WIDEBAND ANTENNA FOR SHIP RADAR USING DGS

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ABSTRACT
The research aims to design a wideband antenna operating within the S-Band frequency range. The antenna is fabricated using PEC material with a height of 0.035 mm, an FR-4 substrate with a height of 1.6 mm, and PEC material for the ground plane with a height of 0.035 mm. The antenna enumeration system utilizes an insert feeding method. The substrate specification specifies an epsilon value of 4.3. Simulation results reveal a return loss of -12.05 at a frequency of 2.2 GHz, and the antenna operates over a frequency range spanning from 1.68 GHz to 2.4 GHz. This antenna demonstrates a standing wave ratio of 1.67 and a total efficiency of -0.408. Regarding radiation patterns, the main lobe magnitude measures 3.34 dBi, with a main lobe direction of 178 degrees and an angular width (3 dB) of 81 degrees. This antenna boasts an innovative design incorporating a Defected Ground Structure.

Keywords: *Microstrip Antenna (MA), Wideband, DGS (Defected Ground Structure)*

1. INTRODUCTION

The continuous evolution of telecommunications has significantly propelled the advancement of microstrip antennas. This antenna type has experienced rapid progress and is now the preferred option in the modern telecommunications industry. Its benefits, including lightweight design, user-friendly characteristics, compact dimensions, and a straightforward manufacturing process, render it an exceptionally pertinent and effective solution across a diverse spectrum of telecommunications applications. Microstrip antennas have found extensive applications in various telecommunications devices, encompassing smartphones, wireless routers, and satellite equipment, [1]–[4] surveillance equipment, among other applications. Its capacity to consistently provide dependable performance in various environments renders it invaluable for sustaining stable and efficient connectivity within telecommunications systems. However, microstrip antennas have the drawback of having a narrow bandwidth.

Microstrip antennas have the drawback of limited bandwidth and relatively low gain characteristics, making them more suitable for use at higher frequencies. [3]–[8]. In the measurement process, it is frequently challenging to obtain accurate parameters because of the absence of essential equipment, such as Vector Network Analyzers (VNAs), high-frequency spectrum analyzers, high-frequency counters, and an electromagnetic wave interference-free environment. However, with the ongoing advancement of telecommunications technology, microstrip antennas persistently undergo enhancements in design, efficiency, and performance. This evolution positions them as crucial components for achieving swifter, more dependable, and more expansive communication capabilities across various sectors.

Ship radar serves as a critical tool in maritime navigation, employing electronic technology for a range of essential functions, including object detection, distance and speed measurement, mapping, water monitoring, and collision prevention, particularly during docking procedures. Inside the [9], [10] ship's radar system, the antenna plays the main role as a transmitter of electromagnetic waves.

2. ANTENNA DESIGN

The material specifications in the design of this antenna encompass several crucial components that dictate its performance and functionality. The patch antenna employs Perfect Electric Conductor (PEC) material with a height of 0.035 mm, while the substrate consists of FR-4 with a height of 1.6 mm. Additionally, the ground layer utilizes PEC material with a height of 0.035 mm. The feeding system implemented is line feeding.

Furthermore, the substrate specification holds a significant role in this design. The chosen substrate is of the Normal type with an epsilon value of 4.3 and a mu value of 1. The substrate material features an electrical conductivity of 0.025 (Constant Fit) and a thermal conductivity of 0.3 [W/K/m]..

The amalgamation of these materials and substrate specifications plays a pivotal role in attaining the intended performance of these antennas. Making informed choices regarding material selection and substrate configuration is paramount to ensuring the antenna operates efficiently in line with its designated purpose. Consequently, these specifications serve as essential foundations in the successful design and development of the antenna system. They not only influence the antenna's performance but also guarantee that it aligns effectively with the application's requirements.

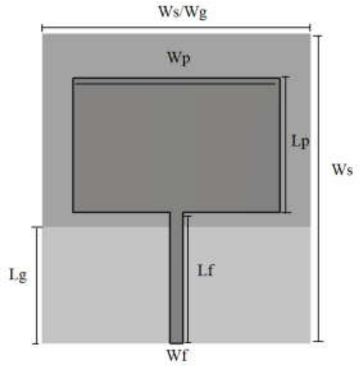

Figure 1 MPA design with *line feeding* enumeration

Figure 1 above depicts a wideband antenna design utilizing PEC material for the ground plane and FR-4 substrate material. In this design, several parameters come into play. The ground width (Wg) and substrate width (Ws) both measure 62 mm, while the ground length (Lg) extends to 27 mm, and the substrate length (Ls) is 72 mm. Furthermore, the substrate has a width (Wp) of 48 mm and a length (Lp) of 31.2 mm. The feeding length (Lf) and feeding width (Wf) are set at 30 mm and 3 mm, respectively. In order to attain the widest bandwidth possible, the ground length is adjusted through a series of experiments in the sweep system model.

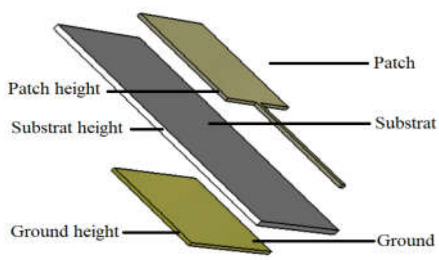

Figure 2 *Three-dimensional wideband* MPA model using *line feeding*

Figure 2 above depicts a three-dimensional representation of a wideband MPA employing the line feeding technique. In this illustration, key components such as the patch, ground, and substrate are clearly visible. The patch measures 0.035 mm in height, while the substrate is 1.6 mm thick, and the ground has a height of 0.035 mm. This image offers a comprehensive visualization of the physical structure of this wideband antenna, showcasing its dimensions and the interplay between its constituent elements. It significantly contributes to comprehending antenna design and aids in the analysis of its performance in diverse wireless communication and radar applications.

Microstrip antennas are characterized by their height (h), width (W), and length (L). When designing a rectangular patch microstrip antenna, the calculations are performed utilizing the following formula:

a. Dimensions of Rectangular Patch MA

In the design of a rectangular patch antenna, it is essential to determine the following dimensions: length (L), width (W), and the height of the substrate material (h), and the dielectric constant of the substrate material (ε_r), Antenna working frequency (f_r) In the design of rectangular patch antenna, the values are expressed in units of Hz, and these values are obtained using equations 1 to 4 [11]–[14].

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$L = L_{eff} - 2\Delta L \quad (2)$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

To calculate the dimensions of the ground plane and substrate, equations 5 and 6 can be employed.

$$L_g = xh + L \quad (5)$$

$$W_g = xh + W \quad (6)$$

L_g is the length of the ground plane and substrate, is the width of the W_g *ground plane* and *substrate* and X is the multiplier factor with a value of ≥6.

b. Supply Channel Width for Rectangular Patch MA

The width of the antenna's feed channel significantly influences the antenna's performance.

As such, it can be determined using equations 7 and 8 [14]–[19].

$$w = \frac{2h}{\pi}\left\{B - 1 - \ln\ln\,(2B-1)\ \frac{Er-1}{2Er}\left[\ln\ln\,(B-1)\ + 0.39 - \frac{0.61}{Er}\right]\right\}$$
(7)

$$B = \frac{60\pi^2}{Zo\sqrt{Er}} \qquad (8)$$

h is the height of the substrate material, is a constant having a value of 3.14π, ε_r. Here, ε represents the dielectric constant of the substrate, while Z denotes the impedance value of the feed line.

3. RESULT AND DISCUSSION

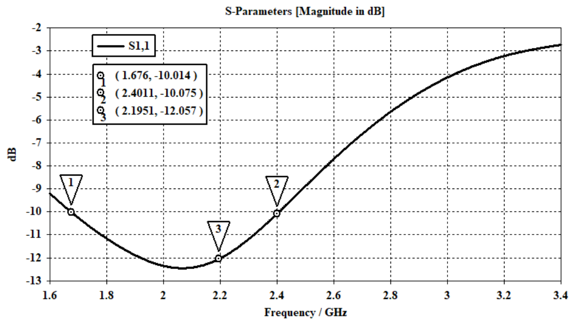

Figure 3 The Return Loss Value of a Wideband MPA with Line Feeding Method

The diagram above illustrates the return loss of a wideband antenna employing PEC as the radiating material and FR-4 substrates. This graph features two axes, namely the x-axis and the y-axis. The x-axis represents the working frequency range spanning from 1.6 GHz to 3.4 GHz, while the y-axis depicts the return loss value. This antenna operates within a frequency range extending from 1.676 GHz to 2.401 GHz. At 2.2 GHz, the return loss is notably -12.057 dB. This data furnishes insights into the antenna's ability to match impedance and its effectiveness in transmitting signals across a variety of frequencies within its operational range. A lower return loss at specific frequencies, such as 2.2 GHz, signifies improved impedance matching and heightened transmission efficiency at those particular frequencies.

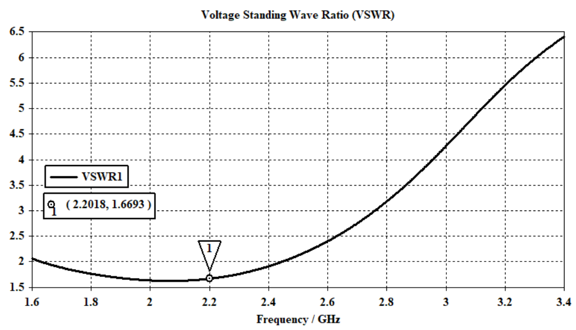

Figure 4 The Standing Wave Ratio Value

Figure 4 above illustrates the Value of Voltage Standing Wave Ratio (VSWR) of the antenna. In this graph, the x-axis represents the working frequency range spanning from 1.6 GHz to 3.4 GHz, while the y-axis displays the VSWR values. Notably, at a frequency of 2.2 GHz, the VSWR registers a value of 1.6693. However, the highest VSWR values are observed near the 3.4 GHz frequency, with values approaching 6.5. This data provides insights into the antenna's ability to match impedance and its efficiency in transmitting signals across various frequencies within its operational range. Lower VSWR values at specific frequencies, such as 2.2 GHz, signify improved impedance matching and enhanced transmission efficiency at those frequencies. Conversely, at 3.4 GHz, higher VSWR indicates an impedance mismatch, potentially affecting antenna performance at that frequency.

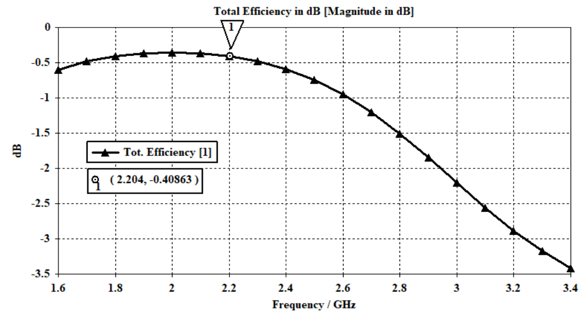

Figure 5 The Total Efficiency of the X-Axis Antenna

In Figure 5 above, you can observe a representation of the total efficiency of the antenna. The x-axis in this chart portrays the ongoing frequency response, while the y-axis signifies the antenna's total efficiency. It's noteworthy that at 2.2 GHz, the antenna's total efficiency is approximately -0.408 dB. This data provides insights into the antenna's ability to convert the received power into emitted power at that specific frequency. Positive efficiency values indicate successful conversion of the majority of received power into emitted power, while negative values, as observed at 2.2 GHz, signify that a small portion of power is inefficiently converted or lost during the process. This efficiency evaluation plays a significant role in assessing the antenna's suitability for a given application at a specific frequency.

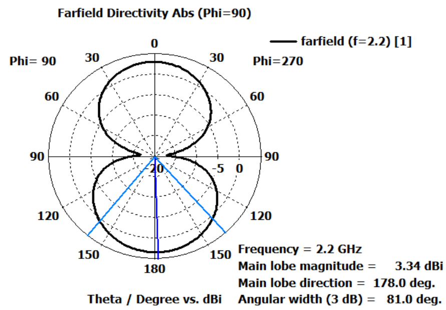

Figure 6 Directivity Graph of the Antenna

Figure 6 above depicts a graph showcasing the directivity of the observed antenna. Within this graph, we can discern the radiation pattern generated by this antenna, which appears to be omnidirectional. An omnidirectional radiation pattern implies that the antenna emits electromagnetic waves uniformly in all directions around it.

The graph also reveals that the magnitude of the main lobe, which is the central part of the radiation pattern, registers at approximately 3.34 dBi. Furthermore, the direction of this main lobe indicates that it is oriented backward by 178 degrees. This observation is intriguing and is associated with the implementation of a radiation pattern referred to as the "Defected Ground Structure" on the antennas.

This defected ground structure seems to mitigate the partial reflection of the electromagnetic field emitted by the patch antenna, resulting in a radiation pattern that points backward. This pattern contributes to the antenna's omnidirectional nature. In this context, comprehending radiation patterns and the impacts of modified ground structures is a pivotal aspect of successful antenna design.

4. CONCLUSION

Based on the study's findings, it can be deduced that the utilization of PEC material and defected ground structure techniques has the potential to enhance the bandwidth of microstrip antennas, particularly at the frequency of 2.2 GHz.

ACKNOWLEDGMENTS

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