32nd URSI GASS, Montreal, 19-26 August 2017

Calculating the Absorption of HF Radio Waves in the Ionosphere

Kate A. Zawdie*(1), Douglas P. Drob(1), David E. Siskind(1), and Clayton Coker(1)
(1) Space Science Division, Naval Research Laboratory, Washington, DC 20375, https://www.nrl.navy.mil/ssd

1. Extended Abstract

High Frequency (HF) radio waves experience absorption during ionospheric propagation which can significantly influence the received signal strength. The calculation of ionospheric absorption is thus vital for many HF applications, including Over the Horizon Radar (OTHR) and satellite signal propagation through the ionosphere. It has long been known that the ionospheric absorption of HF radio waves is dependent on the electron density in the ionosphere, but the impact of the ray trace formulation and electron collision frequency used to calculate the absorption is less clear.

There are two commonly used formulations that are used to calculate ionospheric absorption: Appleton-Hartree [1] is the classic ray trace formulation that is still widely in use today, and the Sen Wyller [2] formulation, which has been assumed to provide more realistic estimates of absorption, especially in the D- and E-regions of the ionosphere as it assumes the electron collision frequency is proportional to the square of the electron velocity. In this talk the two formulations are outlined and compared to each other. In addition, the correct collision frequency specifications for use in each formulation are examined. Comparisons of the two absorption calculations show that the two formulations are effectively equivalent, with maximum errors in the range of 5%, if the correct collision frequency specifications are utilized. When using the Appleton-Hartree formulation, one should use effective collision frequencies, such as those defined in Schunk and Nagy [3]. The mono energetic collision frequency at the most probable energy, as seen in Friedrich and Torkar [4], must be utilized in the Sen Wyller formulation.

The second topic addressed in this talk is how variations in the electron collision frequency influence the total ionospheric attenuation. The electron collision frequency varies as a function of local time, season, latitude and solar cycle. The most significant variations are above 150 km altitude, where the electron-ion collision frequency dominates. Using a collision frequency specification that varies according to climatology results in differences in the total attenuation on the order of 30%, which warrants inclusion in future ionospheric absorption models.

4. References

1. E. V. Appleton, “Wireless studies of the ionosphere,” *J. Instn Elect. Engrs*., **71**, May 1932, pp. 642-650.

2. H. K. Sen and A.A. Wyller, “On the generalization of the Appleton-Hartree magnetoionic formulas,” *J. Geophys. Res.*, **65**, December 1960, pp. 3931–3950, doi:10.1029/JZ065i012p03931.

3. R.W. Schunk and A.F. Nagy, *Ionospheres: Physics, Plasma Physics, and Chemistry*, Cambridge University Press, Cambridge, 2009.

4. M. Friedrich and K.M. Torkar, “Collision frequencies in the high-latitude D-region”, *J. Atmos. Terr. Phys.*, **45 (4)**, April 1983, pp. 267–271 http://dx.doi.org/10.1016/S0021-9169(83)80048-8