

A Novel Antenna Tracking Technique for Maritime Broadband Communication (MariComm) System

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Abstract— Maritime communication is internationally protected because closely related to the maritime safety, and it has evolved slower than terrestrial communication technologies. However, with the recent rapid advances in communication technology, maritime communications have become faster and increasingly modernized. A maritime broadband wireless data communication (MariComm) system was developed to make two-way high-speed internet/multimedia services available at a rate of 1 Mbps or more on the sea by extending the communication coverage of terrestrial wireless communications networks to sea areas. The MariComm system uses high-gain directional antennas to extend the transmission range and has multiple directional antennas to cover 360 degrees in azimuth. In this paper, we introduce a directional antenna tracking technique and apparatus using received RF signal and ship location information in the MariComm system.

Keywords— Antenna Tracking, Maritime, Broadband, Wireless, Communication, MariComm

I. INTRODUCTION

Maritime communication is a very old form of communications and internationally protected because it is closely related to the safety of humans, and it has evolved slower than other communication technologies. However, with the recent rapid advance of communication technology, maritime communication is also in the process of being actively developed [1], and the importance of ship-to-ship and ship-to-shore (4S) communications is being emphasized as the e-navigation policy is internationally driven by the International Maritime Organization (IMO) to ensure the safety of vessel navigation [2][3].

Maritime communication systems include medium frequency (MF), high frequency (HF) and very high frequency (VHF) band communication equipment and satellite communication equipment in order to perform worldwide maritime communication, and provide voice-oriented communication services with the exception of a simple text transfer service.

Although many ships currently navigate coastal waters, it is difficult for the ships to receive various communication services from land because there is no provision for a maritime broadband digital communication network.

Meanwhile, ships on long distance voyages are dependent upon expensive satellite communication. Furthermore, although various communication means for a GMDSS are installed on a ship, most of them are used for voice-based analogue communication. Some communication devices are capable of digital transmission, but provide service at limited speeds and within very limited areas.

Wireless communication between ships is required for the safe navigation of the ships. Currently available land-based wireless communications have the disadvantage of short coverage distances. In particular, satellite communication has the disadvantages of low data throughput and high cost.

II. RELATED WORKS

Many studies, such as Wireless-broadband-access for Seaport (WISEPORT) networks [4], Norway's digital VHF channels [5] and Very Small Aperture Terminals (VSATS) [6], and a Tri-media Telematic Oceanographic Network (TRITON) have been used to compensate for the drawbacks of maritime communications [7]. However, available solutions provide limited transfer rates or communication range from the shoreline. Moreover, a maritime mesh network was developed in Japan [8], but it also shows similar limitations with other solutions. Although there are many other mesh [9]-[10] or ad-hoc [11]-[14] networks, they are still at the conceptual stage for adapting to maritime communication.

Recently we developed a maritime broadband communication system (MariComm) to support the safe maritime navigation of ships and provide a transfer rate of 1 Mbps to ships within 100 km from the shore. In this study, we introduce a directional antenna tracking technique and apparatus using received RF signal and ship location information in the MariComm System for long range and efficient Maritime communication.

III. MARITIME BROADBAND COMMUNICATION SYSTEM

A. Track of Shipping Pollution for requirements Analysis

Most maritime activities such as shipping, fishing, and oil and natural gas exploration take place in exclusive economic zones (EEZs). Figure 1 shows the density of global shipping pollution. As can be seen in Fig. 1, over 70% of global vessels are being operated within 30

kilometers (almost ships track along the coasts), and that goes over 90% within 100 kilometers. This is where most of the ocean life of all our humankind is carried on, and this is the area where most of our marine accidents of the earth are occurring.

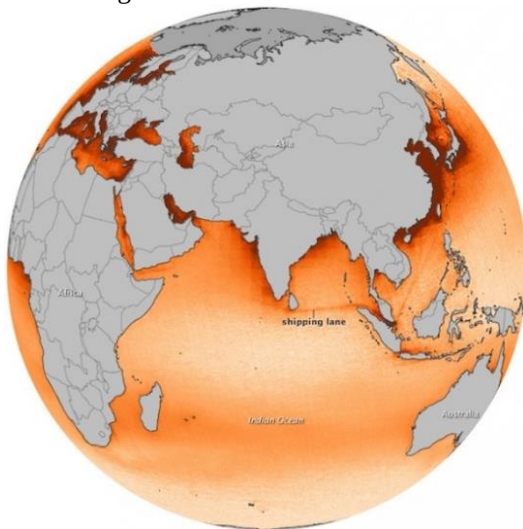


Figure 1. Track of Shipping Pollution by the density color of NO_2 (nitrogen dioxide) Emission, Ozone Monitoring Instrument on NASA's Auro satellite from 2005 through 2012

B. Overview of MariComm System

A maritime broadband wireless data communication (MariComm) system was developed to provide a maritime wireless communication method that can extend land-based wireless communication service to the sea and make the land-based wireless communication service available at sea. An object of the MariComm is to make two-way high-speed internet/multimedia services available at a rate of 1 Mbps or more on the sea by extending the communication coverage of terrestrial wireless communications networks to sea areas. MariComm is a new marine broadband digital communication system to meet the requirement for the coming e-Navigation era. It provides high quality internet services within 100km from the shore, without using satellites. Figure 1 shows the comparison of maritime communications for coverage, throughput and cost.

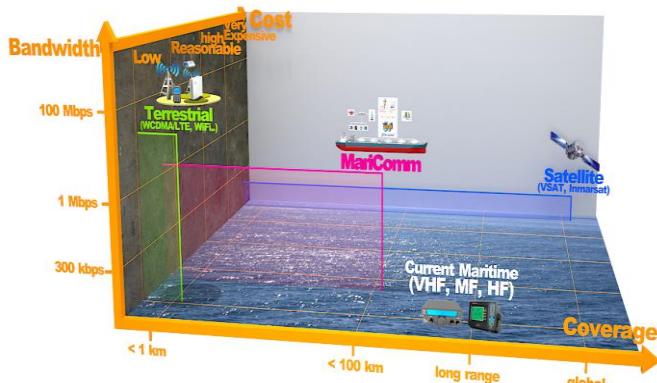


Figure 2. Comparison of Maritime Communications

As can be seen in Fig. 2, MariComm can be beneficial either in cost or in network speed than any other maritime communications, then finally all the vessels or coastal business units can easily apply for the system.

This allows us to have full networking of all the facilities of coastal area, that will be very short cut for us to move into various automation and remote monitoring systems each other by the real time screening in that area. Of course, this can be applied not only for maritime purposes, but for various sections of land monitoring system.

The MariComm system developed in this study is a maritime multihop-relay based broadband system designed to provide broadband services to ships within 100 km from the shore. Figure 3 shows the concept of multi-hop relay maritime broadband communication system.

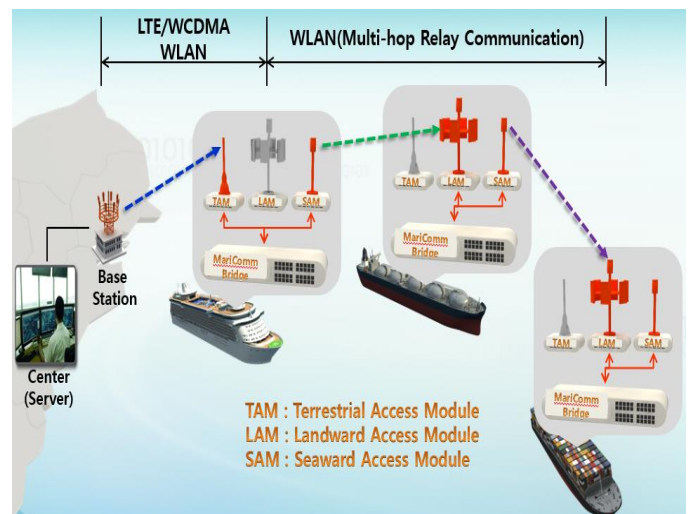


Figure 3. Concept of Multi-hop Relay Maritime Broadband Communication System

As shown in Fig. 3, the MariComm system can be connected to terrestrial wireless communication networks using an LTE/WCDMA base station on land, the WLAN access point developed in this study, or through multi-hop relay communications available from other ships.

C. Configuration of MariComm System

MariComm system is consist of Maritime Communication Server (MariComm Server) on land and Maritime Communication Station (MariStation) on board.

The MariComm server is network management system (NMS) server for MariComm System. It performs with IP allocation, communication channel allocation, registration, certification, and fault management for MariStations.

The MariStation on board consist of a terrestrial access module (TAM), seaward access module (SAM), landward access module (LAM), and MariComm Bridge. As shown in Fig. 3, the TAM can be directly connected to the land-based base station such as LTE and WCDMA, and provide broadband wireless communication service, provided by the land-based base station, at sea. The SAM is installed on the MariStation and serves as a WLAN access point (AP)

that enables other ships can access broadband wireless communication service through the connection of LAM. The LAM is also installed on the MariStation and acts as a WLAN station that can be directly connected to the WLAN base station (AP) on land or SAM of other ships, and accesses broadband wireless communication service. The MariComm Bridge collects communication quality (RSSI, SNR) and status information (positional information from GPS, SSID of SAM, hop count of multi-hop relaying, number of child stations), and controls the TAM(on/off switching, load balancing), SAM(SSID, output power and RF channel setting) and LAM(antenna switching, SAM connecting) modules for multi-hop relaying, and serves as an LTE/WCDMA↔WLAN bridge and an uplink/downlink scheduler.

IV. ANTENNA TRACKING IN MARICOMM SYSTEM

A. Characteristic of Directional Antenna

In the application of the terrestrial broadband wireless communication technology to the maritime communication, there is a problem in that a frequency band higher than UHF band used for terrestrial communications has a distance range shorter than MF, HF, and VHF frequency bands used for maritime communications. To alleviate the problems, a directional antenna may be used, rather than an omni-directional antenna, so as to extend the communication range and simultaneously improve space reuse gain. However, since the directional antenna emits strong radio waves only in a certain direction and has characteristic sensitivity that is increased with respect to radio waves from a certain direction, the directional antenna has been used for Point-to-Point (P2P) communication between fixed stations in terrestrial long distance communication, but it is not suitable for Point-to-Multipoint (P2M) communication between ships sailing at sea. Figure 4 shows the beam pattern example of directional antenna. As shown in Fig. 4, the signal quality (antenna gain) of the center of the directional antenna azimuth is better than the edge of the directional antenna azimuth.

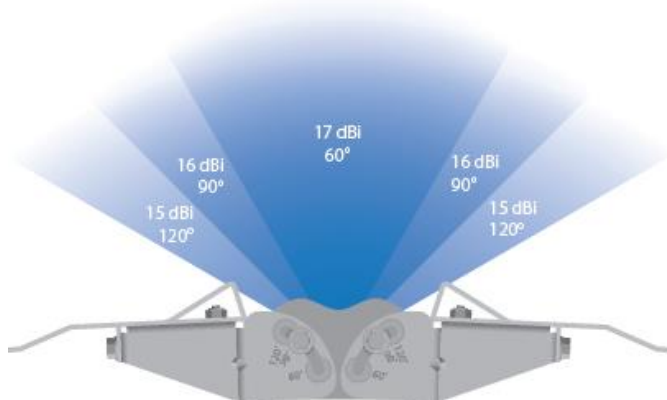


Figure 4. Beam Pattern Example of Directional Antenna (AM-V2G-Ti)

B. Antenna Tracking Techniques in MariComm System

The MariComm system uses high-gain directional antennas to extend the transmission range and has multiple directional

antennas to cover 360 degrees in azimuth. Figure 5 shows the multiple directional antenna in MariComm system.

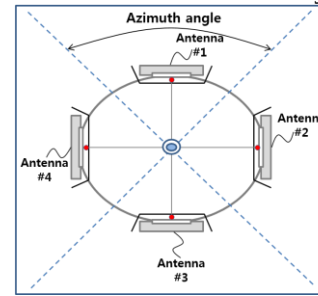


Figure 5. Multiple Directional Antenna in MariComm System

As shown in Fig. 4 and 5, the MariComm system not only uses multiple directional antenna, but also adopts an antenna tracking method for communication quality enhancement.

The directional antenna tracking method uses received RF signal and ship location information in the MariComm system, it is very effective antenna tracking method at the sea, because it is possible to get the both positional information own ship and other ships. Antenna tracking is separated panning (adjusting azimuth angle) and tilting (adjusting elevation angle). The panning is required by the movement of vessel, and continuously predicting the received signal direction to perform the tracking. Panning is made within a defined range (1/2 of the azimuth is sufficient), when the limit range is exceeded the received antenna is switched. The difference of elevation angle is made with installed antenna's height from sea level and ship movement (rolling, pitching), as the vessels are close the elevation angle gives a greater effect on the signal quality. Figure 6 shows the RF based antenna tracking (panning, tilting) for new connection.

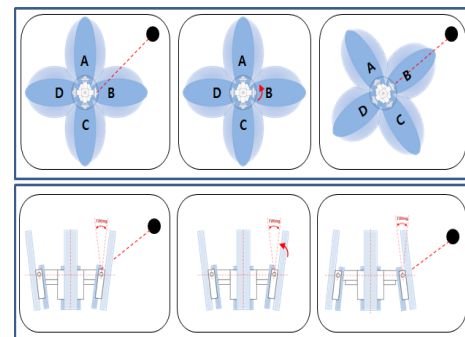


Figure 6. RF Based Antenna Tracking

The following is the sequence of the RF based antenna tracking for new connection.

- Measuring the received signals at the each directional antenna A, B, C, D
: measured signal quality is $B > A > C > D$ or $B > A > D > C$
- Predicting the transmitter signal location
: between A and B, close B
- Tracking the directional antenna
: rotating antenna to the left
- Searching the optimized antenna direction
: iterating the step a) ~ c)

- e) Tilting the panning completion antenna
: similar to panning method except to rotating direction
- Figure 7 shows the RF and Location based antenna tracking (panning, tilting) for keeping the best connection.

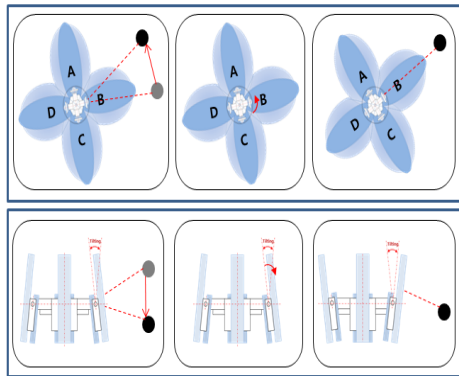


Figure 7. RF and Location Based Tracking

The following is the sequence of the RF based antenna tracking for keeping the best connection.

- Measuring the received signals at the each directional antenna A, B, C, D
: measured signal quality is $B > A > C > D$ or $B > A > D > C$
- Collecting the positional information of ships
: ship (transmitter signal location) moved to the left
- Calculating the transmitter signal location
: calculating the antenna rotating position
- Tracking the directional antenna
: rotating antenna to the calculated position
- Tilting the connected antenna
: panning and tilting is possible concurrently

Figure 8 shows the directional antenna tracking module in MariComm system.

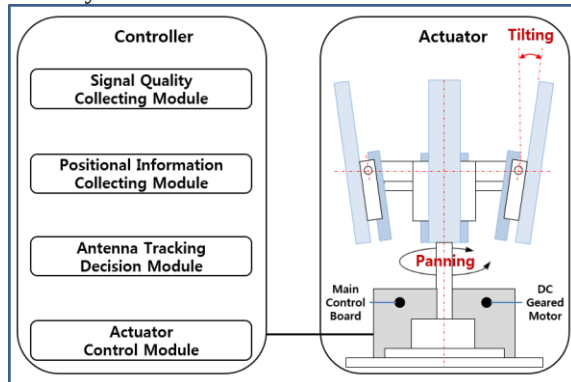


Figure 8. Directional Antenna Tracking Module

As shown in Fig. 4, the directional antenna tracking module is consist of controller and actuator. The controller is consist of signal quality measuring module (collecting the SNR of received signal and measuring the signal quality), positional information collecting module (collecting the location information of ships), antenna tracking decision module (predicting the transmitter signal location and deciding the adjustment of azimuth and elevation) and actuator control

module (controlling the actuator that tracks antenna). The Actuator is consist of main control board that control the motor, tracking motor and panning and tilting apparatus. Figure 9 shows the prototype of directional antenna tracking module in MariComm system.



Figure 9. Prototype of Directional Antenna Tracking Module

V. TESTING AND PERFORMANCE EVALUATION

A. Configuration of testing environment

Two WLAN APs were installed at different on-shore locations to create a test environment for the maritime broadband communication system (MariComm) developed in this study. The MariComm system was then set up on ships to test its functionality and evaluate its performance. Figure 10 shows the installed APs and the test ship.

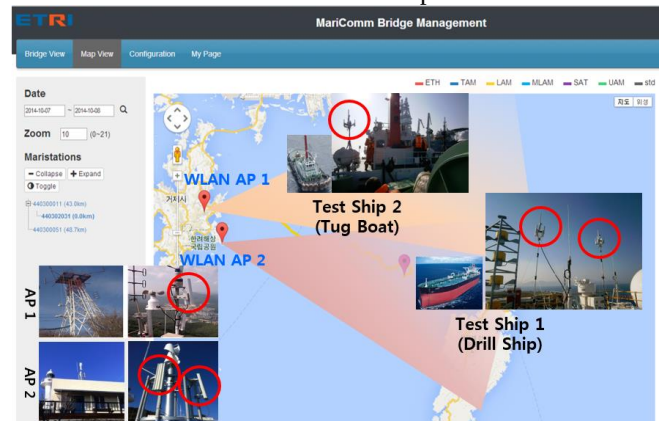


Figure 10. APs on Land and Test Ship

TABLE 1. TEST CONDITIONS FOR MARI COMM SYSTEM

Items	Access Point		Test Ship	
	WLAN AP1	WLAN AP2	Test ship1	Test ship2
Antenna height	Less than 520m	Less than 70m	Less than 30m	Less than 10m
Tx Power	27dB	27dB	27dB	27dB
Antenna type	SAM Directional 90° 20dBi	SAM Directional 90° 20dBi	SAM Omni 13dBi	SAM Omni 13dBi
			LAM Directional 120° 16dBi	LAM Directional 120° 16dBi
Connection Priority	-	-	WLAN > LTE	LTE > WLAN

B. Testing Result

Figure11 shows the installed APs and the sailing routes of the test ships. As shown in Fig. 11, one access point (WLAN AP 1) was installed at Oknyeobong Peak in Geoje,

Gyeongsangnam-do, and the other one (WLAN AP 2) was placed at the Seoimal Lighthouse.

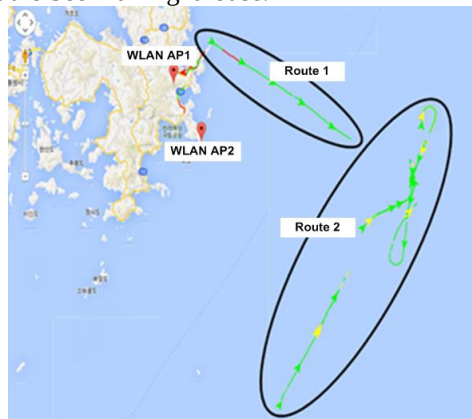


Figure 11. Installed WLAN APs on land and the routes of test ships

Along route 1 in Fig. 11, the red part represents the section when connecting to the LTE base station on land through the TAM, and the green parts represent when connecting to the WLAN AP1 through LAM. The connection priority setting of test ship 1 is WLAN > LTE. In the sections with access to the LTE base station, no LOS (Line of Sight) was secured between AP 1 and test ship 1, and thus the connection to the LTE base station was achieved through the TAM. The test ship 1 did not change the route, so no antenna switching was occurred owing to antenna tracking method.

Along route 2 in Fig. 11, the green parts represent the sections when connecting to the WLAN AP (AP1 or AP2) through LAM, and the yellow parts represent the section when switching to an antenna whose pointing direction was matched with the on-land WLAN AP as the direction of the currently connected directional antenna was exceeded the limit tracking range owing to the ship movement (or rotation) or AP changing. The test ship 2 frequently changed the route for testing (anchoring, speed up/down, slow/normal/quick turning, black out etc.), but minimum antenna switching was occurred owing to antenna tracking method. The empty part is black out testing section and the throughput of the green section is more than up/down 4Mbps and an antenna switching delay is less than 5 seconds. Figure12 shows the results of the download and upload throughput tests.

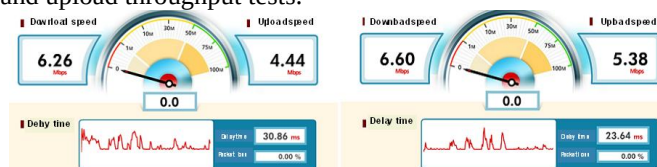


Figure 12. Results of Throughput Tests (<http://speed.nia.or.kr>)

VI. CONCLUSIONS

This paper introduced the multi-hop relay technology based maritime broadband communication system (MariComm). The MariComm system uses high-gain directional antennas to extend the transmission range and has multiple directional antennas to cover 360 degrees in azimuth. In this paper, especially we introduce a directional antenna tracking

technique and apparatus using received RF signal and ship location information in the MariComm System for long range and efficient Maritime communication.

The antenna tracking module in MariComm system may reduce the antenna switching times, extend the communication range and improve the data throughput.

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