International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 24 (2016) pp. 11908-11912

An Optimal Antenna Placement Scheme for UHF Systems in Ships by a Coverage Study

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Abstract

In this paper, we propose an optimal placement scheme of antennae of the UHF systems in ships using coverage study. In the design phase, fringe areas and dead spots of the UHF systems in ships are figured out by driving an attenuation modeling scheme. So it is possible to construct the optimal UHF systems in terms of the coverage. The simulation results show that the coverage study fits well on the actual ship environments and it is applicable to various types of vessels that equipped with UHF systems as well.

Keyword: UHF, Coverage study, ships

INTRODUCTION

Installation method of UHF antenna in vessel design phase nowadays is still the same as the past; to predict shaded area by a rule of thumb and determine locations of UHF antenna. In other words, antenna locations were determined only by the distances among them considered as a key factor of signal attenuation. But UHF radio waves can effectively penetrate solid steel floors and bulkheads. The penetration loss, which is called shadowing, is very difficult to estimate, and it depends on the thickness of the steel plate and the angle of incidence. The other factor affecting indoor propagation and propagation within complex steel structures is multipath propagation; multiple reflections on large surfaces and from scattering by smaller object. Therefore, to precisely design the UHF systems in vessels, various factors should be carefully considered in design stage that may affect the radio coverage.

In this paper, we propose an optimal placement scheme of antenna of the UHF systems by a coverage study. The study takes various factors that may affect performances of the UHF systems into accounts. Through the proposed scheme, we could achieve the reliability of UHF system design, and prevent excessive UHF antenna installations.[1]

A DEFINITION OF UHF SYSTEMS IN SHIPS

Introduce of UHF system

UHF system uses the frequency band of 300MHz~3GHz(Primarily near 460MHz) suited for on-board communication. VHF(Very High Frequency) uses the frequency band of 30MHz~300MHz(Primarily near 160MHz) as ship to ship & ship to shore communication use.[2]

UHF system consists of antenna, base station, repeater, and portable radio. Base station and repeater use the duplex frequency while portable radio uses simple frequency. The duplex frequency has a difference of about 10MHz between the transmission and reception frequency unlike simplex because it has to re-transmit the received frequency. In case there is no separation between the transmission and reception frequency, communication failure occurs such as howling, sensitivity degradation, and miscommunication due to mutual interference. As for transmission sequence, when Tx signal of portable radio is transmitted, it is transferred to the repeater through the antenna installed nearby, and the repeater re-transmit it through the antenna by amplifying the signal. UHF system can cover the entire the work area only through a few antennae, base station, and portable radio comparing to other systems. UHF system is simple in installation, and available to use the portable radio, so that this system is used in various work environments.

UHF System placement and problems on ships

UHF system is one of the most suitable communication methods in an environment like a ship of complicated steel structure. A ship is divided into accommodation and working area according to work environments, and they are always exposed to danger, which requires safety management. However, it is difficult to do proper management due to the inability to identify the location or condition of crews on board, and the field situation in real-time. Accordingly, it is very important to place the UHF antenna in a designing stage to make it possible to freely communicate through the portable radio while navigating a ship.

The output of an antenna decreases according to a distance and environment. The structural gap, material, and complexity, etc. of a ship are the factors which determine the transmission distance of the UHF antenna. Fringe area and dead spot appear when diverse factors are combined with the performance of the antenna. To eliminate the fringe area and dead spot of a large ship, it is necessary to install the antenna suited for the structure and environment of the ship.

Today, the UHF system on a ship uses a whip antenna for outdoor areas while using a spot antenna, leaky antenna, and a repeater for indoor areas, as shown in Figure 1.

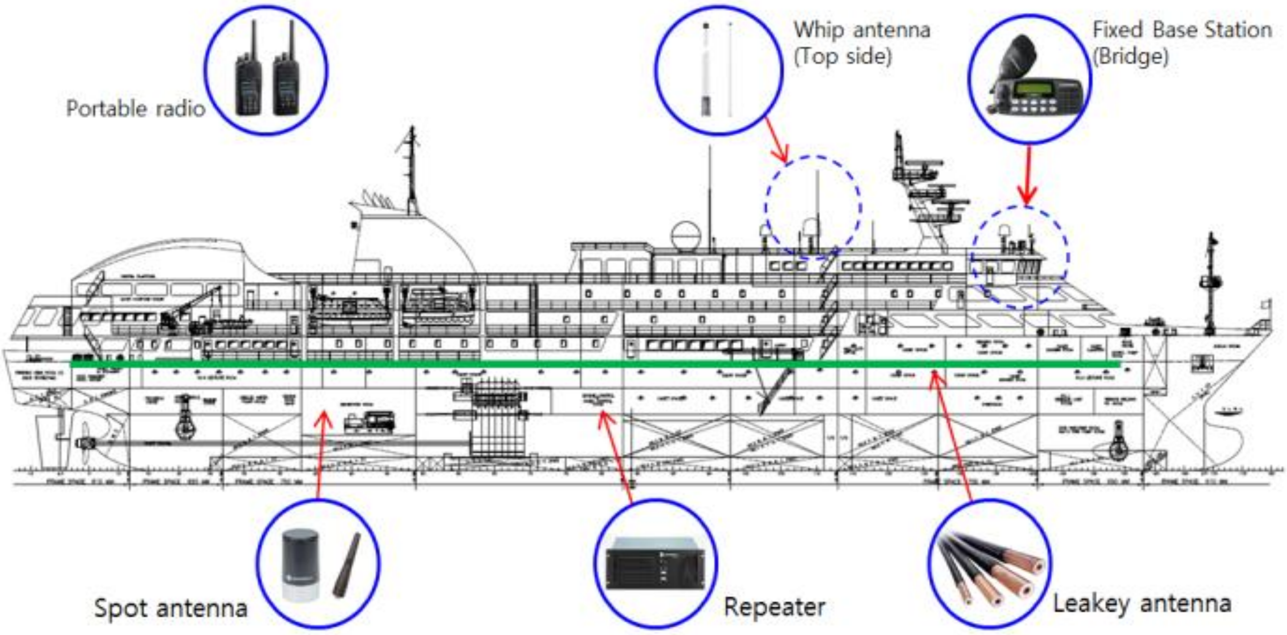

Figure 1: Installation of UHF system in ships

Also, most ship designs at the present day have the problems in the process of placing UHF system as below:

1. Ship design fails to understand the characteristic according to the types of UHF antennae.

2. Ship design fails to reflect the specificity of a ship structure.

The only way available under such circumstances is to place the system depending on a designer's experience. Accordingly, in case fringe area and dead spot occur at the communication stage, an antenna is added, or moved. Likewise, only the approximate position of UHF system is taken at the designing stage, and commonly, its position is corrected at the commissioning stage.

Necessity of UHF Coverage Study

The primary purpose of UHF system is to communicate between workers. Additionally, in a work environment of complicated structure like today's large ship, this system is used as a tool for remotely checking the condition of a working area and workers. Therefore, UHF system plays a vital role in preventing and coping with safety accidents inside the ship.

Basically, UHF system is required to cover the entire ship. To place UHF system suited for the structure and environment of the ship, basic data is needed to compare and check. As a realistic alternative, a coverage study is evaluated as the only method. It is possible to analyze the fringe area and dead spot of a ship and to place the system through its optimization without a waste element in materials.

Also, the coverage study not only reduces the cost but also improves the reliability in design as it can eliminate correction work at the commissioning stage. A ship should be managed by marking the fringe area and dead spot inside the ship like the blind sector of the radar by identifying the two areas through the coverage study.[3]

OPTIMIZATION OF UHF SYSTEMS

The biggest problem in the process of the TMS deployment is re-making decision over and over again due to specification changes through several times of re-examining the matters which had been already decided. Figure 2 shows a flow chart for the TMS deployment process. As the process of selecting proper telecom subsystems is very difficult, and unless a manufacturer of telecom subsystems can provide data, the process of selecting telecom subsystems is to be much harder.

Figure 2 and Figure 3 shows comparison of workflows for installation of the existing UHF systems and that of the proposed UHF systems.

As shown in Figure 2, the placement of the existing UHF system is done by a designer's supervision, and even the verification process is omitted. It is impossible to make a design in consideration of invisible radio signal realistically. In addition, it is impossible to identify the refraction and decrease of the antenna output by structure or environment without design standardization. Additional cost by design change is perceived as natural, leading to low reliability in the designing stage. In addition, the accurate fringe area and dead spot cannot be identified in most ships in operation, thus there exist risk factors in safety accidents. Accordingly, with design standardization, risk factors should be eliminated through the coverage study.

It is possible to eliminate most of the waste elements specified in Figure 2 by making a design of the UHF system using the coverage study as in Figure 3.

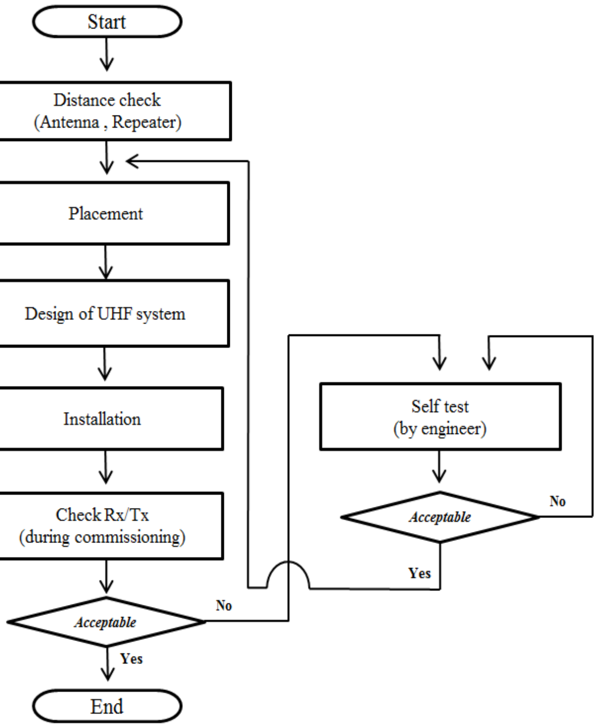

Figure 2: A workflow for the existing UHF system

Coverage study is applied only to the proposed UHF systems, which makes the iterative processes to change locations of antennae in the existing UHF systems unnecessary.

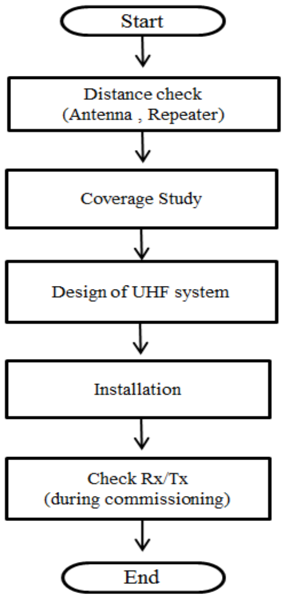

Figure 3: A workflow for the proposed UHF system

Standardization in design phase may bring up much cost savings in most systems in vessels including UHF systems. For not only the design standardization of UHF systems but also the minimization of fringe areas and dead spots, UHF coverage study and inspection method shall be accompanied before installation of whip antennae, spot antennae, leaky antennae and repeaters.

IMPLEMENT THE COVERAGE STUDY

As shown in Figure 4, a ship is divided into the indoor area, i.e. hull side, and the outdoor area, i.e. top side structurally. In the indoor area, a leaky antenna is installed along the cable route while a spot antenna is installed at the dead spot. In case of the top side, the whip antenna is installed by erecting a hand rail or a separate support. In this paper, the coverage study has been carried out by dividing a ship into the hull side and the top side on the basis of leaky antenna and whip antenna.

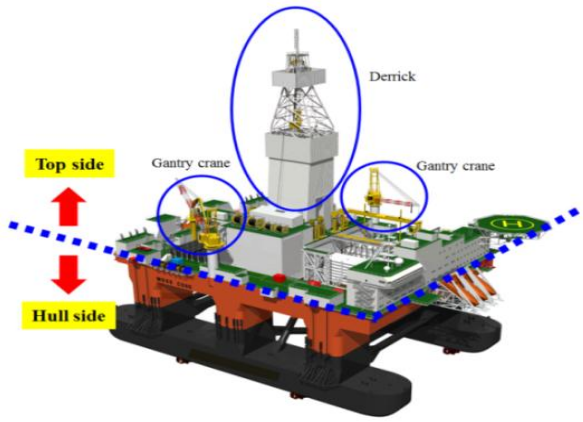

Figure 4: A sample of ship structure

In this paper, target signal strength and target coverage are defined as in Table 1, which are the basis of coverage study.

Target signal strength is expressed in dBm(Decibel-milliwatt). The receiver dynamic sensitivity of most portable radios is from -100dBm to 110dBm.[4]

Table 1: Specific design requirements for the ship

Category	Requirement
Target signal strength	Fringe area : ≤ -85dBm Dead spot : ≤ -100dBm
Target coverage	95%

The coverage study is to be carried out as in Figure 5, and it is repeated until it satisfies Table 1. Table 2 shows the detailed specifications used to environments of the coverage study.[5]

Table 2: Specification of the environment

Division	Specification
H/W	CPU : Intel Core i3 4170 Memory : DDR3 4GB Storage : SATA 200GB OS : Microsoft Windows 7 Professional DSP 32bit
S/W	iBwave Design Enterprise v 6.4.3, 32-bit Edition

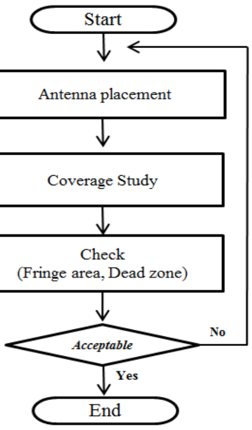

Figure 5: A workflow for coverage study of proposed UHF system

Figure 6 shows the result of carrying out the primary coverage study of the hull side. The coverage is 94.7% when the signal strength is -95dBm smaller than -85dBm of the target signal strength of the fringe area. This numerical value does not satisfy both the target signal strength and target coverage. In addition, it is possible to identify the fringe area smaller than -85dBm, and the dead spot smaller than -100dBm at the working area of the bow.

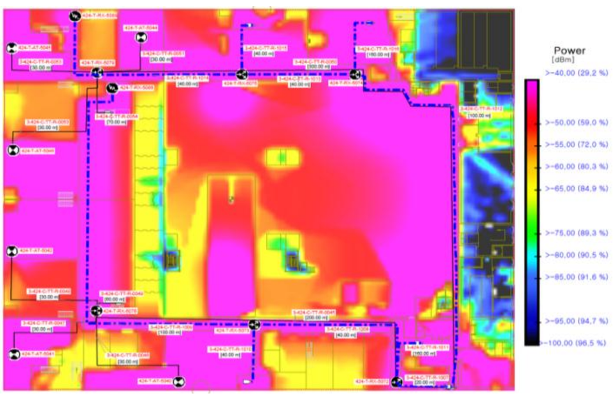

Figure 6: The first coverage study at hull side

In this paper the coverage study has been carried out again by repeating the process of changing the leaky antenna path and adding the spot antenna as shown in Figure 7. The coverage is 95.9% when the signal strength is larger than -85dBm which is the target signal strength of the fringe area. This numerical value satisfies all requirements of Table 1, which can eliminate the fringe area and dead spot of the working area.

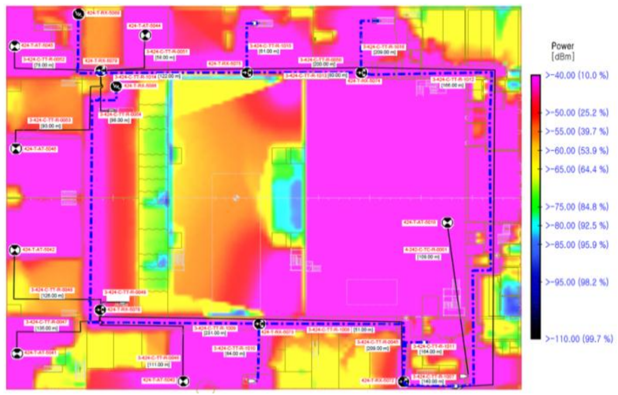

Figure 7: The final coverage study at hull side

The hull side is the section where a leaky antenna is installed, and the leaky antenna is installed as in Figure 8.

Figure 8: Installation of Leaky antenna

Generally, the leaky antenna path is installed near the cable tray. It is because a clamp is installed at the cable tray to support the leaky cable.

If the leaky antenna had been installed as in Figure 6 without the coverage study, an engineer would have repeatedly carried out a self-test holding the antenna in person in order to eliminate the fringe area and dead spot at the commissioning stage in Figure 2.

Figure 9 indicates the result of carrying out the primary coverage study of the top side. Even though the signal strength is smaller than -100dBm which is the target signal strength of the dead spot, its coverage is 93.9%, which does not satisfy both target signal strength and target coverage in Table 1. In addition, It is possible to identify the existence of the fringe area and dead spot even at the working areas of the stern and starboard side as well as the port side.

The top side is an open space perceived as an outdoor area, so that people commonly think that fringe area and dead spot do not occur due to the wireless characteristics. However, actually fringe area and dead spot occur due to the structures(Crane, Derrick, Accommodation, etc.) such as a column at the top side as shown in Figure 4. This phenomenon appears as a ship structure becomes much larger and complicated today.

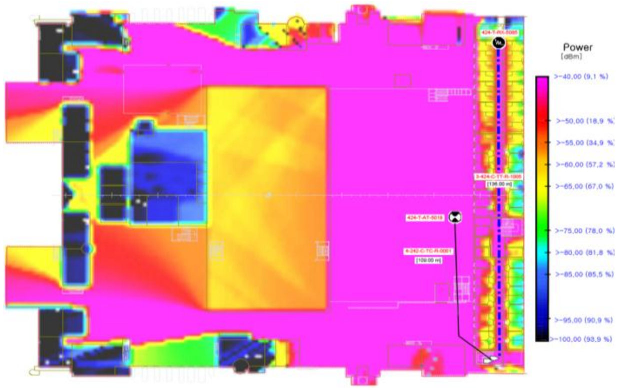

Figure 9: The first coverage study at top side

Accordingly, it is impossible to satisfy the target coverage with only one whip antenna of the bow as shown in Figure 9. The radio signal of the whip antenna located at the bow has been confirmed not to be transferred toward the stern due to the derrick, starboard side, port side and gentry crane, which are located in the middle of the top side.

The coverage study has been carried out again by repeating the process of adding the whip antenna to the stern as shown in Figure 10. The coverage is 95.9% when the signal strength is bigger than -85dBm which is the target signal strength of the fringe area. This numerical value satisfies all requirements of Table 1, and can also eliminate the fringe area and dead spot at the working area.

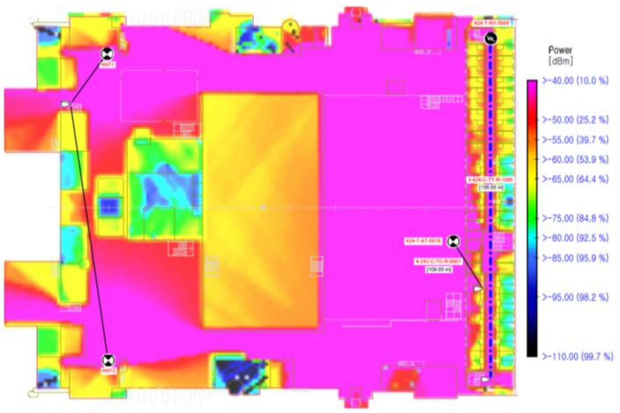

Figure 10: The final coverage study at top side

Results of the coverage study of a UHF system in a ship show visually the sensitivity of the transmitted wave power from antennae which reflect well the architectural shapes in the ship. Coverage study is very good to get not only higher reliability of the UHF system design but also stabilization of the UHF systems itself.

It is possible to reduce design cost and installation expenses by identifying and responding to the fringe area and dead spot in advance at the designing stage.

The design change at the installation stage in the shipbuilding process causes several-fold cost difference at minimum compared to the designing stage. Accordingly, the prediction in advance from designing stage to final inspection stage is very important in the aspect of quality and cost.

The UHF system is required to improve the quality of a ship and price competitiveness by securing the design standard through the coverage study. In case the structure of the existing ship changes, it is necessary to prepare for safety accidents by clarifying the fringe area and dead spot according to a structure change at the time of sailing through the implementation of coverage study.

FUTURE WORK

The UHF coverage study proposed in this paper is applicable to diverse types of ships such as LNG, Tanker, Container, and Offshore plants, etc. It is judged that the UHF coverage study will be helpful to the development of the shipbuilding industry and the reinforcement of competitiveness by inducing quality improvement and cost reduction.

CONCLUSION

This paper shows the coverage study in the design phase is very good tool to figures out fringe areas and dead spots before antennae installation of the UHF systems in ships. As a conclusion, the study can achieve the optimal placement of antennae for UHF systems in ships. It, therefore, is possible to radically reduce modification costs in installation phase and to get higher reliability of the UHF systems in ships.

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