Dx radius in Aurora and FAI radio propagation

Geographical signature of backscattering aligned to the Earth's magnetic field

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1. Introduction

In Aurora and FAI radio propagation, radio waves are scattered by structures of short duration (minutes to several tens of minutes) located in the E-layer of the ionosphere (105-110 kilometers). Aurora and FAI propagation may be considered the backscattering version of Sporadic-E in which the direction of the scattering is correlated with the direction of the Earth magnetic field line passing through the scatter volume. As a result, the transmitter views the scatter volume and the receiver in directions which generally differ significantly in azimuth. This paper analyses the dx radius of European and North American amateur radio stations in Aurora and FAI radio propagation. Because the inclination of the Earth's magnetic field varies between approximately 51 and 78 degree from south to north Europe, the dx radius may change considerably depending on the geographical position of the radio station. For example, the maximum distance in Aurora/FAI dxing is approximately 2000 kilometers in the south of Europe while the distance is zero in the far north of Europe, i.e. Aurora and FAI radio propagation is not possible there at all.

In this paper, backscattering of radio waves is calculated according to [2], which adopts BOOKER's model of scattering by nonisotropic irregularities [1]. In 1988, the AURORA program was the first amateur radio software to apply this model in Aurora and FAI real time analyses in order to calculate the geographical position of Aurora and FAI with high degree of accuracy [3], [4]. The successor to the AURORA program, i.e. the BeamFinder analysis software [5], is used in this paper to calculate the maximum distances in Aurora and FAI dxing.

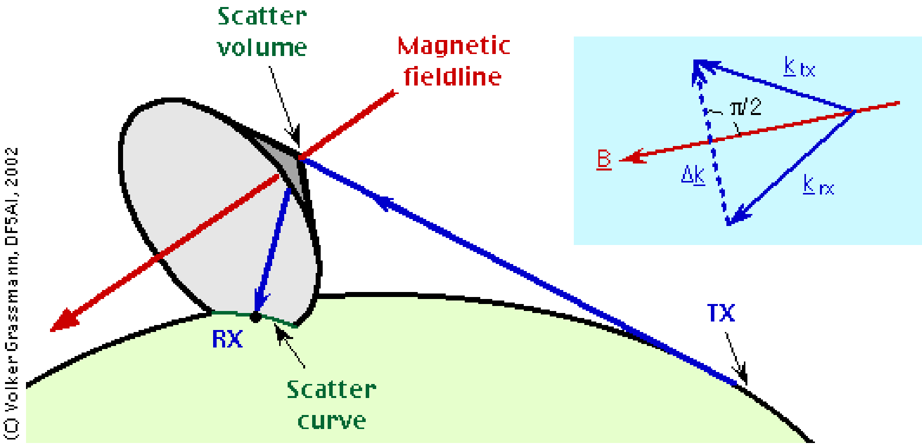


Figure 1. The cone of scattering in Aurora and FAI radio propagation.

The backscatter geometry in Aurora and FAI radio propagation

In figure 1, the vector k tx denotes the wave vector of the incident radio wave (along the line TX - scatter volume) and the vector k rx denotes the wave vector of the scattered radio wave (along the line scatter volume - RX). Aurora and FAI radio propagation corresponds to the so-called bistatic radar case in which the difference between the wave vectors is directed perpendicular to the magnetic field line passing through the scatter volume. The vector orientation may be interpreted geometrically by a cone which originates at the scatter volume and spans around the field line at an angle identical to the angle between the wavevector k tx and the field line B. Note that both the wave vectors, i.e. k tx and k rx, are located on the curved surface area of the cone. On the other hand, the receiver RX is also located on the surface of the Earth, i.e. the receiver is located on the line where the curved surface area intersects the surface of the Earth (scatter curve).

2. The scatter curve

The geometry of backscattering in Aurora and FAI propagation is explained in the box. Figure 2 shows a practical example in which the transmitter (TX) targets a scatter volume in northern direction. The crosses denote the scatter curve, i.e., the intersection of the cone of scattering and the surface of the Earth.

The region of backscattering is generally not spot-like in nature, as in the example shown in figure 2, but is, more or less, an extended geographical area. Therefore, the geographical pattern is much more complicated in practice and, of course, may vary due to dynamical processes in the ionosphere. Note that the characteristics of a dx opening are also affected by the actual antenna direction and by the antenna's radiation pattern, both of which control the illumination of the scatter region.

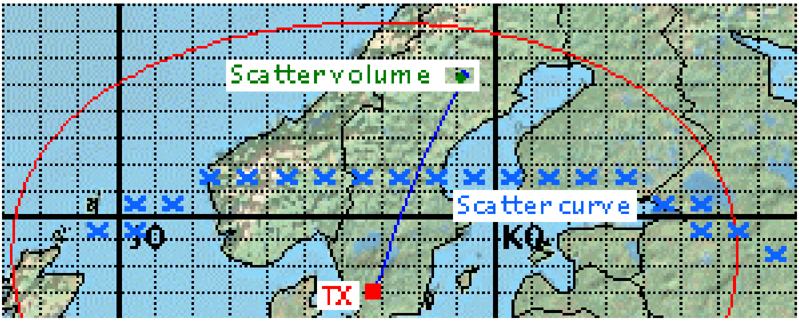


Figure 2. Example of the scatter geometry.

3. Available scatter volumes and the dx radius

In principle, any scatter volume in the E-layer of the ionosphere (105 km) closer than 1150 km may be targeted by the transmitter. The scatter volume disappears below the horizon for longer distances and cannot be accessed (see the red circles in figure 2). In the forwardscatter mode of Sporadic-E, any scatterer within the range of vision may fulfill the geometrical requirements for terrestrial radio communication. However, this is not the case for Auroral and FAI backscattering: for example, radio amateurs in the far north of Europe cannot use Auroral backscattering at all because the cone of scattering always opens into space. In other words, it never intersects with the surface of the Earth and, as a consequence, even the strongest Auroral scattering cannot facilitate communication to terrestrial radio stations (this feature may perhaps motivate new types of experiments in amateur radio satellite communication). In principle, all European radio amateurs are at least partially affected by this phenomenon, i.e. each radio station has a specific range in azimuth for which Aurora and FAI is blanked out.

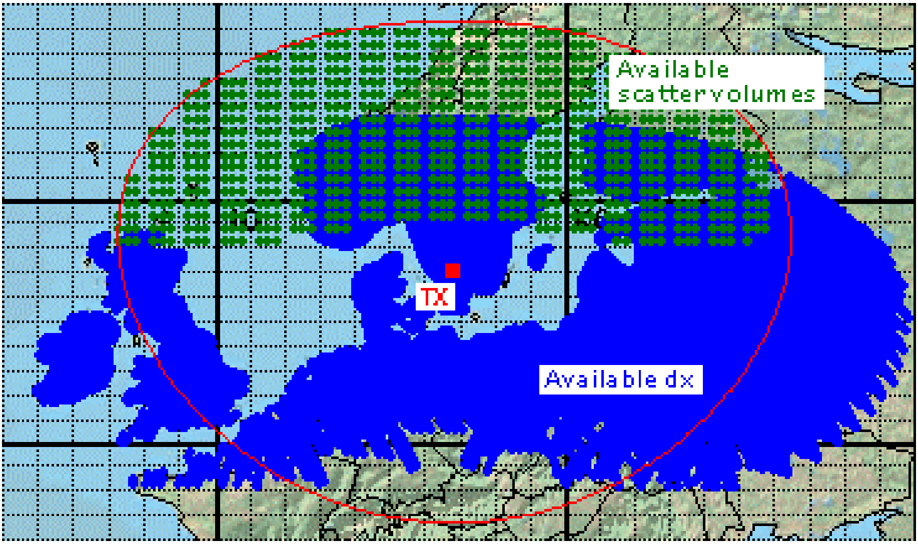


Figure 3. Available scatter volumes (dots) and the dx radius (solid) in Aurora and FAI radio propagation. Note that the dot marks correspond to locations in the ionosphere (105 km), while the solid contour corresponds to ground locations.

Using the BeamFinder analysis software, all scatter volumes were calculated in the above example which support terrestrial Aurora and FAI radio propagation (see the dot marks in figure 3). Assuming, these scatterers would all simultaneously provide backscattering, a large number of scatter curves is obtained which reflect the total dx radius in Aurora and FAI radio propagation (i.e. the geographical region in which the scattered radio waves may be received by other radio stations, see the solid area in figure 3).

4. Analysing variations of the dx radius

The size and the shape of dx radius may change with the transmitter's geographical position considerably. Six European locations were therefore selected to represent the dx ranges in various European regions, see the figures 4 to 9. Another seven locations were selected to represent the dx range of Aurora and FAI in North America (see figures 10 to 16). Please refer to the webpage http://www.df5ai.net to view more examples of the dx range calculations. This web site also provides a download section with the BeamFinder analysis software.

5. References

[1] A theory of scattering by nonisotropic irregularities with application to radar reflections from the aurora
Booker, H. G., J. Atm. Terr. Phys. 8, 204-221, 1956

[2] Analyse von Rückstreubeobachtungen ultrakurzer Wellen an Polarlichtern
Czechowsky, P., Diplomarbeit, Max-Planck-Institute for Aeronomie, 1966

[3] Aurora - Ein Computerprogramm zur Analyse von Aurora- und FAI Rückstreuungen
Grassmann, V., DF5AI, Dubus, 1, 18-21, 1988

[4] Aurora - A computer program to analyse Auroral- and FAI-scattering
Grassmann, V., DF5AI, Dubus, 2, 125-126, 1988

[5] The BeamFinder analysis software
Grassmann, V., DF5AI, http://www.df5ai.net

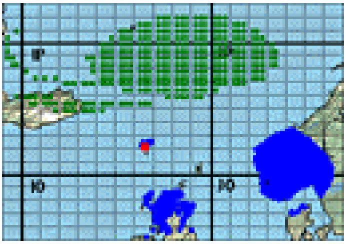
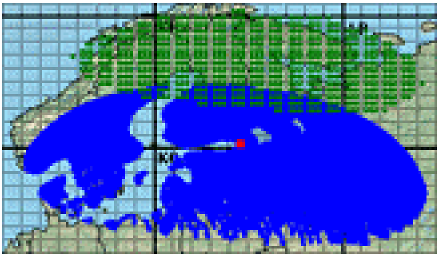



Figure 4 (left). The Faroe Islands (OY).
Figure 5 (right). St. Petersburg (UA).

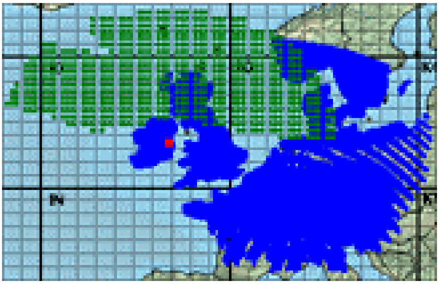
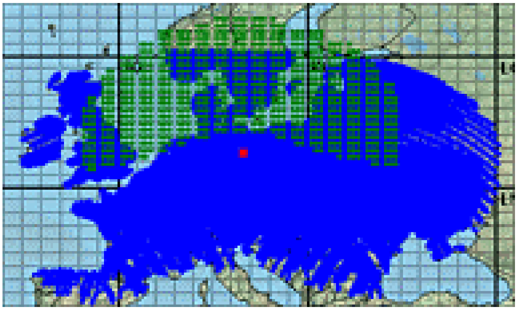



Figure 6 (left). Dublin (EI).
Figure 7 (right). Berlin(SP).

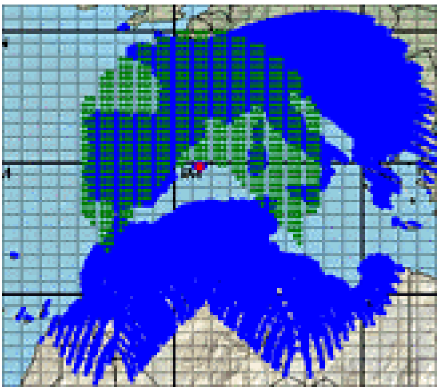
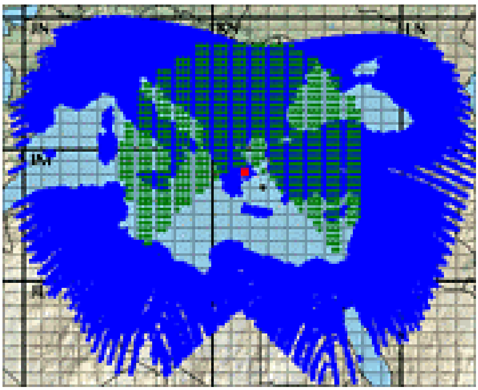
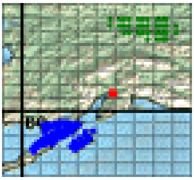
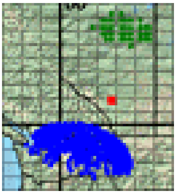



Figure 8 (left). Palma (EA6).
Figure 9 (right). Athens (SV).





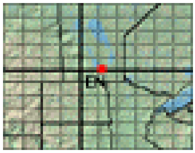


Figure 10 (left). Anchorage.
Figure 11 (center). Calgary.
Figure 12 (right). Winnipeg (Aurora/FAI not available).

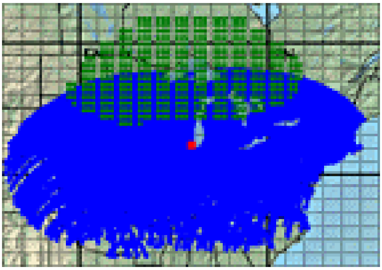
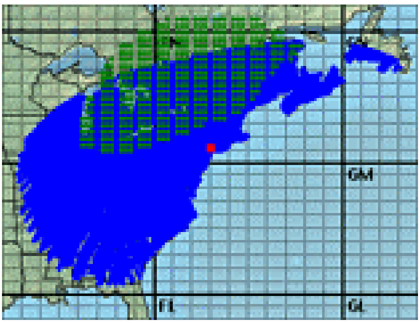


Figure 13 (left). Vancouver
Figure 14 (right). Chicago.



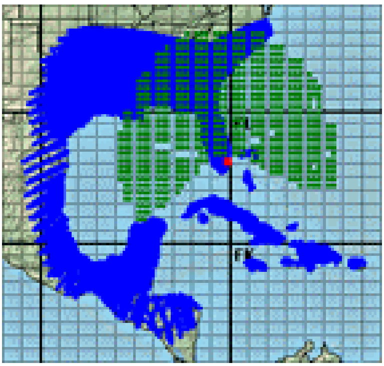


Figure 15 (left). Anchorage.
Figure 16 (right). Calgary.