Ionospheric Clutter Simulator for High Frequency Radars Wave Propagation

Abi Akl M.-J. * (1), Jangal F. (1), Darces M. (2), and Hélier M. (2)
(1) ONERA-The French Aerospace Lab, Palaiseau, France
(2) Sorbonne Universités, UPMC Univ Paris 06, UR2, L2E, F-75005, Paris, France

The HF (High Frequency) radars can be impacted by the instabilities of the ionosphere while they perform continuous surveillance of very large and far off areas. The hybrid HF radar combines the two types of HF radars using both sky wave and surface wave propagation. The latter takes advantage of the propagation along the sea surface to detect targets up to 200 NM (Nautical Miles), and the sky wave radar uses the ionosphere as a reflector to reach far regions beyond 1000 km. When long-term integration is performed, ionospheric instabilities lead to an increased false alarm rate. This is the typical case when detecting slow targets such as vessels. The surface wave reception can be affected by the direct reflection on the irregularities, resulting in the appearance of ionospheric clutter, and the sky waves are affected by the ionization turbulence resulting in a Doppler shift.

In order to estimate the impact of ionospheric irregularities on the actual performances of the radar, we aim to render various ionospheric effects in the radar image, with a simulation tool. Therefore, we have built a behavioral model able to include the ionospheric spatial and temporal variations. Previous work implemented a model of the sea clutter with a statistical approach in order to be more representative of the real data (Jangal, F.; et. al, Antennas and Propagation (EuCAP), 2013 7th European Conference on , vol., no., pp.2692-2693, 8-12 April 2013). In this work, we have introduced probabilistic models of the ionospheric effects assuming that only the phase path fluctuation has a meaning in the radar point of view. Booker's density profile (H. G. Booker, Journal of Atmospheric and Terrestrial Physics, Vol. 39, pp. 619 to 623, Pergamon Press, 1977) has been randomly modified over the whole ionosphere. We have validated our approach with two probabilistic types of variations of two different parameters of Booker's model. We have firstly disturbed the Booker's altitude vector parameter by means of a multi-normal probabilistic law and we have found an ionospheric electron density distribution following a log-normal law as expected (T. W. Garner, et. al, Journal of Geophysical Research, Vol. 115, A07306, 2010.). The random process, in the second case, is based on the spatial power spectral density as established by Shkarofsky (I. P. Shkarofsky, Canadian journal of physics, 1968, Vol. 46, N° 19, pp. 2133-2153), applied on the Booker's electron density reference. The temporal aspect has been taken into account by filtering the random phase paths in the slow time direction. The cut-off frequency of this filter is calculated thanks to the TEC spectrum observed by G. Li (G. Li, et. al, Earth Planets Space, 59, 279–285, 2007). In both cases, ray tracings are performed in order to evaluate the phase paths, to derive the radar signals and then to compute the range-Doppler images. Using such an approach, we have generated ionospheric clutter phenomena similar to those observed on real radar images.

At the APS/URSI conference, we will present the final results obtained notably the sensitivity of the power spectral density parameters on the Doppler and the distance spreading. We will, also, compare the Doppler and distance spreading for different cut-off frequency values of the low pass filter. Finally, other results dealing with the impact of each Booker's parameter will be discussed in order to find the sets of parameters which allow generating all kinds of clutter observed in real radar images.