Input paper: [1] ENAV30-5.1.2.2

Input paper for the following Committee(s):	check as appropriate		Purpose of paper:
X ARM	X ENG	□ PAP	X Input
□ ENAV	□ VTS		□ Information

Agenda item [2]	6.2
Technical Domain / Task Number [2]	……
Working Group	WG1 and 2
Author(s) / Submitter(s)	Woo Seong SHIM(KRISO), Bu Young KIM(KRISO)
	Hak Sun KIM(UNIST), Jin Woo KONG(Sunny Wave Tech)

Metal Surface at Magnetic Substance (MS@MS) wave

1 SUMMARY

The MS @ MS wave is a kind of radio-free wireless communication, more efficient and capable of overcoming the limitation of metal surrounding structure for wireless network and for primarily applying to the wireless IoT network in maritime sector.

We present annex including problem of wireless communication environment application in maritime sector including ships and Aids to Navigation, introduction of MS@MS wave technical, experimental case of the technology implementation.

1.1 Purpose of the document

The purpose of the document is to provide the information of MS @ MS wave.

1.2 Related documents

ENAV30-n.n.n Radio-free wireless communication based on Metal Surface Wave in the maritime sector

2 ACTION REQUESTED OF THE COMMITTEE

We would like to present the annex and would appreciate fruitful discussions.

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

ANNEX PRESENATION OF MS@MS WAVE TECHNICAL NOTE

1-1. Necessity

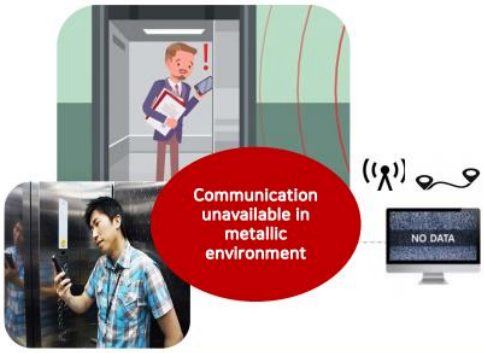
Communication in Metallic Structures

Shadow zones in metallic facilities due to reflection/absorption of electromagnetic waves

In industries…

Causes critical risks that are related to safety as well as work efficiency

'EM shielding facilities'



Undergrounds

Metal Process Chamber

Ships

Needs of new technology for data transfer
in Radio basedcommunication environment

SWAVE

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1-2. MS@MS wave

MS@MS Wave Communication

An innovative technology that allows communication using Metal surface wave technology in constrained spaces

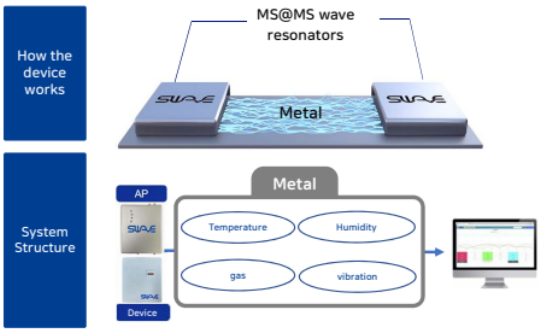
Sunny Wave Tech.'s Total Solution

"Aurora Solution"

Metal Surface at Magnetic Substance

Radio free that
uses Sunny Wave Tech.'s unique
Metal surface-wave communication technology
and collects/analyzes data generated in metallic industrial fields

Metal Surface Magnetic substance wave Configuration



The 'Radio Free' platform for data in extreme industrial environment

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1-3. Products of Aurora

Aurora Resonator (ISM band)	Aurora Device (MS@MS wave/Wireless)	Aurora Access Point (ISM Band)	Aurora UX/UI S/W

Item	Specification
Application	Under 6GHz (Wi-Fi, BT, Zigbee, LoRa)
Distance	Maximum distance 1km(Wi-Fi)
Interface	UART, SPI, I2C
Size	Resonator : 60 X 60 X 5 mm
	Device : 50 X 50 X 40 mm
	AP : 100 X 100 X 30 mm
S/W specification	Based on Window program

Item	Specification
TRx speed	10Kbps ~ 100Mbps
TRx rate	20Mbit/s ~ 100Mbit/s
Supply voltage	Device 2.1~3.6V(Charging battery Type) AP 12V(Commercial power supply)
Sensor	Changeable based on customer demand
Storage Temperature	-20℃~+70℃

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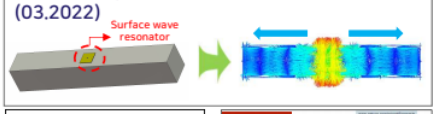
1-4. Distinctiveness

Proprietary technology

Surface wave communication has introduced in journals as a technology that allows communication under metallic environment, and the resonators have been successfully developed for productization (03.2022)




Alignment- and metallic-obstacle-insensitive contactless power transmission system utilizing surface-guided mode

ak-Sun Kim[1], Franklin Bien[1]

IET (19'08)


nature SCIENTIFIC REPORTS

Experimental Realization of Zenneck Type Wave-based Non-Radiative, Non-Coupled Wireless Power Transmis

Franklin Bien[1*]

Haksun Kim[1]

Scientific Reports (20'01)

Benefits

(1) Overcoming limits	Build communication network in metallic environment (ships, chambers)
(2) Process efficiency	Provide solutions for energy optimization, problem analysis and prediction
(3) Cost reduction	Harness Free Solution (Automobiles, smart ships)

Productization based on the outstanding technology

SWAVE

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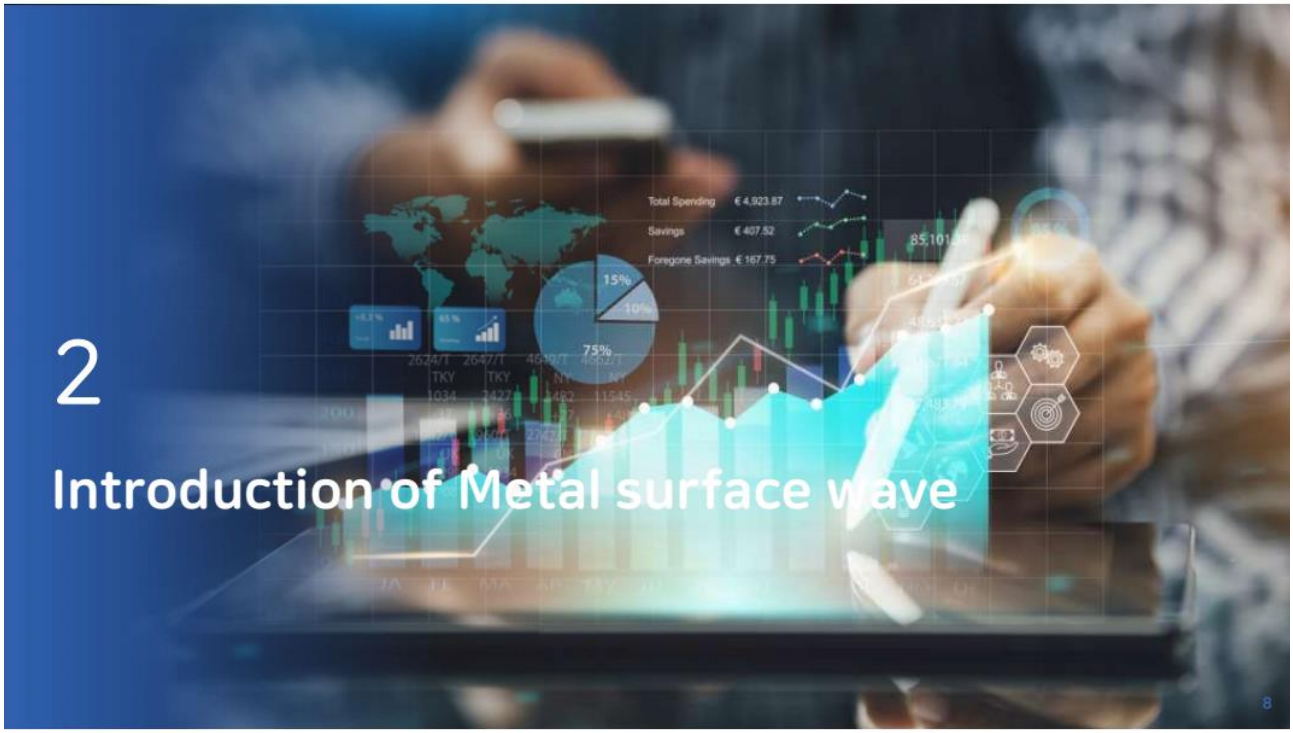

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2-1. Theoretical Background

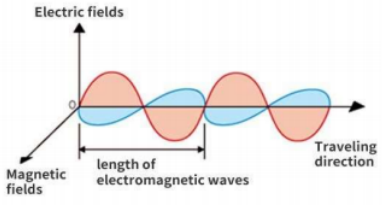
Maxwell's Equation (3rd, 4th Laws)

The electric field is generated in the vertical direction of the signal, and the magnetic field is formed in the horizontal direction.

(1) Derived from 3rd Law	An electric field(E), which rotates along the axis of the magnetic flux density, is generated in the direction that prevents the time change of the magnetic flux density (B)
(2) Derived from 4th Law	A magnetic field(H) is generated, in which it rotates along the axis of the total current density that is sum of the conduction current density(J) and the displacement current density (D)

$$\nabla \cdot \mathrm{D} = \rho$$
$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$
$$\nabla \times H = J + \frac{\partial D}{\partial t}$$



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2-2. Theoretical Background

Metal surface wave communication

Refference
Surface Plasmons-Polaritons, Surface Waves, and Zenneck Waves: Clarification of the terms and a description of the concepts and their evolution

Surface wave is generated along the metal interface and calculated by the formulas of electric field and magnetic field to the pointing vector theorem

$$\vec{E} = (E_z\hat{z})e^{(jkz-j\omega t)}e^{-\alpha|z|}$$

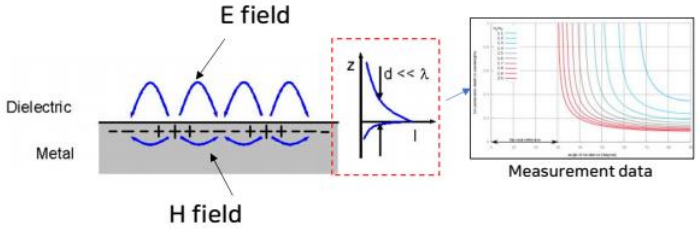
Direction of electric field: Z- axis

$$\vec{H} = (H_x\hat{x} + H_y\hat{y})e^{(jkx,y-j\omega t)}e^{-\alpha|x,y|}$$

Direction of magnetic field: X-Y-axis

Pointing Vector Theorem

$$\vec{P} = \frac{1}{2}H_{x,y}(E_z)e^{-2\alpha z}$$



"Evanescent Theory"

- Signal applied to the z-axis forms an electric field of the z-axis
- The electric field attenuates much faster than the wavelength
- The resulting magnetic field of x,y axis flows along the metal surface

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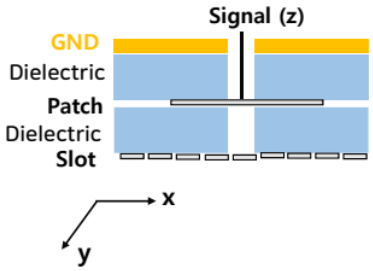
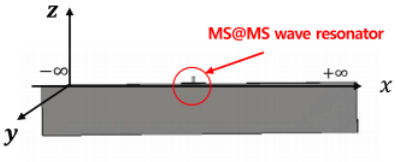
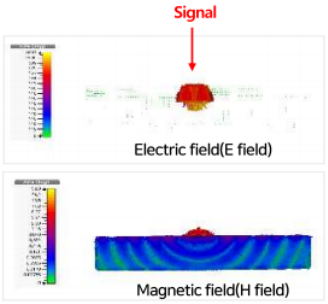
2-3. MS@MS Wave Resonator

Structure of MS@MS wave Resonator

- Insert a slot of a periodic arrangement for surface wave behavior into the patch on the dielectric plane
- A magnetic field signal can be transmitted to the metal surface using the inductive impedance of the filter characteristics generated when metal and dielectric are attached







The MS@MS resonator attaches to the metal and converts the E/M signal into a magnetic signal and transmits the signal through the metal surface

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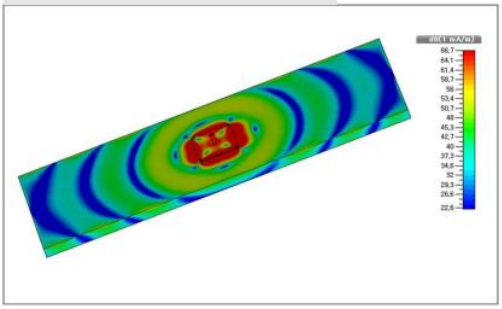
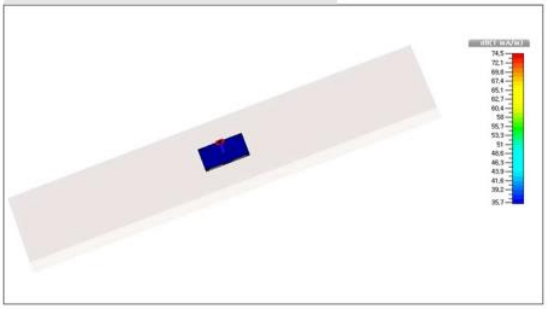
2-4. Metal Surface wave resonator simulation

On Metal



On Non-metal



Using a surface wave resonator, the signal propagates in the form of Zenneck waves along the metal surface

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2-5. MS@MS wave FAQ

Is the performance dependent to metal types?

- Paramagnetic does not incompletely cancel electron spin and orbital magnetic moment and is magnetized in a magnetic field in the same direction.
- Diamagnetic completely cancels electron spin and orbital magnetic moment and is not magnetized in a magnetic field in average.
- Ferromagnetic is oriented in the same direction as the external magnetic field.

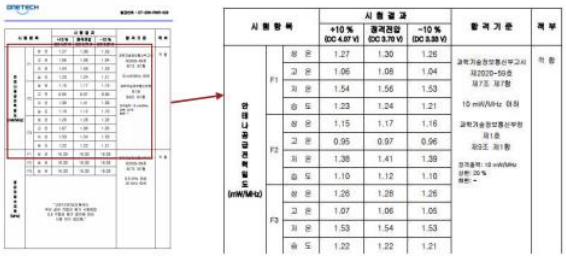
	Relative permeability	Form	MS@MS wave
Ferromagnetic	$\mu_s \gg 1$	Steel, Nickel, Cobalt	O
Paramagnetic	$\mu_s > 1$	Aluminum, Magnesium	O
Diamagnetic	$\mu_s < 1$	Glass, Tree, Water, Copper	X

Metal + Paints?

- If dielectric substances are in between MS@MS wave resonators, the substances cause magnetic resistance and decrease communication distance.

Spectral Power?

- As a result of the EMI test, the spectral power of Wi-Fi based MS@MS wave is lower than the limitation.
- Limitation (10mW/MHz), Test results (lower than 2mW/MHz)



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3-1. Application cases

	Case 1	Case2	Case3
			
Model	Tugboat	Tugboat	Ferry
Material	Aluminum	Steel	Steel
Objective	Application of MS@MS wave Technology in the constrained space	1. Application of MS@MS wave Technology in the constrained space 2. Analysis of communication impact by engine and generator	Validating applicable communication distances
Comparative technology	Radio communication Technology	Radio communication Technology	
Model size	15*4*2 m	33*10*4.5 m	192*30*10m

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3-2. Equipment used in cases application

Equipment condition

Signal Analyzer

Model	Keysight N9010B (10Hz~26.5GHz)
Usage	1. Analyzing TRx Power of the AP 2. Analyzing the channel frequency of the AP 3. Measure the noises in wireless communication

Device & AP

Setup	1. Wi-Fi 802.11 n 2. Frequency : 2.437GHz(CH 6) 3. Device Tx Power : Max 20dBm 4. AP TX Power : Max 17dBm 5. Rx Sensitivity : Max -91dBm(Device & AP) 6. Data rate : Max 100Mbps in 2.4GHz(AP)

MS@MS wave Resonator
RF cable
Wireless ANT

MS@MS wave Resonator	3 types(same gain, different sizes)
RF cable	1. ANT cable(loss 0.3dB) 2. Signal analyzer cable(loss 1dB)
Wireless ANT	1. Dipole ANT 2. 3dBi gain

For the objectivity of the application case, the setting of the equipment was clearly defined.

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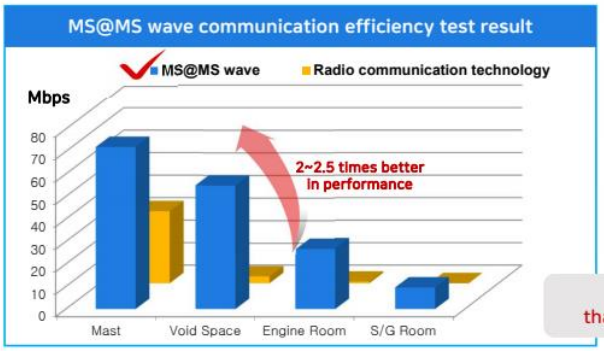
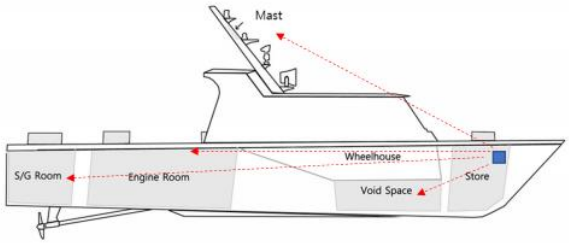
3-3. Application Results – case(1)

Communication performance test in a tugboat (Aluminum)





MS@MS wave communication shows better performance than RF technology in the constrained space of maritime domain

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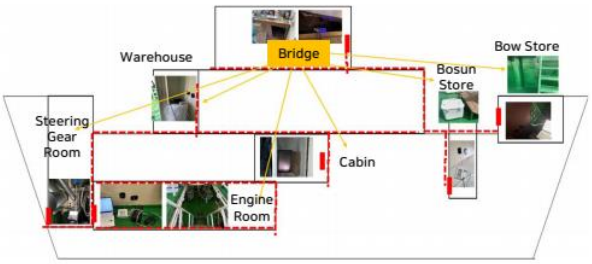
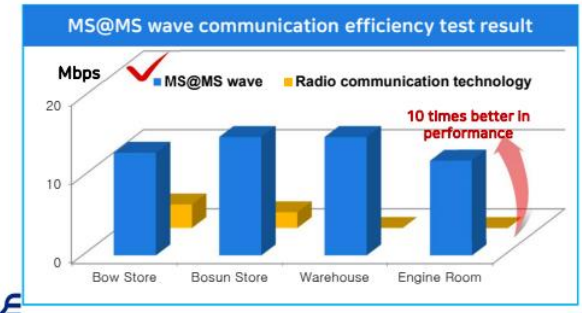
3-4. Application Result – case(2)

Communication performance test in a tugboat (Steel)





MS@MS wave communication shows better performance than RF technology in the constrained space of maritime domain

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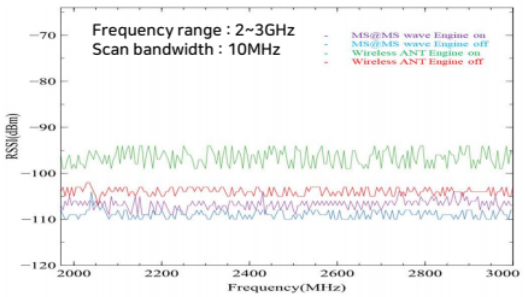
3-5. Application Result – case(2)

Interference

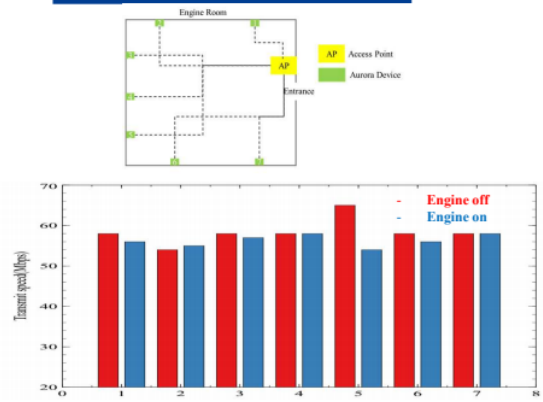
Equipment that uses MS@MS wave is not interfered by communication equipment in the maritime equipment
The performance of MS@MS equipment is independent to states of maritime equipment such as generators and engines

Noise Analysis



	MS@MS wave	Wireless(RF)
Engine off	-110dBm(Avg.)	-105dBm(Avg.)
Engine on	-107dBm(Avg.)	-96dBm(Avg.)

MS@MS wave communication test



MS@MS wave communication is less interfered by generators and engines than Radio communication technology

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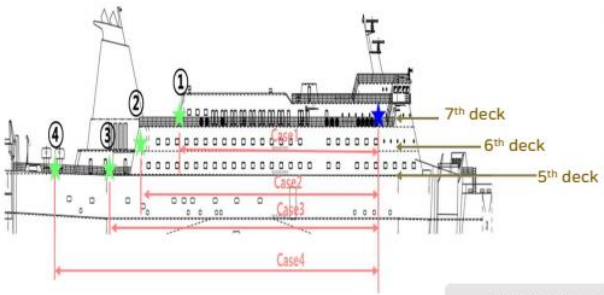
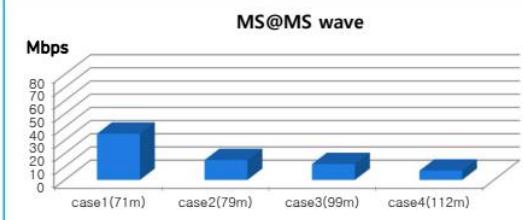
3-6. Application Results – case(3)

Communication performance test in a Ferry (Steel)



MS@MS wave communication efficiency test result



MS@MS wave communication shows can connect a distance of up to 100m

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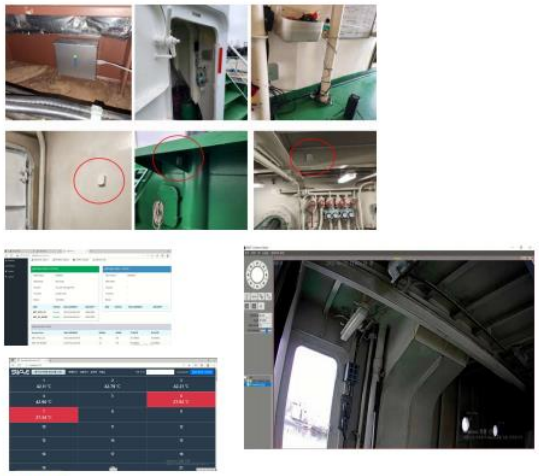
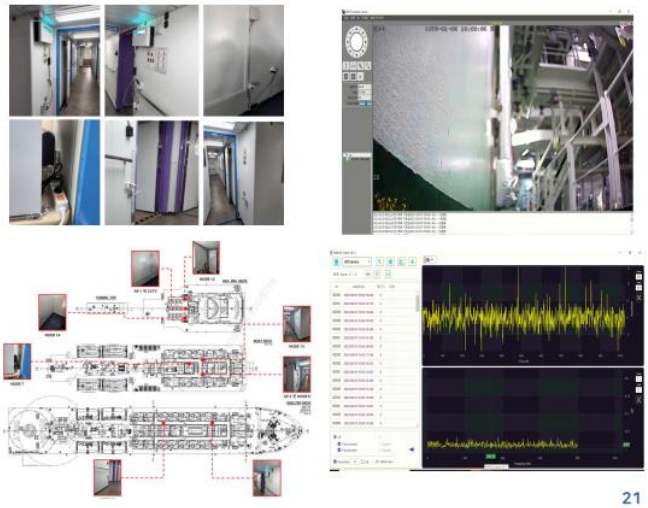
3-7. Cases in pilot application

The pilot application of maritime domain(two kind of ships)

- Temperature Sensor : real time monitoring
- Camera : real time monitoring
- Application Type : Aurora products using MS@MS wave technology



- 3-axis vibration sensor : real time monitoring
- Camera : real time monitoring
- Application Type : Aurora products using MS@MS wave technology



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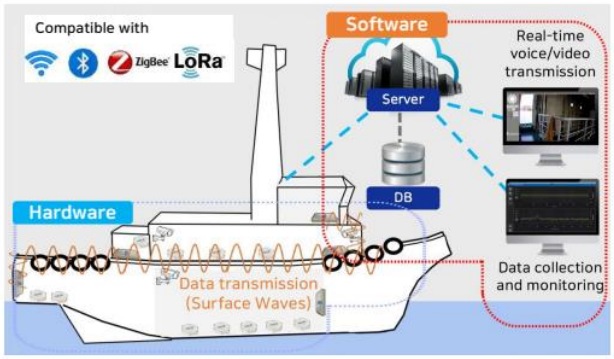
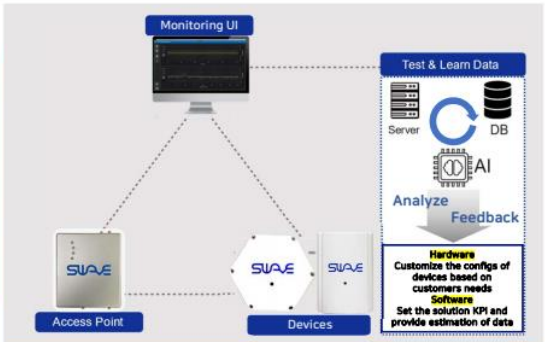
3-8. Usage Model of Maritime domain

Aurora

Configuration



Products & Services



Building ▶ Analysis ▶ Consulting ▶ Management

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5. Conclusion

1. A technique called MS@MS wave is based on the theory of metal surface wave(Metal surface @ Magnetic substance wave)
2. Our products including MS@MS wave technology are called Aurora
3. Our products can build 'RF Free' in situations where Radio communication is difficult through application in the marine domain.
4. We are still acquiring and analyzing meaningful data by applying our products to ships.
5. We hope provide guidance for the optimization, promotion and application of MS@MS wave technology in the maritime domain such as ships and A to N.
6. We sincerely invite the committee to make use of the ship communication system built by the project to carry out multi-party cooperation for the applications of Aurora products.

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