Deliverable D1.17
Project Summary Report – VDES Channel Model Refinement

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Review

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Approach

The approach taken in performing this work was to extend the analysis already performed by General Lighthouse Authorities of the UK and Ireland (GLA) on an earlier phase of the work, the GLA VDE Channel Sounding Campaign from 2015, and subsequent data analysis. The purpose of the project work was to quickly review, and then perform additional analyses on the GLA channel sounding measurements and to perform analysis of a new dataset based on space AIS received signal power provided by ExactEarth Ltd. to this project. The results were to be analysed and presented to IALA in the form of channel model types (Rician, Rayleigh, Nakagami, etc.), and the parameters of the distributions. The correlation with channel model parameters versus environmental characteristics, such as sea state, or for satellite data, the satellite elevation angle and range to satellite.

Tasks Performed

1. Review of past GLA sounding trial, data and analysis methods.
2. Recommendation on new analyses to extend the value of the GLA measurements, including correlation of higher-order taps, and channel coherence time.
3. Literature survey for additional channel modeling performed at VHF frequencies for a maritime environment.
4. Analysis of channel coherence time using Doppler spread formula, for moving and stationary ships.
5. Analysis of higher-order tap fading statistics relative to main reflected/scattered signal (1st tap).
6. Analysis of space AIS signal power data from ExactEarth and fitting of fading model.
7. Automation of GLA analysis of channel sounding campaign software in Matlab environment.
8. Preparation and organisation of study methodology and channel model results in presentations to IALA ENAV Committee WG3 meeting in Capetown in February 2017, and to IALA ENAV Committee session 20 in March 2017 (ENAV20).

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Findings

The project had a number of findings. More careful review and further analysis confirmed earlier findings from the GLA trial that the line of sight, and non-line of sight ship to ship terrestrial channel had flat losses (slow fading) in line with ITU-R P.1546-5 loss curves, the fast fading was Ricean in distribution, and that the K-factor varied dependent on the particular environment for the test. Analysis of the tap weight results, namely the cross-correlation of higher-order tap weights to main tap was unexpectedly found very consistent over measurement intervals of over a minute. This implies that a single fading mechanism is causing the main and higher order taps to fade simultaneously, careful review of analysis code confirmed this result. Subsequent discussion at ENAV20 identified the fact that the reflections that create higher-order TDL taps are often from different objects and mechanisms and are less likely to be correlated. The author's suspicion is that the data analysed for this project by ITR using a pre-processing routine has higher-order variations suppressed or somehow normalised in the pre-processing routine. If so, a more detailed analysis of measured raw data, especially the process of deriving the channel model TDL tap weights, should be reviewed to assess what type of averaging or smoothing may be applied.

The coherence time of the maritime VHF channel (time for which the channel fading can be considered basically constant) was found by analysis to vary between about 100 ms, and 1.1 seconds for the data examined. The fading was analysed using Doppler spread of the received messages, with wider Doppler spread leading to shorter channel coherence time, such as for stationary ships. The upper end of the calculated channel coherence time can accommodate up to about 40 VDE (or AIS) message slots, while at the low end can accommodate up to about a 4 slot VDE message. The recommendation to keep VDE messages at or below 3 slots is consistent with this finding. Single slot messages are not expected to suffer serious per packet degradation due to channel coherence time. Further measurements between 2 moving ships or ship to satellite or vice-versa may result in even shorter channel coherence times, and should be measured and assessed in the future.

Analysis of the large set of satellite AIS data from ExactEarth which provided satellite information, ship location and RF received power data provided a few important results. First, it was found that the variation in signal level was far less than predicted by free space (distance) loss variation only (7dB less), which is potentially largely due to the shaped-gain of typical ship AIS antennas. This high antenna directional gain to the horizon provides some significant mitigation to the higher losses generally experienced at the edge of satellite coverage where free space loss is highest. This fact implies that VDE-SAT operations to the earth's limb (furthest visible location), which is a ship looking toward the satellite located just above the horizon, is quite feasible from an RF link

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standpoint, which greatly increases potential link time for VDE-SAT services, and consequently viability of VDE-SAT services.

The statistical distribution of the fast fading of the satellite VDES channel was examined next. It was found to be quite different to the terrestrial case. The best statistical fit was a Nakagami distribution with parameter mu (μ) = 0.6 to 1.50, with an average of 0.85, which has higher statistical variation in signal levels than a Rayleigh distribution ($\mu = 1$), and interestingly, the distribution does not change with satellite elevation angle relative to the ship horizon. Statistical values were also calculated for the rate of change of the channel fading levels on a dB per second basis on a probabilistic basis. Only 12% of observed power samples had fading rates of 10 dB per second or higher.

Outputs

Updated channel model included coherence time, statistics of variation, and correlation of higher order taps to first tap in tapped delay line (TDL) model. New channel model analysis routines for space AIS obtained from exactEarth, can be used to analyze VDE-SAT (ship to space and vice versa) channel model characteristics, and sources of variation of these parameters. Matlab software was updated to better automate analysis of large datasets with minimum operator effort to select files, directories and change constants in analysis software (delivered to Jan Safar, March 2017). Other activities, included review of previous GLA channel sounding plans and reports, recommendations for further work, such as access to raw data from the sounders, for future in-depth analysis of signal characteristics such as TDL tap correlation (latter recommendations delivered via email and telecom to GLA).

Primary Deliverables

D1.17 This Report, Project Summary Report – VDES Channel Model Refinement;

D1.17A Presentation on VDES satellite test results to IALA ENAV20 v3, March 2017;

D1.17B Presentation on terrestrial test results to IALA ENAV WG3 inter-sessional v4, February 2017.

Acronyms

AIS	Automatic Identification System
GLA	General Lighthouse Authorities of UK and Ireland
TDL	Tapped delay line

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VDES	VHF Data Exchange System
VDE-SAT	VHF Data Exchange Satellite link

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