Input paper: [[1]](#footnote-2) ENG21-3.1.2.8

Input paper for the following Committee(s): check as appropriate Purpose of paper:

**□** ARM **X** ENG **□** PAP **X** Input

**□** DTEC **□** VTS **□** Information

Agenda item [[2]](#footnote-3) n.n

Technical Domain / Task Number 2 Radionavigation services / 3.2.2

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MF R-Mode performance prediction of ROK

# Summary

The Republic of Korea proposes to present and discuss the results of its Medium Frequency (MF) R-Mode performance prediction study as a contribution to the performance prediction chapter of the “Guideline on Implementation of MF and VDES R-Mode System and Service” currently being developed by the IALA ENG Committee.

## Purpose of the document

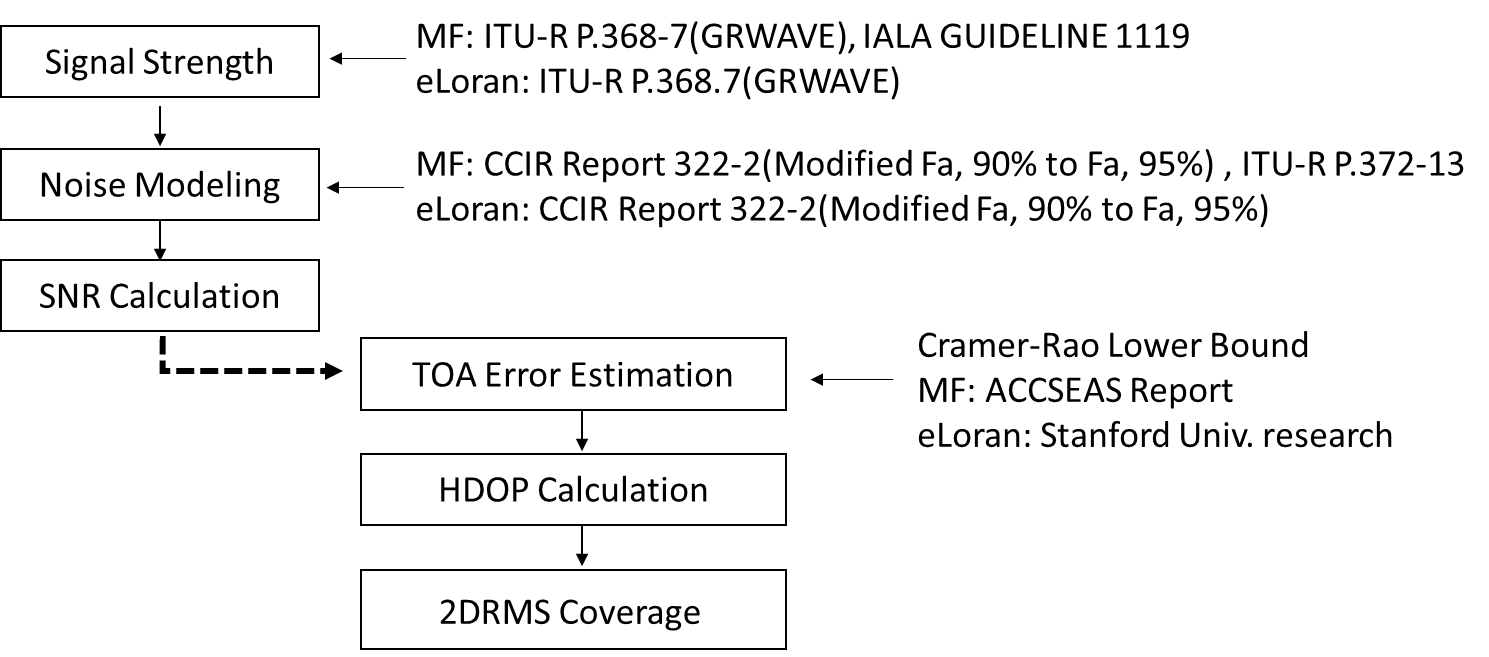
The Republic of Korea intends to share the results of its Medium Frequency (MF) R-Mode performance prediction study and to discuss ways to utilize them in the performance prediction chapter of the new R-Mode Guideline.

# Background

The IALA ENG Committee has completed the development of Guideline G1187 on MF R-Mode signal structure and navigation messages, and is currently developing guidelines on the implementation of MF and VDES R-Mode systems and services. The Republic of Korea carried out the TRACE project from 2019 to 2023, which involved the establishment and testing of an R-Mode testbed. The testbed is being maintained and operated on a trial basis with the aim of supporting international technical standardization efforts and enhancing technological maturity. As part of the TRACE project, a study on MF R-Mode performance prediction in the Republic of Korea was conducted, and it is expected that the results of this study could contribute to the performance prediction chapter of the Guideline on Implementation of MF and VDES R-Mode System and Service currently under development.

# Discussion

To assess the feasibility of R-Mode in the Republic of Korea, an accuracy prediction study was conducted. The scope of this simulation was limited to the maritime region, with existing maritime DGNSS stations assumed as MF R-Mode transmitting stations. To address geometric limitations, eLoran and Loran-C stations were also considered. The overall simulation procedure is summarized in Figure 1. First, signal strength and noise levels were estimated based on ITU documentation, from which the signal-to-noise ratio (SNR) was derived. Subsequently, the time-of-arrival (TOA) error variance was estimated, and the horizontal dilution of precision (HDOP) was calculated using the station geometry. Finally, the positioning accuracy and coverage of MF R-Mode in combination with eLoran were predicted.

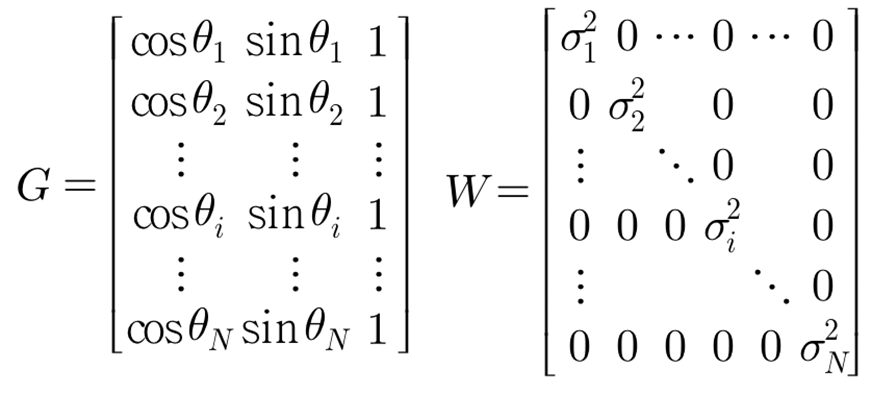


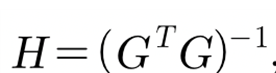
1. Summary of the performance simulation procedure

For the estimation of MF R-Mode and eLoran signal strength, ITU-R P.368-7 was applied. Since the ITU document assumes a transmitter output of 1 kW, an offset value was determined for specific DGNSS stations and applied as compensation. The output power offset of the Korean DGNSS stations was calculated with reference to IALA Guideline G1119, which provides procedures for deriving transmitter output offsets.

The noise model for eLoran had previously been studied by Stanford University, and their results were referenced. In addition, CCIR Report 322-2 provides the external antenna noise factor (Fa), representing stochastic atmospheric noise levels. The Leeboyce model applies Fa at the 95% level; thus, an adjustment from 90% to 95% was made to derive the eLoran atmospheric noise. While IALA G1119 provides an atmospheric noise model for MF, its applicability is limited to the European region. Therefore, MF R-Mode noise was estimated in the same manner as eLoran. However, due to the frequency difference between 100 kHz and 300 kHz, compensation was made using the offset derived from ITU-R P.372-8 between the MF and eLoran frequency bands.

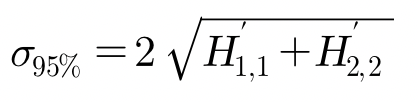
The time-of-arrival (TOA) error was estimated using the Cramér–Rao Lower Bound (CRLB). For MF R-Mode, reference was made to the ACCSEAS project report, and for eLoran, to research results from Stanford University. Finally, HDOP and positioning errors were derived using the following equation.

 (1)

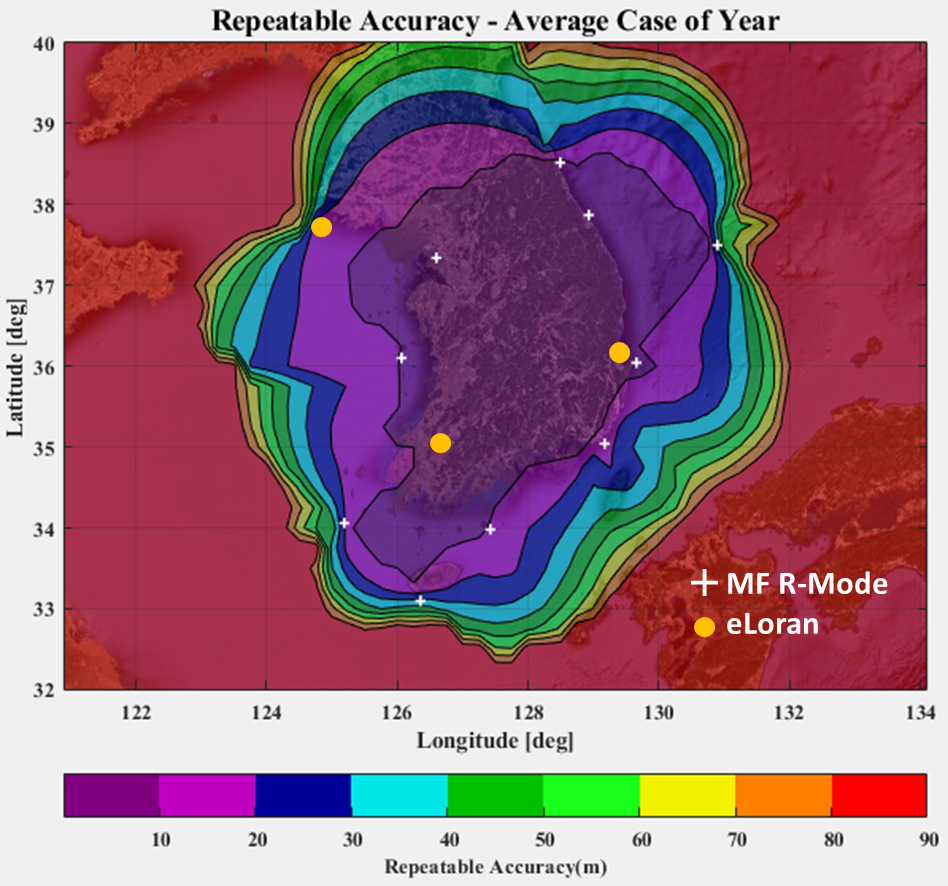
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The performance prediction results of MF R-Mode and eLoran in the Republic of Korea are presented in Figure 2. In the coastal waters of the Republic of Korea, an accuracy level of approximately 10 to 20 meters is predicted. It should be noted, however, that this simulation result reflects daytime conditions only and does not take sky-wave effects into account.



1. Performance prediction result of MF R-Mode with eLoran in ROK

# References

1. Younghoon, H. and et al., “A Measurement Based Accuracy Prediction of Terrestrial Radio Navigation”, ION System for Maritime Backup in South Korea”, ION GNSS+ 2019, September 2019.
2. Pyo-Woong, S. and et al., “Development of the Simulation Tool to Predict a Coverage of R-mode System”, Journal of Navigation and Port Research, Vol. 43, No. 6, December 2019.
3. ACCEAS Project(2014a) report, “Feasibility of R-Mode combining MF DGNSS, AIS, and eLoran Transmissions”
4. ITU-R P.368-7 Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz.
5. IALA Guideline 1119 Marine beacon coverage prediction, December 2016.
6. Lee, B., “Atmospheric Noise Mitigation for Loran”, Stanford University, Ph.D. dissertation, 2007.

# Action requested of the Committee

The ENG Committee is requested to consider this document and act as appropriate.

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-2)
2. Leave open if uncertain [↑](#footnote-ref-3)