International Journal on Recent and Innovation Trends in Computing and Communication
***ISSN:** 2321-8169* ***Volume:** 11* ***Issue:** 9*
Article Received: *25 July 2023* ***Revised:*** *12 September 2023* ***Accepted:*** *30 September 2023*

Design of Multiband Microstrip Patch Antenna for Satellite Applications

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Abstract—In the fields of satellite communication and aerospace, the multiband microstrip patch antenna has emerged as a game-changing technology that meets crucial needs of the contemporary day. The use of this antenna is essential as the need for faster data transfer rates and wider coverage keeps rising. In this paper, a microstrip patch antenna is designed for operating into Ku band for satellite communication and aerospace communication. The antenna is operating at 15.8 GHz and in the Ku band. The antenna is designed with slot configurations on the patch, forming an 'H' shape, and on the feed, resembling a 'U' shape. The integration of these slot structures enhances the antenna's gain, achieving 7.44 dB with useful bandwidth of 3.2 GHz. Furthermore, the antenna exhibits ultrawide band properties, extending its versatility and potential applications.

Keywords-Sattelite Communication; aeroscpacel microsrip patch; gain; hardware

I. INTRODUCTION

In the realm of aerospace and satellite communication, the multiband microstrip patch antenna emerges as a transformative technology, addressing crucial needs of the current era. As the demand for higher data transmission rates and extended coverage continues to increase, the application of antenna proves provides solution for these challenges. Its capability to operate across diverse frequency bands, including the critical 15.9 GHz and the Ku band, equips satellites with the power to communicate seamlessly, amplifying data throughput and ensuring reliable connections. Designing and implementing a multiband microstrip patch antenna for satellite communication represents a critical endeavor within the aerospace industry, where efficient and reliable connectivity is paramount. The demand for enhanced data transfer rates, seamless coverage, and improved communication capabilities has fueled a paradigm shift in antenna technologies. The multiband microstrip patch antenna, with its unique design and advanced features, offers a promising solution to meet the evolving needs of satellite communication in the current era of aerospace exploration [1] [2].

Satellite communication plays a fundamental role in modern society, enabling a myriad of applications, including broadcasting, internet access, weather monitoring, navigation, and global connectivity. These applications are reliant on the effective transmission and reception of signals between ground stations and satellites orbiting the Earth. Achieving optimal performance and robust connectivity in satellite communication necessitates the use of antennas that can operate efficiently across specific frequency bands, such as the Ku band and 15.9 GHz, while also catering to ultrawide band requirements [3,4].

The multiband microstrip patch antenna, characterized by its compact size, low profile, and versatility, has emerged as a prominent candidate to address the multifaceted demands of satellite communication. Its ability to operate across multiple frequency bands while maintaining a small physical footprint is a critical advantage. This antenna design typically consists of a radiating patch placed on a dielectric substrate, with slots incorporated to enhance performance and widen the frequency bandwidth [5, 6].

In the aerospace industry, the need for a multiband antenna stems from the requirement to maximize spectral efficiency and accommodate diverse frequency allocations. Traditional single-band antennas are often limited in their capacity to adapt to evolving communication protocols and frequency bands. Consequently, the multiband microstrip patch antenna serves as a flexible and adaptable solution, enabling seamless communication across a range of frequencies. This adaptability aligns with the dynamic nature of modern communication systems in the aerospace sector [7,8].

The key challenge in designing a multiband microstrip patch antenna lies in achieving optimal performance across multiple frequency bands. The antenna's dimensions, slot configurations, and substrate properties must be meticulously designed to resonate at the desired frequencies while maintaining high gain and efficiency. Additionally, achieving good impedance matching across the frequency bands is crucial to ensure efficient signal transmission and reception [9].

The use of slots on the patch and feed of the antenna, shaped as 'H' and 'U' respectively, represents an innovative approach to enhance its performance. These slot configurations alter the current distribution on the patch and feed, influencing the antenna's impedance and radiation characteristics. By strategically placing these slots, the antenna's bandwidth is broadened, enabling multiband operation and ultrawide band [10].

In the realm of aerospace, where satellite missions are becoming increasingly complex and sophisticated, the multiband microstrip patch antenna offers a viable solution to address the intricate communication requirements. The antenna's ability to operate within the Ku band is especially pertinent, as these frequency bands are extensively utilized for satellite communication. The integration of such antennas enhances data throughput, enables seamless connectivity, and contributes to the success of satellite missions [11].

Recent years demonstrate the incredible progress achieved by researchers to improve this subject in light of antenna technology gaps. Antenna structure is a crucial component of many wireless communication systems, including the Global Positioning System (GPS), mobile phones, traffic radar, military, biomedical, and aerospace systems. [12] At the same time, several users, including corporate organisations, healthcare providers, space agencies, oil and gas firms, and others, make extensive use of this sector. Therefore, because improving the communication sector and its infrastructure is equally crucial, it should be taken into consideration [13].

It is almost hard to cover the whole region and give direct access among the many users when you take into account landline communication and equalise it with the size of the world, the numerous dispersed human attentions, rural areas and industries, and enormous ocean ships. As a consequence, many businesses turned to satellite communication to grow and get beyond the limitations of ground infrastructure. Since the antenna plays a significant role in the satellite communication system, its presence cannot be removed. As contemporary civilization has developed and entered the information era, the demands placed on antenna have increased. Studying multiband and miniature antennas is thus vital. Typical microstrip antennas offer numerous benefits, but they also have three main drawbacks: restricted bandwidth, poor gain, and relatively big bulk. The compact antenna layout, which accounts for the connection between the antenna's bandwidth, size, and efficiency, further degrades these metrics. In addition to that connection, the gain and antenna size also have a connection. Electrically tiny antennas often have lower gains than big ones [14] [15].

The Ku-band is one of the most widely utilised technologies for high-speed satellite internet today. The electromagnetic spectrum's Ku-band, which runs between 12 GHz and 18 GHz, is the lowest of the three NATO K bands that operate at frequencies from 20 GHz to 40 GHz. In the realm of satellite communications, it is commonly used. suitable for the higher-powered satellite services used in digital TV, such as foreign programming, news feeds, educational networks, teleconferences, sports, and entertainment programmers. Additionally, it is used by NASA in space, as well as Very Small Aperture Terminal (VSAT) systems on ships and for commercial aeroplanes. Some of the benefits of Ku-band include its ability to increase uplink and downlink power as needed, its superiority over lower frequency microwave bands due to its shorter wavelength and ability to distinguish the signals of various communication satellites using a smaller parabolic antenna, its flexibility for users due to its freedom from land operations, which makes it simpler to locate a properly functioning dish site, and most importantly, its cost advantage over other options [16] [17].

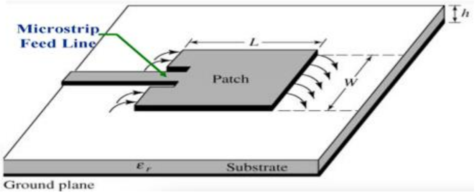

Figure 1. Structure of microstrip patch

The important thing about micro strip antennas is that they can transmit well even though they are small. Figure 1 shows microstrip patch antenna. The electric fringing fields between the conductor element's edges and the ground plane behind it are the main source of this radiation. In order to create an effective antenna for deep space applications, it is necessary to build the antenna for a certain frequency range, such as the K, Ka, Ku, and X bands, with a particular dielectric constant and feeding method. Additionally, the proper implementation of the slotting and array approaches is required. In order to construct an antenna with the necessary frequency range, such as at the X or Ku band, random experiments with all the parameters and current feed methods must be conducted [18].

II. DESIGN AND MODELING

In our proposed design, a Microstrip line feed is employed. A conducting strip is immediately attached to the edge of the Microstrip patch in this kind of feed technology. The benefit of this kind of feed arrangement is that the feed may be etched on the same substrate to give a planar structure. The conducting strip is narrower than the patch. Without the use of any extra matching components, the inset cut in the patch is intended to match the impedance of the feed line to the patch. By correctly managing the inset position, this is accomplished. Because of its simplicity, ease of manufacture, and ability to tune impedance, this feeding method is simple. However, surface waves and spurious feed radiation also rise with the thickness of the dielectric substrate being employed, which reduces the antenna's bandwidth. Unwanted cross-polarized radiation is also produced by the feed radiation. The “U” Type slot structure is added to overcome the above problems and better radiating. Table 1 shows design parameters and Figure 2 shows design geometry [19] [20].

Linear slots, whether horizontal or vertical, can change the current distribution along the antenna's radiating patch. Horizontal slots, for instance, tend to increase the effective length of the patch, lowering the resonant frequency. Conversely, vertical slots alter the current flow and can influence the resonant frequency and radiation pattern [21] [22].

TABLE I. DESIGN DIMESNSIONS

Parameter	**Modeled Value (mm)**
Width of Dielectric, W_d	20.70
Length of Dielectric, L_g	30
Width of Patch, W	11.13
Length of Patch, L	10.63

Feed line Length, F_l	14
Feed line Width, F_w	3
Length of H, H_l	7.77
Width of H, H_w	5.70
Feed line U length, U_l	5.63
Feed Line U width, U_w	1.4

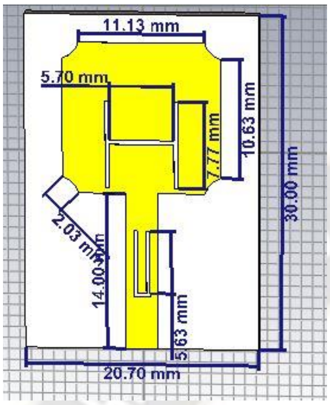

Figure 2. Design Geometry

The antenna is modeled and simulated in CST 2019 environment. After simulation, the antenna is fabricated. Figure 3 shows antenna in anechoic chamber for measurement of gain. The measured gain of fabricated antenna reaches 7.44 dB near 15.8 GHz. Figure 4 shows simulated gain of antenna over frequency. The simulated gain was found to be 7.26 dB.

Figure 3. Antenna in anechoic chamber

Figure 4. Frequency over gain plot

For calculating s11, a sweep of frequency is provided from 6 GHz to 18 GHz from VNA Agilent model N5247A. The range of VNA is 10 MHz to 67 GHz. The antenna is connected through probe. The figure 5 shows antenna connected with VNA. The band for Ku is from 13.749 GHz to 17 GHz. The useful bandwidth is 3.2 GHz. The antenna shows Ultra-wideband characteristics. The s11 of simulated antenna and fabricated antenna is shown in figure 6.

Figure 5. Antenna connected to VNA

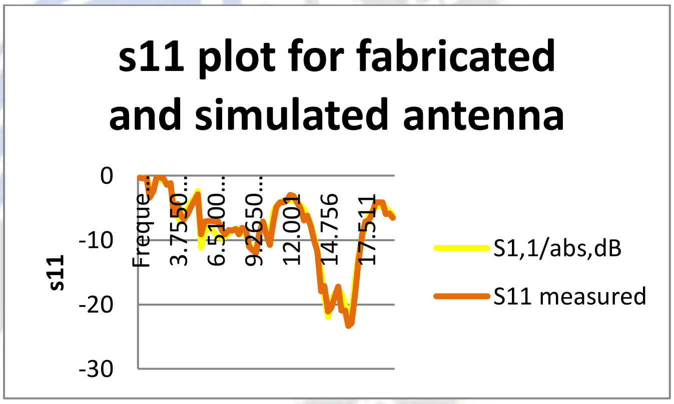

Figure 6. Comparison of simulated and fabricated s_{11}

The proposed fabricated multiband microstrip patch antenna has a measured gain of 7.44 dB near 15.8 GHz, aligning well with the Ku band range from 13.749 GHz to 17 GHz. The antenna can be used for satellite communication and aerospace applications.

III. CONCLUSION

In the contemporary era of aerospace and satellite communication, antennas are fundamental components driving connectivity and data transmission. The fabricated antenna operates effectively within the desired Ku band range, showcasing resonance near 15.8 GHz with gain of 7.44 dB. Moreover, its ability to cover a wide bandwidth of about 3.2 GHz emphasizes its adaptability and potential for modern communication needs. In the rapidly evolving landscape of communication technology, this antenna stands as a significant advancement, particularly for satellite communication and similar applications, meeting the growing demand for efficient and expansive connectivity

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