BAE Systems Naval Ships

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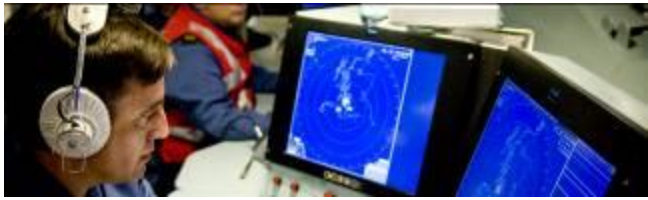
Theoretical and Practical Results from the Cloudnet Orkney Isles Ferries TVWS Pilot

Glasgow TVWS Pilot Event, Strathclyde University, Thursday 14th May 2015






Introduction

Scope of Presentation

- Background and BAE Systems' Interest in the Orkney TVWS Pilot
- Acknowledgements – Cloudnet IT Solutions Ltd. and Carlson Wireless Technologies Inc.
- Orkney Isles TVWS Pilot System Design Arrangement
- Theoretical Range Calculations
- Practical Ranges Achieved and Analysis/Interpretation
- Some thoughts on interference/co-existence
- BAE Systems' conclusions from the Pilot
- Some thoughts on future applicability of TVWS to maritime and naval applications

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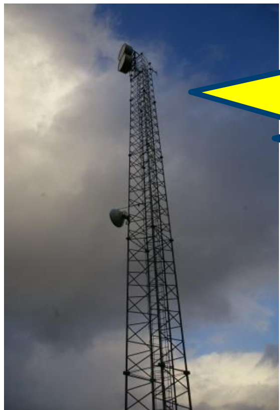
Orkney Isles TVWS Pilot System Design Arrangement



Ayre of Cara Internet PoP

Microwave Backhaul Link to Global Internet

Wideford Hill Mast Base Station

TV White Spaces UHF Link to the ferries

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Remote Analysis in Dorchester, Dorset

- MarineTraffic.com to monitor ferry positions via AIS
- Carlsonwireless.com to interrogate/monitor TVWS parameters
- Live video camera monitor

Allowing us to gather and analyse vast amounts of data without leaving the office!

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Theoretical Range Calculations

Theoretical ranges calculated from 'first principles' taking into account:

- Radio Line of Sight or Horizon Distance
- Transmitter and Receiver Line Losses
- Transmitter Power Output
- Transmitter Frequency
- Receiver Sensitivity
- Transmitter and Receiver Array gains
- Free Space Path Loss

Governing equation:

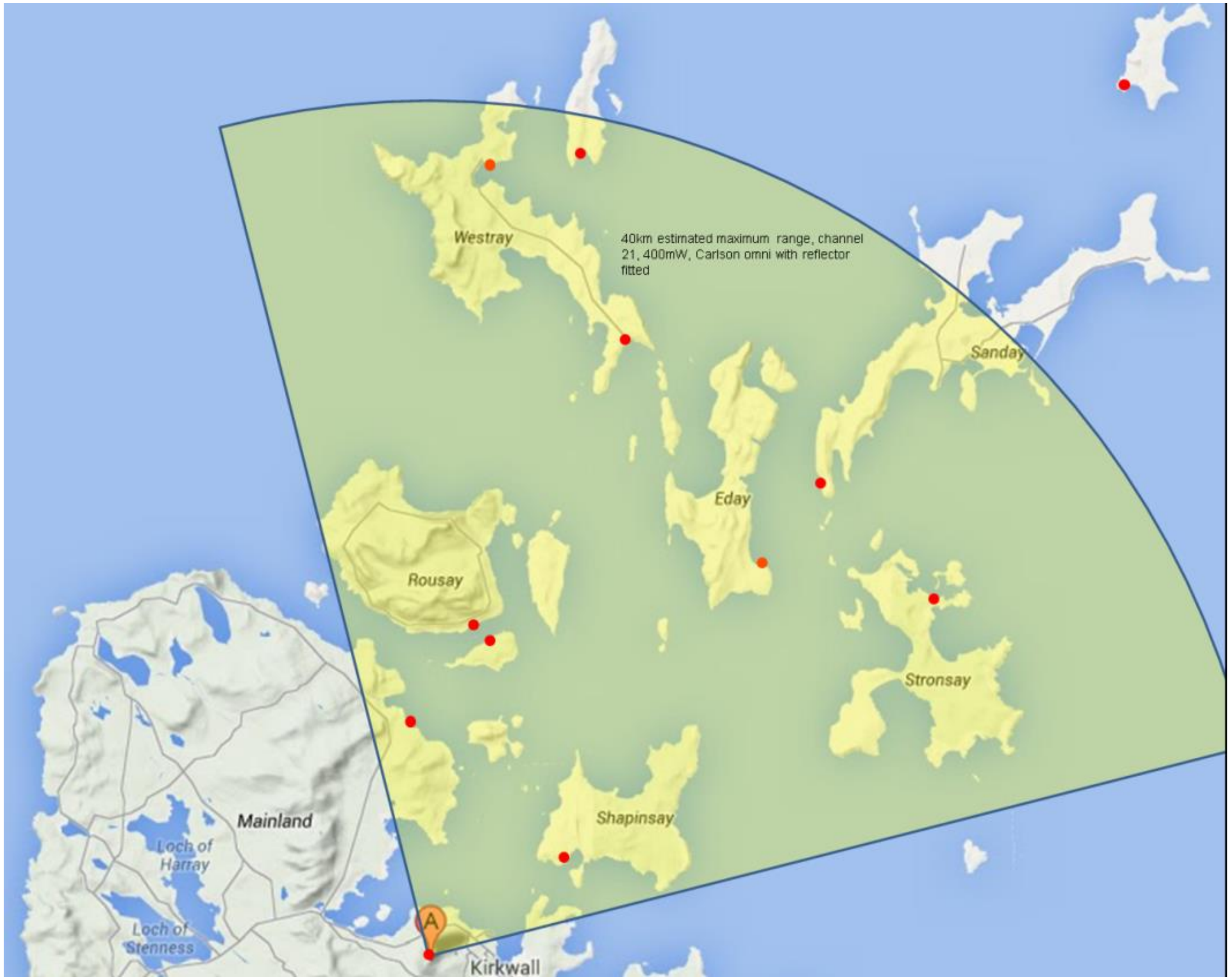
$$R = (c/4\pi f)(10\text{^}(P_T + G_T + G_R - P_R))$$

These parameters have been built into a simple spreadsheet model to predict range R under a variety of system design considerations, antenna types and configurations etc.

ORKNEY TVWS PILOT BAE SYSTEMS RANGE PERFORMANCE SPREADSHEET	Transmit Power (dBm)	Carrier Centre Frequency (MHz)	BS Antenna Gain (dBi)	BS Feeder Loss (dB)	EIRP (dBm)	CPE Sensitivity (dBm)	CPE Antenna Gain (dBi)	CPE Feeder Loss (dB)	Total CPE Sensitivity	Max Allowable Free Space Path Loss (dB)	Max Range (km)
Omni BS, Omni CPE CH21	26	474	5	2	29	-80	5	2	-83	112	20
Omni BS, Omni CPE CH61	26	786	5	2	29	-80	5	2	-83	112	12
90 Degree Sector BS, Omni CPE CH21	26	474	11	2	35	-80	5	2	-83	118	40
90 Degree Sector BS, Omni CPE CH60	26	786	11	2	35	-80	5	2	-83	118	24
90 Degree Sector BS, Omni CPE 5W Booster CH21	37	474	11	2	46	-80	5	2	-83	129	142
90 Degree Sector BS, Omni CPE 5W Booster CH60	37	786	11	2	46	-80	5	2	-83	129	86
Twin Stacked 90 Degree Sector BS, Omni CPE CH21	26	474	14	2	38	-80	5	2	-83	121	56
Twin Stacked 90 Degree Sector BS, Omni CPE CH60	26	786	14	2	38	-80	5	2	-83	121	34
8 Bay Stacked Dipole BS, Omni CPE CH21	26	474	15	2	39	-80	5	2	-83	122	63
8 Bay Stacked Dipole BS, Omni CPE CH60	26	786	15	2	39	-80	5	2	-83	122	38
90 Degree Sector BS, Trainable 8 Bay Stacked Dipole CPE CH21	26	474	11	2	35	-80	15	2	-93	128	126
90 Degree Sector BS, Trainable 8 Bay Stacked Dipole CPE CH60	26	786	11	2	35	-80	15	2	-93	128	76
Twin Stacked 90 Degree Sector BS, 8 Bay Stacked Dipole CPE CH21	26	474	14	2	38	-80	15	2	-93	131	179
Twin Stacked 90 Degree Sector BS, 8 Bay Stacked Dipole CPE CH60	26	786	14	2	38	-80	15	2	-93	131	108
180 Degree Sector BS, Omni CPE CH21	26	474	8	2	32	-80	5	2	-83	115	28
180 Degree Sector BS, Omni CPE CH60	26	786	8	2	32	-80	5	2	-83	115	17
Carlson High Gain Log Periodic BS, Omni CPE CH21	26	474	13	2	37	-80	5	2	-83	120	50
Carlson High Gain Log Periodic BS, Omni CPE CH60	26	786	13	2	37	-80	5	2	-83	120	30
Carlson Yagi 610MHz CH37	26	610	11	2	35	-80	5	2	-83	118	30
Omni BS, Omni CPE, 5W Booster (Flaughton Hill configuration) CH21	30	474	5	2	33	-80	5	2	-83	116	32
Omni BS, Omni CPE, 5W Booster (Flaughton Hill configuration) CH60	30	786	5	2	33	-80	5	2	-83	116	19
Baseline System Design highlighted in Green											

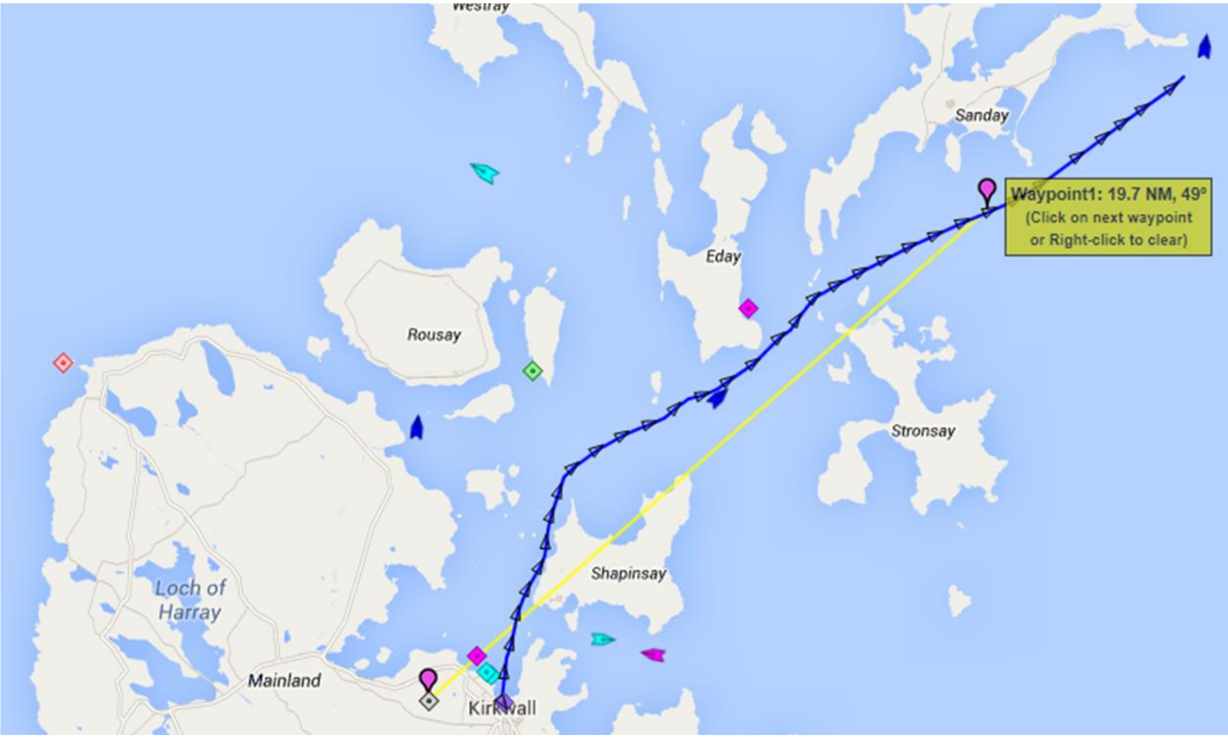
Theoretical Range of the ‘Baseline’ System

- Horizon distance from Wideford Hill Base Station (215 metres above sea level) is 64km so can be ignored
- Theoretical range is 40km with +26dBm Tx power, a 90 degree Sector BS antenna and omnidirectional CPE antenna on the ferries
- Red dots are the ferry terminals
- A single BS on Wideford Hill can therefore theoretically reach out as far as all remote ferry terminals EXCEPT North Ronaldsay



Practical Ranges Achieved

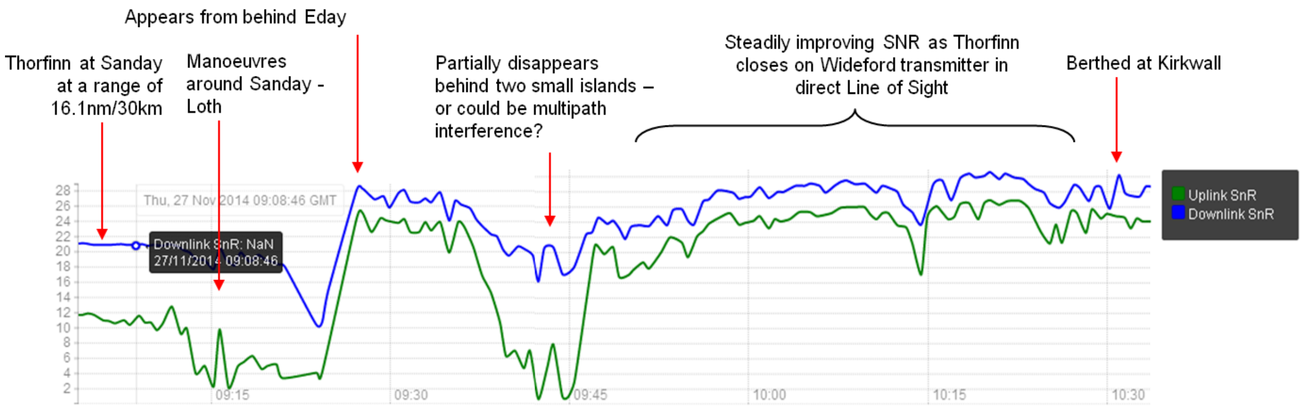
- MV Sigurd run from Kirkwall to North Ronaldsay
- TVWS Link maintained out to 19.7 nautical miles or 37km
- This aligns very closely with the theoretical maximum range calculated previously of 40km
- Contact maintained over the tops of the islands Shapinsay and Stronsay
- SNR follows an approximate inverse square law as expected



All SNR Plots acknowledgement/courtesy Carlson Wireless Inc.
All Map Plots acknowledgement/courtesy Marinetraffic.com

In more detail . . . a typical ferry run

- Link maintained whilst Thorfinn was in port at Loth, Sanday, at a range of 16.7nm or 31km, giving further confidence in the theoretical predictions (this being a different ship)
- Again, the TVWS Link is able to operate over the tops of islands (this time Eday and Shapinsay)
- The ‘dropout’ whilst passing close to the western coast of Shapinsay has been consistently noted, on different vessels, and is not understood – it may be a multipath effect?
- Good agreement between short-range SNR for both Thorfinn and Sigurd, again giving confidence in system consistency and predictability



Signal to Noise Ratio (dB) – MV Earl Thorfinn during Passage from Sanday to Kirkwall

Some images transmitted via TVWS

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Ships that pass in the night . . .
MV Varagen passing MV Thorfinn in Kirkwall Harbour

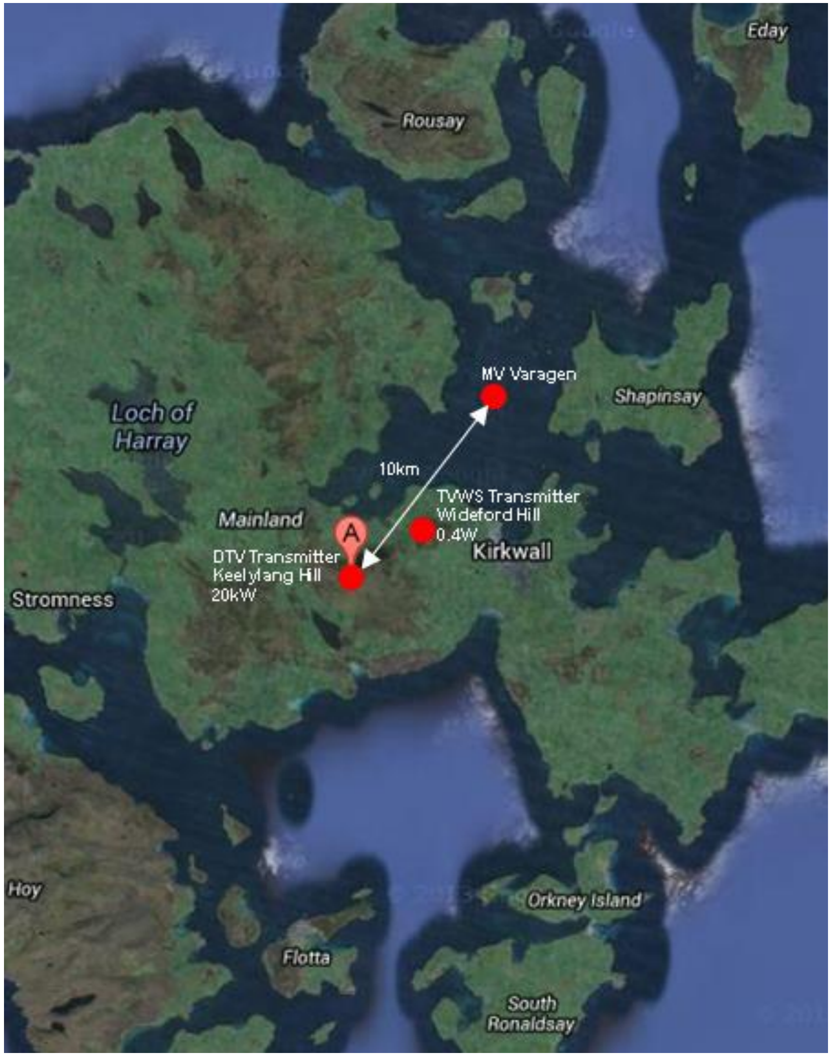
MV Earl Thorfinn, Bow Section lifting on approach to Kirkwall Harbour. The vehicle loading ramp is to the left

All shots are stills from live video feeds transmitted over TVWS and captured on a smartphone

Kirkwall harbour from MV Earl Sigurd

Some thoughts on interference/co-existence

- On one of the ferries, MV Varagen, the TVWS system was found to interfere with the ship's DTV system, prompting some interesting analysis of the causes
- The local Keelylang TV transmitter is sited on a hill closely spaced in bearing to the TVWS transmitter used in the Pilot
- Keelylang transmits three channels at 10kW and three channels at 20kW (Source: Ofcom DTV database); a total peak power of 90kW
- TVWS transmits at just 0.4W – indicating a very high degree of other-channel interference rejection by the TVWS radios (at least 54dB)
- Calculation of the Desired (DTV) signal level and the Undesired (on-board TVWS CPE) signal level showed that there is only a -4dB margin, therefore interference would be a possibility
- Remedial improvements in the DTV installation onboard the ferry eliminated the problem



BAE Systems’ Conclusions from the Pilot

- This programme of work has developed a theoretical foundation for the application of emerging TVWS technology to a marine or maritime environment
- The principal conclusion of the work that has been conducted to date is that TVWS technology is able to provide a viable, useful communications bearer in maritime regions
- Significant data rates may be achieved at ranges up to 40km from a single hop, at transmitter power levels that are remarkably low (in the order of half a watt). This high performance is largely attributable to state-of-the-art developments in digital radio technology.
- A good understanding of the antenna systems needed to operate in this region of the UHF band, and the factors that determine their installed performance, have been developed
- There has been remarkably close correlation between theoretical predicted performance and actual installed performance, giving confidence in the underlying theory. This in turn means that it is now easy to ‘play tunes’ with different antenna designs and beamwidths, pointing directions, antenna heights, transmitter power levels, modulation schemas etc. with a high degree of confidence that the results will be as predicted.
- The fundamental mechanisms of mutual interference have been analysed, and an understanding of how they can be mitigated onboard marine platforms has been developed

Some thoughts on possible future applications of TVWS to maritime and naval applications

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- Commercial networks for harbours, port areas and marinas etc, extending out to approximately 30-40km
- Commercial networks and dedicated point to point links for oil rigs, offshore wind farms
- Offshore oil well monitoring
- Environment monitoring
- Persistent surveillance
- Lifeguard surveillance
- Conservation monitoring
- Support to Search and Rescue co-ordination
- Networks for Maritime Autonomous Systems
- Naval Maritime Tactical Networks
- *and many more besides*

Questions?