DESIGN OF VHF BAND RECTANGULAR MICROSTRIP ANTENNA FOR ROBUST MARINE COMMUNICATIONS

M. Anukeerthana[1], Dr.G.Kavithaa[2]

[1]PG Scholar, Department of Electronics and Communication Engineering, Government College of Engineering – Salem-11, Tamil Nadu, India
[2]Associate Professor, Department of Electronics and Communication Engineering, Government College of Engineering – Salem-11, Tamil Nadu, India

---***---

ABSTRACT: *The research paper presents a rectangular microstrip antenna that was simulated and constructed to improve marine communication demands. This communication antenna performs consistently in harsh maritime environments. This study focuses on designing and optimizing a rectangular microstrip patch antenna for navy applications in the very high frequency (VHF) band. The antenna has a length of 441.6 mm, a width of 563.9 mm, a permittivity of 4.4, and a height of 2.0 mm. The patch and ground plane are made of copper. This uses the High Frequency Structure Simulator (HFSS) software and operates with a return loss of -20.1860 db. The results illustrate an efficient design with good impedance matching and radiation properties, making it a feasible alternative for maritime communication applications. The performance of the patch antenna was evaluated using several antenna characteristics such as return loss (S11), directivity, gain, bandwidth, VSWR radiation pattern, antenna efficiency, and input impedance.*

Keywords: ANSYS HFSS (high-frequency structure simulator), (VSWR) voltage standing wave ratio, (VHF) Very high frequency, (MHz) megahertz, (RL) return loss, (RPA) rectangular microstrip patch antenna, (FR4) flame retardant for woven glass reinforced epoxy resin.

1. INTRODUCTION

An antenna is a transmitter that converts electrical signals to electromagnetic waves and vice versa. An antenna is a device designed to broadcast or receive electromagnetic waves successfully. It is often composed of conductive materials such as metal rods, wires, or printed circuits that interact with the electromagnetic field to achieve the intended transmission or reception. Microstrip antennas were first introduced in the 1950s. However, it took almost 20 years for this vision to become a reality, with the introduction of printed circuit board (PCB) technology in the 1970s. Because of their small size, microstrip antennas have found use in a variety of civilian and military applications, including radio-frequency identification (RFID), broadcast radio, mobile systems, vehicle collision avoidance systems, satellite communications, surveillance systems, direction finding, radar systems, marine communication remote sensing, missile guidance, and others. In microstrip antenna research, a new trend or solution emerges in which researchers try to increase bandwidth by incorporating new features into the antenna form. Demand for broadband, low-profile, and small antennas has grown dramatically in recent years due to the widespread deployment of wireless communication technology. Because of its low profile, light weight, and affordable price, the microstrip patch antenna has been suggested as a solution to meet the requirements. Marine communication is a critical component of maritime operations, ensuring the safety, coordination, and efficiency of activities at sea. The maritime industry relies heavily on robust and reliable communication channels to connect ships with each other and with shore-based facilities. Effective VHF antennas are greater in demand because of the increasing significance of dependable marine communication, especially in navigation, safety, and search and rescue operations. Because of its small size, lightweight, and durability, this paper focuses on the design and optimization of a rectangular microstrip patch antenna for marine communication at 156 MHz, a standard frequency for VHF maritime radio systems. The FR4 epoxy substrate provides a good blend of cost-effectiveness, mechanical durability, and acceptable dielectric characteristics, with a relative permittivity (εr) of 4.4 and a thickness of 2.0 mm.

Table-1: Marine application frequency bands

Frequency Band	Range	Primary Applications
VHF -Very High Frequency	30 - 300 MHz	Distress and safety communication (e.g., Channel 16 on 156.800 MHz), inter-ship communication, port operations, and bridge-to-bridge communication. Channels 6, 13, and 70 are often used
HF -High Frequency	3 - 30 MHz	wide-range communication, including ship-to-shore and intership

		communication over great distances, GMDSS (Global Maritime Distress and Safety System) frequencies, such as 2182 kHz for distress and safety.
MF -Medium Frequency	300 - 3000 kHz	Frequencies such as 2182 kHz are mostly utilized for distress and safety communication on ships. Also used for navigation and coastal communication.
LF -Low Frequency	30 - 300 kHz	Used for navigational aids, especially marine nautical beacons, and occasionally for maritime communication in specific zones.
UHF -Ultra High Frequency	300 - 3000 MHz	Typically utilized for port operations, on-board communications, and some specific applications such as navigational aids and digital communication systems.

VHF (Very High Frequency) is superior for marine communication to other frequency bands due to severalof major features. To begin, VHF delivers optimal range and clarity, allowing for smooth voice communication at distances of up to 20-30 miles while being less influenced by atmospheric noise and interference. VHF signals' line-of-sight propagation is suitable for broad seas with low obstructions, making them useful for both ship-to-ship and ship-to-shore communications. VHF radios also offer special distress and safety channels, such as Channels 16 and 70, which allow for speedy and dependable communication during an emergency. In addition, VHF radios are small, power-efficient, and appropriate for many types of watercraft, from small boats to huge ships. VHF is required by international maritime laws, particularly those of the International Maritime Organization (IMO), to provide uniformity and interoperability among vessels worldwide. Finally, VHF is less congested than lower frequency bands, resulting in more dependable transmission without interference. These properties make VHF the best choice for naval communication, since it successfully balances range, clarity, and reliability.

2. OBJECTIVE

The primary objective of this paper is to create a highly efficient and dependable rectangular microstrip patch antenna for marine communication at 161.77 MHz. The ultimate goal is to improve the reliability and efficiency of marine communication, which will improve global maritime safety, coordination, and operational efficiency. This study seeks to present a reliable, cost-effective antenna solution that may be widely used, thereby contributing to the growth of marine communication technology.

3. DESIGN SOFTWARE

ANSYS HFSS is a 3D electromagnetic (EM) simulation software that allows you to design and simulate high-frequency electronic devices such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages, and printed circuit boards. Ansys HFSS software is used by engineers all around the world to design high-frequency, high-speed circuits for communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) products. ANSYS HFSS (High-Frequency Structure Simulator) is a powerful simulation tool used to build and analyze high-frequency electromagnetic structures in industries such as telecommunications, aerospace, defense, and electronics. It offers 3D full-wave electromagnetic field simulation utilizing the finite element technique (FEM) to accurately model complicated structures such as antennas, RF/microwave components, PCBs, and IC packages. HFSS contains powerful optimization tools, S-parameter analysis, and full-wave and eigen mode solvers, making it critical for understanding the performance of RF and microwave devices. It works smoothly with other ANSYS tools and third-party software, providing a streamlined workflow for multiphysics simulations that combine electromagnetic, thermal, and structural assessments. HFSS uses high-performance computing (HPC) capabilities to efficiently handle large-scale models. Its applications include antenna design and optimization, analysis of signal integrity, power integrity, and electromagnetic interference (EMI) in PCBs and IC packages, and the development of wireless communication systems such as 5G and satellite communications. The software ensures that the design process is accurate, reliable, and efficient, eliminating the need for physical prototypes and experiments and, as a result, lowering development costs and promoting innovation in high-frequency domains.

4. PROPOSED DESIGN METHDOLOGY

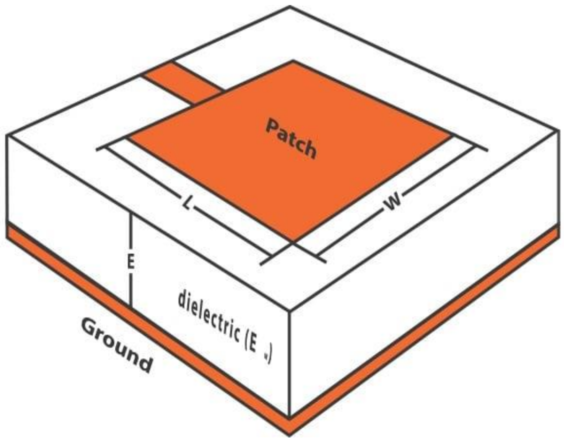

Fig-1 Microstrip patch antenna

4.1 SHAPE OF DESIGN

A rectangular microstrip patch antenna is ideal for marine applications due to its small size, lightweight design, and ability to be easily fitted into vessel surfaces. These antennas are frequently used in communication systems for navigation, ship-to-ship and ship-to-shore communication, as well as satellite communication. A rectangular microstrip patch antenna for marine applications consists of a copper or other conductive metal patch attached on one side of a dielectric substrate. The substrate, which divides the patch from the ground plane on the opposite side, is typically constructed of marine-compatible materials such as FR4 or Rogers. The ground plane acts as a reference and directs the radiation from the patch. The antenna is powered by a microstrip line or coaxial probe, which excites the patch and detects the input impedance. The rectangular microstrip patch antenna's low profile allows it to be easily fixed on the vessel's deck, mast, or other elements without severely affecting aerodynamics or adding weight. Its ease of production and integration with existing marine communication systems make it an excellent alternative for improving ship navigation, safety, and communication capabilities.

4.2 FEEDING TECHNIQUE OF THE DESIGN

Edge feeding is a typical approach for activating a rectangular microstrip patch antenna, which is especially useful in marine applications where space and integration are crucial. In this method, the feed mechanism, such as a microstrip line or coaxial probe, is placed along the edge of the rectangular patch. This method allows for more efficient signal coupling and impedance matching, which is critical for improving antenna performance. Edge feeding contributes to a wider bandwidth and improves the antenna's radiation properties, making it appropriate for reliable marine communication. Its design advantages include a small footprint and ease of installation, making it perfect for ships with limited room. Furthermore, choosing proper substrate materials and protective coatings guarantees that the antenna can endure harsh marine circumstances, such as seawater exposure.

Table-2: Dimensions of proposed antenna

Name of the parameters	Length
Length of the Substrate (Ls)	563.9 mm
Width of the Substrate (Ws)	441.6 mm
Length of the Patch (Lp)	883.2 mm
Width of the Patch (Wp)	1127.8 mm
Relative permittivity of the substrate (FR4), εr	4.4mm
Height of the Substrate (H_s)	2.0mm
Length of the Feedline (L_f)	-211.5mm
Width of the Feedline (W_f)	5mm
Width of the Ground (Wg)	1127.8 mm
Length of the Ground (Lg)	883.2 mm

5. DESIGN EQUATION OF RECTANGULAR MICROSTRIP PATCH ANTENNA

$C = 3 \times 10^8$
$fo = 161.770$ MHz

5.1 DESIGN FORMULA

Width of the patch,

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}} \quad [1]$$

Length of the patch,

$$Length = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right) \quad [2]$$

Width of the Substrate,

$W_s=6h+w$ [3]

Length of the Substrate

$L_S = 6h + L$ [4]

Length of the Ground

$L_g =$ L+6h [5]

Width of the Ground

W_g=w+6h [6]

Where,

c is the velocity of light

f_0 is resonant frequency,

εr is the relative permittivity

εreff is the effective relative permittivity,

h height of substrate

W is the width of the substrate.

5.2 DESIGN CALCULATION OF PROPOSED ANTENNA

From the equation [1], Width of the patch, W_p = 563.9 mm

From the equation [2], Length of the patch, L_p = 441.6 mm

From the equation [3], Width of the substrate, W_s = 1127.8 mm

From the equation [4], Length of the substrate, L_s = 883.2 mm

From the equation [5], Width of the ground, W_g=1127.8 mm

From the equation [6], Length of the ground, L_g= 883.2 mm

Width of the feedline, W_f = 5 mm

Length of the feedline, L_f =-211.5 mm

Height of the substrate, H_s =2.0mm

Relative permittivity of the substrate (FR4), εr= 4.4

6. PROPOSED ANTENNA DESIGN

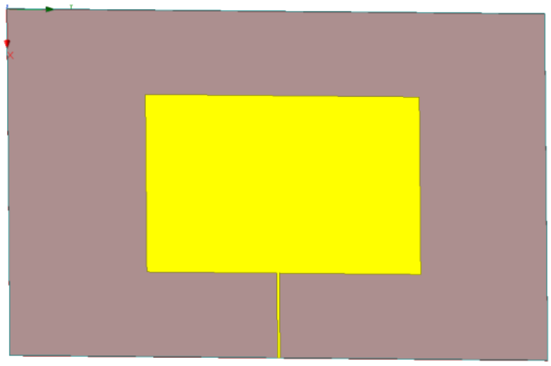

Fig-2 Top view of marine antenna design

The design of a rectangular microstrip patch antenna at the operating frequency of 161.77 MHz in very high frequency (VHF) using FR4 epoxy substrate. The patch has a length of 441.6 mm, a width of 563.9 mm, permittivity of 4.4, and a height of 2.0 mm sandwiched between the patch and ground plane made up of copper.

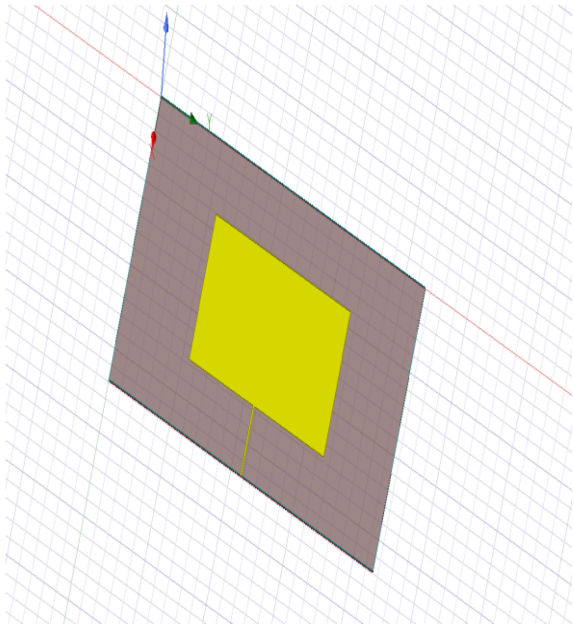

Fig-3 3D View of RPA marine antenna design

7. RESULT IN HFSS SOFTWARE

Right-click on the project manager results. Choose to generate a data report for Modal Solutions. Decide on a rectangle plot. After selecting the S parameter, click S(1,1) and then dB. Choose "New Report." It shows a return loss plot. Plots are created in the same manner for VSWR, gain, directivity, and radiation pattern.

7.1 RETURN LOSS

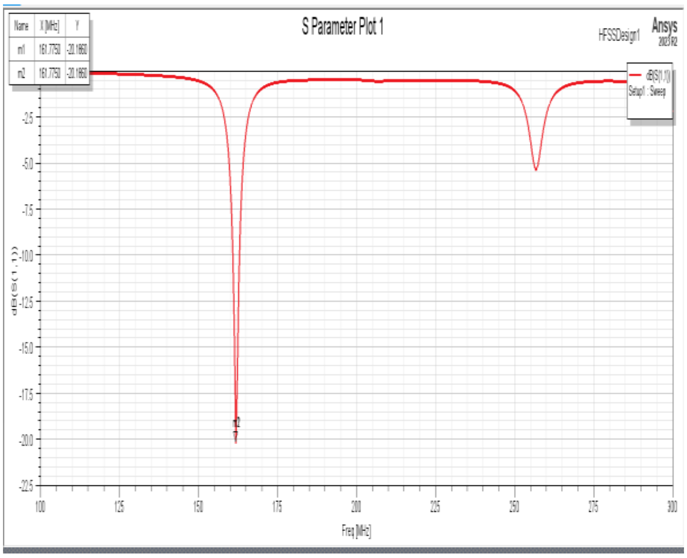

Fig-4 Return loss

Return Loss (s11) Importance: Lower return loss indicates better impedance matching, which means more power is transmitted while less is reflected. Typical values: A return loss of -10 dB or less (more negative) is usually considered satisfactory. Proposed return loss: This antenna's return loss was -20.1860 db.

7.2 VOLTAGE STANDING WAVE RATIO

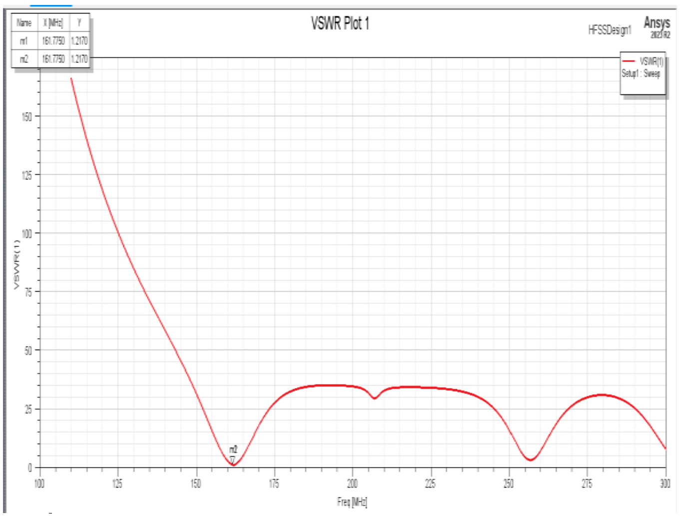

Fig-5 Voltage standing wave ratio

VSWR (Voltage Standing Wave Ratio) Importance: VSWR is defined as the ratio of maximum voltage to minimum voltage in a standing wave pattern on a transmission line. It is commonly stated as a ratio, such as 2:1, or as a single number, like 2. The optimum VSWR is one, indicating perfect impedance matching with no reflected power. VSWR is proportional to the reflection coefficient (Γ), which is the percentage of incident power reflected back from the load. VSWR is critical for achieving efficient power transfer and avoiding power loss. High VSWR can cause power loss, signal distortion, and transmitter damage. Typical values:

Lower VSWR implies better matching, with a value ranging from 1 to 2.

7.3 SMITH CHART:

A Smith Chart is a graphical representation used to solve problems involving transmission lines and matching circuits. It represents the plot of complex reflection coefficients (S11) or impedance.

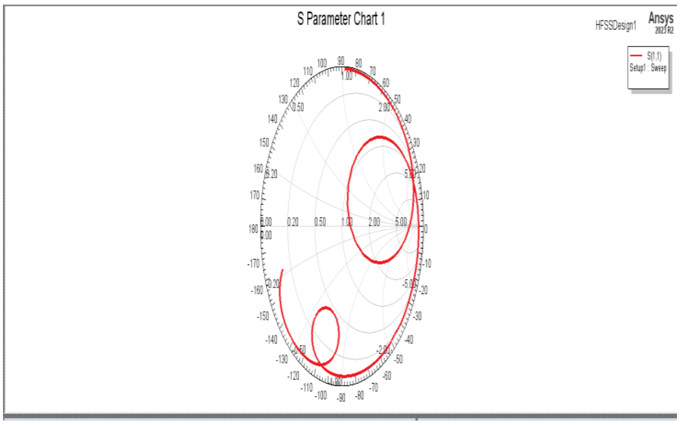

Fig-6 Smith chart

7.4 3D POLAR PLOT OF GAIN

Fig-7 3D polar plot of gain

This graphic illustrates the antenna gain in three dimensions, demonstrating how power is emitted in various directions. It provides a full perspective of the antenna's directional characteristics, allowing you to better comprehend its performance in real-world circumstances.

7.5 DIRECTIVITY PLOT

Directivity show concentrated the antenna's radiation is in a specific direction. Higher directivity means that more power is radiated in one direction, making the antenna more directional.
Units: Directivity is generally measured in dBi.

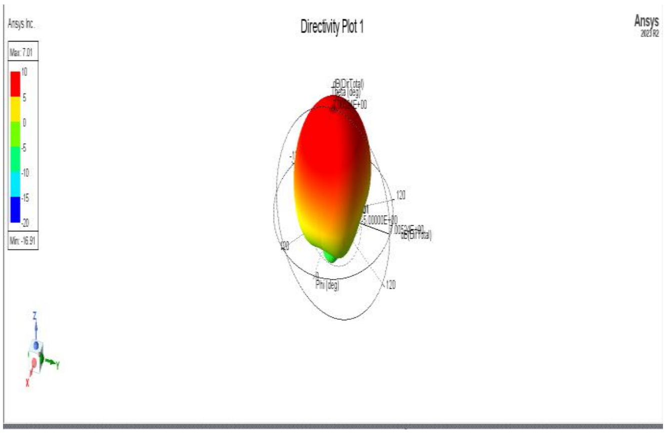

Fig-8 Directivity plot

7.6 GAIN

Gain is a measure of how much power is transmitted in one direction versus an isotropic antenna (which radiates equally in all directions). Gain often is stated as dBi.

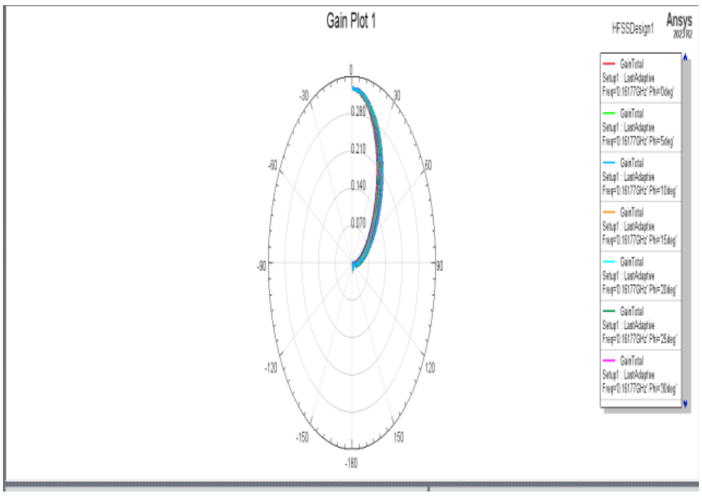

Fig-9 Gain

7.7 E-FIELD AND H- FIELD RADIATION PATTERN OF THE ANTENNA

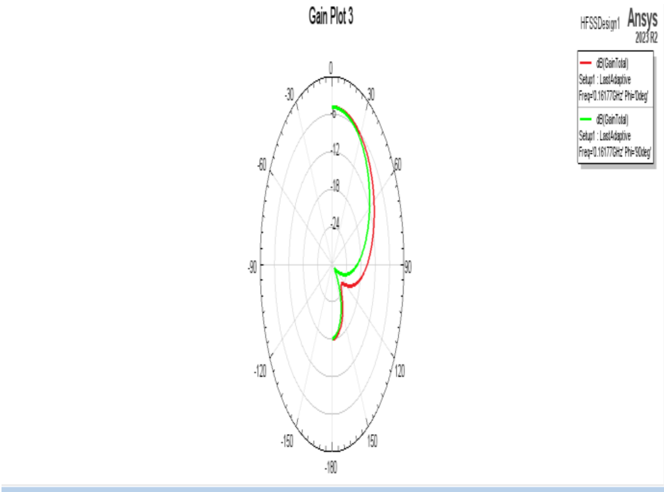

Fig-10 E-field and H- field radiation pattern of the antenna

E-field (Electrical Field) Radiation Pattern:
This figure depicts the distribution of electric field strength surrounding the antenna. It shows how the electrical field radiates from the antenna, which is important for understanding polarization and radiation properties. A shade of red indicates an electrical field in specific direction.

H-field (magnetic field) Radiation Pattern:

This figure displays the distribution of magnetic field strength around the antenna. It complements the E-field pattern and is critical to understanding the antenna's overall radiation properties. The shade of green represents a magnetic field.

8. CONCLUSION

The design and simulation of a rectangular microstrip patch antenna tailored to VHF marine communication offer promising results for upgrading maritime communication systems. The return loss of -20.1860 dB shows a good impedance match between the antenna and the feed line, reducing reflected power and ensuring efficient transmission. A VSWR of 1.21 is close to the ideal value of one, suggesting that the antenna is properly matched to the transmission line, resulting in little signal loss and great efficiency. The antenna's impedance matching, radiation pattern, and gain at VHF frequencies are optimized through careful selection of substrate materials, patch design, and feed mechanisms, allowing for reliable communication over long distances.

REFERENCES

[1] F. S. Alqurashi, A. Trichili, N. Saeed, B. S. Ooi and M. -S. Alouini, "Maritime Communications: A Survey on Enabling Technologies, Opportunities, and Challenges," in *IEEE Internet of Things Journal*, vol. 10, no. 4, pp. 3525-3547, 15 Feb.15, 2023, doi: 10.1109/JIOT.2022.3219674.

[2] W. An, H. Wang, J. Wang, Y. Luo, K. Ma and J. Ma, "Low-Profile Wideband Microstrip Antenna Integrated With Solar Cells," in *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 9, pp. 8530-8535, Sept. 2022, doi: 10.1109/TAP.2022.3188647.

[3] L. Xing *et al.*, "A High-Efficiency Wideband Frequency-Reconfigurable Water Antenna With a Liquid Control System: Usage for VHF and UHF Applications," in *IEEE Antennas and Propagation Magazine*, vol. 63, no. 1, pp. 61-70, Feb. 2021, doi: 10.1109/MAP.2019.2946556.

[4] M. Pehlivan and K. Yegin, "X-Band Low-Probability Intercept Marine Radar Antenna Design With Improved Bandwidth and High Isolation," in *IEEE Transactions on Antennas and Propagation*, vol. 69, no. 12, pp. 8949-8954, Dec. 2021, doi: 10.1109/TAP.2021.3096952.

[5] W. Kim *et al.*, "Ferrite-Loaded, Low-Profile Grounded Bowtie-Loop Antenna for VHF Communication," in *IEEE Antennas and Wireless Propagation Letters*, vol. 22, no. 12, pp. 3132-3136, Dec. 2023, doi: 10.1109/LAWP.2023.3311965.

[6] I. G. A. K. Diafari D.H., I. Made Oka Widyantara, D. M. Wiharta, P. Ardana and N. Pramaita, "Design and Simulation of Log Periodic Dipole Array Antenna for 162 MHz AIS receiver," *2021 International Conference on Smart-Green Technology in Electrical and Information Systems (ICSGTEIS)*, Sanur, Bali, Indonesia, 2021, pp. 136-141, doi: 10.1109/ICSGTEIS53426.2021.9650382

[7] H. Jia and P. X. . -L. Feng, "Very High-Frequency Silicon Carbide Microdisk Resonators With Multimode Responses in Water for Particle Sensing," in *Journal of Microelectromechanical Systems*, vol. 28, no. 6, pp. 941-953, Dec. 2019, doi: 10.1109/JMEMS.2019.2920329.

[8] GozalNurRamaditya and YulisdinMukhlis, "Design And Manufactured Of Lpda Antenna At 400 Mhz - 800 Mhz Frequency And Its Implementation On Television Antenna", *JEEMECS*, vol. 2, no. 2, pp. 25-29, August 2019.

[9] Y. -H. Qian and Q. -X. Chu, "A Broadband Hybrid Monopole-Dielectric Resonator Water Antenna," in *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 360-363, 2017, doi: 10.1109/LAWP.2016.2577049.

[10] H. Liang, M. Yao and Q. Zhu, "Design of a fractal antenna for marine rescue," 2016 IEEE International Symposium on Antennas and Propagation (APSURSI), Fajardo, PR, USA, 2016, pp. 275-276, doi: 10.1109/APS.2016.7695846.

[11] C. Hua, Z. Shen and J. Lu, "High-Efficiency Sea-Water Monopole Antenna for Maritime Wireless Communications," in *IEEE Transactions on Antennas and Propagation*, vol. 62, no. 12, pp. 5968-5973, Dec. 2014, doi: 10.1109/TAP.2014.2360210.

[12] F. Bass, I. Fuks, A. Kalmykov, I. Ostrovsky and A. Rosenberg, "Very high frequency radiowave scattering by a disturbed sea surface Part I: Scattering from a slightly disturbed boundary," in *IEEE Transactions on Antennas and Propagation*, vol. 16, no. 5, pp. 554-559, September 1968, doi: 10.1109/TAP.1968.1139243.

[13] M. L. Parkinson, "Observations of the broadening and coherence of MF/lower HF surface-radar ocean echoes," in *IEEE Journal of Oceanic Engineering*, vol. 22, no. 2, pp. 347-363, April 1997, doi: 10.1109/48.585954.

[14] A. Scorzolini, V. De Perini, E. Razzano, G. Colavolpe, S. Mendes, P. Fiori, et al., "European enhanced space-based AIS system study", *2010 5th Advanced Satellite Multimedia Systems Conference and the 11th Signal Processing for Space Communications Workshop*, pp. 9-16, 2010.

[15] P. Last, M. Hering-Bertram and L. Linsen, "How automatic identification system (AIS) antenna setup affects AIS signal quality", *Ocean.Eng.*, vol. 100, pp. 83-89, 2015.

[16] Vijay S. Kale and Dnyandev B. Patil, "Software Development and Construction of Log Periodic Dipole Antenna Using MATLAB", *International Journal Of Innovative Research In Electrical Electronics Instrumentation And Control Engineering*, vol. 3, no. 12, pp. 83-87, December 2015.

[17] Z. M. Abdullahi and K Ahmad, "Design And Simulation Of High Gain Log Periodic Dipole Array Antenna", *Bayero Journal Of Engineering And Technology (Bjet)*, vol. 13, no. 2, pp. 28-36, August 2018.

[18] Glen Dash, "Designing Log Periodic Antennas", *GlenDash at alum.mit.edu Copyright 2000 2005 Ampyx LLC*.

[19] C. A Balanis, Antenna Theory Analysis And Design, New Jersey:John Wiley & Sons., 2005.

[20] Y. Kosta, "Liquid antenna", *IEEE AP-S Int. Symp. Dig.*, vol. 3, pp. 2392-2395, 2004-Jun.

[21] H. Fayad and P. Record, "Wideband saline-water antenna", *Proc. Inst. Electr. Eng. Wideband and Multi-band Antennas and Arrays Conf.*, pp. 197-201, 2005.

[22] H. Fayad and P. Record, "Broadband liquid antenna", *Electron. Lett.*, vol. 42, no. 3, pp. 133-134, 2006.

[23] E. Paraschakis, H. Fayad and P. Record, "Ionic liquid antenna", *Proc. IEEE Int. Workshop Antenna Tech.: Small Antennas and Novel Metamaterials*, pp. 552554, 2005.