



CREATING GROWTH, ENHANCING LIVES

Joint Paper from A*STAR-I²R, ST Engineering and MPA

Ship-borne VDES Mobile Station Development and Trial Results in Singapore

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Agenda

- **Ship-borne VDES Mobile Station – Overview**
- **Ship-borne VDES Mobile Station – RF System Design**
- **Ship-borne VDES Mobile Station - Baseband System Design**
- **Simulation Results**
- **Field Trial Results**
- **Conclusions**

Ship-borne VDES Mobile Station – Project Overview

- The ship-borne VDES mobile station is jointly developed by A*STAR-I²R, ST Engineering with co-funding by MPA Singapore;
- A series of comprehensive field trials have been conducted in the lab, land and open sea in Singapore Straits to measure the performance of the developed ship-borne VDES mobile station;
- To follow up on this field trial, we aim to explore opportunities for interoperable testing with other interested parties;

Ship-borne VDES Mobile Station - Overview

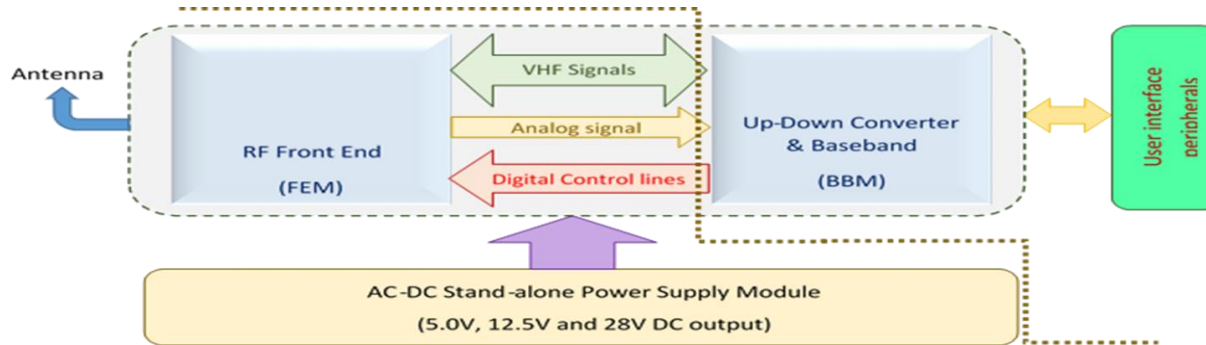


Figure 1. Ship-borne VDES Mobile Station - Transceiver Architecture



Figure 2. Ship-borne VDES Mobile Station - Final Prototype Hardware Version

Ship-borne VDES Mobile Station – RF System Design

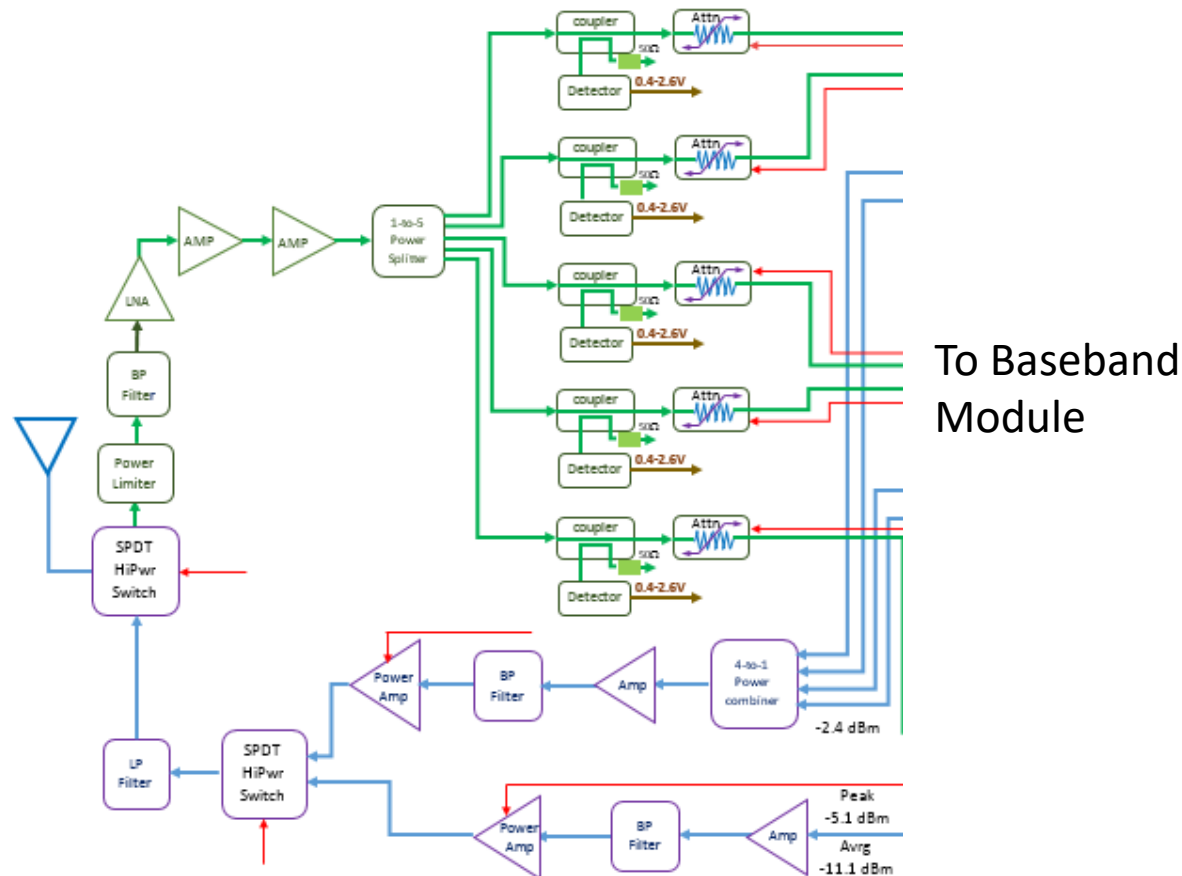


Figure 3. Ship-borne VDES Mobile Station – RF Front-end Module

Ship-borne VDES Mobile Station – Baseband System Design

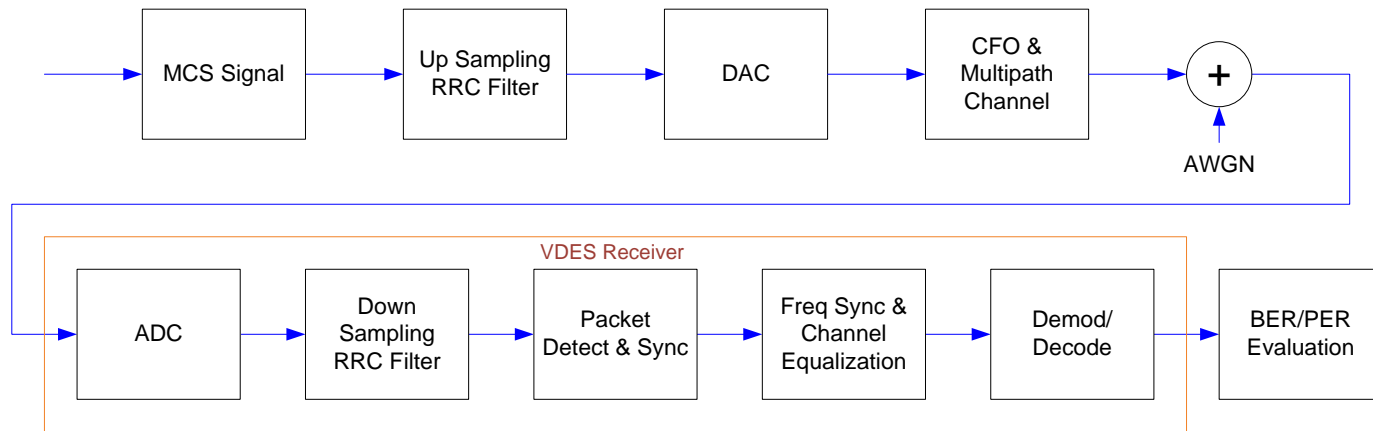


Figure 4a. VDES Baseband Simulation System Block Diagram

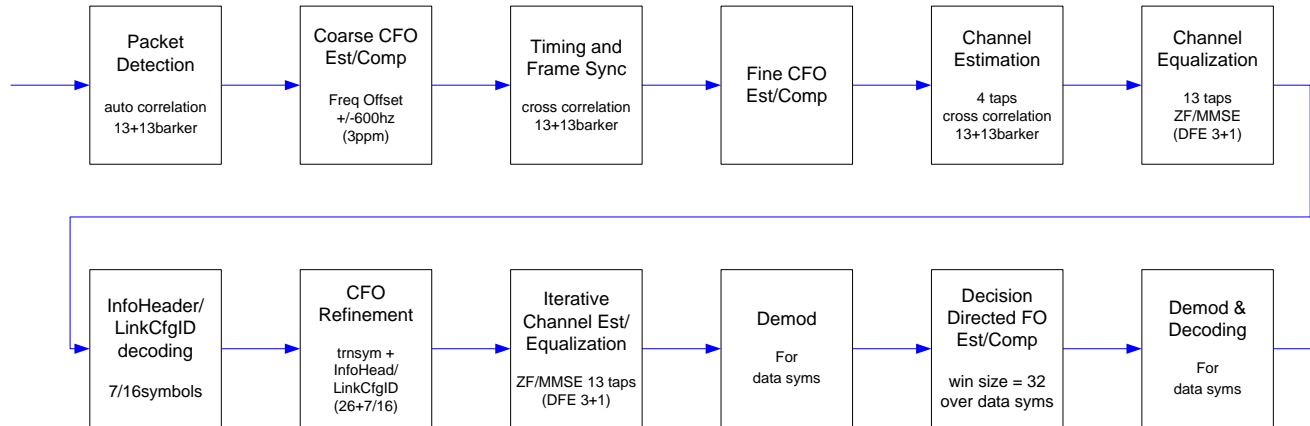


Figure 4b. VDES Receiver System Block Diagram

Simulation Results

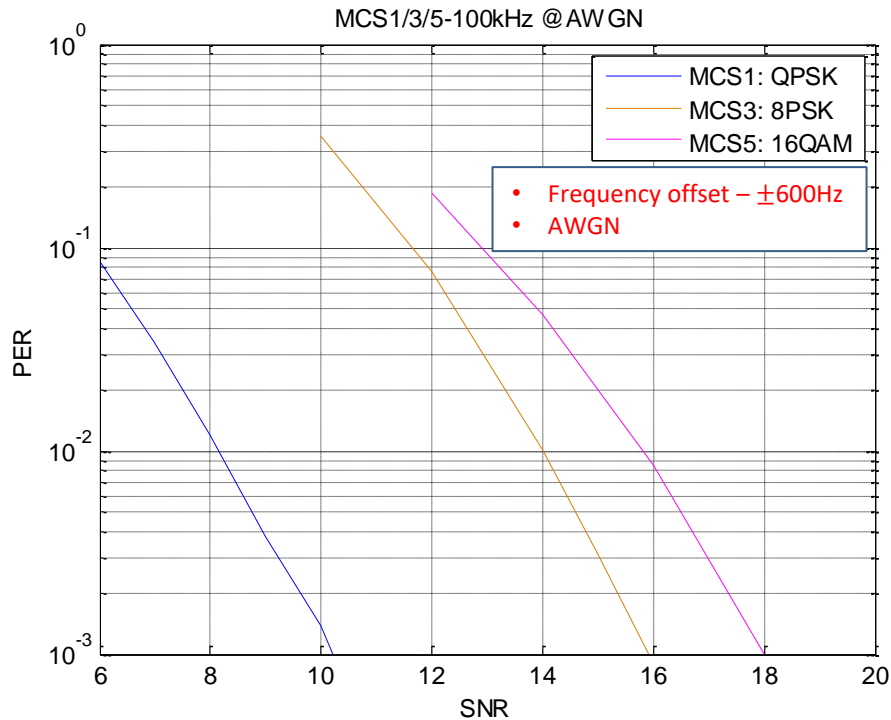


Figure 5. Simulation Results of our VDES @ AWGN

MCS/Bandwidth	Ours	EfficienSea	Difference
MCS1/25 kHz	2.2 dB	3.6 dB	1.4 dB
MCS1/50 kHz	1.8 dB	3.6 dB	1.8 dB
MCS1/100 kHz	1.7 dB	4.0 dB	2.3 dB
MCS3/25 kHz	10.3 dB	10.2 dB	-0.1 dB
MCS3/50 kHz	9.2 dB	10.2 dB	1.0 dB
MCS3/100 kHz	9.0 dB	10.0 dB	1 dB
MCS5/25 kHz	11.1	12.0 dB	0.9 dB
MCS5/50 kHz	10.5	11.7 dB	1.2 dB
MCS5/100 kHz	10.4	11.7 dB	1.3 dB

Table 1. Simulation Performance comparison between our VDES and EfficienSea in terms of the minimum SNR (dB) required to achieve PER = 10% (Assumption: Doppler shift = 5Hz)

Field Trials - Overview

- Field trials were conducted under 3 different environments:
 1. Lab Test
 2. Land Trial
 3. Sea Trial
- The following **performance measures** are obtained from the field trials:
 1. **PER vs RSSI** – This set of lab test results is to ensure that the sensitivity of the receiver conforms to the specifications.
 2. **PER vs SNR** – This is the set of measured PER of the receiver when the received SNR is varied.
 3. **Net Throughput vs SNR** – The set of measured net throughput of the system when the received SNR is varied.

Field Trials – Lab Test

Lab Test Parameters	
Test Environment	Typical enclosed room of about 6m x 4m dimension
Height of antenna	1m
MCSs	MCS1, MCS3, MCS5
Bandwidth	25, 50, 100 kHz
Distance between transmit and receive antennas	4m
Obstacles between transmit and receive antennas	None
Transmit power	1 W (max)
Source of attenuation	Analog adjustable attenuator to emulate path loss and varied the received SNR.

Table 2. Lab test parameters

Field Trials – Lab Test

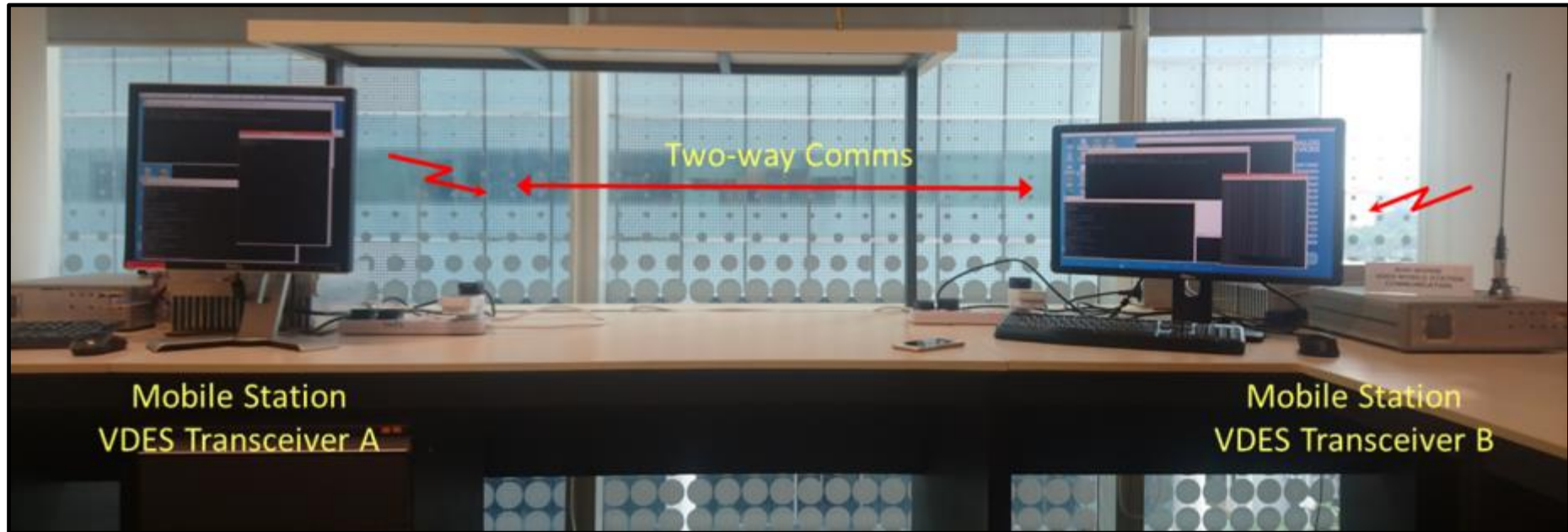


Figure 6. Setup for the lab test

Field Trials – Lab Test

MCS/BW	Standards Requirements	Our Results	Margin
MCS1 25 kHz	-110 dBm	-113 dBm	3 dBm
MCS1 50 kHz	-107 dBm	-112 dBm	5 dBm
MCS1 100 kHz	-104 dBm	-109 dBm	5 dBm
MCS3 50 kHz	-101 dBm	-102 dBm	1 dBm
MCS3 100 kHz	-98 dBm	-99 dBm	1 dBm
MCS5 25 kHz	-102 dBm	-104 dBm	2 dBm
MCS5 50 kHz	-99 dBm	-101 dBm	2 dBm
MCS5 100 kHz	-96 dBm	-99 dBm	3 dBm

Table 3. Receiver sensitivity results

- The VDES mobile station **exceeds** the standards requirements for all MCS and bandwidth with a **margin of at least 1 dBm**.
- About **2-4 dB performance degradation** between lab test and simulation due to implementation loss.

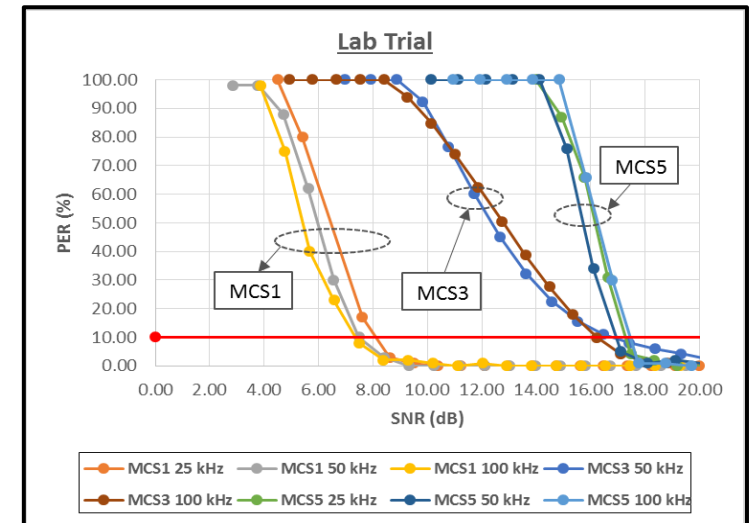
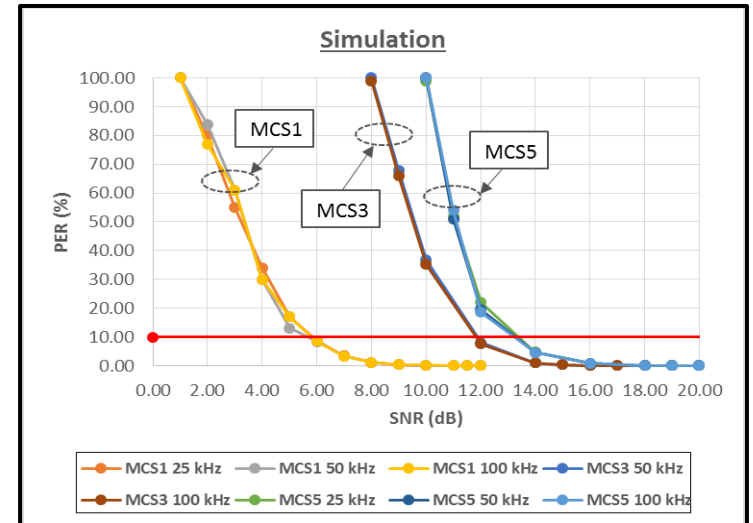


Figure 7. Lab test results with comparison to simulated result

Field Trials – Land Trial

Land Trial Parameters	
Test Environment	Relatively flat terrain with line-of-sight and surrounded mainly by trees and a couple of 1-storey buildings.
Height of antenna above ground	4m
MCSs	MCS1, MCS3, MCS5
Bandwidth	25, 50 kHz
Distance between transmit and receive antennas	1.8km
Obstacles between transmit and receive antennas	None
Transmit power	1 W (max)
Source of attenuation	Analog adjustable attenuator to emulate path loss and varied the received SNR.

Table 4. Land trial parameters

Field Trials – Land Trial



Figure 8. Setup for the land trial

Field Trials – Land Trial

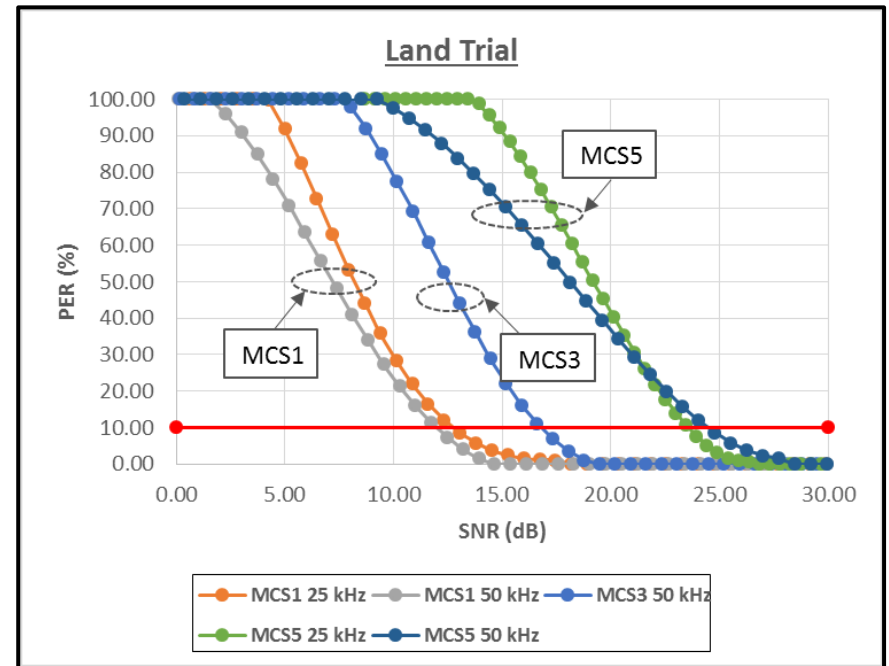
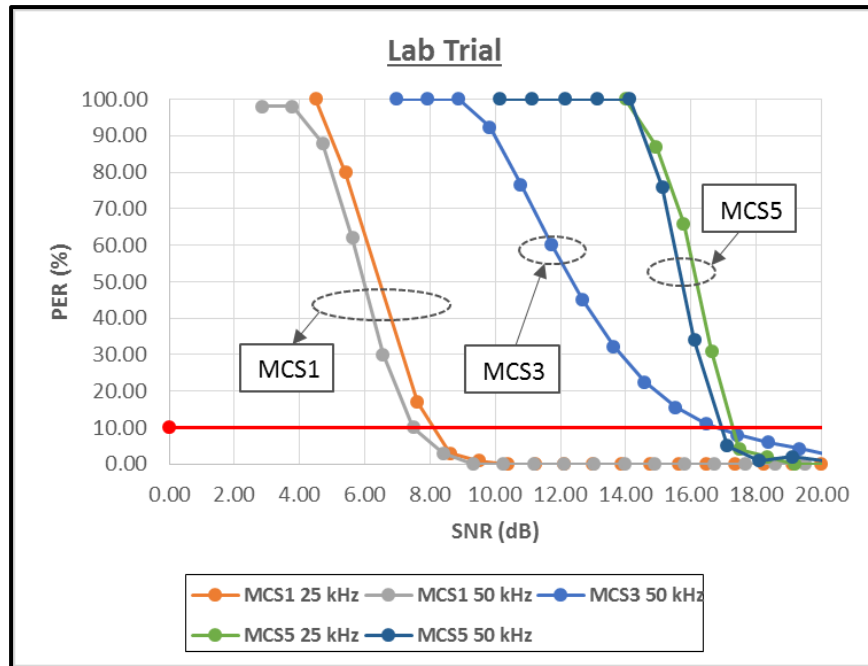


Figure 9. Land trial results with comparison to lab test results

- About **0-7 dB performance degradation** between land trial and lab test.
- **Performance deviation** between the land trial and lab test are due to the **presence of channel impairments in the outdoor environment**, namely **adjacent frequency interference** and **multi-paths**.

Field Trials – Sea Trial

Sea Trial Parameters	
Test Environment	Open sea on the Straits of Singapore surrounded by ships of various sizes.
Height of shore station antenna above ground	76m
Height of ship station antenna above ground	3m
MCSs	MCS1, MCS3, MCS5
Bandwidth	25, 50, 100 kHz
Distance between transmit and receive antennas	1-20km
Obstacles between transmit and receive antennas	Other ships may sometimes block the line-of-sight between the transmit and receive antenna.
Transmit power	1 W (max)
Source of attenuation	None

Table 5. Sea trial parameters

Field Trials – Sea Trial



Figure 10. Setup at shore station (Bedok Lighthouse) for sea trial



Figure 11. Setup at ship station for sea trial (The ship is provided by MPA)

Field Trials – Sea Trial

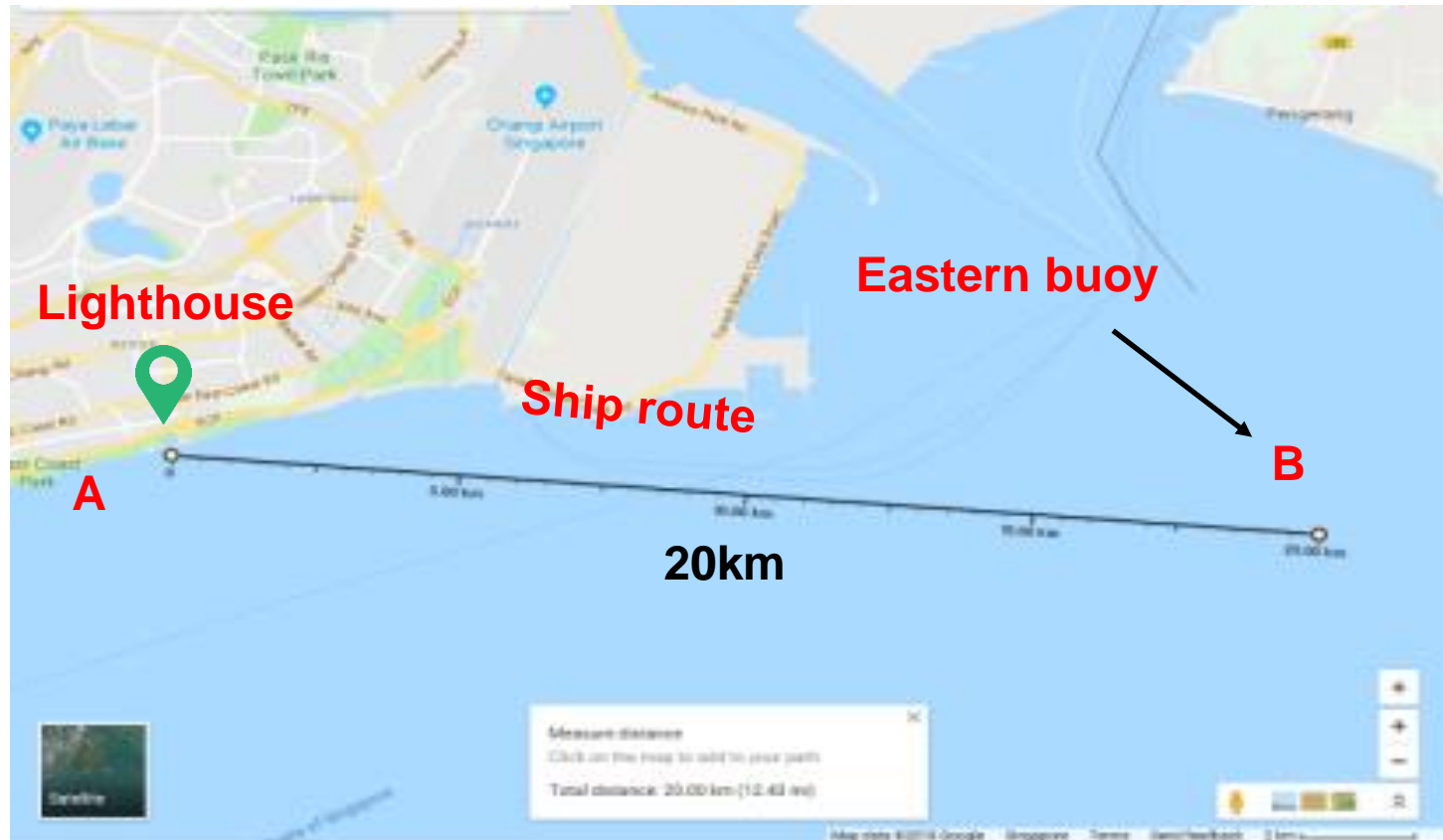


Figure 12. Shore-to-ship and ship-to-ship test methodology for sea trial

Field Trials – Sea Trial

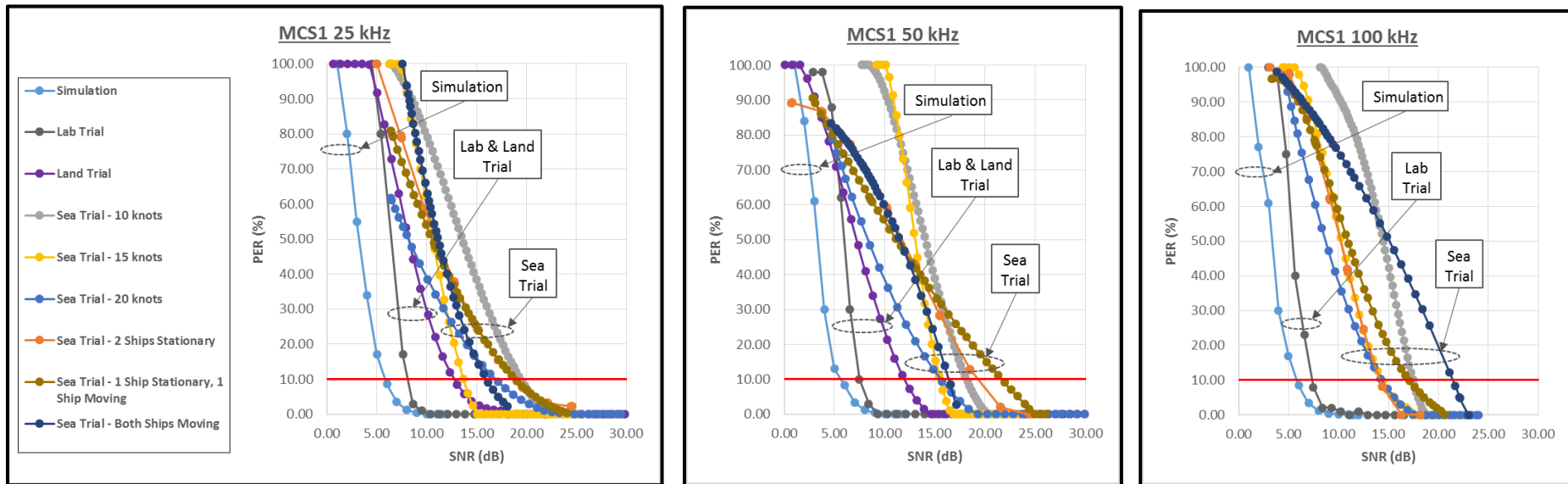


Figure 13. Sea trial results for MCS1 with comparison to simulation, lab test and land trial results (as example)

- SNR required to achieve PER = 10% varies between **14 - 22 dB** for sea trial.
- Performance deviation is due to the **dynamically changing environment** as the sea trial was conducted at different times and dates.
- Performance degradation between land and sea trial is due to a **significantly higher adjacent frequency interference observed at sea.**
- Similar trends were also observed for MCS3 and MCS5.

Field Trials – Sea Trial

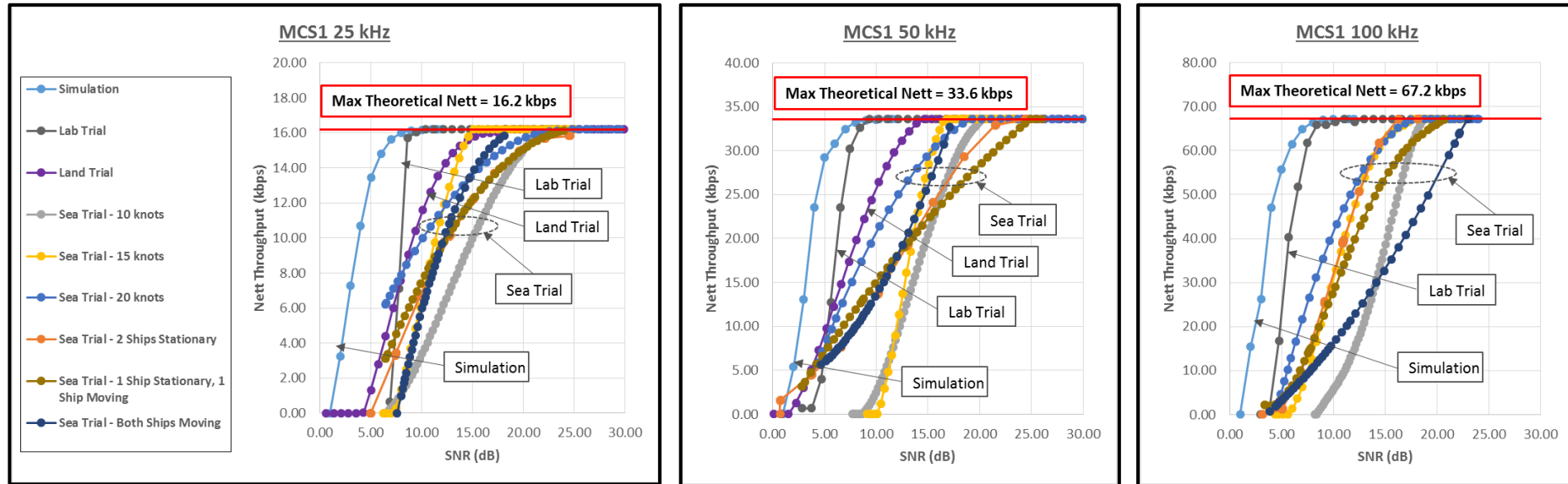


Figure 14. Sea trial nett throughput results for MCS1 with comparison to simulation, lab test and land trial results

- **Maximum theoretical nett throughput** is achieved at SNR of at least **15 dB**.
- Similar trends were observed for MCS3 and MCS5.

Conclusions

- A ship-borne VDES mobile station transceiver was developed in accordance to the M.2092 Standards.
- A series of tests in the lab, land and sea were conducted in order to measure its performance.
- The sensitivity of the receiver meets the minimal requirements stipulated in the Standards.
- Results obtained at sea trial demonstrated that the transceiver is able to achieve good performance.

We are exploring opportunities for further interoperable testing of our developed VDES mobile station with other interested parties.

Reference

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2. Research & Radionavigation Directorate, The Quay, Harwich, CO12 3JW and University of South Australia, "VDES channel sounding campaign trial report," RPT-09-JSa-14, version 1.1, 3 Apr 2014.
3. EFFICIENSEA, "Appendix 2: Report on the software simulator for the analysis of VDES system terrestrial segment," 21 June 2016.

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