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Analysis of the influence of superstructure elements on the mutual coupling of shipboard antennas

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Abstract. Reducing the mutual coupling between the antennas installed on board the ship is an important element in ensuring the electromagnetic compatibility of the transmitters and receivers. The paper analyzes the influence of superstructure elements on the mutual coupling of antennas considering that any metal line or superstructure element can become radiant element and can influence the radiation pattern of an antenna.

1. Introduction

The safe navigation of a ship involves the operation of the equipment installed on board (radar, radiocommunication equipment, satellite communications, NAVTEX, etc.) at maximum performance. The installation of this equipment on board a ship is carried out on the basis of:

- compliance with the installation rules provided by the equipment manufacturer to ensure / maintain intra-system compatibility;
- compliance with the requirements of the standards for ensuring electromagnetic compatibility on board ships.

The first requirement for the installation of equipment on board a ship is that it be produced and tested in accordance with the applicable electromagnetic compatibility standards, therefore including a certificate of conformity issued by a notified body.

Equipping the ship with the equipment necessary to ensure safe navigation also requires the installation of antennas or antenna systems specific to these equipment, a process that begins in the design phase of the ship in order to ensure the electromagnetic compatibility of the equipment on board.

Equipment must be installed on board a ship in such a way as to meet the requirements of SOLAS '74 for ensuring electromagnetic compatibility as well as the requirements of applicable international standards and IMO regulations for electromagnetic compatibility [20, 21, 26]:

- be installed in such a way that electromagnetic disturbances do not affect their operation;
- be so installed as not to interfere with the operation of other electronic, electrical or navigational equipment on board the ship;
- be installed to ensuring high operational availability;
- by installing the equipment on board to ensure the protection of the magnetic compass and the gyrocompass (unless otherwise specified the minimum distance from the magnetic compass must be at least 700 mm, the spare parts of a radiocommunication equipment must be stored at a

distance of at least 1 meter and, for example, a marine computer must not be installed at a distance of less than 1.5 meters from the magnetic compass [16, 26].

Equipment antennas must be installed in such a way that they:

- reduce the mutual coupling between them (between transmitting and receiving antennas);
- ensure adequate separation from the superstructure of the ship;
- shield of the connecting cables of the receiving antennas, cables that are in the radiation zone of the transmitting antennas (shielded / feeder connection cables will be installed in an additional screen or will be double-shielded heads);
- use non-metallic materials for the superstructure elements that protect the antennas;
- make the connection to the protective earth of the superstructure elements (masts, strays, yardarms, etc.) that are in the radiation zone of the emission antennas.

The metallic, superstructure elements of the ship that are in the radiation zone of an antenna become secondary radiator, causing the appearance of intermodulation interference (hull generated intermodulation interference - IMI). Regarding hull-specific intermodulation interference, the MIL-STD-464C standard stipulates that the requirements for intra-system electromagnetic compatibility are met when interference products are greater than 19, due to transmitters on board the ship, do not cause interference receiver connected to the respective antenna [15].

2. Analysis of the influence of superstructure elements

This paper addresses the influence of secondary radiators on the directional feature of the antennas and on the mutual coupling of the antennas on board a ship, given that incorrect installation of an antenna causes a degradation of the operational characteristics of that equipment (for example a reduction in the range of radio communications).

The superstructure elements of the ship, by deforming the directivity characteristic, also influence the antenna performance [2, 6, 10].

The installation of radiocommunication equipment on board a ship involves establishing the locations of the antenna and radiocommunication equipment (equipment units) as well as the signaling and power connections between the radio-coupling apparatus and the equipment and its antenna.

The installation of radiocommunication equipment (depending on the navigation area) and radars on board ships can be performed taking into account IMO resolutions which provide for minimum distances between their antennas but also certain distances between antennas and superstructure elements [14, 17 - 25].

Knowing the radiation areas and the directivity characteristics of the antennas allows taking measures to ensure the compatibility of the equipment on board the ship and in particular by reducing the coupling between the antennas. The directivity characteristics of the antennas and therefore the radiation zones on board a ship are influenced by the superstructure elements, which requires an analysis by simulation of the electromagnetic environment on board and followed by the measurement of the maximum level of the electric field in the radiation zones determined by simulation, to optimize the location of the antennas.

The radiation of the superstructure elements is determined by its reflection surface, the angle of incidence and the polarization of the electromagnetic wave [3, 4].

Reducing the mutual coupling between antennas by optimizing the location of each antenna on board solves to a large extent the problem of mutual interference in the case of a radiating system installed on the ship. This measure is applicable to VHF and UHF antennas because the distances between the antennas can be considered large compared to the wavelength [5, 13].

In the analysis of the electromagnetic compatibility of the equipment on board a ship, after determining the mutual coupling between the antennas (also influenced by the superstructure elements), the possibility of electromagnetic interference between the equipment (jamming) is established by determining the interference margin [8, 12].

For analysis, the deck of a ship (on which the antennas are installed) was considered as a conductive surface measuring 8x7m, Figures 1 to 4. The monopole antenna is installed at 0.2m from the edge of the deck and at a distance varying from 1 meter to 6 meters, compared to a 7x1m rectangular metal structure (case 1), 7x2m (case 2), 7x1m metal grid (4 metal bars arranged at 0.1m, 0.4m, 0.7m and 1m from the deck surface - case 3) and 4m high mast with the lower diameter of 0.5m (case 4). The simulation was performed in ANSYS Savant for monopolar antennas with vertical polarization for a frequency of 156MHz (the influence of a superstructure on the directivity characteristic of the antenna) and in the frequency band 156 - 163MHz for the analysis of the mutual coupling between two monopole antennas installed on board [7, 9, 10, 11, 27].

The variation of the antenna power density as a function of the height of the vertical metal structures (1m and 2m) and the distance between the antenna and these structures is shown in Figures 5 to 8. An increase in lobe level is observed in the 0° - 90° quadrant, and in particular, an increase with the distance of the power density (narrow lobes) compared to the situation in which the height of the vertical metal structure was 1 meter. If the vertical metal structure is in the form of a metal grid (Figure 3), the power density decreases a lot compared to the situations in which the metal plates had a height of 1 and 2m respectively, Figure 7.

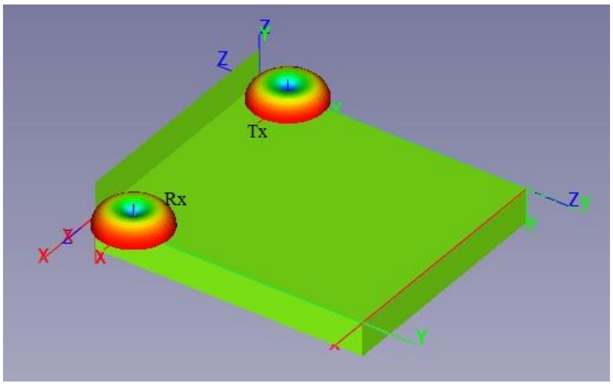


Figure 1. Structure for case 1

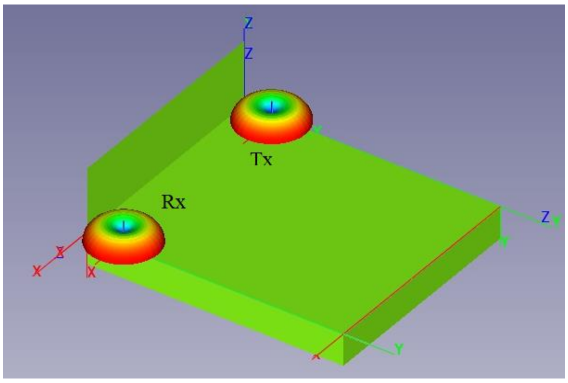


Figure 2. Structure for case 2

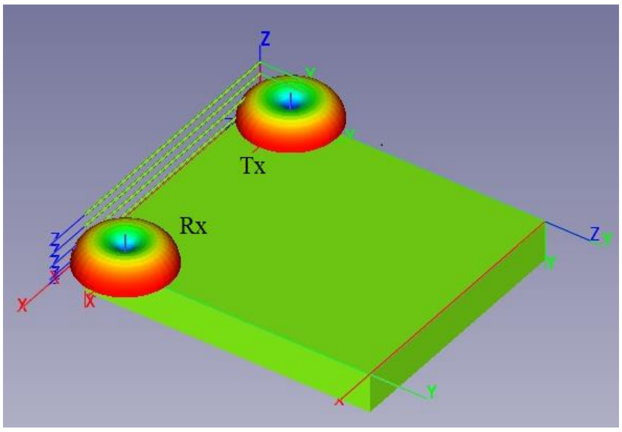


Figure 3. Structure for case 3

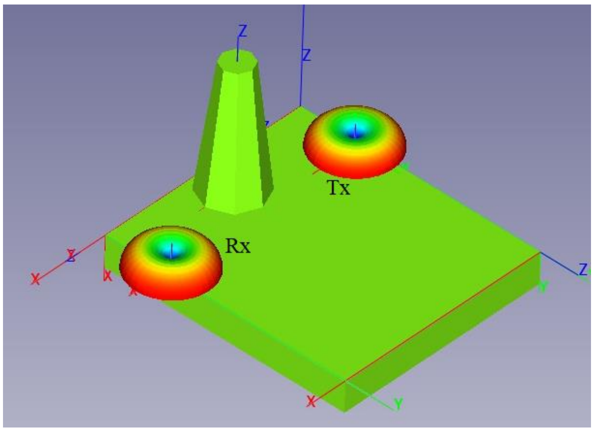


Figure 4. Structure for case 4

The variation of the mutual coupling between 2 monopole antennas for cases 1 to 4 are shown in Figure 9 to 12. The coupling analysis was performed with a distance of 6m between the 2 antennas, the Tx and Rx antennas being arranged at the same distance from the vertical metal structures (from 1 to 6m). The mutual coupling between the two antennas, in this configuration, depends on the appearance of directions with a high directivity of the transmitting antenna, due to the vertical metal structure that acts as a reflector but also on the variation of these directions with frequency.

If the metal structure is in the form of a metal grid, the variation of the mutual coupling between the 2 antennas is relatively constant, the grid determining directions with a lower directivity compared to the other vertical metal structures, Figure 11. It can be seen that the mast also influences the radiation characteristics of the two antennas on the port and starboard sides of the ship, and hence the mutual coupling between them (Figure 8 and Figure 12). When both antennas are placed on the port or starboard side, the influence of the mast is much less [1].

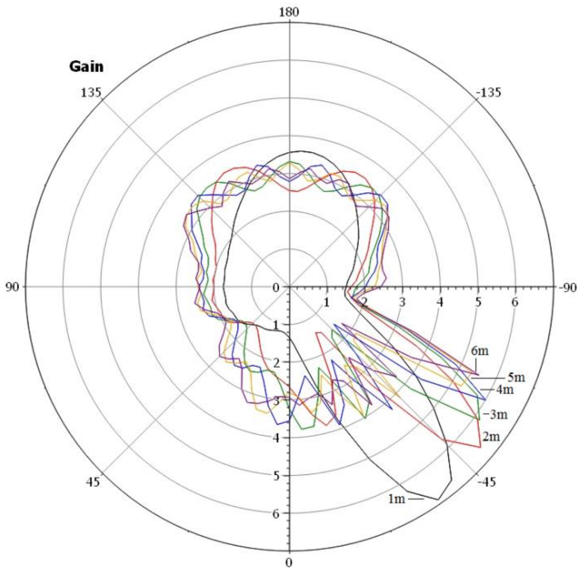


Figure 5. Antenna radiation pattern (Watt) - case 1

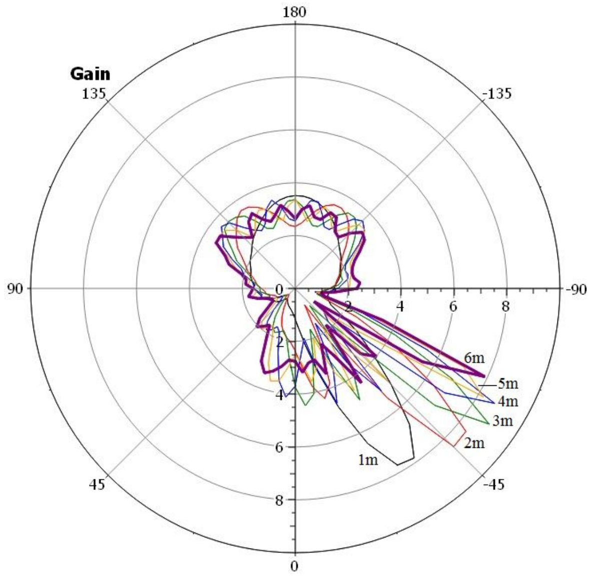


Figure 6. Antenna radiation pattern (Watt) - case 2

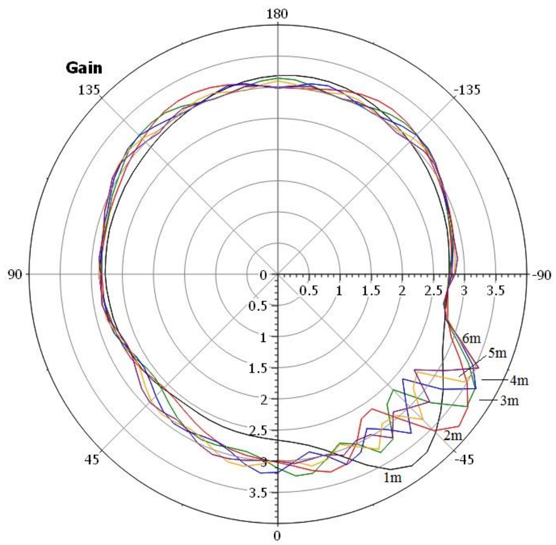


Figure 7. Antenna radiation pattern (Watt) - case 3

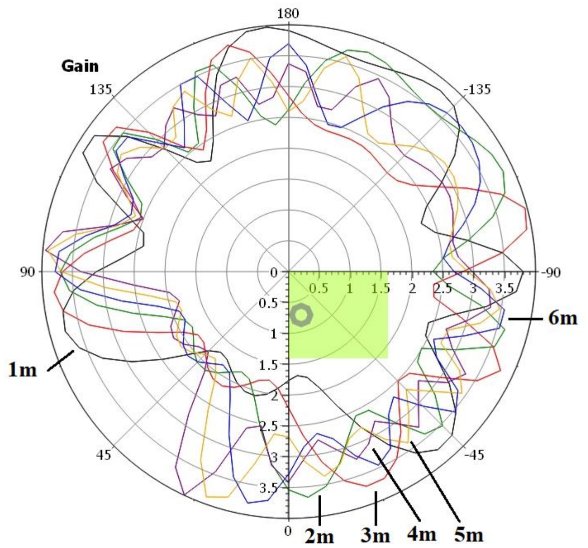
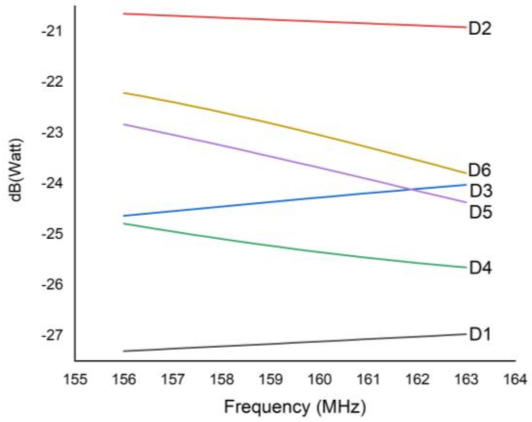


Figure 8. Antenna radiation pattern (Watt) - case 4



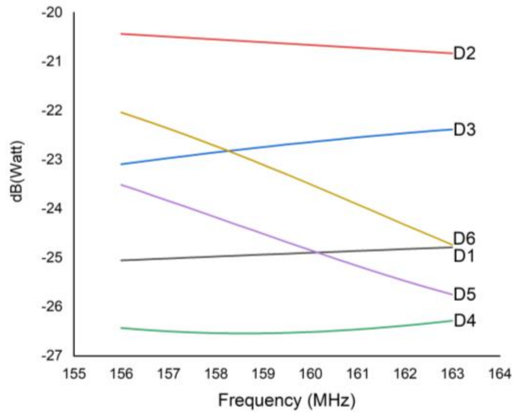
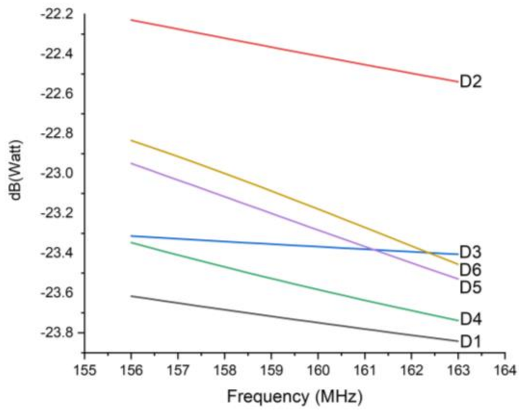


Figure 9. Mutual coupling Tx and Rx antennas - case 1

Figure 10. Mutual coupling Tx and Rx antennas - case 2



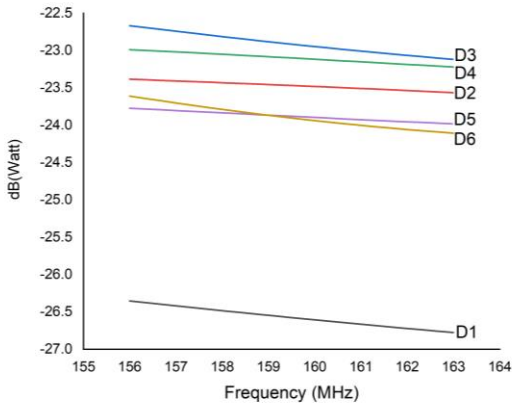


Figure 11. Mutual coupling Tx and Rx antennas - case 3

Figure 12. Mutual coupling Tx and Rx antennas - case 4

3. Conclusions

Antennas for radiocommunication equipment must be installed on board a ship in such a way as to ensure adequate separation from the superstructure of the ship so that its influence on the directivity / radiation characteristic of the antennas is kept to a minimum. The shape of the superstructure elements (which determine their reflection surface) as well as the distance from the antenna installation location influence the directivity / radiation characteristic of the antennas, resulting in the appearance of lobes with larger or narrower aperture, which determines an increase in the mutual coupling between the antennas that are in the areas where this energy concentration occurs.

References

[1] Assumpção F.C.S, Dias, M. H. C., Positioning Analysis of HF Monopole Antennas on a Frigate, Journal of Microwaves, Optoelectronics and Electromagnetic Applications, Vol. 20, No. 3, September 2021 DOI: http://dx.doi.org/10.1590/2179-10742021v20i3254756.

[2] Bayseferogullari, C., Ural, M., Improving performance of shipboard HF communication antennas by antenna placement, IEEE 2018 IEEE International Symposium on Electromagnetic Compatibility and 2018 IEEE Asia-Pacific Symposium on Electromagnetic Compatibility (EMC/APEMC) - Suntec City, Singapore, doi: 10.1109/ISEMC.2018.8394016.

[3] Bassem M., Atef E., MATLAB Simulations for Radar Systems Design, CHAPMAN & HALL/CRC, 2004 (&2.5.6).
[4] Berkowitz, R., Modern Radar – Analysis, Evaluation and System Design, John Wiley & Sons, Inc., New York, 1965.
[5] Bird, T., Mutual Coupling Between Antennas, Wiley, 2021.
[6] Jung-Chun Tsai, Meng Donglin, Yung-Chi Tang, Kai-Pin Huang, Liang-Yang Lin, Improvement of the mutual coupling effect between biconical antenna and antenna mast, IEEE 2016 Asia-Pacific International Symposium on Electromagnetic Compatibility.
[7] Levin, B., Antenna Engineering – Theory and Problems, CRC Press, 2017.
[8] N. Valentin, S. Gheorghe, C. Iancu and B. A. Rodica, ,,Electromagnetic compatibility of radiocommunication equipment on board a ship. Interference margin analisys", *7th International Symposium on Electrical and Electronics Engineering (ISEEE)*, 2021, pp. 1-6, doi: 10.1109/ISEEE53383.2021.9628851
[9] Preston E. L. Jr, Shipboard Electromagnetics, Artech House, 1987.
[10] F. Obelleiro, L. Landesa, J. M. Taboada and J. L. Rodriguez, ,,Synthesis of onboard array antennas including interaction with the mounting platform and mutual coupling effects" in *IEEE Antennas and Propagation Magazine*, vol. 43, no. 2, pp. 76-82, April 2001, doi: 10.1109/74.924606.
[11] J. Lundgren, J. Malmström, J. -M. Hannula, B. L. G. Jonsson, ,,Visualization and Reduction of Mutual Coupling Between Antennas Installed on a Platform," in *IEEE Transactions on Electromagnetic Compatibility*, vol.64, no.1, pp.92-101, Feb. 2022, doi: 10.1109/TEMC.2021.3102875.
[12] Tamas, R. ,,Evaluation of the mutual coupling between shipborne antennas", *Europe Oceans 2005*, 2005, pp. 1343-1346 Vol. 2, doi: 10.1109/OCEANSE.2005.1513255.
[13] Samoilescu, G., Ciocioi, I., Nae, V., International regulations on the installation of antennas on board a ship, AGIR Bulletin, no. 1/2020, pag. 32-39.
[14] IEC 60533, Electrical and electronic installations in ships - Electromagnetic compatibility.
[15] MIL-STD-464C, Electromagnetic environmental effects requirements for systems.
[16] Maritime and Coast Guard Agency, Instructions for the guidance of surveyors on radio installations MSIS27 chapter 12 Rev 09.21.
[17] IMO SN/Circ.227, Guidelines for the installation of a shipborne automatic identification system (AIS).
[18] IMO COMSAR/Circ.32, Harmonization of GMDSS requirements for radio installations on board SOLAS ships.
[19] IMO, A694(17) - General requirements for shipborne radio equipment forming part of the GMDSS and for electronic navigational aids.
[20] IMO, A.813 (19) - General requirement for electromagnetic compatibility (EMC) for all electrical and electronic ship's equipment.
[21] IMO, A.698(17) - Ship earth stations capable of two-way communications.
[22] IMO, A.663(16) - Performance standards for INMARSAT standard - C ship earth stations capable of transmitting and receiving direct-printing communications.
[23] IMO, A.807(19) - Performance standards for INMARSAT-C ship earth stations capable of transmitting and receiving direct-printing communications (Amended by MSC.68(68)).
[24] INMARSAT – Maritime design and installation guidelines.
[25] SIMRAD ES70/PI50 Marine Computer, Installation manual.
[26] IMO, SOLAS 1974 - Safety of Life at Sea.
[27] *** https://www.ansys.com/