ECE4871 – Culminating Design Project

Evaluation Form – Technical Background Review

Student Name: Mohammed Deafalla

Project Advisor: Dr. Nima Ghalichechian

Team Name: Low-cost VHF Antenna

Team Members: Kenneth Holder, Seidi Kartal, Seunghwan Lee, Sanket Sane

_______ / 30

Technical Content

- Current state-of-the-art and commercial products
- Underlying technology
- Implementation of the technology
- Overall quality of the technical summary

_______ / 30

Use of Technical Reference Sources

- Appropriate number of sources (at least six)
- Sufficient number of source types (at least four)
- Quality of the sources
- Appropriate citations in body of text
- Reference list in proper format

_______ / 40

Effectiveness of Writing, Organization, and Development of Content • Introductory paragraph

- Clear flow of information
- Organization
- Grammar, spelling, punctuation
- Style, readability, audience appropriateness, conformance to standards

_______ / 100 Total - Technical Review Paper

Operating Frequency for Low Frequency Radar Antenna

Introduction

An important consideration when designing an antenna is the frequency at which that antenna will operate. The frequency influences parameters such as the transmit power, range, and physical size of the antenna [1]. These parameters play a role in two others: the antenna's performance and cost, making the operating frequency a key property that needs to be carefully chosen. There exists a motivation to operate radar antennas at low frequencies because these antennas can subvert the stealth technology used against higher frequencies. While lower frequency antennas come with the disadvantage of larger structures, they are more equipped to detect targets with low radar cross-sections [2]. This paper reviews existing low frequency radar antennas, the motivation behind their usage, and how their creators handled any drawbacks.

Commercial Applications for Low Frequency Antennas

Due to the classified nature of many applications of low frequency radars, it is difficult to locate and provide details about their specifications and cost. However, applications of low frequency antennas are widespread, particularly in marine vehicles.

In the case of marine vehicles, low frequency antennas are used to receive and send radio signals for communication [3]. While there are stark differences between antennas created for the purpose of radar and those used for radio, there are several elements of marine antennas that can be taken into consideration when designing a radar antenna. Like radar, marine antennas need to be omnidirectional, propagating signals in all directions. Although antennas operating in low frequency bands such as VHF are large, marine antennas are limited in the size a boat can hold. Because of this, steps need to be taken to maintain the effectiveness of a VHF antenna while keeping the size small enough to fit on a boat. One popular marine antenna is Shakespeare's Galaxy 5400-XT. This antenna operates in the VHF band with a length of 4ft (1.22m) and a gain of 3dB costing $179.99 [4]. Similar to the 5400-XT, is Shakespeare's Mariner 8700 which also operates in the VHF band. However, the 8700 is double the length at 8ft (2.44m), and a gain of 6dB and a price of $179.99 [5].

Another antenna operating in the upper UHF band is RAK's 860-930MHz LoRa Antenna. The LoRa antenna, with a price of $35, has a length of 0.8m, and a gain that changes with frequency. [6] portrays how the gain decreases with frequency, with the 860MHz operating frequency having a gain of 5.1dB. When comparing RAK's antenna to Shakespeare's, two relationships can be concluded: the gain of an antenna decreases as operating frequency decreases, while the length of the antenna increases.

Technology of Low Frequency Radars

Like most radars, low frequency radars have low gain. With a low gain, antennas achieve omnidirectionality that allows signal propagation in a wide area [7]. What sets apart low frequency radars from more typical radars at higher frequencies is their ability to use resonance to detect and track objects with low radar cross-sections. Low frequency radars are characterized by the electromagnetic bands in which they operate. Typically, these bands are UHF, VHF, and HF, which correspond to frequencies of 3MHz-3GHz and wavelengths of 0.1-100m [8]. The cross-sections of many objects of interest fall within or near this wavelength range. If the wavelength of the antenna is chosen to be approximately double the target's cross-section, the resonance from the relationship creates larger signals returning to the radar [9]. The resonance provided by low frequency radars provides an incentive to utilize them for detection and tracking of stealth aircraft, especially for those aircraft that can escape detection from higher frequencies [10].

Depending on the antenna type and radiation pattern, the physical size of low frequency antennas can be very large. A half-wave antenna operating at 30MHz would be 5m in diameter. An infinitesimal dipole would allow greater flexibility in choosing the antenna's size. However, due to the radiation resistance associated with an infinitesimal dipole, the antenna would have a reflective efficiency of only 2.4% [7].

Special consideration needs to be taken when selecting an operating frequency so that the antenna does not interfere with any other systems operating at that particular frequency. To aid in the selection, the National Telecommunications and Information Administration provides data on the allocations of frequency across the radio spectrum [11]. By looking at [11], frequencies between 54 and 72MHz are reserved for television broadcasting, so the usage of an antenna at that frequency has the potential to both interfere with others as well as be interfered with.

Implementation of Low Frequency Radars

An antenna is just one part of a radar system that works in tandem with the other components. The antenna requires a modulator and a demodulator so that a signal can be transmitted and received signals can extract information about range and speed. In addition to this, a power supply is needed to transmit power to the antenna and the processing unit implementing the modulation. A transmission line then connects the power supply to the antenna. The characteristic impedance of the transmission line depends on both the wavelength and input impedance of the antenna [7]. By matching the characteristic impedance, the antenna's radiated power is maximized.

[1] G.W. Stimson, *Introduction to Airborne Radar*, 3rd ed. Mendham, NJ, USA: SciTech Publishing, 2014, pp. 83-86.

[2] N. Balal, Y. Balal, Y. Richter, and Y. Pinhasi. "Detection of Low RCS Supersonic Targets with a High Resolution MMW Radar," *Sensors (Basel)*, vol. 20. Jun. 9, 2020. [Online] Available: doi:10.3390/s20113284.

[3] T. Burden. "Selecting a VHF Antenna," *westmarine.com*, Aug. 21, 2019. [Online]. Available: https://www.westmarine.com/WestAdvisor/Selecting-a-VHF-Antenna. [Accessed: Oct. 4, 2021]

[4] West Marine. "SHAKESPEARE – 5400-XT 4' Galaxy Little Giant VHF Marine Band Antenna," *westmarine.com*. [Online]. Available: https://www.westmarine.com/buy/shakespeare--5400-xt-4-galaxy-little-giant-vhf-marine-band-antenna--1186097. [Accessed: Oct. 4, 2021]

[5] West Marine. "SHAKESPEARE – Mariner 8700 Extra Tough 8' 6dB VHF Antenna," *westmarine.com*. [Online]. Available: https://www.westmarine.com/buy/shakespeare--mariner-8700-extra-tough-8-6db-vhf-antenna--6966063?recordNum=6. [Accessed: Oct. 4, 2021]

[6] RAK Wireless, 860-930MHz 5.8dBi Fiberglass LoRa Antenna Specification. Jun. 25, 2019. [Online]. Available: https://downloads.rakwireless.com/Accessories/Antenna/Fiberglass-Antenna/RAK_860-930MHz_5.8dBi_Fiberglass_Antenna_Specification.pdf

[7] N. Ghalichechian. ECE 4370. Class Lecture, Topic: "Introduction to Antennas", School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, Aug. 18, 2021.

[8] C.A. Balanis, *Antenna Theory: Analysis and Design*, 4th ed. Hoboken, NJ, USA: Wiley, 2016, p. 235.

[9] C. Mantovani, L. Corgnati, J. Horstmann, A. Rubio, E. Reyes, C. Quentin, S. Cosoli, J. L. Asensio, J. Mader, and A. Griffa, "Best practices on high frequency radar deployment and operation for ocean current measurement," Frontiers, Apr. 9, 2020. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fmars.2020.00210/full. [Accessed: 04-Oct-2021].

[10] TNI Staff. “Could Low-Frequency Radars Become The F-35 And F-22's Achilles Heel?” *nationalinterest.org*, May 28, 2020. [Online]. Available: https://nationalinterest.org/blog/reboot/could-low-frequency-radars-become-f-35-and-f-22s-achilles-heel-158151. [Accessed: Oct. 4, 2021]

[11] National Telecommunications and Information Administration, “United States Frequency Allocations: The Radio Spectrum,” *National Telecommunications and Information Administration*, January 2016. [Online] Available: https://www.ntia.doc.gov/files/ntia/publications/january_2016_spectrum_wall_chart.pdf. [Accessed: Oct. 4, 2021]