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Agenda item [[2]](#footnote-2) 6.2

Technical Domain / Task Number 2 …………………………………

Author(s) / Submitter(s) ………China MSA……….

Proposal on the Revision of IALA Guideline G1158 VDES R-Mode

# Summary

This document introduces the technical implementation of the ASM-TER R-Mode, including ranging signal, slot management and navigation message. It is proposed to supplement to the IALA G-1158.

## Purpose of the document

This document is intended to add the technical implementation of the ASM-TER R-Mode to the IALA G1158, providing users with an alternative solution besides the VDE-TER R-mode.

## Related documents

[1] IALA, Guideline G1158-VDES R-Mode, Edition 1, 2020.

# Background

In order to mitigate the impact of GNSS service interruption on maritime navigation and ensure the safety of ships, ships should be equipped with both space-based and land-based positioning and navigation systems. R-Mode is a low-cost land-based positioning and navigation system that utilizes the existing maritime radio communication infrastructure.

The AIS Ship Autonomous Navigation System (AAPS) project in China (2012-2015) initially realized the positioning function of the AIS R-Mode, and conducted theoretical research on the VDES R-Mode from 2016 to 2017. Based on the above research, the Project of VDES R-Mode Testbed (2018-2020) has built an R-Mode testbed in the Yellow and Bohai Sea.

This paper is to give suggestions on the technical implementation of ASM-TER R-mode based on the results of the AIS/VDES R-Mode Testbed Project.

| **Comment Number:**  **Name-#** | **Change Log ID #[[3]](#footnote-3)** | **Annex / Section** | **Section, Table, Figure** | **Type of change** | **Reason for the change, or what you want to accomplish** | **Proposed change to G1158, short editorial changes can be included here (large changes should be documented below)** |
| --- | --- | --- | --- | --- | --- | --- |
| *RMODE-1* | *1* | *IALA G1158 Ed. 1, Chapter3* | *Section 3.1 and Section 3.2* | *supplement* | *Add ASM-TER R-Mode physical layer technology implementation.* | *Change is documented and discussed below.* |
| *RMODE-2* | *2* | *IALA G1158 Ed. 1, Chapter4* | *Section 4.1 and Section 4.2* | *supplement* | *Add ASM-TER R-Mode link layer technology implementation.* | *Change is documented and discussed below.* |
| *RMODE-3* | *3* | *IALA G1158 Ed. 1, Chapter5* | *Section 5.1 and Section 5.2* | *supplement* | *Add ASM-TER R-Mode application layer technology implementation.* | *Change is documented and discussed below.* |
|  |  |  |  |  |  |  |

# Discussion

IALA G-1158 introduces the R-Mode physical layer, link layer and application layer technical implementation based on the VDE-TER signal. We propose to supplement the R-Mode technical implementation based on the ASM-TER signal to facilitate the promotion and application of R-Mode.

*Proposed changes are documented and discussed in the Annex.*

# Action requested of the Committee

The Committee is requested to note the proposal in this document and take actions as appropriate.

Annex

**3. PHYSICAL LAYER**

**3.1. VDE-TER R-Mode**

VDES R-Mode is based on the specification of the VDE-TER specification in *G1139* ed.4 (submitted to ITU-R WP5B to revise *ITU-R M.2092-1*). The physical layer of the R-Mode application requires a ranging sequence and additional navigation data to determine the distance between VDES R-Mode base stations, transmitters, and receiver. The ranging sequence is predefined and adapted by the network depending on the expected coverage areas. VDE-TER schedules the resources based on a TDMA scheme between VDES base stations that are coordinated by the network provider(s). The VDES R-Mode base stations shall transmit their ranging sequence every second based on the configuration of link-ID 37. The additional navigation data shall be communicated every minute via the link-ID 11 within the network and via one VDES R-M-mode base station.

**~~3.1.~~ 3.1.1. Ranging sequences**

The ranging sequence is a concatenation of two known sequences to customize the required performance based on the given scenarios. The scenarios considered are:

……

**~~3.2.~~ 3.1.2. Navigation data**

The navigation data contains all the data used to calculate the range between the VDES R-Mode base station and the receiver. The navigation data is transmitted every minute by a regular VDE-TER message. The navigation data of multiple R-Mode base stations can be combined in one VDE message and should indicate which base station the navigation data addresses with the network. This shall be covered by the network provider of the base stations.

**3.2. ASM-TER R-Mode**

The general slot format of ASM-TER is shown in Table 1. Each slot consists of six parts: Ramp up, Training sequence, Link ID, Data, Ramp down and Guard. The ramp-up time for power change from -50 dBc to -1.5 dBc is 416 microseconds (us), to provide spectral shaping and reduce interference, and the modulation is not specified for the ramp up. The training sequence is described in detail in the next paragraph. The Link ID based on π/4 QPSK modulation follows the training sequence to define the channel configurations. The Data payload with its Cyclic Redundancy Check (CRC) is interleaved encoded scrambled and bit mapped. The ramp down time from full power to −50 dBc should be no more than 416 us. The rest Guard time is for delay and jitter.

1. *ASM-TER General Slot Format*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ramp up** | **Training Sequence** | **Link ID** | **Data** | **Ramp Down** | **Guard** |
| 0.41 ms | 27 symbols  (1 1111100110101 0000011001010) | 16 symbols | Data with CRC | 0.41 ms | 0.83 ms |

The training sequence of ASM-TER is a 27-symbols sequence with π/4 QPSK modulation. The last 26 symbols are barker13 code (1 1 1 1 1 0 0 1 1 0 1 0 1) and inverted barker13 code (0 0 0 0 0 1 1 0 0 1 0 1 0) with ideal autocorrelation, which can be used to detect the weak target signal submerged in noise. The ideal autocorrelation of the double Barker 13 code can be used for ranging. In the training sequence, the symbol “1” maps to π/4 QPSK symbol “3” (1 1), and the symbol “0” maps to π/4 QPSK symbol “0” (0 0).



1. *Bit Mapping for π/4 QPSK and Phase Alternating of the Training Sequence*

Figure 1 shows the bit mapping for π/4 QPSK used in ASM-TER, and the phase alternating of the training sequence. There are 4 possible phase variations of ± π/4 and ±3π/4 when the symbol changes. Since there are only "11" and "00" in the training sequence, without "01" and "10", it has only four kinds of phase alternating as shown in Figure 2. The first the symbol “1” of the training sequence maps to π/4 QPSK symbol “3” (1 1), is mapped to the constellation defined by the point (1+j)/√2; the next symbol “1” is mapped to the constellation defined by point 1+0j (shown in blue in Figure 2); the next symbol “1” is mapped to the constellation defined by point (-1-j)/√2 (shown in green in Figure 2) and so on.

According to the structure of the training sequence shown in Table 2, if the first symbol of the link configuration ID is 0, as received sequence shown in Figure 2, the correlation value is the maximum when the local reproduced 26 symbols exactly match the received signal. Because *ms* is 26 and *ns* is 0, where *ms* is the number of matched symbols and *ns* is the number of mismatched symbols. The correlation value is the minimum when the locally re-produced 26 symbols are 1 symbol time *Ts* earlier or later than the received signal, for *ms* is 13 and *ns* is 13, as shown in Figure 3. Therefore, the navigation data can be transmitted via ASM-TER with the link-ID 54 to make the first symbol 0. (It is recommended here to reserve the last 10 link IDs those are 54-63 for ASM)



1. *Number of matched symbols ms and number of mismatched symbols ns*

**3.3. Clock requirements**

For a positioning system, which provides time information in the ranging signals, synchronisation and calibration are essential for the performance of the R-Mode service. Therefore, each ranging signal generator, the VDES base station for VDES R-Mode, has to be synchronised to the RMST in this region. The time information will be given by a 1 PPS and 10 MHz signal. Additionally, information to disambiguate the PPS pulses and about the clock error will be given over a data channel from the timing source, if not supplied internally. Further information about the clock requirements can be found in Section A.3.

For the generation of accurate ranging signals, it is important that all internal oscillators of the VDES base station are synchronised with the external 10 MHz signal.

**4. LINK LAYER**

The link layer of VDE-TER enables VDES R-Mode together with precise timing at the transmitter. The VDES R-Mode base station broadcasts the ranging sequence via the Ranging Channel once per second at a known and defined time instance with link-ID 37.

**~~1.1.~~ 4.1. R-mode integration with VDE-terrestrial link layer**

In the link layer the ranging sequence shall be transmitted by the Ranging Channel and utilizes the shore-to-ship short message (#93). The navigation data shall be communicated by a shore originated broadcast message.

**4.2. R-mode integration with ASM-terrestrial link layer**

There are two transmission modes of the ASM-TER R-Mode ranging signals can be used, synchronous mode and asynchronous mode. The synchronous transmission of ranging signals will reduce the error of the receiver clock jitter and the error of time different of arrival (TDOA) caused by ship motion. However the complexity of synchronous transmission is higher and the ranging performance of the weaker signal would be affected.

**4.2.1. Synchronous Transmission**

The ASM-TER R-Mode ranging signal transmission from the VDES base station can be carried out in the way shown in Figure 3. The transmission modes of all base stations are divided into three types: A, B and C:

• Type A base stations continuously transmit two slots on ASM1, and then stop one slot;

• Type B base station transmits one slot on ASM2 first, and after a slot interval, transmits one slot on ASM1;

• Type C base stations stop for one slot, and then continuously transmit two slots on ASM2.

The base station management system first defines the base station as A1, B1, C1; A2, B2, C2. At the beginning of the transmission period (for example 6 seconds), transmit ASM ranging signals in order of A1 B1 C1; B1 C1 A2, C1 A2 B2, A2 B2 C2.....

Therefore, if the transmission period is 6 seconds, it allows 225 base stations to transmit the signals once in the period. The base station capacity of ASM-TER R-mode network can be up to 225. If the transmission period is extended, the capacity of the base station can be increased correspondingly, but the location update rate of the user receiver will be decreased accordingly.



1. *ASM ranging signal synchronous transmission slot diagram*

**4.2.2. Asynchronous Transmission**

The asynchronous transmission rule of the base station ranging signal is shown in Figure 5. The base station management system firstly numbers the base stations according to the position as No1, 2, 3, 4, 5, 6..... At the beginning of the transmission period (for example 6 seconds), the ranging signal is transmitted on the same channel (ASM1 or ASM2) in sequence in the order of numbers.



1. *ASM ranging signal asynchronous transmission slot map*

Similarly, if each transmission period is 6 seconds, the base station capacity of the ASM-TER R-Mode network is 225.

**5. APPLICATION LAYER**

**5.1. VDE-TER R-Mode Navigation data**

The VDES R-Mode receiver requires additional information, termed navigation data, to determine the distance to the base station utilizing the received ranging sequence.

The navigation data is transmitted via VDE-TER from a VDES base station with the link-ID 11 every minute. It accommodates information to allow a cold start and determines a position latest after 16 minutes. Up to 16 VDES R-Mode base stations have a unique ID within the local VDES R-Mode network. Each ID of a VDES R-Mode base station is linked to clock and delay correction data and the coordinates of the phase centre of the VDES R-Mode base station.

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**5.2. ASM-TER R-Mode Navigation data**

The navigation data is transmitted via ASM-TER from a VDES base station with the link-ID 54 every 6 seconds. Scheduled broadcast ASM message #10 can be used to transmit ASM-TER R-Mode navigation message. Its training sequence can be used to obtain ranging values. The navigation message is as shown in Table 3. It comprises of the source station information, UTC time, and differential correction parameter.

1. *ASM-TER R-Mode navigation message format*

|  |  |  |
| --- | --- | --- |
| Parameter | Length(bit) | Comment |
| Message ID | 4 | Identifier for Message 10;  always 10 |
| Source ID | 32 | MMSI number of source station |
| Reserved | 4 | Set to 0 |
| Shore station longitude | 28 | Longitude in 1/10 000 min |
| Shore station latitude | 27 | Latitude in 1/10 000 min |
| Shore station height | 12 | 0-4094 m |
| UTC year | 14 | 1-9999 |
| UTC month | 4 | 1-12 |
| UTC day | 5 | 1-31 |
| UTC hour | 5 | 0-23 |
| UTC minute | 6 | 0-59 |
| UTC second | 6 | 0-59 |
| Synchronization States | 2 | 0.GNSS valid；  1.GNSS short-term invalid；  2. GNSS long-term invalid，synchronized with reference station；  3. GNSS long-term invalid and is not synchronized with the reference station。 |
| Slot number /Communication status | TBD | TBD |
| Differential correction parameter | TBD | Set to 0 |
| Reserved | TBD | Set to 0 |
| Total | 352 |  |

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
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