TRANSHORIZON UHF RADIOWAVE PROPAGATION ON OVER-SEA PATHS IN THE BRITISH CHANNEL ISLANDS

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ABSTRACT

Three transhorizon, 2 GHz radio paths have been established in the British Channel Islands in order to investigate the characteristics of long-range UHF propagation over the sea. During the measurement period considered in this paper (August 2003 to September 2004), signal strength enhancements occurred about 8% of the time, predominantly in the late afternoons and evenings and in the summer months. The propagation conditions have been modelled using the AREPS radiowave propagation assessment software package, the results of which suggest that low-level evaporation ducting is not the only propagation mechanism responsible for enhanced signal strengths.

INTRODUCTION

Enhanced signal strengths of UHF radio waves are caused by super refraction and tropospheric ducting. These are important effects since they not only result in lower signal losses than expected but also enable signals to travel to beyond line of sight distances. Furthermore, in addition to improved communications, tropospheric ducting may also result in unwanted interference to/from distant stations to take place. Ducting depends on micrometeorological conditions in the troposphere, in particular the spatial and temporal distributions of temperature and water vapour. These in turn, influence the variation of the refractivity of air with height. Over the years, extensive research has been conducted to explain the propagation of radio waves in the context of tropospheric ducting [1] [2] [3] [4] [5].

In this paper, since we are dealing with over-sea propagation, it is expected that evaporation ducting is the principal propagation mechanism involved [2] [3] [4]. Evaporation ducts occur immediately above the surface of the sea and other large water bodies and exist primarily because the amount of water vapour present in the air decreases rapidly with height in the first few metres above the surface of the sea. Typically, the evaporation duct height is of the order of only a few metres [1] [2] [3] but there may be large variations in this, depending on the conditions in the atmosphere and the state of the sea. By virtue of how they are formed, evaporation ducts are practically permanent features over the sea surface [1] [2] [3] [4]. Preliminary results of experiments undertaken to investigate the occurrence of super refraction/ducting over several over-sea paths in the British Channel Islands are presented here.

EXPERIMENTAL ARRANGEMENT

Three transhorizon 2 GHz radio paths have been established in the British Channel Islands (Fig.1) in order to investigate the characteristics of long-range propagation of UHF radio waves over the sea. These are from Jersey to Alderney (48.5 km), Jersey to Guernsey (33.5 km) and Jersey to Sark (21 km). This network of purpose-built transmitters and receivers is operated by the Radio Systems Research Group, University of Leicester, as part of a research project sponsored by Ofcom, UK. Meteorological data are available from the Channel Light Vessel anchored in the English Channel, northwest of all three radio paths, and from weather stations at the Alderney, Jersey and Guernsey airports with heights of 71, 84 and 102 metres above mean sea level respectively. The distance of the Channel Light Vessel to the midpoint of the Jersey-Alderney link is approximately 70 km.

Each site has two antennas positioned at different heights above the sea, and signal strength measurements are made using alternately the high and the low antenna. All antennas are of the shrouded UMTS Yagi design with a beamwidth of approximately 26° and a gain of 14.5 dBi. The 100 W transmitter at Jersey radiates vertically polarised signals and the system has been synchronised such that transmissions are only from high antenna to high antenna and low antenna to low antenna. One pair of high and low transmit antennas points towards Alderney while the other pair points in a direction that is midway between Guernsey and Sark and is utilised for both these receiving stations. Finally, the effect of the tide on the antenna heights is accounted for by using the published tide tables for Jersey, Guernsey and Alderney. Since there are no tide tables available for the smaller island of Sark, the Guernsey tables are used to estimate the antenna heights at Sark.

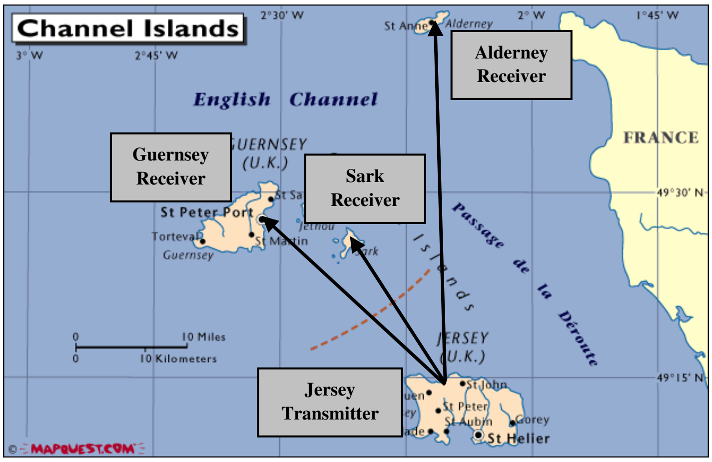


Fig.1. Map depicting transmitter and receiver locations in the British Channel Islands

MEASUREMENTS

Hourly averages of signal strength for the transhorizon Jersey-Alderney radio link (mean LOS range = 27.8 km) during a one-year period from August 2003 to September 2004 are presented here. In this paper, an enhanced signal has been defined as one with a measured signal strength that exceeds that for free space propagation (–71.5 dBm). The effect of the various weather parameters (e.g. air and sea temperatures, humidity, pressure, wind speed and direction) on the signal strength received at Alderney has already been reported [6]. During periods of signal enhancement there appear to be marked departures from the mean values of the meteorological parameters, although no definite combination of parameters appears to be a sufficient condition for enhanced signal propagation. These signal enhancements can have a sudden onset and are typically about 30 dB in magnitude, well in excess of the normal ±5 dB variation caused by the tide (high signal strengths during low tides and vice versa).

Furthermore, it has been observed that enhanced signal strengths occur predominantly during the late afternoon and evening periods [6] [7] (Fig.2) and, on a seasonal scale, occur more often during the summer months [7] (Fig.3). This strong diurnal variation may be evidence of a sea breeze/land breeze oscillation. During the measurement period considered in this paper, approximately 8% of signals received at the Alderney high antenna show enhancements, however the monthly values peak at 38% in May 2004 and have a minimum of 0% in October 2003, December 2003, January 2004 and February 2004. It should be noted that due to outages and other technical problems with the data acquisition system at Alderney, signal strength measurements could not be carried out for extended periods in June 2004 and July 2004.

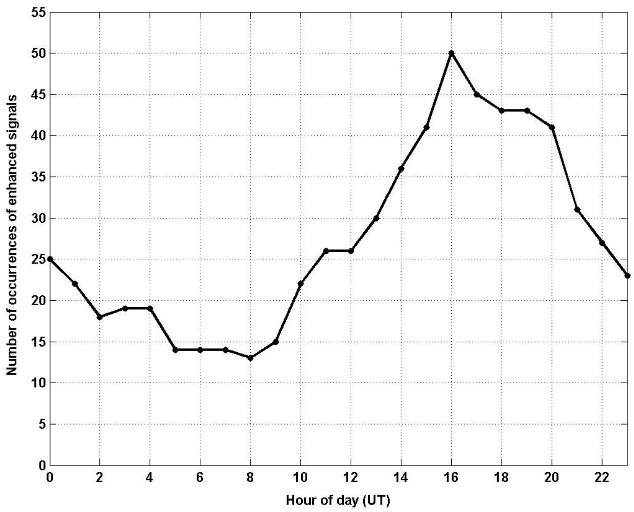


Fig.2. Diurnal variation in the frequency of occurrence of enhanced signals at the Alderney high antenna

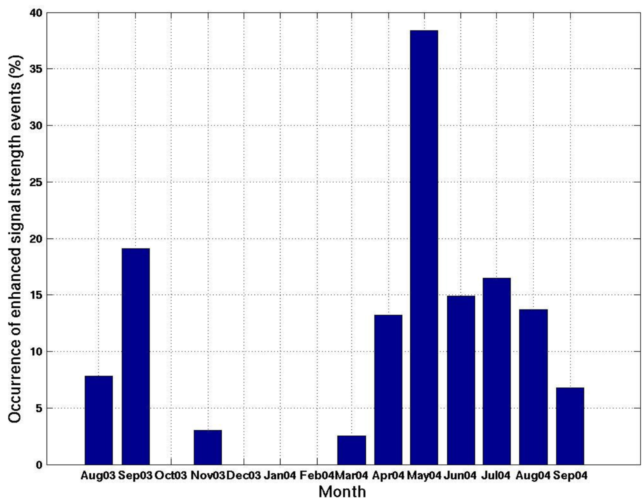
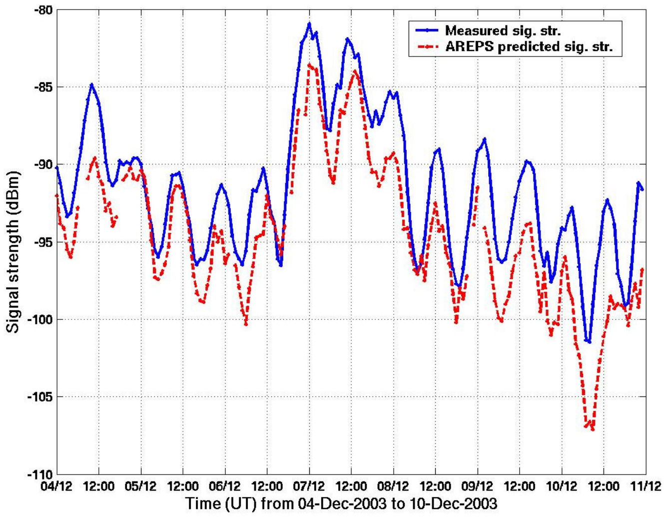


Fig.3. Monthly statistics of enhanced signal strength data at the Alderney high antenna (August 2003 to September 2004)

COMPARISON WITH AREPS PREDICTIONS

By default, the AREPS [8] software utilises the Paulus-Jeske method [2] [3] [4] to semi-empirically model the evaporation duct in the marine boundary layer. This requires the surface observation values of air temperature, sea temperature, relative humidity and wind speed as inputs in order to determine a low-altitude refractivity profile.

During a cold weather period (04-10 December 2003) when normal reception occurs, there is very good agreement between the measured and the AREPS predicted signal strengths at the Alderney high antenna (Fig.4). This behaviour was noted with the Guernsey and Sark measurements as well and for both the high and low antenna readings. On the other hand, for a typical period of signal enhancement during late summer (13-18 September 2003), there is little correlation between the observations and the AREPS predicted values, though the phases do match up (Fig.4). Given that only the effect of the evaporation duct has been accounted for in these cases, this suggests that the refractivity profile assumed within AREPS during periods of enhanced reception is incorrect, at least as it impacts on our paths/antenna heights.



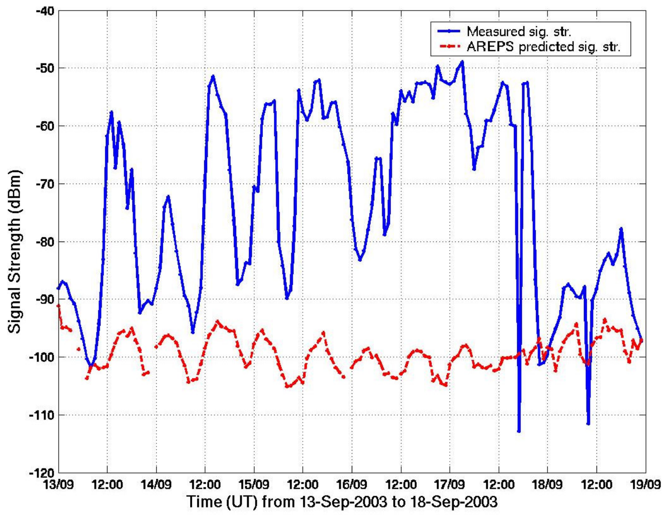


Fig.4. Comparison between the hourly measured signal strength and the AREPS predicted signal strength (using marine surface climatology) at the Alderney high antenna during a period of normal reception (left frame) and during a period of signal enhancement (right frame)

In the absence of more detailed meteorological data, refractivity measurements from the Channel Light Vessel (5 m) and the weather stations in Alderney (71m), Jersey (84 m) and Guernsey (102 m) were combined to provide an atmospheric profile for the first 100 m to input to AREPS. While using this profile, the evaporation duct model within AREPS was not used. It has been observed that the hourly variation in the refractivity measured at the land weather stations is more pronounced than that of the Channel Light Vessel.

Fig.5 presents a comparative plot of the predicted signal strength and the measured signal strength at Alderney for the same two periods of investigation. Weather statistics at the land stations were available only for a restricted period of time on each day (0600 UT to 1700 UT) during the duration of investigation, hence the gaps in the plots of the predicted signal strength. In this case, we observe that there is a much better correlation between the measured and predicted signal strengths during the period of signal enhancement compared to the period of normal reception. Thus, for the period of enhanced signal strength, the correlation between measurements and predictions is higher when this refractivity profile is used than when the evaporation duct model is used, whereas for the period of normal propagation, the evaporation duct model provides a better correlation. This result points towards the existence of higher layer refractive structures or stratifications that could also be influencing UHF radiowave propagation over the sea, in addition to the low-lying evaporation ducts, during periods of signal enhancement.

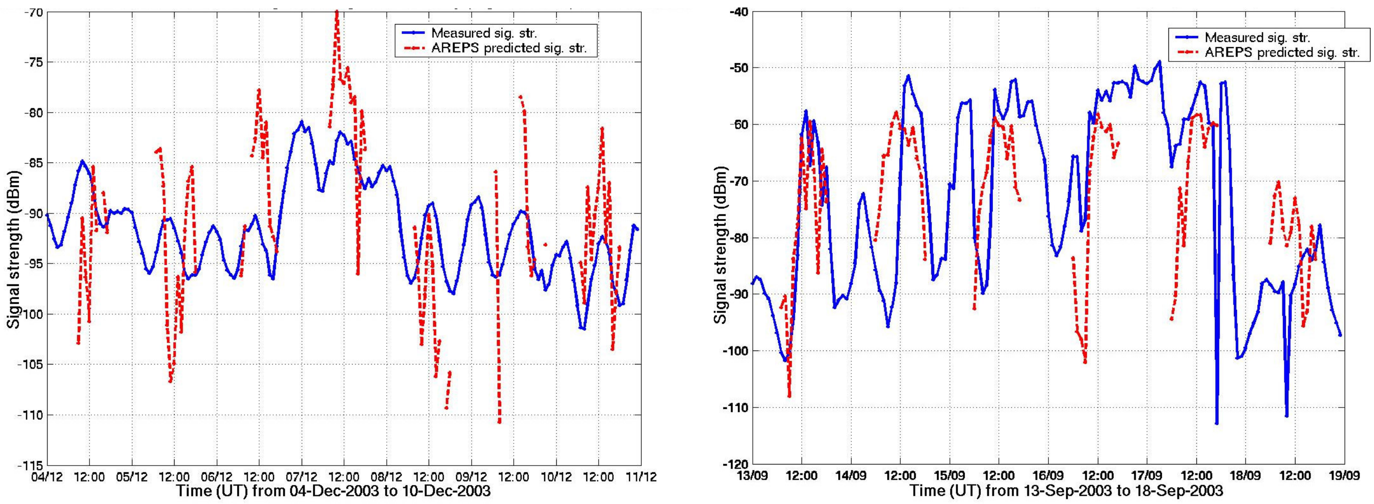


Fig.5. Comparison between the hourly measured signal strength and the AREPS predicted signal strength (using land station and marine surface refractivities) at the Alderney high antenna during a period of normal reception (left frame) and during a period of signal enhancement (right frame)

CONCLUDING REMARKS

The relatively long-term observations made during this study confirm the fact that the constantly changing weather patterns in the troposphere are directly responsible for the occurrence of enhanced signal strengths at certain periods. Our observations demonstrate that signal strength enhancements occur primarily during the late afternoon and evening periods and, on a seasonal scale, occur more often during the summer months. The propagation conditions in the Channel Islands were modelled using the AREPS propagation assessment software and the various signal strengths predicted by the program were compared to the measured signal strengths. Preliminary results indicate that evaporation ducts are not exclusively responsible for the enhanced signal propagation; higher layer tropospheric ducting structures could also be influential factors. These can be modelled to some extent using meteorological data from nearby land stations. Signal strength statistics provided in ITU-R recommendations (e.g. ITU-R P.1546 [9]) are based on extrapolations from lower frequencies, and some of our results should provide more accurate information for signal behaviour at 2 GHz.

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