Investigation of the EMI Problems Caused by the Cables that are not Grounded at Superstructure Penetrations

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Abstract—Electric field belonging to external RF electromagnetic environment (EME) may unintentionally couple to cables which are not grounded at the penetrations of superstructures of ships. This phenomenon can cause EMI problems due to high electric field levels on electrical and electronic equipment placed inside superstructures of ships. These problems can be solved with proper antenna placement, proper cable routing, shielding, grounding and bonding.

In this study, EMI problems caused by the cables that are not grounded at superstructure penetrations have been analyzed. Therefore, electric field levels inside the superstructure are calculated for three different cases, while HF antenna near the superstructure is transmitting at 1 kW RF output power. In the first case, the electric field levels are calculated inside of the hull for a cable penetrating superstructure and not grounded at penetration point. In the second case, the same calculations are done for the cable partially grounded at the penetration point, in order to simulate improper grounding case. In the third case, the same calculations are done for the cable properly grounded at the penetration point. Finally, all of the results obtained for three cases are compared.

Index Terms—Cable Penetration, Shielding Effectiveness

I. INTRODUCTION

Ever since Marconi’s successful experimentation, there has been a steady increase in the applications of electromagnetic based capability to the military platforms. In the past two decades, this increase has shown an exponential trend on Navy ships. As a result of this trend the number of transmitting antennas on ships has increased. For example, current corvettes have more than 50 antennas. Additionally, the emitted power levels have also been increased and the amount of electric field generated on the topside of the ship reached to hazardous values for personnel, fuel and ordnance. Therefore topside design of naval ships should be done according to a special design procedure and EMI control engineers should be a part of this design team.

The increased use of electrical and electronic equipment aboard naval ships introduces risk of EMI problems to ship operation and performance. As systems are added, they all contribute and could become susceptible to an intense EME. Considering the corrosive salt water environment in which ships must operate and the interaction of a ship’s electrically conductive metallic superstructure, topside hardware, antenna systems, etc., the potential for interoperability problems is significantly increased.

There are several standards addressing EMI control in military platforms. MIL-STD-464 and MIL-STD-1310 are the well-known and most used standards for EMI control in ships. MIL-STD-464 establishes electromagnetic environmental effects (E3) interface requirements and verification criteria for airborne, sea, space, and ground systems, including associated ordnance. This includes intra-ship and inter-ship EMC, electromagnetic pulse (EMP), intermodulation interference (IMI), and electromagnetic radiation hazards to personnel, fuel, and ordnance [1]. However, MIL-STD-1310 contains the requirements for shipboard bonding, grounding, and other techniques for EMC, EMP mitigation, and safety. The revision H of MIL-STD-1310 has been expanded to include procedures for EMP hardening. It also provides procedures and guidance to more easily address MIL-STD-464 requirements in relationship to intra- and inter-ship EMC, hull-generated IMI, lifecycle E3 hardness, EMP, and electrical bonding [2].

Electric field belonging to external RF electromagnetic environment (EME) may unintentionally couple to cables which are not grounded at the penetrations of superstructures of ships. This phenomenon can cause EMI problems due to high electric field levels on electrical and electronic equipment placed inside superstructures of ships.

These problems can be solved with proper antenna placement, proper cable routing, shielding, grounding and bonding. The guidance and procedures for shielding, grounding and bonding of cables routed on topside areas are given in MIL-STD-1310. For example, it is stated in section 5.3 that “all cables routed in topside areas shall be electromagnetically shielded and grounded at deck and superstructure penetrations”.

In this study, the EMI problems caused by the cables that are not grounded at superstructure penetrations have been analyzed.

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II. COMPUTATIONAL MODEL

In this study, the electromagnetic energy emitted by an HF monopole antenna and coupled to a cable that is not grounded at superstructure penetrations, has been analyzed. Therefore, the electric field value inside the metal structure is calculated for three different cases.

In the first case, the computational model represents a cable penetrating superstructure and not grounded at penetration point. In the second calculation, the model is representing the case when the penetrating cable is partially grounded (improper grounding) at the penetration point. The third model shows the case when the penetrating cable properly grounded as stated in MIL-STD-1310 at the penetrating point. The computational models for calculations are given in Fig. 1, 2 and 3.

The electromagnetic analysis is done by using Finite Integration Technique (FIT) method in CST Microwave Studio® electromagnetic simulation software. In naval ships, HF transmitters usually emit more power than VHF or UHF transmitters and since these antennas are omnidirectional, they may have an effect on whole ship and cause more EMI problems. Therefore, analysis frequency range is chosen as HF frequency band between 1 MHz and 30 MHz.

In these models, the emitter antenna is an HF monopole wire antenna having a height of 12 meters and placed vertically on a ground plane at the origin. The antenna is fed by a discrete excitation port modeled by a lumped element, consisting of a current source with 50 Ω input impedance placed in parallel that excites and absorbs power. The amplitude of the excitation voltage is defined such that radiated power of the antenna is 1kW at resonant frequencies. Since the cables used in the ships are usually shielded and long enough, the victim cable is modeled as an infinitely thin wire representing only the shield of that cable. The both ends of the thin wire are grounded on ground plane (modeled as perfect electric conductor) simulating proper ground connections at the equipment input ports.

The electric field values are calculated at the E-field probe points given in Fig. 4 and 5. It can be seen from Fig. 4 that the first probe point is chosen inside the metallic structure at a distance of 1 meter from thin wire. The second probe point is at the outside of the metallic structure and the distance to the thin wire is the same.

![Fig. 1 The computational model for the cable that is not grounded at the penetration point](image1)

![Fig. 2 The computational model for the cable that is partially grounded (improper grounding) at the penetration point](image2)

![Fig. 3 The computational model for the cable that is properly grounded at the penetration point](image3)

![Fig. 4 The E-field probe point at the inside of the metallic structure](image4)

![Fig. 5 The E-field probe point at the outside of the metallic structure](image5)
III. NUMERICAL SIMULATION RESULTS

The calculation results are shown in Fig. 6, 7 and 8 for three cases at the probe points indicated above.

The red lines in the Fig. 6, 7 and 8 show the electric field values for the probe point at the outside of the metallic structure and the green lines show the values inside the metallic structure. It can be seen from Fig. 6 that, electric field values inside the metallic structure can reach as high as 600 V/m, if the cable is not grounded at the penetration point. Also, one can see that these values can be reduced substantially (green line in Fig. 7), if the cable is partially grounded at the penetration point. Finally, these values can be reduced to zero (green line in Fig. 8), if the cable is properly grounded at the penetration point. The comparison of the calculation results is given in Fig. 9.

Fig. 6 Calculated electric field values in linear and logarithmic scales at the probe points for the cable not grounded

Fig. 7 Calculated electric field values in linear and logarithmic scales at the probe points for partially grounded cable (improper grounding)

Fig. 8 Calculated electric field values in linear and logarithmic scales at the probe points for the properly grounded cable

Fig. 9 Comparison of the results of three cases
IV. CONCLUSION

Metallic structures on the ships are used as a shield for electrical and electronic equipment and personnel located in these areas. In MIL-STD-464, it is required that the measured electric field values shall be lower than 10V/m inside of the metallic hull. But, it can be concluded from the results that, shielding effectiveness of the hull is decreased and high electric field values can be measured when proper grounding techniques are not used. This high amount of electric field may be a potential risk for EMI problems and HF transmitter can interfere with the electrical and electronic systems inside hull structure.

REFERENCES


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