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Technical Domain / Task Number [2]	Working Group 2 (Emerging Digital Technology)
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Introduction of Digital HF Communication System in SMART-Navigation Project

1 SUMMARY

This document introduces digital HF communication system based on ITU-R Recommendation M.1798-1 standardization and development status in SMART-Navigation project of Republic of Korea

1.1 Purpose of the document

This document is to introduce to IALA of development status and implementation plan in Korea as well as inform IALA of ITU-R Recommendation M.1798-1 standardization in ITU-R WP5B.

1.2 Related documents

None.

2 BACKGROUND

The Republic of Korea will implement Digital HF communication system from 2020 to enhance of safety navigation of the domestic non-SOLAS ships especially fishing boats. The non-SOLAS ships especially fishing boats are currently operating analogue HF voice communication in Korea. These ships may be used satellite service but the fisherman are reluctant to satellite service because of economic reasons.

We would like to introduce IALA of digital communication system in SMART-Navigation project. It is helpful for non-SOLAS ships reluctant to use satellite service because of economic reasons.

3 DISCUSSION

3.1 SMART-Navigation project

1 Input document number, to be assigned by the Committee Secretary
2 Leave open if uncertain

3.1.1 Concept of digital maritime communication system in SMART-Navigation project

The SMART-Navigation project is organized and funded by Ministry of Oceans and Fisheries (MOF) in Korea. The project implements e-navigation services in Korea waters based on IMO's e-Navigation concept as well as additional special features: (1) services for non-SOLAS ships and (2) develop broadband communication (LTE-Maritime) for better connectivity between ship and shore and (3) develop wider communication (Digital HF) for sailing over LTE-Maritime coverage.

The project develops and constructs digital maritime communication system, which consist of three digital communication system like the followings.

- LTE-Maritime
- VDES-Terrestrial
- Digital HF

LTE-Maritime provides high data rates of megabits per second within the communication coverage of 100km from the land for non-SOLAS ships. The Digital HF provides maximum data rate of 51 kbps for operating vessels over 100km from the land.

VDES-Terrestrial is developing and has a plan to operate testbed network for SOLAS ships in the future. However, the VDES-SAT will not be developed during the project period.

In addition, Korea will construct SMART-Navigation Operation Centre which enables information or data link between different communication means. It makes to be possible to exchange the digital data between SOLAS ships and non-SOLAS ships.

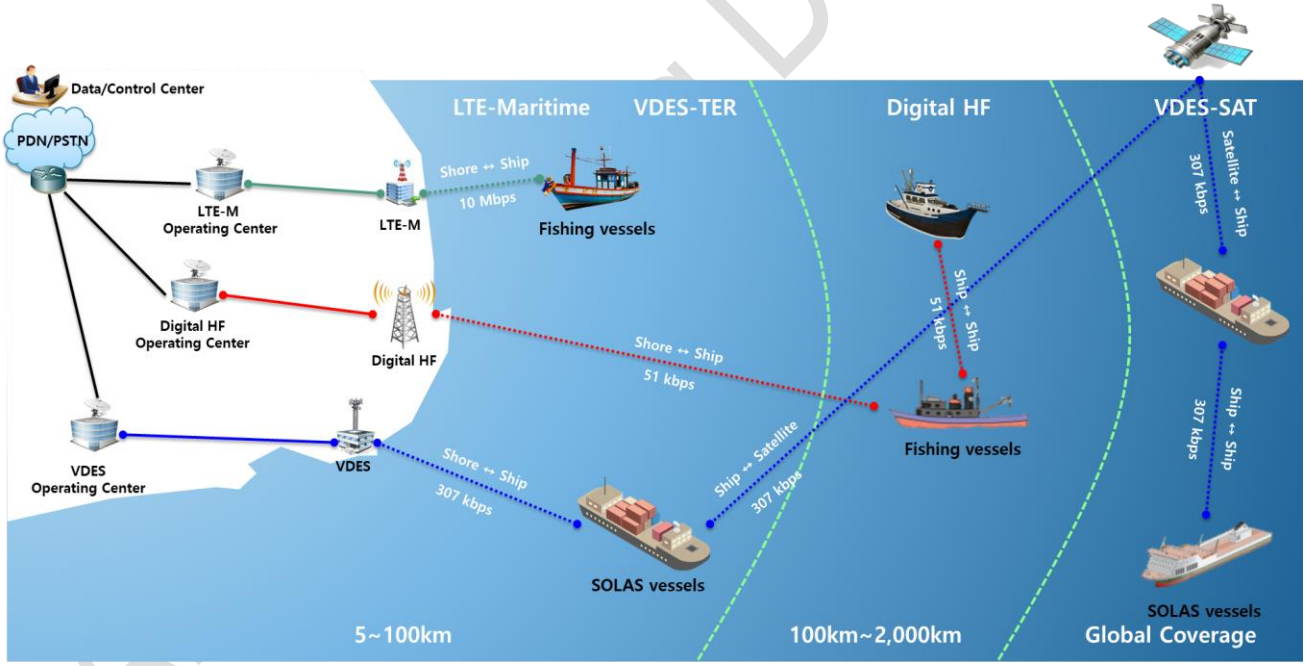


Figure 1 Digital Communication Concept in Korea

3.1.2 Needs of Digital HF in Korea

The Republic of Korea requires to ships sailing on inland waterways for reporting their positioning information to authority in domestic regulation for their safety reasons.

The SOLAS ships or fishing boats sailing on within 100km from land equipped with AIS (Automatic Identification System) or satellite communication system such as Inmarsat for mandatory service as well as equips with VSAT (Very Small Aperture Terminal) system for crew's entertainment service. The satellite communication system are not reasonable for operative cost to fisherman sailing on a small fishing boat. The fishing boats sailing over 100km from land has equipped with SSB (Single Side band), analogue voice communication equipment. Following the Korea`s domestic regulation, the authority manages by calling

each fishing boat once a day and requires to report their position by analogue voice communication, and if ship owner responses the position by voice, the authority managed it by manual.

If the ships suddenly occurred accident or entered the navigational danger zone, it is difficult to prevent in the currently operating system in Korea.

The Digital HF communication system under developing in Korea has an additional functions, automatically transmitting positioning information for evert 10 minutes.

3.2 Overview of Digital HF

The digital HF communication system under development in Korea is based on the ITU-R Recommendation ITU-R M.1798-1.

The Recommendation ITU-R M.1798-1 provides characteristics of HF radio equipment for the exchange of digital data and electronic mail in the maritime mobile service. It was published in April 2010. The Recommendation includes the three following systems.

System 1(see Annex 2) describes an HF data service using orthogonal frequency division multiplexing (OFDM) with 32 subcarriers in which each subcarrier is modulated using differential quadrature PSK (DQPSK).

System 2 (see Annex 3) describes an electronic mail system using the Pactor-III MODEM with up to 18 subcarriers in which each subcarrier is modulated using DBPSK or DQPSK.

System 3 (see Annex 4) describes wideband HF data system for internet access and electronic mail services using OFDM. This system supports 10 kHz channel bandwidth with 228 subcarriers and 20 kHz channel bandwidth with 460 subcarriers. Each subcarrier is modulated using 4-QAM, 16-QAM, or 64-QAM. The maximum raw data rate is about 102 kbit/s.

However, the existing ITU-R Recommendation M.1798-1 system did not match the concept to operate in Korea, so a new type of protocol was developed to enable the vessel to transmit automatic location information to suit the situation in Korea.

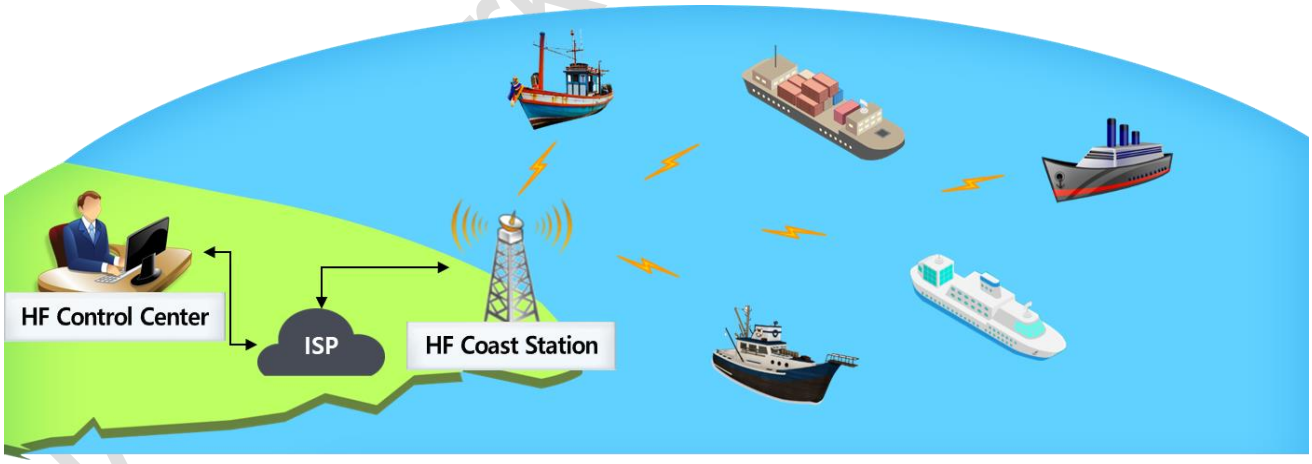


Figure 2 Overview of Digital HF

3.3 Major Characteristics

3.3.1 Digital HF prototype

The digital HF communication system under development in Korea is Point to Point Communication, which is designed to exchange digital data between shore-to-ship, ship-to-shore, and ship-to-ship.

The shore station consists of a transmitter, a receiver, a gateway as shown in Figure 3.

The transmitter is connected to the Whip antenna and used to match the designated frequency between 4MHz and 26MHz through the antenna matching unit.

The receiver is connected to a wideband wire antenna and uses a multiple receiver coupler.

Transmission power designed about 500W ~ 1kW RMS (Root Mean Square) for Shore station and 100W ~ 150W RMS for ship station. However, the transmission power may change according to the field test result.

Modulator establishes link establishment using FSK and data communication using OFDM.

The OFDM modulator has 4 QAM, 16 QAM and 64 QAM schemes, and they are designed to be operated differently depending on the communication environment.

In addition, the ship station is designed to transmit the location information to the shore stations every 10 minutes for the ship's location information management.

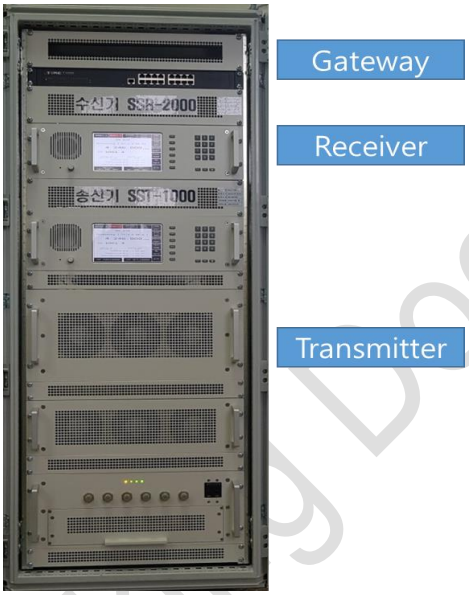


Figure 3 Digital HF Shore station Prototype

3.3.2 Potential Specifications

Digital HF uses maritime HF band designated in ITU-R Radio Regulation Appendix 17, and designated domestic frequency for the field test in Korea as shown table 1.

Table 1 Digital HF Transmitter potential Specifications

Parameter	Potential Specifications
Domestic Frequency in Korea	4.2460MHz, 6.3575MHz, 8.4730MHz 12.6835MHz, 16.9295MHz, 22.4705MHz
Transmitter Power	1kW[PEP]
Carrier frequency tolerance	Within ±0.3 ppm
Spectrum occupancy	Comply with the requirement of Figure 17
Carrier suppression	≥ 40 dBc
Spurious emission	≥ 50 dBc, without exceeding the absolute mean power of 50mW (+17 dBm)

Table 2 Digital HF Receiver Potential Specifications

Parameter	Potential Specifications

Domestic Frequency in Korea	4.2460MHz, 6.3575MHz, 8.4730MHz 12.6835MHz, 16.9295MHz, 22.4705MHz
Adjacent channel protection	20 dB (at ±10 kHz) 25 dB (at ±20 kHz) 35 dB (at ±30 kHz)
Sensitivity	-91.4 dBm (BER = 0.05 after error correction with a block length of 1,000 bits)
Spurious response rejection	≥ 60 dB
Intermodulation	≥ 50 dB
Blocking	≥ 40 dB ($\|f-f_c\|$ > 30 kHz)

3.3.3 Transmitting Antenna prototype

The transmission antenna of will use WHIP antenna and the main specifications are shown in Table 3.

Table 3 Digital HF Transmitting antenna specification

Frequency range(Rx)	0.1 ㎒ ~ 30 ㎒
Polarization	Vertical
Radiation pattern	Omni-directional
Height	15.3M
Impedance	50 Ohm
Gain	10dBi

Figure 4 shows the transmitting antenna specifications and radiation pattern.

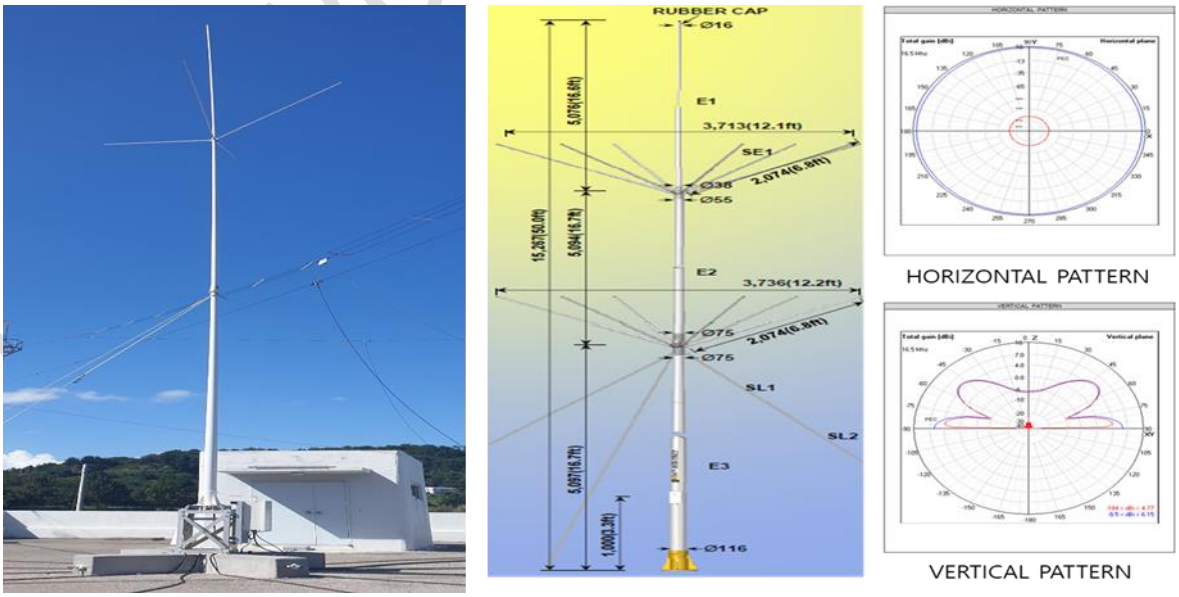


Figure 4 Digital HF Transmitting Antenna Prototype

3.3.4 Receiving Antenna prototype

The receiving antenna uses a broadband wire antenna and the main specifications are shown in Table 4.

Table 4 Digital HF Receiving antenna specification

Frequency range(Rx)	0.1 ㎒ ~ 30 ㎒
Polarization	Horizontal
Radiation pattern	Directional
V.S.W.R	1.6-18 ㎒ 2:1, 18-30 ㎒ 3:1
Impedance	50 Ohm
Gain	2.15dBi
Length	25M (85ft)
Total weight	10Kg
Wind loading	60m/s (216km/h) = 134mph

Figure 5 shows the specifications of the receiving antenna prototype.

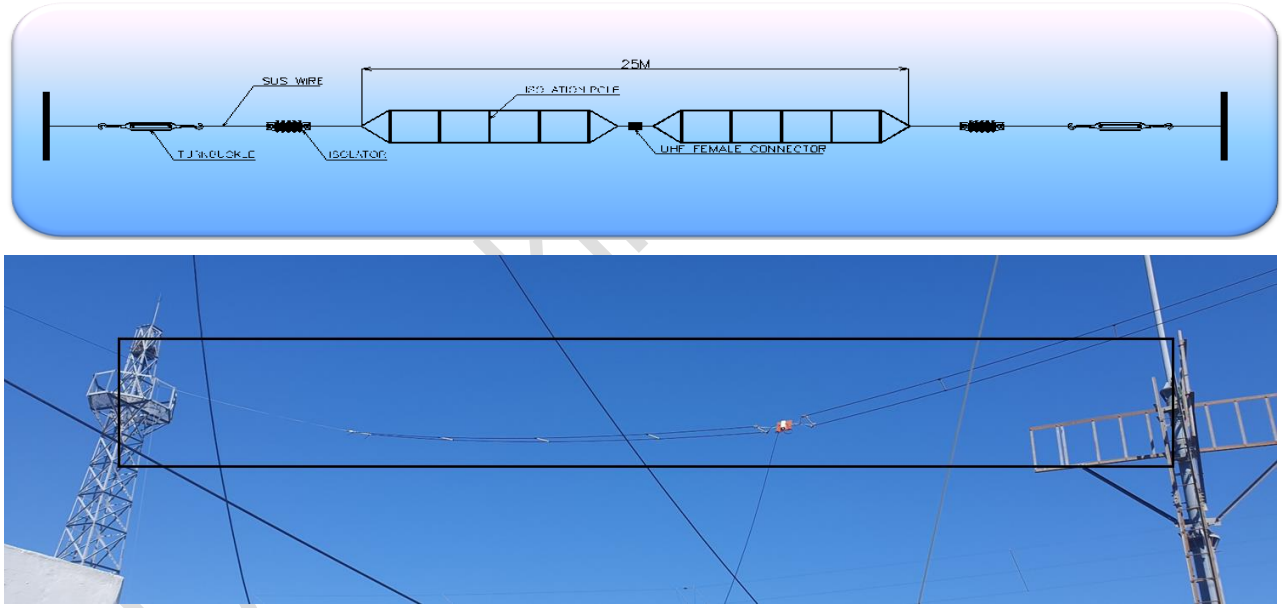


Figure 5 Digital HF Receiving Antenna Prototype

3.4 Digital HF testbed and implementation plan

3.4.1 Example field test cases

Field testing will be ongoing at the end of this year and next year in Korea

Figure 8 below shows some test cases, the first field test is being performed between shore stations. The tests are underway with test bed sites in Po-hang and Gun-san, with coverage of approximately 250 km. The result of this test will be determined about the Transmitting Power of the shore station.

The second field test will be conducted between ship station and shore stations. The result of this test will be determined about the transmitter power level for the ship station. The coverage is expected to be around 300 km.

Final test will be conducted between shore station and ship station, ship station and shore station. It will be conducted for 500-600km coverage.

This test is scheduled for next year, and the results of this test will also be provided for next year's ITU-R WP5B meeting

- **Test case 1**
  - Test Plan : 2019.08 ~ 2019.09
  - Shore Station 1 : Po-hang
  - Shore Station 2 : Gun-san
  - Test case : Shore to Shore
  - Coverage : 250km
- **Test case 2 [not fixed]**
  - Test Plan : 2019.10 ~ 2019.11
  - Test case : Ship to Shore
  - Coverage : 300km
- **Test case 3 [not fixed]**
  - Test Plan : in 2020
  - Test case : Shore to Ship, Ship to Shore
  - Coverage : 600km

Figure 6 Digital HF testbed plan in Korea

3.4.2 Propagation environment

In the HF frequency band 4 to 30 MHz, two propagation modes can be also considered.

- Ground wave
- Sky wave

The skywave refers to the signal that travels away from the Earth's surface towards the ionosphere. Unlike a ground wave it does not follow the contour of the ground, but instead it is directed towards the ionosphere.

The angle between the line of the sky wave signal and the Earth's surface at that point may be shallow or steep.

The skip distance is the distance over the Earth's surface between the point where a radio signal is transmitted, and the point where it is received having travelled to the ionosphere, and been refracted back by the ionosphere.

If the frequency of the signal is increased, a point is reached where the signal starts to penetrate the D region and signals reach the E region. Here it is reflected and will pass back through the D region and return to earth a considerable distance away from the transmitter.

The skip distance is dependent upon a variety of factors:

- **Frequency**: The frequency of operation has a major influence on the skip distance that can be achieved. Typically as the frequency increases a lower angle of radiation is needed to return the signals to Earth in a shorter distance. Also higher frequencies tend to be reflected or refracted by higher layers or regions in the ionosphere. This will mean that higher frequencies tend to lead to longer skip distances.

- **Ionospheric conditions**: The ionospheric conditions play a major role in governing the skip distance. Under some circumstances when ionisation levels are high it may be possible for signals to achieve very short skip distances.
- **Angle of radiation**: The angle of radiation from the transmitting antenna will also have an impact on the skip distance. A lower angle of radiation will lead to longer skip distances as a result of the geometry.

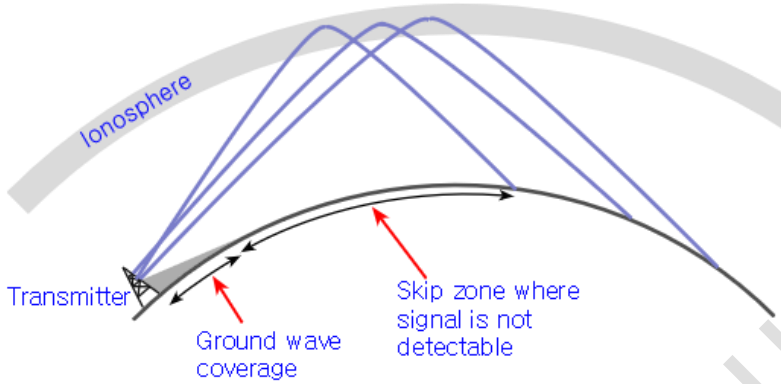
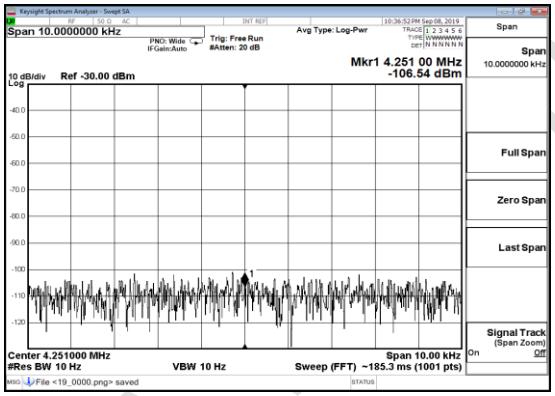
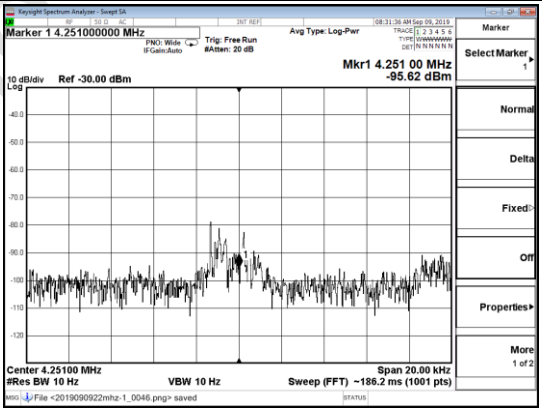
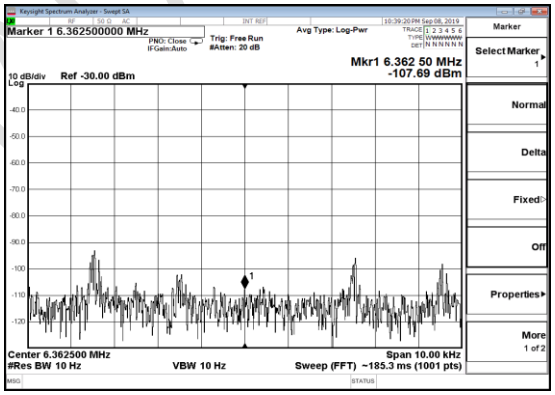
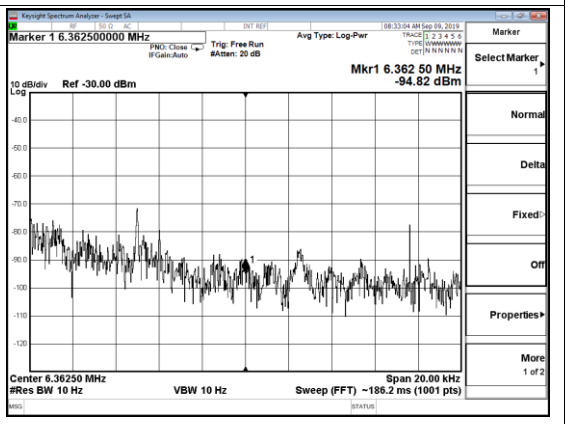


Figure 7 Characteristic of propagation in HF band

The following Table 5 illustrate the results of the measured propagation environment at 4MHz in Po-hang, Korea. Because of the Ionospheric conditions, the radio environment is different during the day and at night, and that the radio environment is particularly bad at night.

Table 5 Measured propagation environment at 4MHz in Po-hang, Korea

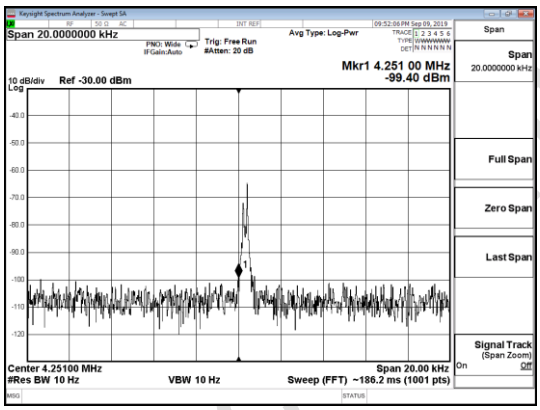
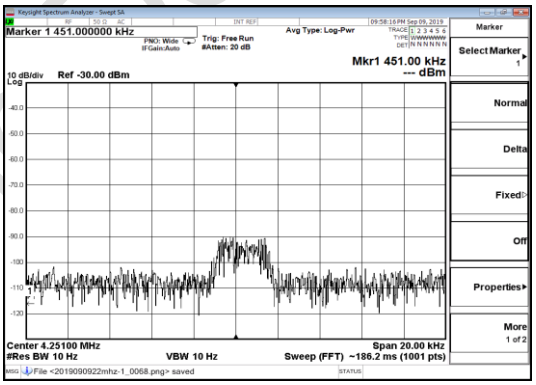
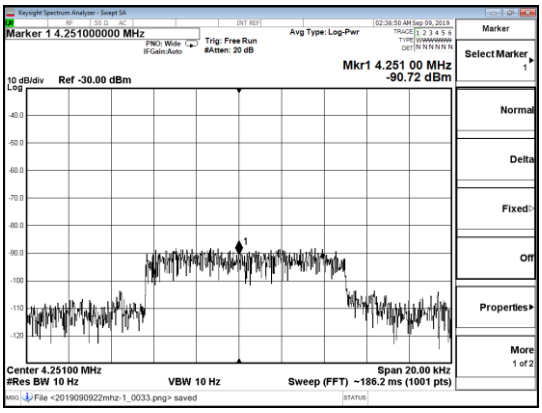
	
4.2460MHz at 10:00 AM	4.2460MHz at 22:00 PM
	
6.3575MHz at 10:00 AM	6.3575MHz at 22:00 PM

3.4.3 Field test result

The first field test is being performed between shore stations from September 2019 to November 2019. The tests are underway with test bed sites in Po-hang and Gun-san, with coverage of approximately 250 km.

The result is shown as table 6.

Table 6 Field Test result of FSK, OFDM signal

Transmitting Station	Receiving Station
	
FSK at 4.2460MHz	
	
OFDM 3 kHz bandwidth at 4.2460MHz	
	
OFDM 10 kHz bandwidth at 4.2460MHz	

3.4.4 Implementation plan in Korea

The Republic of Korea plans to construct and implementation a digital HF system from 2020 to 2021.

The shore stations will be constructed in three locations in Korea and one shore station will be equipped with separately from the transmitting stations and receiving stations.

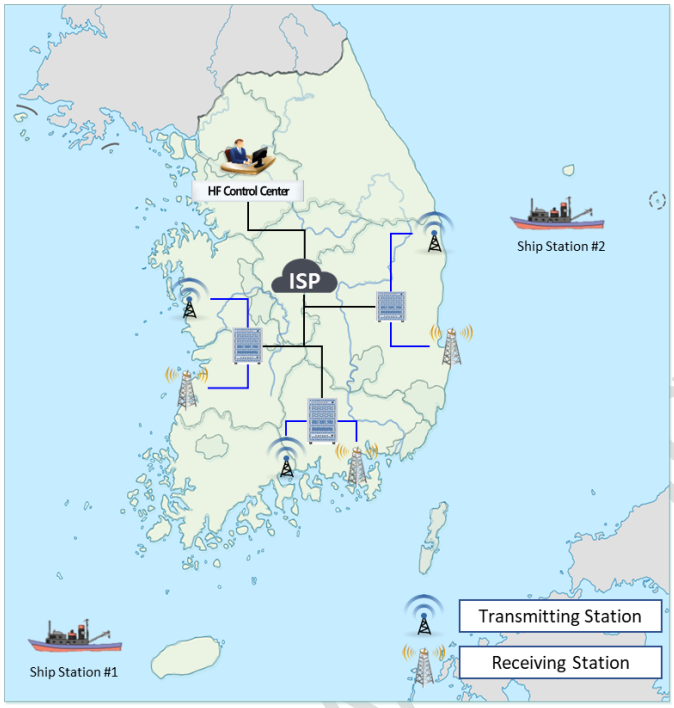
These shore stations are controlled by the digital HF operating center and managed ship's positioning information.

The operating frequency is expected to be at least 6-8 in maritime HF bands and in the case of ship station, it is designed to report the automatic positioning to the HF control center.

The ship station will report their position once every 10 minutes.

The shore station can send Broadcast message, Multicast, Unicast message to ship station.

The one shore station will be equipped with six transceivers, one for each frequency band.



- **Operating Frequency Band**
  - 4 MHz, 6 MHz, 8 MHz, 12 MHz 16 MHz, 22 MHz
- **Ship Station [not Fixed]**
  - Automatic positioning report (1 times per 10 minute)
  - Emergency request
- **Shore Station**
  - Broadcast message
  - Multicast message
  - Unicast message
  - 6 transceiver
  - Independently operate each band

Figure 8 Digital HF testbed implementation plan in Korea

3.5 Digital HF Standardization

Details of draft revision of ITU-R Recommendation M.1798-1 are found in annex 1

4 REFERENCES

[1] E-Navigation Underway Asia-Pacific 2019, Digital Maritime Communication focusing on VDES and Digital HF

[2] Working Document towards a Preliminary draft revision of Recommendation ITU-R M.1798-1

5 ACTION REQUESTED OF THE COMMITTEE

This paper is only for information and requires no action by the committee.

ANNEX 1

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT REVISION OF RECOMMENDATION ITU-R M.1798-1 - CHARACTERISTICS OF HF RADIO EQUIPMENT FOR THE EXCHANGE OF DIGITAL DATA AND ELECTRONIC MAIL IN THE MARITIME MOBILE SERVICE