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# Design of Optimized low-power GPS-Yagi Antenna using Machine Learning techniques

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***Abstract*—The time-consuming process of developing analytical models can be accelerated with the help of machine learning, which is a technique for data processing. Using machine learning, antenna designers can quickly and intelligently optimize their physical antenna designs. This is achieved by developing trained models of the designers' designs. Consequently, antenna designers can create more efficient antennas. Due to this, antenna designers can continue developing new designs despite the increasing complexity of antennas. When discussing this specific type of antenna, "Yagi" is frequently used as an abbreviation for "Yagi-Uda" the full name of the antenna. The length of the "driven dipole" may be equal to or shorter than the length of the "directors." The ability to rapidly execute a diverse set of optimization algorithms and objectives, made possible by the trained models, makes it easier to conduct rapid comparisons and a diverse set of studies (including stochastic analysis for tolerance studies, etc.). While the device was operating at a frequency of ten gigahertz, the concept of two parasitic directors was conceived, and these parasitic directors were designed and optimized to improve the device's directivity further. This antenna offers numerous advantages, one of which is its simplicity of manufacture. This antenna can be manufactured relatively easily due to its diminutive size and uncomplicated overall layout. The stochastic global search and optimization method known as simulated annealing (SA) is extraordinarily effective. This method is implemented instead of more conventional ones to achieve optimal element spacing.**

***Keywords*— *GPS, Yagi Antenna, Machine learning, Radia-waves***

## I. INTRODUCTION

Typically, antennas are made of metal, used to transmit and receive radio waves. All radio transmissions, including broadcast radio, television, and point-to-point radio, require an antenna [1]. There is no method of radio transmission that does not involve an antenna. This directional antenna design, also known as a "Yagi-Uda array," focuses radio waves in a particular direction. The length of the reactor element will be same or longer. This antenna configuration increases both its gain and directional capabilities compared to a standard dipole [2]. The gain, resonant frequency, and directivity of an antenna, as well as its radiation pattern and efficiency, are among its most crucial performance characteristics. Additionally essential is the antenna's efficiency. Antennas are the link between the transmitter and the outside world. In addition to their primary function, antennas can connect the sender and the receiver [3]. Even though there are numerous advantages to using printed antennas, there are also disadvantages. Initially, the output power level is significantly lower than before. Typically, they have extremely limited bandwidths. On the other hand, Vivaldi and tapered slot antennas rely on traveling waves to provide broad bandwidth [4]. In recent years, computer-aided design (CAD) software has become increasingly important for designing, analyzing, optimizing, and fabricating microstrip antenna arrays and individual antennas. Many different simulation programs, such as HFSS®, CST®, MWO®, and many others, were used to model electromagnetic fields to a significant degree. The evaluation of a system's merits heavily depends on its antennas' performance. Antennas are adaptable devices with a wide variety of uses and can take on a variety of shapes. Some systems use antennas to direct the flow of electromagnetic energy, whereas other systems use antennas in an omnidirectional capacity. This is because some antennas are designed to transmit signals in a specific direction, while others are designed to transmit signals in all directions. Because some systems rely on antennas for point-to-point communication, increasing the gain of antennas while simultaneously reducing the amount of wave interference they encounter is essential. When discussing electromagnetic energy, any device capable of receiving or transmitting signals is referred to as an "antenna". An antenna is considered a receiver if it generates a variable current distribution in response to radiation from the outside, and a transmitter generates radiation in response to a variable current distribution on the antenna that is driven from the outside. These definitions are both widely accepted. Depending on their orientation, the majority of antennas can either transmit or receive signals. In addition, certain antennas can concentrate incoming electromagnetic waves, allowing them to receive and transmit signals simultaneously. In recent years, the development of the vast majority of



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currently available wireless communication systems has accelerated significantly. Due to the increasing prevalence of GPS functionality in consumer electronics like smartphones and navigation systems, commercial and academic researchers have become more interested in embedded GPS antennas[5]. The proliferation of GPS functionality in consumer electronics has sparked this interest. Antennas require both a high level of directivity and a high level of radiation performance. To function properly, embedded GPS antennas require a high degree of directivity. It is advised that the primary radiation lobes of a GPS antenna face upward. By doing so, the antenna's ability to receive electromagnetic signals transmitted by the satellite will be greatly enhanced [6]. The three primary components of the vast majority of quasi-Yagi antennas are a dipole driver, a parasitic director, and reflector elements. The ground plane, which also serves as an antenna, serves as a reflector that aids in forming a directional radiation pattern. In addition, two parasitic directors were designed and optimized at the operating frequency of ten gigahertz to enhance the directivity further. This antenna's small size and straightforward design contribute to its ease of manufacture, which is just one of its numerous benefits. Yagi-Uda antennas are ideal for RF transmission due to their exceptionally high level of directivity. Compared to C-band and S-band applications, the L-band GPS application requires fewer resources and is easier to implement, as demonstrated by our comparison results. A Yagi-Uda antenna with enhanced tuning capabilities for microwave, VHF, and UHF frequencies. The Yagi-Uda antenna mounted on the boom consists of three components: a folded dipole-shaped driven element, a parasitic element, and a concave reflector. Signal transmission is the responsibility of the component being driven.

## II. Literature Review

The Yagi-Uda antenna has been called one of the greatest technological achievements in the history of directive antennas [7]. At any given operating frequency, it has high efficiency in directivity and losses throughout the antenna, and its construction is not at all complicated. This efficiency can be attributed to the antenna's overall design. Additionally, the overall design is not overly complicated. In order to use the L1-band and S-band China Mobile Multimedia Broadcasting (CMMB) bands, electronic devices used in China, such as smartphones, tablets, notebooks, and navigators, must have antennas integrated directly into the device. This is due to the increasing demand for L1-band GNSS functions and the emergence of promising China Mobile Multimedia Broadcasting S-band digital TV broadcasting services. These two factors contributed to this outcome. These two factors have each contributed to our present predicament. The CMMB service generates hybrid coverage modes by transmitting data from terrestrial base stations and S-band satellites to extend the range of transmissions [8]. This enables a larger number of individuals to receive the transmissions. The frequency range of the CMMB S-band is between 2635MHz and 2660MHz. The primary radiation beam direction of a superior GNSS or CMMB antenna must always point upwards. As a result, the antenna can improve the quality of the satellite reception it provides while simultaneously reducing the amount of unwanted reception caused by the device's internal noise interferences. This is because mobile devices continue to shrink in size. Due to the exceptional end-fire directivity of Yagi-Uda antennas, it is common knowledge that these antennas are ideal for situations requiring directive wireless technology. The Yagi-Uda antennas have attracted so much research and interest in recent years. Due to the limited dimensions and thicknesses of portable devices, however, printed and simple designs are in high demand for their implementation. This demand is driven by the increasing prevalence of portable electronic devices. This research aimed to optimize and develop a dual-band Yagi-Uda antenna suitable for GPS systems by analyzing previously published antenna designs and utilizing the most recent technological advancements. These two frequencies were within the L1 band. Using the results of the measurements, calculations were made (S-band). For the fabrication of a printed directive Yagi-Uda antenna with end-fire radiation for use in GPS applications, several simple and novel designs with a single stage of directors, as opposed to multiple stages of directors, were proposed [9]. It is constructed from FR4 material, a relatively inexpensive material option. In recent years, there has been significant interest in the concept of building a planar Yagi-Uda antenna for use in microwave bands. This is due to the distinct end-fire radiation patterns that the antenna type in question produces.

The six directors on this antenna are all of the same size and are evenly spaced apart. There is no correlation between the board members' length and the distance between them. With the aid of the radial stub, an accurate field match can be accomplished [10]. The transformation's resulting topological change was brought about by replacing the microstrip line with a coplanar strip line. A coplanar strip line is employed as the source of power for the driven dipole. The simple Yagi-Uda antenna has a novel design that allows it to achieve excellent levels of directivity, front-to-back ratio, cross-polarization level, bandwidth, and radiation efficiency, as measured by its average gain across all three dimensions. This is now possible due to the antenna's ability to achieve an excellent front-to-back ratio. The recommended antenna is the superior choice for mobile devices with GPS capabilities, such as smartphones and tablets. Numerous users have expressed an interest in obtaining the highly directive pattern that Yagi-Uda antennas can provide and have indicated their desire to do so. Increased radiation directionality is among the numerous benefits of employing a concave parabolic reflector surface [11]. This is merely one of the numerous advantages that come with the territory. This indicates that it has the potential to enable the targeted application of energy, which would be highly beneficial.

Consequently, the proposed design employs the cutting-edge innovation of the concave parabolic reflector with the driven dipole situated around its focus to transform a conventional Yagi-Uda antenna into an entirely new one that is not only highly directive but also easy to operate. To achieve this result, the driven dipole and concave parabolic reflector are combined. Microstrip Yagi-Uda arrays can be arranged in a square, and then common parasitic elements can be added so that they branch off at each of the square's four corners to create a simple four-sector antenna design. This has been proposed as a simple method for constructing a four-sector antenna. This presentation will be titled "Compact Planar Four-Sector Antenna," One of its components will be a Microstrip Yagi Uda Array. The antenna can be smaller than it otherwise would be because its four microstrip Yagi - Uda arrays are arranged in a square and share elements. This allows the antenna to be smaller as a result. The unexpected disappearance of the common element, which makes this possibility possible, allows for a significant front-to-back ratio. In this section, we will discuss a technique that can be used to integrate various components. This method enables the incorporation of ferrite circulators into the design of antenna systems. The authors present two distinct antenna configurations, each comprised of a microstrip circulator and a Yagi planar antenna, to demonstrate the efficacy of the proposed method. Experiments and simulations demonstrate that both systems have pass-band characteristics that are optimal and superior to those of other systems. Theoretically, a Global Positioning System (GPS) receiver could operate more efficiently with a three-dimensional planar inverted F antenna [12-13]. It is necessary to minimize the antenna size as much as possible so it can be incorporated into a handheld device. Optimizing the gain of a Yagi-Uda antenna can be difficult due to its sensitivity to and dependence on a large number of parameters [14]. To maximize the effectiveness of the element spacing, however, a technique known as simulated annealing (SA), a robust stochastic global search and optimization method, is employed.

## III. Proposed Antenna Design

A Yagi antenna consists of three distinct parts, all of which work together to form the antenna as a whole when reduced to their most fundamental components. The length of each parasitic component is distinct when measured concerning the resonance value of the half wavelength. The element has inductive properties and can function as a reflector if its length has increased by more than 15%. Any component whose length has increased by more than 15% possesses an inductive property, and it is possible to use such a component as a reflector. This is because the electromagnetic force arises from the driven dipole, as would appear to be the case due to the capacitive property. To ensure that you have a firm grasp of the fundamental principle, we will begin with the resonant dipole and then move on to the array in which the parasite element is positioned close to the fed dipole. Due to the physical separation between the parasite and the host, the parasite component of an organism experiences a phase delay whenever it radiates away from the host. Due to the shorter length of this element, the capacitive property introduces a delay in the current and voltage. If the phase delay is inversely proportional to the separation between the elements, the two radiating fields will be in phase in one direction while out of phase in the other. Because the amplitudes of oscillation in each component are different, the combined field expands in one direction while contracting in the other. Because a driven dipole and director alone can only produce a single end-fired beam, it is hypothesized that an additional improvement can be obtained by placing a reflector and director on opposite sides of the driven dipole. This would make it possible to generate multiple end-fired beams. Roughly speaking, this is the current state of affairs. The diploe based Yagi antenna is shown below. Figure 1 depicts a schematic illustration of the proposed dual-band printed Yagi-Uda antenna.

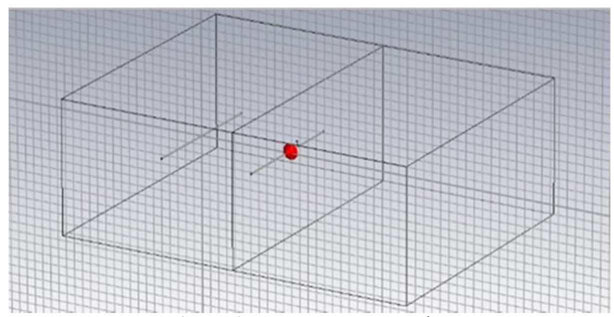

**Figure 1**. YAGI-Antenna Design

The three-element Yagi antenna has a maximum gain of 6 dB at its maximum setting. The longer reflector incorporates an induced current, which generates a wave travelling in the opposite direction of the propagation of the initial wave. This wave's only effect is to cancel out the effect produced by driven elements moving in the opposite direction. Gain is crucial when transmitting with a Yagi or Yagi-Uda antenna because it allows you to concentrate all of your signal in the area where it is needed. Gain is also important when using an antenna for reception, as it allows you to pick up as much of a signal as possible from the area where it was originally broadcast. These two skills are absolutely essential. These are two abilities that must be possessed. As was previously discovered, increasing the Yagi gain concentrates the electromagnetic energy beam. Extremely high-gain antennas are renowned for their exceptional performance in directive communication. The relationship between the gain and beam width of Yagi-Uda antennas' signals.

The front-to-back ratio is an essential factor that must be considered when attempting to reduce coverage or interference in the opposite direction. Unfortunately, due to internal conditions, the antenna must be optimized to achieve maximum forward gain or front-to-back ratio. The total number of elements used in the antenna's construction is one of the most influential factors in determining its gain. When assembling a Yagi antenna, it is customary to attach the reflector to the antenna prior to attaching the remaining components. This is because it has the most potential for further development. Following this, the board of directors is assembled. One can modify the feed impedance of a Yagi antenna using several distinct methods. However, this value differs significantly from what it would be in free space, where the dipole's impedance is calculated to be 73 ohms. This is due to the proximity of parasitic elements, which causes the value to be impacted by their presence. The feed impedance presented by the dipole to the feeder. It is influenced by various factors, including the separation between the dipoles and the length of the dipoles themselves. In reality, adjusting the element spacing has a larger effect on impedance than on gain. As a result, the required feed impedance can be fine-tuned by adjusting the required spacing. This is merely one example: It was discovered that when the distance between adjacent elements is less than 0.2 wavelengths, the impedance decreases significantly. If you wish to increase the impedance of your Yagi antenna, you can employ the time-tested method of folding a dipole.

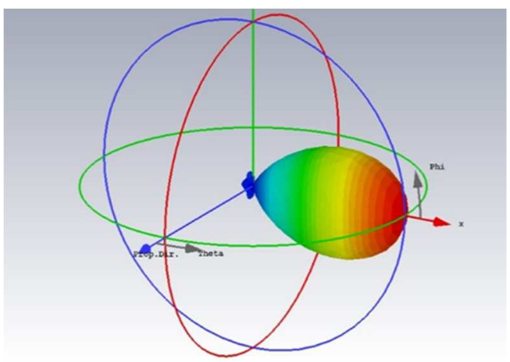


**Figure 2** Far field F=1

Fig. 2. shows the Far field value along with theta differences. Here, the radiation efficiency is 0.9996. The gain leads to 8.508. This will facilitate improved signal reception. It is most frequently found in Yagi antennas, of which the most well-known examples can be found in television and FM broadcasting equipment. The simple folded dipole produces a fourfold increase in impedance enhancement. When exposed to free space, the impedance of a dipole significantly increases. A standard dipole is associated with an impedance of 75 ohms, and a folded dipole is associated with an impedance of 300 ohms. The components of this antenna are a reflector dipole, a curved strip dipole, and a straight strip dipole. This is printed on a fragile and dielectric substrate. Both the arm of the curved strip dipole and the arm of the straight strip dipole reside in the very top metal layer of the structure. There is zero continuity between the two levels.

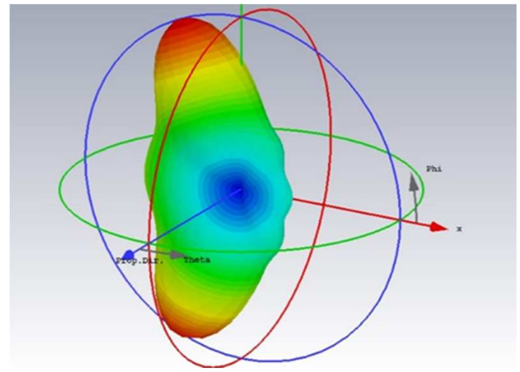


**Figure 3** Far field F=2

The far field value for F=2 is shown is Fig. 3. The radiation efficiency is leaded to 0.9999, but the gain is reduced to 4.056. 1585 MHz and 2650 MHz. The antenna is visually comparable to a standard single-band model. The antenna's top reflector layer was removed to enable operation on both frequencies, and two capacitor-containing strip lines were added to connect the antenna's meandered and straight strip dipoles. All of this was done so that the antenna would function properly in both of these bands. The low-band GNSS antenna has a concave parabolic shape for optimal performance. This is done to keep the antenna compact while still providing the same degree of directivity as would be attained by using a traditional straight reflector. In order for the Yagi antenna to work, the following materials must be used in its assembly: 1 m long, 5 mm wide, aluminium rod with the appropriate dimensions for the job at hand. Each of the five brackets has a diameter of about 7/8 inches and is about 5 millimeters high. These brackets on the pipe boom have been set up to hold everything in place (R, D1, D2, D3, and D4).

The bracket size has a 7/8-inch hole diameter (5 mm). We can get a better DE and gamma match on the pipe boom with the help of this bracket. On top of the chassis, the connector is where you'll find the N chassis connector. The gamma-ray tube and RG8 Coax cable are both located in the same general area. It is possible to generate end-fire radiation from the driven dipole by directing its centre of mass toward the concave parabolic reflector's focal point. To accomplish this, the antenna's footprint must be decreased by adding a meander to the driven dipole. Power is transferred from the initially driven dipole to the shorter director by means of a pair of strip lines in high-band CMMB configurations. The capacitors that are located on the traces serve as matching components for the power. This procedure is carried out in the event that a CMMB setup consisting of a high-frequency band is utilised. It takes place when energy moves from the dipole that is being driven to the dipole that is directing the motion. For this reason, the low-band antenna will no longer use a reflector but rather a driven dipole, and the director from the high-band antenna will take its place. In this case, the power produced by the first driven dipole is sent to the controller.

The midpoints of the GNSS band (1559 to 1610.44 MHz) and the CMMB band, are selected as the design frequencies (2635 to 2660 MHz). The designer determines the length of the two arms of the driven dipole for CMMB or the original director for GNSS. Using a reflector surface in the ground plane, such as an a concave parabolic, the directivity of a Yagi-Uda antenna can be improved. This surface is helpful in directing the flow of energy during radiation in a particular direction. A driven element, a single director, and a concave parabolic reflector are on the ground plane of this planar antenna. The driven dipole consists of two arms, one on the top substrate layer and the other on the ground plane layer beneath it.

## IV. Results And Discussion

The optimized antenna design data is extracted using Machine learning techniques. The newly implemented beam selection path and its many components were thoroughly inspected before release. This research focused on alignment probability and throughput matrices. Several machine learning models have been tested to evaluate beam selection. After that, the forecast was tested by changing the number of simulated vehicles. This work also examines ambiguous aspects of real-world issues. A Cartesian feature set will be encoded if the GPS is reliable. With 85.10% alignment probability, the random forest outperformed the other classifiers. Naive Bayes and gradient boosting have similar throughputs to random forest despite having lower alignment probabilities. Throughput is unaffected by alignment probability. The striking similarity between power beams causes this. The model locates useful beams despite its flaws. To alter the balanced condition, two capacitors, one on each of the top and bottom layers, have been inserted there. This layout's substrate is composed of FR4-epoxy, an inexpensive and widely available material. Having a driven element and concave reflector to the bottom layer on one arm of the director and a concave reflector on the substrate with a height of 0.8 mm produced a loss tangent of 0.02. Two capacitors, one on the substrate and one on the bottom layer, are utilized for matching. With the aid of capacitors, driven elements transmit power signals to directors. Table 1 displays the optimized simulation parameters which are obtained using machine learning techniques.

TABLE I. Antenna Simulators

| Substrate/Parameters | Yagi Antenna |
|---|---|
| Operating Frequency in MHz | 1200 |
| Reflector Length | 0.12375 |
| Dipole Length | 0.11825 |
| Director length | 0.11 |
| Reflector to Dipole Spacing | 0.03125 |
| Dipole to Director Spacing | 0.03125 |
| Boom length [m] | 0.099 |

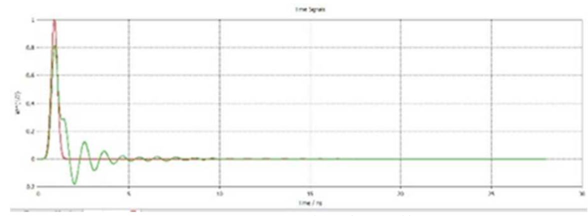

**Figure 4** Port Signal Details

Fig. 4. Shows the port signals values of the Proposed Yagi Antenna. By installing a Yagi Cellular Antenna with a frequency of 800 MHz, the mobile phone's signal strength can be significantly boosted in remote areas. To deploy it in locations where 5G service is already available, the 1200 MHz frequency must be secured.

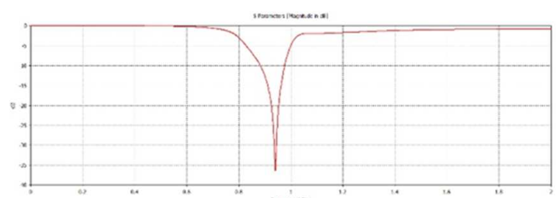

Figure 5 S-Parameters

The S-Parameters of the proposed antenna model is shown in Fig.5. It mainly depends on Reflector Length which is 121 mm and Reflector Position which is 0 mm.

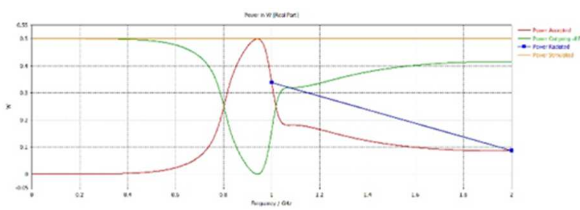

**Figure 6** Radiated Power

Fig. 6. Shows the radiated power of the proposed antenna which is designed using its optimized values. The d/lambda values are 0.040 (min.: 0.002, max.: 0.01).

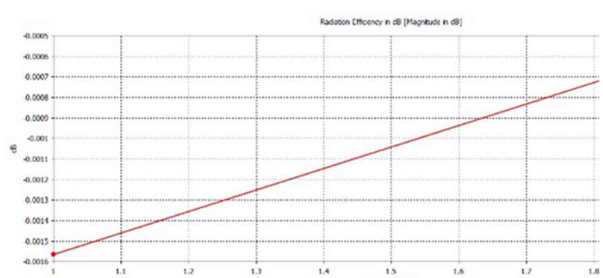

**Figure 7**. Radiating Efficiency

At 1 GHz, the radiated power is very high. But at 2 GHz the radiation efficiency is very high which is shown in Fig. 7.

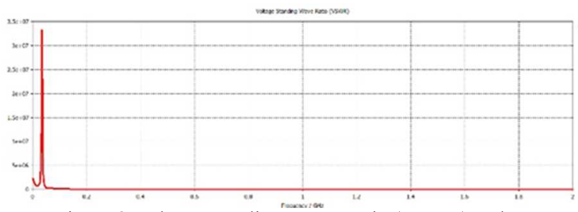

Figure 8 Voltage Standing Wave Ratio (VSWR) Value

In designing antenna, requirement value for Voltage Standing Wave Ratio (VSWR) will be near by 1.5. Figure 8 shows a surface current for 3.5e3 voltage. It is observed that good intensity of current flow is delivered at 1.2 GHz.

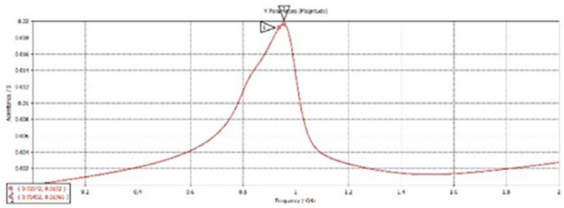

**Figure 9** Y parameters

Fig. 9. Shows the magnitude of Y-parameters in the proposed Antenna. It reached high near 1 GHz frequency. Even though the Eθ values in the Eϕ plane are much larger than those in the H plane, the Eθ values in the H plane are more analogous to the Eϕ plane. There is no difference between the two frequencies, which is true for both. Due to the randomness of environmental polarization, this boost in the cross-polar component is not thought to interfere with wireless communications. As a result, the rise in the cross-polar component is of lesser concern. Although the simulated and measured patterns generally agree, there is some discrepancy around 270 degrees, which may result from the positioner shadowing effect in the experimental setup. Further, there is a discrepancy somewhere around 90 degrees, most likely caused by interference from the feeding cable.

## V. Conclusion

In the suitable parameter settings, the proposed beam selection model employing the RFC (Random Forest Algorithm)-based beam selection scheme can provide a better balance between sum rate and complexity. The optimized values have been achieved using random forests algorithms or deep neural networks, which achieve more accuracy. It has been shown that the proposed Yagi-Uda antenna which is derived using Machine learning techniques with two bands and a thin substrate shall be used in Global positioning systems. The single-band antenna can be turned into a dual-band antenna by removing the reflector from the top layer and adding a pair of strip lines with capacitors on their traces. So, the antenna can use both frequencies at the same time. This change is needed to turn the single-band antenna into a dual-band antenna. To test how well GNSS and CMMB work on two different frequency bands, the proposed antenna has been carefully designed, built, and tested to ensure it works well on both. The transmitting power, radiation, and ability to work on two frequencies make this antenna a good choice for wireless communication systems that need to be quiet. For these kinds of antennas, which can work on both bands at the same time should be smaller in size. A Yagi-Uda antenna can be fine-tuned by changing the lengths of its elements and the distance between them. The reflector and the driven dipole can change the front-to-back ratio of the signal. But the driven dipole changes the antenna's input impedance in a big way.

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