrate materials. Additionally, simulation tools and experimentation are often used to optimize antenna designs with specific substrates for desired performance outcomes. We can infer the results of using silicon dioxide as a substrate gives the -12.1DB gain at 45 GHZ frequency Fig(6)

Eventually, The usage of AIR as a substrate for this antenna has been chosen because using air as a substrate in antenna design can offer advantages such as low dielectric losses and predictable radiation patterns.[10] However, it may require larger physical dimensions compared to antennas designed with higher dielectric constant materials[7] The choice of substrate depends on the specific requirements of the antenna design, including frequency, size constraints, and desired performance characteristics. As shown in the Fig(7),the dual band gain is obtained as -0.16 and

-0.28 DB which is very low at a frequency of 9 and 46 GHZ. Therefore, The Following thorough analyses of the antenna design, conductor material, and substrate material, it has been determined that the highest gain is achieved exclusively when employing the arrow antenna configuration with an indium conductor and FR_4 as the substrate material. This optimal configuration is characterized by the absence of spokes and the inclusion of rectangular strips in its design, making it the resultant antenna.



Radiation pattern of a resultant antenna



The current field of the resultant Antenna

III. CONCLUSION:

In conclusion, following an in-depth analysis of satellite communication antennas, considering advanced technologies and innovative designs, this study focuses on arrow-shaped antennas within the 0-60 MHz frequency range. The trends highlight the significance of antenna miniaturization, integration, and the growing popularity of phased array antennas for their beam-steering capabilities. Through an extensive examination of various designs, including one-side spokes, double-side spokes, and lower strips, the behavior of the antenna is explored with different substrate materials (Air, FR_4, silicon dioxide) and exposure to conductors (indium and copper). The conclusive findings emphasize that the arrow antenna achieves high gain when designed with indium conductors and FR_4 as the substrate material, specifically without spokes and featuring rectangular strips. These optimized parameters provide valuable insights for practical applications in satellite communication, contributing to the overall effectiveness of the antenna system.

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