Input Impedance of Dipole Antenna

To predict the power required for the topside soundings, we need to estimate the input impedance of the transmitter, a center-fed dipole of half-length L and radius a. The equivalent circuit of the input impedance is a series of two resistors and one capacitor:

$$Z_{in} = R_{ohmic} + R_r - jX_A$$

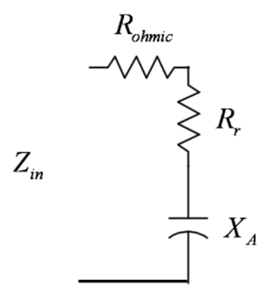

Figure 1: Equivalent Circuit for Input Impedance on Dipole Antenna

In a linear, isotropic, homogeneous plasma of infinite extent, the capacitive reactance, the radiation resistance, and the Ohmic resistance are given by:

$$X_A = -Z \frac{\ln\left(\frac{2L}{a}\right)}{2\pi(2L)} \left(\frac{\omega}{c}\right)^{-1}$$

$$R_r = Z \frac{(2L)^2}{6\pi} \left(\frac{\omega}{c}\right)^2$$

$$R_{ohmic} = \sqrt{Z} \left(\frac{2L}{2\pi a \sqrt{2\sigma}}\right) \left(\frac{\omega}{c}\right)^{\frac{1}{2}}$$

In free space:

$$Z = Z_0$$

and in a linear, isotropic, homogeneous medium:

$$Z = \frac{Z_0}{n}$$

where *n* is the index of refraction. The index of refraction depends on the electron and ion plasma frequencies:

$$\omega_{pe}^2 = \frac{n_e e^2}{\varepsilon_0 m_e} \quad \text{and} \quad \omega_{pi}^2 = \frac{n_i e^2}{\varepsilon_0 m_i}$$

where n_e and n_i are the electron and ion densities and m_e and m_i are the electron and ion masses; and the electron and ion gyromagnetic frequencies:

$$\omega_{ce} = -\frac{eB_0}{m_e} \quad \text{and} \quad \omega_{ci} = \frac{eB_0}{m_i}$$

where B_0 is the ambient magnetic field. When the propagation vector is along the magnetic field line, then the indices of refraction for the right- and left- circularly polarized light are given by:

$$n_R^2 = 1 - \frac{\omega_{pe}^2}{\omega^2}\left(\frac{\omega}{\omega + \omega_{ce}}\right) - \frac{\omega_{pi}^2}{\omega^2}\left(\frac{\omega}{\omega + \omega_{ci}}\right)$$
$$n_L^2 = 1 - \frac{\omega_{pe}^2}{\omega^2}\left(\frac{\omega}{\omega - \omega_{ce}}\right) - \frac{\omega_{pi}^2}{\omega^2}\left(\frac{\omega}{\omega - \omega_{ci}}\right)$$

The antenna in the proposed effort is 10 m in length, is 1 mm in radius, has a conductivity of 3.5×10^7 S/m (Aluminum), and operates from .1 to 6.48 MHz. To estimate the input impedance, IRI and IGRF model the environment at 80°N 110°W 800 km to have electron density, n_e, of 20,000/cm^3 and a magnetic field B_0, of 0.41G. For these conditions, the electron plasma frequency, fpe, is 1.27 MHz and the electron gyromagnetic frequency, fce, is 1.15 MHz. Therefore, transmission only occurs at operating frequencies above 1.27 MHz, when the plasma parameter $X = (fpe/f)^2$ is less than 1 (Figure 2).

Since the soundings will be radial to Earth center, the propagation vector is nearly parallel to the magnetic field and the above equations hold. Ion contributions are negligible. The index of refraction, radiation resistance, capacitive reactance, and Ohmic resistance at the operating frequencies that result in travelling waves are given in Figure 3, 4, 5, and 6, for free space, and for the right- and left- circularly polarized waves in the model environment.

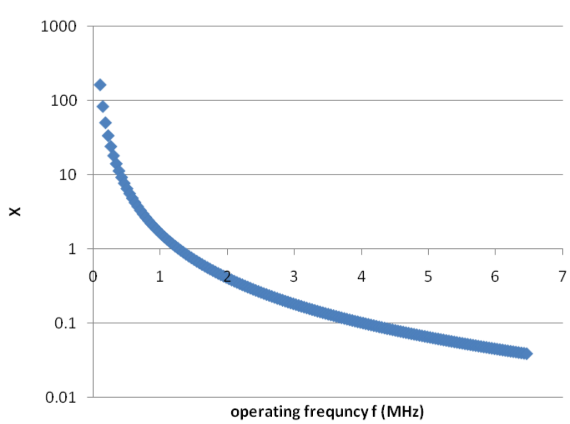

Figure 2: Transmission only occurs when plasma parameter X is less than 1.

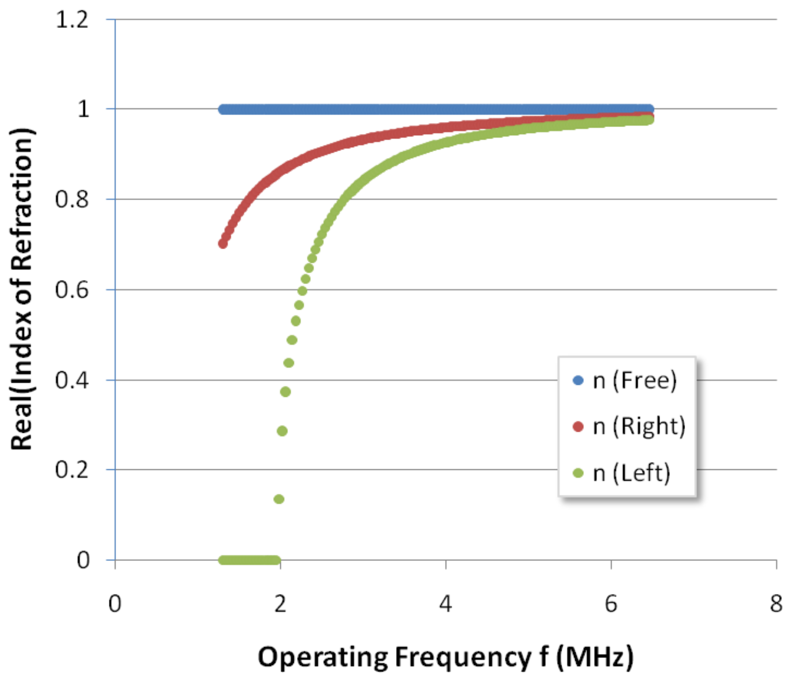

Figure 3: Index of refraction.

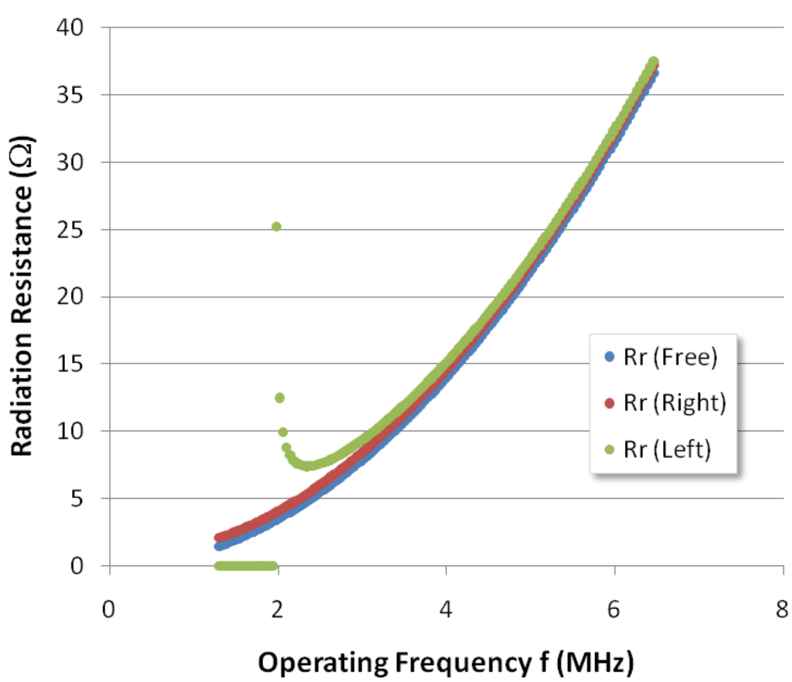

Figure 4: Radiation Resistance

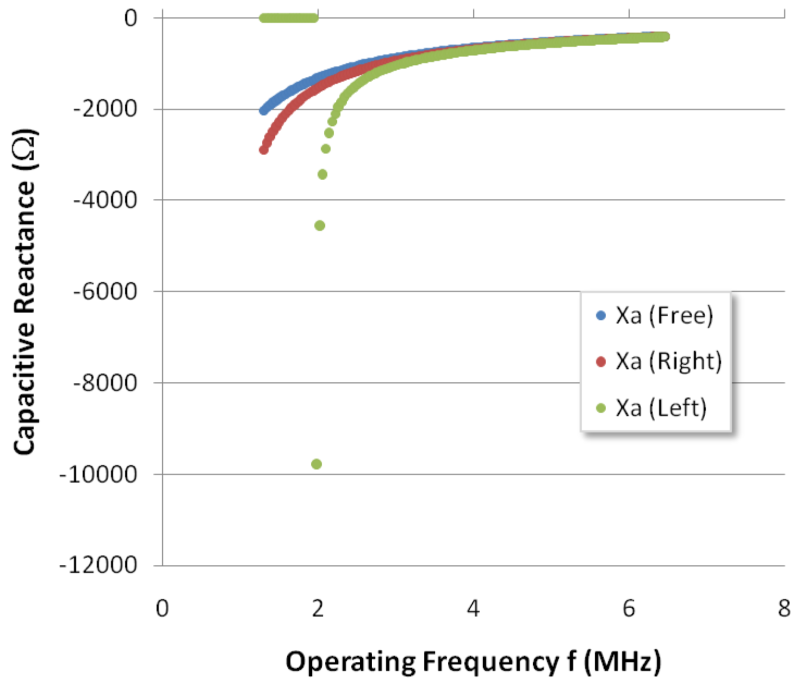

Figure 5: Capacitive Reactance

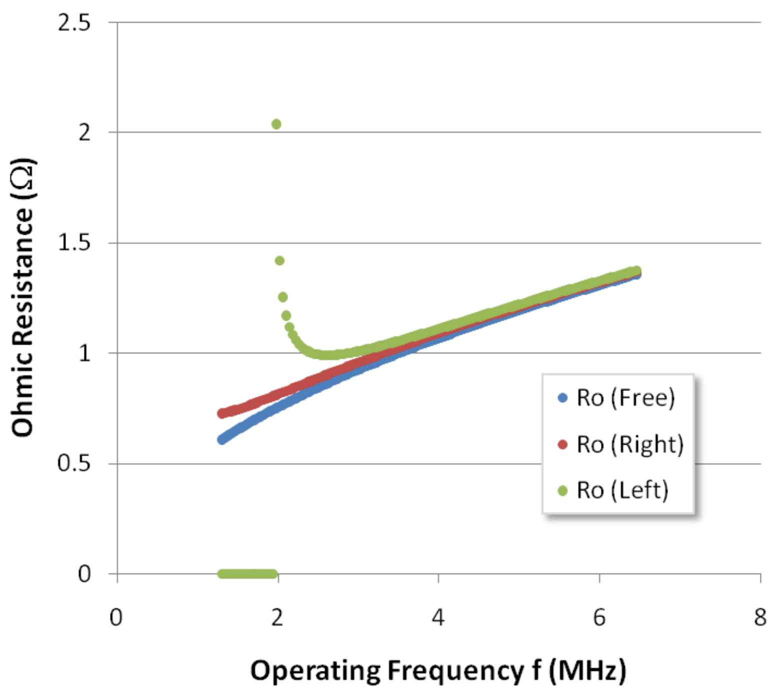

Figure 6: Ohmic Resistance