MEASUREMENTS AND SIMULATION OF HF OFF-GREAT CIRCLE PROPAGATION EFFECTS OVER NORTHERLY PATHS

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Large deviations in the direction of arrival of ionospherically propagating radio signals from the great circle path (GCP) have serious implications for the planning and operation of communications and radiolocation systems operating within the HF band. Measurements made over several paths will be presented in this paper, and the principle causes of off-great circle propagation outlined. Significant progress has been made recently in modelling the propagation effects and work is now in hand to incorporate the results into tools to aid the planning and operation of HF radio systems operating at northerly latitudes.

Deviations of a few degrees from the great circle direction are associated with tilts due, for example, to the solar terminator and to travelling ionospheric disturbances. Very large deviations are particularly prevalent in the northerly regions where signals often arrive at the receiver with bearings displaced from the great circle direction by up to ±100° or more. Within the mid-latitude trough, these large deviations from the GCP arise from the electron density depletion and the consequent reduction in MUF along the great circle path. Propagation may then occur by scatter from irregularities in the north wall of the trough or within the auroral zone (which may be coincident) or by reflection from one or both of the tilted trough walls or via ground / sea scatter. Within the polar cap, off great circle propagation is attributed to the presence of convecting patches and arcs of enhanced electron density. It is important to note that the off-great circle mechanisms give rise to propagation at times which is not predicted by current prediction codes, and that techniques to account for this type of propagation are therefore required.

The situation is further complicated since, in addition to the large scale tilts which cause gross deviations of the signal from the great circle direction, irregularities in the electron density distribution cause signals associated with each propagation mode to arrive at the receiver over a range of angles in both azimuth and elevation. Such directional spread of the received signal energy is an important parameter to be considered in the design of multi-element receiving arrays and the associated signal processing methods used, for example, in radiolocation or adaptive reception systems. It is often assumed in the design of such systems that the signal environment comprises a limited number of specularly reflected signals arriving at the antenna array from well defined directions. However, for northerly paths, this is often not the case, and azimuthal standard deviations of several tens of degrees have been measured over polar cap paths.

In order for these propagation effects to be properly taken into account in system design and operation, it is necessary for the propagation mechanisms to be fully understood and incorporated into prediction tools. The authors are currently working towards this, and significant progress has been made in modelling the off-great circle propagation effects. The results of the modelling are very reminiscent of the characteristics observed in the experimental measurement programmes, and enable the nature of off-great circle propagation effects to be estimated for paths which were not subject to experimental investigation. Although it is not possible to predict individual events, due to the unpredictable nature of the precise positions of polar patches and arcs, it is possible to predict the periods during which the large deviations are likely to occur, their magnitudes and directions. The modelling relies on ray tracing through model ionospheres which is computationally intensive. Consequently, it is not envisaged that any propagation prediction tools developed as part of this research will contain ray tracing elements. An alternative approach is being made whereby a large number of ray tracing results will be included in a data-base which will form part of a rule base for predicting the effects of off-great circle propagation on any path impinging on the northerly ionosphere. Further work is addressing the development of a channel simulator incorporating directional effects for the development and testing of multi-channel receiver systems for operation in the difficult northerly environment.