Reflection from ionized meteor trails at 50 and 144 MHz; *WB2FKO, February 2008.*

This document makes a simple estimate of the ionization density in a meteor trail to support efficient reflection of radio waves at 50 and 144 MHz. It attempts to explain the experience of amateur radio operators: the useable ping rate is higher and duration longer on 50 MHz compared to 144 MHz.

Assume meteors ionize the E-layer at an altitude of $h = 100$ km. This altitude will define the angle of incidence of the radio wave when it encounters the ionization trail. Also assume a spatially homogeneous trail is produced parallel to the earth's surface. It is known that two stations with antennas pointed at the horizon can communicate via meteor scatter over a working range of approximately $d = 800 - 2000$ km. Ignoring the curvature of the earth, the angle of incidence is:

$$\theta_i = \arctan\left(\frac{d}{2h}\right) \tag{1}$$

This sets $76^\circ \leq \theta_i \leq 84^\circ$. When a meteor with high kinetic energy enters the E-layer it will ionize gas atoms there to form a plasma, i.e. equal numbers of ions and electrons that are required to reflect the radio wave. Making the reasonable assumption that ions are much heavier than electrons, the refractive index of the meteor plasma trail is:

$$n = \sqrt{1 - \frac{Ne^2}{4\pi^2 f^2 m\varepsilon_0}} \tag{2}$$

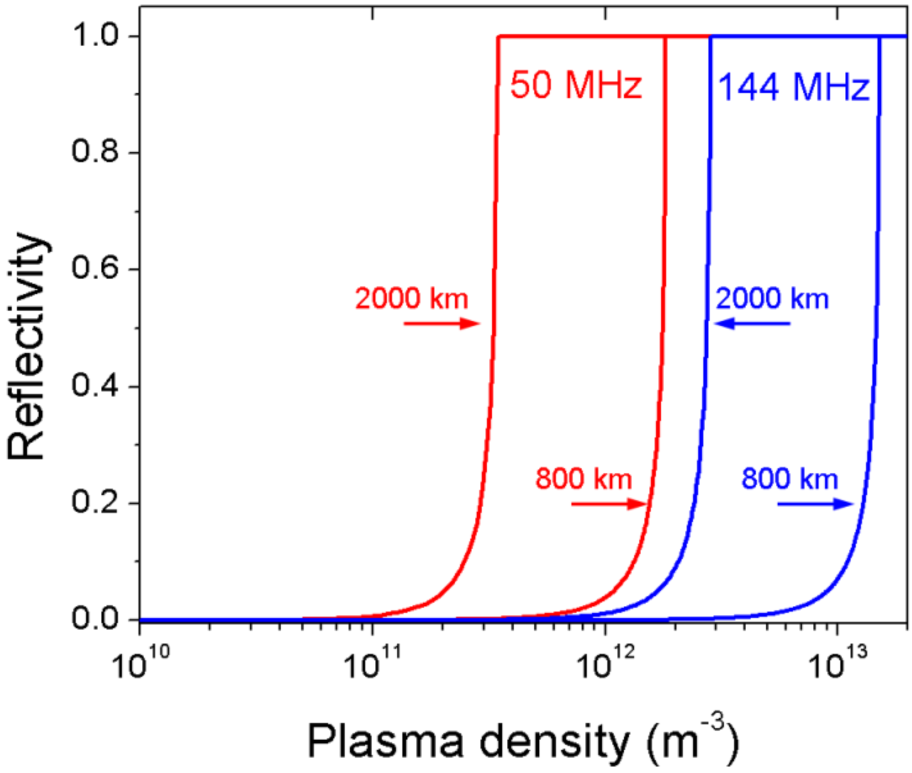
where N is the electron density, $e = 1.6 \times 10^{-19}$ Coul is the electron charge, $m = 9.11 \times 10^{-31}$ kg is the electron mass, $f = 50$ or 144 MHz, and $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m. The wave will be refracted by the plasma at an angle θ_T according to Snell's Law:

$$\sin(\theta_i) = n \ \sin(\theta_T) \tag{3}$$

The condition $\sin(\theta_i)/n \geq 1$ defines total reflection of the radio wave – the meteor trail is sufficiently dense to appear metallic at the frequency of interest. At lower ionization density, the wave will be partially reflected and partially transmitted into space. The Fresnel formula determines the power reflection coefficient (R) for horizontal antenna polarization:

$$R = \left|\frac{\sin(\theta_i - \theta_T)}{\sin(\theta_i + \theta_T)}\right|^2 \tag{4}$$

Now it is possible to estimate the ionization density necessary for communication on the two amateur VHF frequencies. Results are shown in the plot below. The two curves at each frequency (red: 50 MHz, blue: 144 MHz) define the minimum plasma density for station separation in the range 800–2000 km. The condition $R = 1$ means the ionization trail completely reflects the wave. All else being equal, the plasma density must be about 10 times higher on 2-m compared to 6-m. A meteor that provides efficient reflection at 144 MHz will always work at 50 MHz, but not vice-versa. As the electrons and ions recombine, the plasma density drops below that needed for reflection and the communication path is lost. The lower density threshold for reflection at 50 MHz explains why pings are generally perceived to be longer at that frequency.



The required plasma density becomes lower as station separation increases. This is due to the angle-dependence of reflectivity. It should not be concluded, however, that extreme distance contacts will be easier. There are other factors not considered here such as increased path loss, beam divergence, and scattering geometry. Irrespective of meteors, the calculation also shows why the existence of a short path via 6-m sporadic-E can be an excellent predictor of an impending long-path opening on 2-m.