Input paper: [1] ENAV23-3.1.9

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☐ ARM ☐ ENG ☐ PAP

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Purpose of paper:

☒ Input

☐ Information

Agenda item [2] (from agenda)	3
Workplan Task Number / Technical Domain [2]	…………………………………
Working Group	WG 3
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UTC-based VDE-SAT Uplink Transmission Timing Advance

1 SUMMARY

The present document provides a UTC-based uplink transmission timing advance (TA) design for VDE-SAT. By performing the UTC-based uplink TA on the mobile station (e.g., a ship) side, the one-way propagation delay between the control station (i.e., satellite) and the mobile station is compensated, and the guard time overhead of an uplink transmission burst is reduced even after taking into account the timing advance errors. The adoption of this uplink TA design in the VDE-SAT is therefore recommended.

1.1 Purpose of the document

The input document aims to propose a UTC-based uplink transmission timing advance scheme to minimize the guard time overhead of a VDE-SAT uplink transmission burst.

1.2 Related documents

[1] IALA Guideline G1139, The Technical Specification of VDES, Working Draft, 201812, Edition 2.
[2] ITU, Technical characteristics for a VHF data exchange system in the VHF maritime mobile band, Rec. ITU-R M.2092-0, 2015.

2 BACKGROUND

As defined in [1], a VDE-SAT transmission burst includes ramp up, synchronization word (or sync word for short), data, ramp down and guard time as shown in Figure 1.

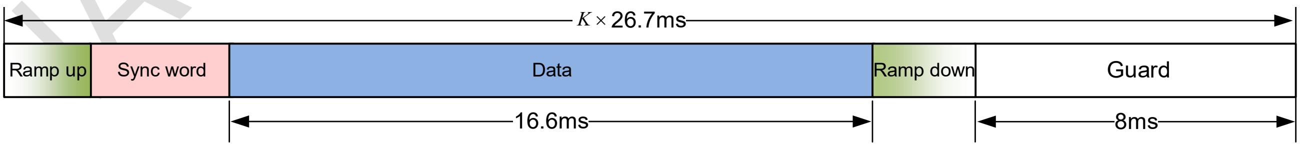

Figure 1 Illustration of a VDE transmission burst (K=1,3,or 5), where K=1 is shown.

1 Input document number, to be assigned by the Committee Secretary
2 Input papers should be assigned to a work task as listed in the Committee work plan which is available in input papers. Leave open if uncertain but consider how the paper is to be processed if not relevant to a work task

An 8-ms guard time at the end of a VDE-SAT uplink transmission burst is used to absorb the one-way propagation delay difference among ships between 2 ms (zenith) and 10 ms (horizon), given a LEO satellite station orbiting at a 600-km altitude [2]. This guard time is almost half of the data time, creating an overall overhead of up to $8\text{ms}/26.67\,\text{ms} = 30\%$ (K=1). This further reduces the already-low spectral efficiency of VDE-SAT.

This input document provides a UTC-based uplink transmission timing advance scheme to minimize the guard time overhead in a VDE-SAT uplink transmission burst.

3 DISCUSSION

The proposed solution is that each ship advances its uplink transmission such that the uplink signal that arrives at the VDE-SAT satellite receiver aligns with the UTC slot boundary. Therefore, the 8-ms guard time can be saved.

1.3 Uplink Transmission Timing Advance Scheme

A ship first acquires the timing from the VDE-SAT downlink signal, which includes a one-way propagation delay, Δ， whose value depends on the ship's position relative to the satellite, which ranges from 2 ms (zenith) to 10 ms (horizon). Currently, the VDE-SAT downlink transmission time is advanced by the minimum 2ms; as a result, a ship sees a delay of 0 to 8ms relative to the UTC slot time, as shown in Figure **2**. The ship estimates this time delay, and advances its uplink transmission timing by the amount of this delay plus 2 ms such that the one-way propagation delay is pre-compensated.

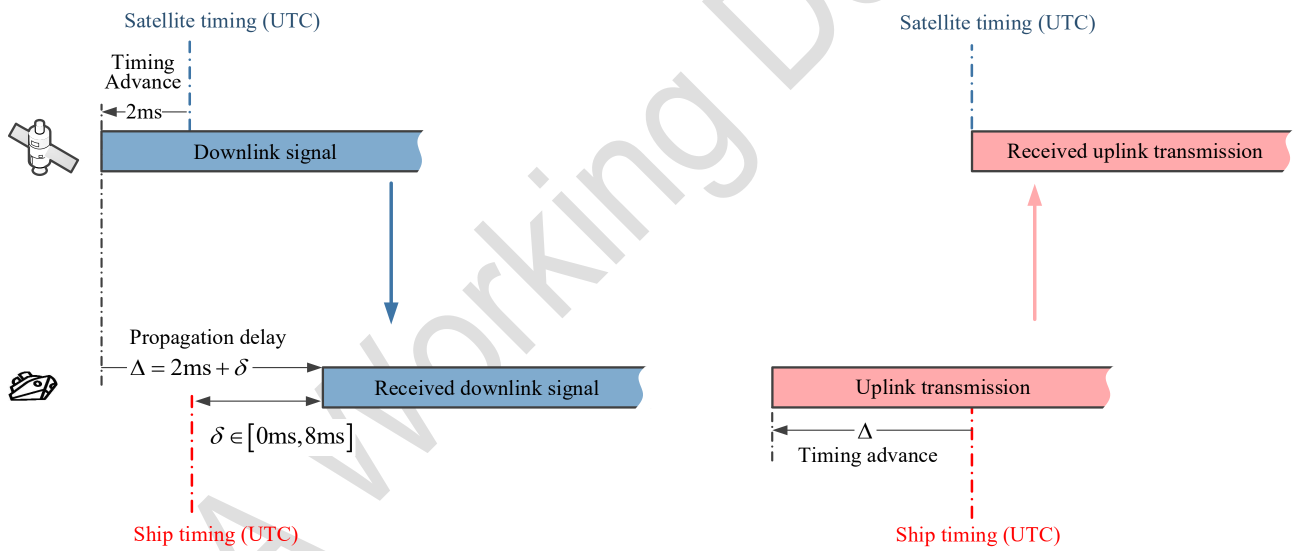

Figure 2 Illustration of a UTC-based uplink transmission timing advance of a ship, where both satellite and ship are synchronized to UTC.

1.4 Timing Advance Error

Ideally, the uplink time alignment at the satellite receiver can be established by this timing advance process as illustrated in Figure 2, and the guard time is no longer needed. In practice, however, this process can be compromised by errors introduced by 1) the UTC time synchronization at both ship and satellite; 2) downlink timing detection from the ship; and 3) mobility by both ship and satellite.

The UTC synchronization error is typically far less than 100 μs for mobile and 50 μs for satellite. Therefore, it is safe to assume UTC timing error $\delta_{\text{UTC\_error}}^{\text{ship}} = \pm 100\ \mu\text{s}$ for ship and $\delta_{\text{UTC\_error}}^{\text{satellite}} = \pm 50\ \mu\text{s}$ for satellite. The downlink timing detection error, δ_{d}, is assumed to be within one Nyquist sample interval, e.g., $\delta_{\text{d}} = \pm 15\ \mu\text{s}$ (assuming the Nyquist sampling rate of 33.6 kHz). Since there is a time gap between the estimation of Δ or

δ and the application of Δ, the movement of both ship and satellite (especially the satellite) within this gap may introduce a change in propagation distance, and hence in Δ. Given the LEO satellite velocity of $8\ \mathrm{km/s}$, and assuming there is a maximum 540-slot ($14.4\ \mathrm{sec}$) separation between the downlink and uplink transmissions under the default half-duplex VDE-SAT transmission mode [1], the maximum error introduced by mobility is $\delta_{\mathrm{m}} \approx \pm 450\ \mu\mathrm{s}$. Taking those errors into consideration, the timing advance error off the satellite timing is evaluated as

$$\begin{aligned} \delta_{\mathrm{UTC\_TA}} &= 2\delta_{\mathrm{UTC\_error}}^{\mathrm{ship}} + 2\delta_{\mathrm{UTC\_error}}^{\mathrm{satellite}} + \delta_{\mathrm{d}} + \delta_{\mathrm{m}} \\ &= \pm 765\ \mu\mathrm{s}. \end{aligned} \tag{1}$$

Therefore, a guard time of $2\delta_{\mathrm{UTC\_TA}} = 1.53\ \mathrm{ms}$ is required to absorb the advance error, which corresponding to an overhead of $1.53\ \mathrm{ms}/26.67\,\mathrm{ms} \approx 6\%$ assuming the burst length of one slot.

Clearly the required time guard is a function of the uplink and downlink partition, and hence can be pre-specified.

4 REFERENCES

5 ACTION REQUESTED OF THE COMMITTEE

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