The VT Ray Tracing Tool: a primer

The SuperDARN HF radars observe backscatter from ionospheric density irregularities and from the ground. Ionospheric backscatter is observed when the HF rays become perpendicular to the background magnetic field where a density irregularity is present. Ground backscatter is observed when rays are reflected in the ionosphere down to the ground.

The ray tracing tool determines the specific propagation path of each ray from a given radar and beam direction. The ray tracing is calibrated to mimic radar operation: rays are launched over an elevation range from 5° to 55°, at the selected operating frequency. Fig. 1 below illustrates a ray-tracing run for a single beam from the Blackstone SuperDARN radar.

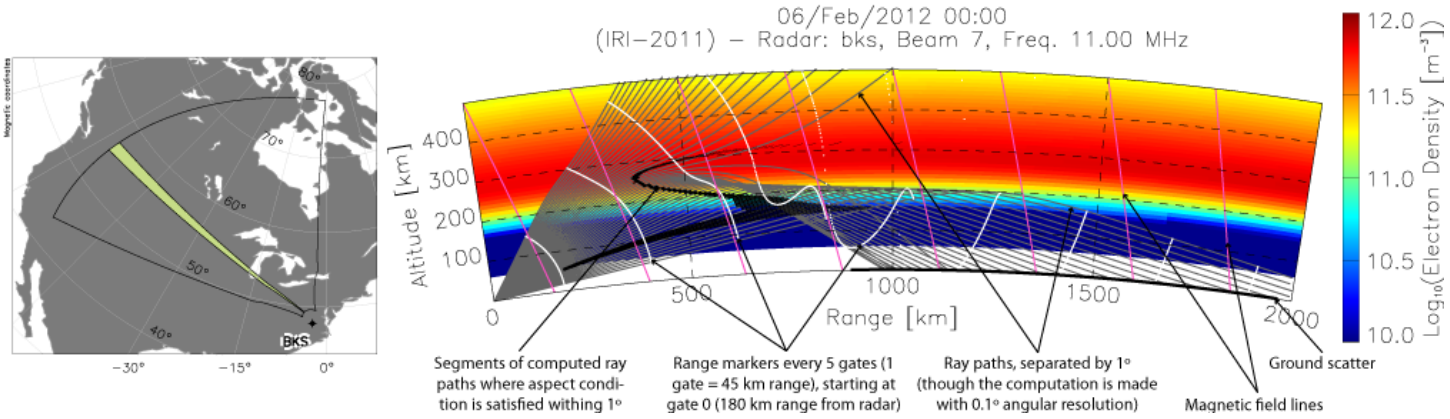

Fig. 1 (Left) Blackstone radar field of view with beam 7 highlighted. (Right) Ray tracing for beam 11 of the Blackstone radar at 11MHz on Jan 16, 2001.

The ray paths are computed using a 2D scheme based on work by *Coleman* [1998] and integrated using an adaptive Runge-Kutta Cash-Karp numerical method. Ionospheric profiles are generated by the latest International Reference Ionosphere (IRI-2011), and the non-collisional transverse Appleton-Hartree formula is used to compute refractive indices. The computation time for a full day with 30-minute time resolution is between 10-20 seconds.

The ray tracing can be used to predict the occurrence of backscatter, both from the ionosphere and from the ground. The basic idea is to count the number of rays scattering within a given 45 km range gate. In the ionosphere, each scattered ray is weighted by N^2/R^3 where N is the background electron density and R is the slant range. The code outputs power distribution, reflection altitude (virtual and real), elevation angle, refractive index in scattering volume and aspect conditions. An example of a power plot is shown in Fig. 2, with labeling for scatter type.

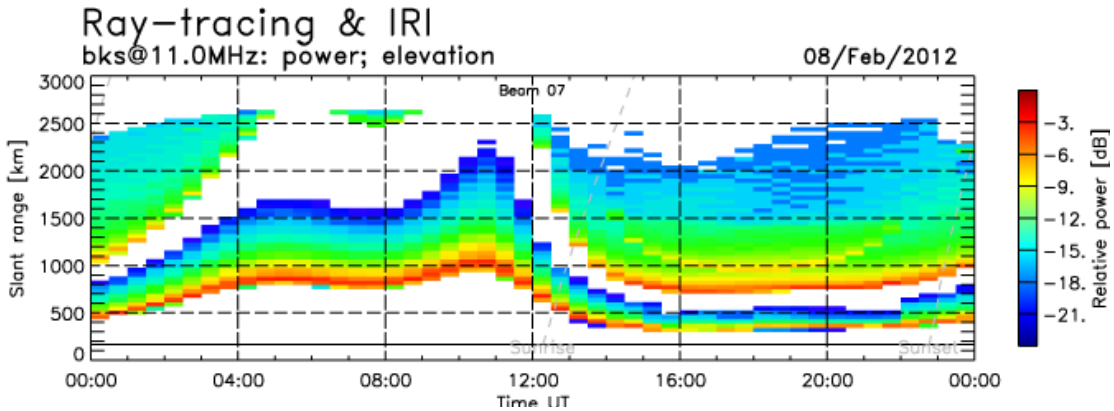

Fig. 2 Range-time plot for beam 7 of the Blackstone radar.

F.A.Q:

- *What does 'Relative power' represents?*

Each 45 km range cell is composed of a certain number of ray segments either having reached the ground (ground scatter) or satisfying aspect conditions (ionospheric scatter). We represent this range-time distribution of counted and weighted ray segments on a log scale relative to the maximum value of each specific scatter type (ionospheric or ground scatter) and call it 'Relative power'.

- *If there is ionospheric scatter and ground scatter in the same range cell (i.e., low angle rays reaching the ground at the same range as high angle rays reach good aspect conditions), which one of ionospheric or ground scatter is plotted on top of the other in range-time plots?*

By default, ionospheric scatter is always plotted over ground scatter, so that if both scatter types occur in the same range cell, ionospheric scatter will mask ground scatter. To bypass this, or to make sure you properly identify scatter, use the options at the bottom of the menu to plot either ionospheric, ground or both scatter types.

References:

- Coleman, C.J. [1998], A ray tracing formulation and its application to some problems in over-the-horizon radar, Radio Sci., 33(4), p. 1187-1197
- Ponomarenko, P.V., J.P. St-Maurice, C.L. Waters, R.G. Gillies, and A.V. Koustov [2009], Refractive index effects on the scatter volume location and Doppler velocity estimates of ionospheric HF backscatter echoes, Ann. Geophys., 27, p. 4207–4219
- IRI-2011: iri.gsfc.nasa.gov