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

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

Author(s) / Submitter(s) Hyejin KIM, hyungjick RYU (COMESTA, Republic of Korea)

Juntae KIM (Korean Register)

Review of VDE-TER Sensitivity Requirements

# Summary

This paper describes the PER (Packet Error Ratio) performance degradation problem due to frequency offset when the VDES transceiver physical layer is implemented according to the ITU-R M.2092-1 recommendation.

This document also provides information on the necessary margin to satisfy the receiver sensitivity requirements of VDE-TER of ITU-R M.2092-1 in the presence of frequency offset.

## Purpose of the document

This document provides the information on the required margin for the receiver sensitivity requirements in the presence of frequency offset, which can be applied to the VDE-TER test specification.

## Related documents

IEC PAS 63343:2021, Maritime navigation and radiocommunication equipment and systems — VHF data exchange system — Requirements and methods of testing for stations including ASM functionality

IEC 61993-2:2018, Maritime navigation and radiocommunication equipment and systems – Automatic identification systems (AIS) – Part 2: Class A shipborne equipment of the automatic identification system (AIS) – Operational and performance requirements, methods of test and required test results

ITU-R M.2092-1:2022, Technical characteristics for a VHF data exchange system in the VHF maritime mobile band

# Background

ITU-R M.2092-1 was published in February 2022, starting with the ITU-R M.2092-0 Recommendation on the radio access and transmission standards of the VDES system.

In addition, the test standard IEC PAS 63343:2021 was published which contains the technical requirements, methods of test and required test results for equipment implementing ASM part of the VHF Data exchange system (VDES) as defined in ITU-R M.2092-1.

ASM Receiver sensitivity requirements test/verification of VDES transceiver is tested as specified in IEC PAS 63343:2021, 6.2.5.2.1.

As IEC PAS 63343:2021 only specifies the ASM part of the VHF data exchange system (VDES) as defined in ITU-R M.2092-1, it is necessary to review the required margin for the receiver sensitivity requirements which is applicable to VDE-TER test specification.

## VDES Physical Layer parameter

The VDES physical layer is designed by TDMA method and the frame structure of the burst signalling method is used according to ITU-R M.1371-5, in addition, turbo code, CRC-32, bit scrambler, PSK/QAM modulation are used. The following table 1 summarizes the main system parameters of the VDES physical layer.

Table 1 Link ID parameters of VDES

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Link ID | Modulation  Type | Syncword (Symbols) | Link ID  (Symbols) | Symbol Rate  [sps] | FEC  rate | roll-off  factor |
| 1,2,3 | PI/4-QPSK | 27 | 16 | 9600 | Uncoded | 0.35 |
| 5,6,7 | PI/4-QPSK | 27 | 16 | 9600 | 3/4 | 0.35 |
| 11,14,17 | PI/4-QPSK | 27 | 16 | 19,200  38,400  76,800 | 1/2 | 0.3 |
| 12,15,18 | 8PSK | 27 | 16 | 19,200  38,400  76,800 | 3/4 | 0.3 |
| 13,16,19 | 16QAM | 27 | 16 | 19,200  38,400  76,800 | 3/4 | 0.3 |

In general, it is expected that the receiver for PSK or QAM can accomplish ideal demodulation performance when demodulated in the condition of achieving signal amplitude stabilization, timing and frequency synchronization. In addition, synchronization algorithms typically for this purpose use some known symbols, which is known both at the transmitter and at the receiver, such as training symbols.

The training symbol used in VDES is named as 'Syncword' and defined as 27 symbols. The Syncwords are generated by modulating them with PI/4-QPSK after extending 2 Barker code sequences defined in the following table 2 by repeating 2 bits each, to fit QPSK.

Table 2 Syncwords for VHF data exchange system

|  |  |  |  |
| --- | --- | --- | --- |
| Usage | Symbol size | Sequence | Type |
| ASM-TER | 27 | 1 1111100110101 0000011001010 | 1+ Barker13+ inverted Barker13 |
| VDE-TER |

## Test and required test results for equipment implementing ASM part of the VDES in IEC PAS 63343

IEC PAS 63343 specifies the minimum operational and performance requirements, methods of testing and required test results for ASM stations. Among them, the sensitivity of the receiver of the ASM stations must comply with the requirements of Table 3.

Receiver sensitivity test is performed using Test Signal 6 as defined in IEC PAS 63343 according to the method described in IEC 61993-2:2018, 15.2.1.2 at channel center frequencies 161,950 and 162,000 MHz.

Table 3 Receiver requirements without FEC (using Link ID 1) - IEC PAS 63343

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Signal | Receiver parameters | Requirements | | Note |
| Normal | Extreme |
| 6 | Sensitivity | 20% PER at −107 dBm  20% PER at -104 dBm at +/-250 Hz offset | 20% PER @ -104 dBm | 3 |
| NOTES:  3: The offsets are half the values used in AIS (61993-2) as the frequency accuracy in ASM is much better | | | | |

# PER Performance Analysis Under Carrier Frequency Offset

## Carrier Recovery for the estimation and compensation of frequency offsets with ITU-R M.2092-1

VDES uses π/4-QPSK, 8PSK and 16-QAM modulation methods according to ITU-R M.2092-1, but these kinds of modulation methods are sensitive to frequency offsets, therefore, it should be designed with coherent receiver which applying CR(Carrier Recovery) algorithm for the estimation and compensation of frequency offsets.

The test to confirm the receiver sensitivity requirements in IEC PAS 63343 should be repeated at 161,950 MHz ± 250 Hz and 162,000 MHz ± 250 Hz with the receiver input level adjusted to -104 dBm under normal conditions.

Since the frequency offset 250Hz corresponds to 2.6% of ASM symbol rate and 1.3% in case of VDE-TER Link ID 11, it is not easy to perform the CR function using the syncwords of 27 symbols. Generally, CR is composed of the coarse CR to handle a wide frequency offset and a CR tracking to track a narrow range of residual frequency offset as shown in Figure 1.



Figure 1 Components for Carrier Recovery Algorithm

Sections 3.2 and 3.3 include the analysis for the required SNR for each Link ID to satisfy PER 20% (ASM) and PER 1% (VDE-TER) when a frequency error exists. The transmitter/receiver function block for the simulation test was implemented according to the ITU-R M.2092-1 recommendation.

For the test environment, frequency offsets of 250Hz and 500Hz were applied in the AWGN channel, and the frequency recovery algorithm shown in Figure 1 was applied.

## ASM PER Performance on Carrier Recovery Algorithm with ITU-R M.2092-1

Figure 2 and Table 4 show the PER performance results for ASM Link ID 1 when frequency offsets of 250 Hz and 500 Hz are given, respectively, under normal conditions.

|  |  |
| --- | --- |
| (a) Carrier Frequency Offset: 250Hz | (b) Carrier Frequency Offset: 500Hz |

Figure 2 PER Performance with CR under Carrier Frequency Offset (ASM Link ID 1)

Table 4 PER Performance with Carrier Recovery (ASM Link ID 1)

|  |  |  |  |
| --- | --- | --- | --- |
| Link ID 1  (uncoded, π/4-QPSK) | with Coherent  Ideal sync. | Carrier Frequency Offset  with General CR | |
| 250Hz | 500Hz |
| Required SNR[dB]  @ PER 20% | 10.3 | 10.3 | 10.5 |
| Performance degradation with CR via ideal sync.  (Gap for required SNR)  [dB] | - | Almost none | ca. 0.2dB |

Figure 3 and Table 5 show the PER performance results for ASM Link ID 5 when frequency offsets of 250 Hz and 500 Hz are given, respectively, under normal conditions.

|  |  |
| --- | --- |
| (a) Carrier Frequency Offset: 250Hz | (b) Carrier Frequency Offset: 500Hz |

Figure 3 PER Performance with CR under Carrier Frequency Offset (ASM Link ID 5)

Table 5 PER Performance with Carrier Recovery (ASM Link ID 5)

|  |  |  |  |
| --- | --- | --- | --- |
| Link ID 5  (3/4 π/4-QPSK) | with Coherent  Ideal sync. | Carrier Frequency Offset  with General CR | |
| 250Hz | 500Hz |
| Required SNR[dB]  @ PER 20% | 4.4 | 5.5 | 5.6 |
| Performance degradation with CR via ideal sync.  (Gap for required SNR)  [dB] | - | ca. 1.1dB | ca. 1.2dB |

Figure 2 and Table 4 (for Link ID 1), Figure 3 and Table 5 (for Link ID 5) show the result confirmed by simulating the required SNR to satisfy PER 20% performance under normal conditions when frequency offsets of respectively 250Hz and 500Hz are given.

From the above results, it was confirmed that frequency offset processing is possible within about 1.2dB of performance degradation compared to coherent ideal synchronization by applying the CR algorithm for the SNR required for PER 20%.

Therefore, it is expected that the margin of SNR 3dB in the test specification meets the receiver sensitivity requirements PER of 20% in Link ID 1 and 5 considering to the above simulation result.

## VDE-TER PER Performance on Carrier Recovery Algorithm with ITU-R M.2092-1

Figure 4 and Table 6 show the PER performance results for VDE-TER Link ID 11 when frequency offsets of 250 Hz and 500 Hz are given, respectively, under normal conditions.

|  |  |
| --- | --- |
| (a) Carrier Frequency Offset: 250Hz | (b) Carrier Frequency Offset: 500Hz |

Figure 4 PER Performance with CR under Carrier Frequency Offset (VDE-TER Link ID 11)

Table 6 PER Performance with Carrier Recovery (VDE-TER Link ID 11)

|  |  |  |  |
| --- | --- | --- | --- |
| Link ID 11  (1/2 π/4-QPSK) | with Coherent  Ideal sync. | Carrier Frequency Offset  with General CR | |
| 250Hz | 500Hz |
| Required SNR[dB]  @ PER 1% | 2.0 | 7.8 | 7.8 |
| Performance degradation with CR via ideal sync.  (Gap for required SNR)  [dB] | - | ca. 5.8dB | ca. 5.8dB |

Figure 5 and Table 7 show the PER performance results for VDE-TER Link ID 17 when frequency offsets of 250 Hz and 500 Hz are given, respectively, under normal conditions.

|  |  |
| --- | --- |
| (a) Carrier Frequency Offset: 250Hz | (b) Carrier Frequency Offset: 500Hz |

Figure 5 PER Performance with CR under Carrier Frequency Offset (VDE-TER Link ID 17)

Table 7 PER Performance with Carrier Recovery (VDE-TER Link ID 17)

|  |  |  |  |
| --- | --- | --- | --- |
| Link ID 17  (1/2 π/4-QPSK) | with Coherent  Ideal sync. | Carrier Frequency Offset  with General CR | |
| 250Hz | 500Hz |
| Required SNR[dB]  @ PER 1% | 1.5 | 7.5 | 7.5 |
| Performance degradation with CR via ideal sync.  (Gap for required SNR)  [dB] | - | ca. 6.0dB | ca. 6.0dB |

Figure 4 and Table 6 (for Link ID 11), Figure 5 and Table 7 (for Link ID 17) show the result confirmed by simulating the required SNR to satisfy PER 1% performance under normal conditions when frequency offsets of respectively 250Hz and 500Hz are given.

In spite of using the frequency recovery algorithm, it was confirmed that the SNR required for PER 1% degraded by about 5.8dB and about 6.0dB, respectively, compared to coherent ideal synchronization.

Such performance degradation occurs due to a malfunction of the CR algorithm during frequency offset processing at low SNR. This is because the SNR range in which the receiver operates is lowered due to the low FEC code rate (1/2), whereas the CR algorithm generally operates more effectively at a relatively high SNR.

Therefore, if the ASM test specification in Table 3 is applied to Link ID 11 and 17 as it is, degradation exceeding the 3dB margin of the test specification occurs, so that the required result of the test specification cannot be satisfied. In other words, in the case of Link ID 11 and 17, it is expected that it will be difficult to satisfy the receiver sensitivity requirements if the same requirements as for ASM receivers are applied.

Figure 6 and Table 8 show the PER performance results for VDE-TER Link ID 19 when frequency offsets of 250 Hz and 500 Hz are given, respectively, under normal conditions.

|  |  |
| --- | --- |
| (a) Carrier Frequency Offset: 250Hz | (b) Carrier Frequency Offset: 500Hz |

Figure 6 PER Performance with CR under Carrier Frequency Offset (VDE-TER Link ID 19)

Table 8 PER Performance with Carrier Recovery (VDE-TER Link ID 19)

|  |  |  |  |
| --- | --- | --- | --- |
| Link ID 17  (3/4 16QAM) | with Coherent  Ideal sync. | Carrier Frequency Offset  with General CR | |
| 250Hz | 500Hz |
| Required SNR[dB]  @ PER 1% | 11.0 | 13.3 | 13.3 |
| Performance degradation with CR via ideal sync.  (Gap for required SNR)  [dB] | - | ca. 2.3dB | ca. 2.3dB |

Figure 6 and Table 8 (for Link ID 19) show the result confirmed by simulating the required SNR to satisfy PER 1% performance under normal conditions when frequency offsets of respectively 250Hz and 500Hz are given.

From the above results, it was confirmed that frequency offset processing is possible within about 2.3dB of performance degradation compared to coherent ideal synchronization by applying the CR algorithm for the SNR required for PER 1%.

Furthermore, even considering the implementation, since there is a margin of SNR 3dB in the test specification, Link ID 19 is expected to meet the receiver sensitivity requirements PER of 20%.

# Conclusion

In this paper, simulation tests were performed to verify that test requirement for receiver sensitivity according to IEC PAS 63343:2021 can be satisfied and whether this test requirement may be applicable to VED-TER.

The simulation test was performed by applying frequency offsets of 250Hz and 500Hz in the AWGN channel for ASM Link ID 1, 5 and VDE-TER Link ID 11, 17, and 19, and applying the general frequency recovery algorithm shown in Figure 1.

In the case of ASM, in the presence of a frequency offset of 250Hz, both Link ID 1 and 5 used frequency recovery algorithms to confirm performance degradation within 1.2dB compared to the coherent ideal synchronization condition at PER 20%.

On the other hand, in the case of VDE-TER Link ID 11 and 17, performance degradation of about 6dB was confirmed at PER 1% compared to the coherent ideal synchronization condition.

Since this exceeds the 3dB margin given under the presence of frequency offset in IEC PAS 63343, it is expected that it will be difficult to satisfy the receiver sensitivity requirement when the same receiver sensitivity requirement as that of ASM is applied.

Therefore, for Link ID 11 and 17 operating in the low SNR region, it is considered that a sufficient receiver sensitivity margin more than ASM is required in the presence of frequency offset, and this paper may be referred when developing IEC test requirement for sensitivity of VDE-TER.

# References

N/A

# Action requested of the Committee

The Committee is requested to note the information and take appropriate action.

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