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Reply (to "Comment on 'The Absolute Scattering Cross Section at50 MHz of Equatorial Electrojet Irregularities' by Farley et al." by N. D'Angelo)

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REPLY

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In the preceding commentary D'Angelo [1981] wonders how our recent radar observations [Farley et al., 1981] in Peru could lead to values of the scattering cross section of electrojet irregularities so different from those suggested by a remark in Bowles et al. [1963]. The difference is surprising, no doubt about that, but we stand by our conclusions, one of which is that the equatorial scattering is far too weak to explain fluctuations in riometer records, a suggestion advanced by D'Angelo [1976] on the basis of the Bowles et al. remark. Furthermore, we believe that it is very unlikely that scatter will affect riometer data even in the auroral zone, although our observations do not deal directly with this case. Hence we also reject the suggestion of Mehta and D'Angelo [1980].

One must remember that Bowles et al. [1963] were reporting on the earliest VHF studies of the equatorial electrojet irregularities, and the absolute power estimate was a minor part of the paper. We have rechecked the very rough numerical estimate given by Bowles et al. (p. 2488) and have also conferred with one of the authors (B. B. Balsley, private communication, 1981). We all agree that the numbers given in the 1963 paper are reasonable, although perhaps slightly optimistic; a signal/noise ratio of 20 dB seems a bit too high for the small radar system which they describe. However, the remark in Bowles et al. [1963] that follows the calculation and claims that the cross section could be 'several orders of magnitude greater' is simply not correct. No one now claims credit for it nor can remember how it came to be written.

D'Angelo [1976] interpreted 'several' to mean at least three, which is a plausible interpretation, but unfortunately the statement quoted should never have been written. The signal/noise ratio of 20 dB quoted as typical is probably near the maximum that one could expect; a value three orders of magnitude or 30 dB larger is completely out of the question for the small radar system described. Only the large Jicamarca 50-MHz radar with an antenna area of 9×10^4 m^2 and a megawatt transmitter routinely observes such strong returns. These general conclusions are supported by years of observations at Jicamarca, not just the two different types of carefully calibrated measurements discussed in Farley et al. [1981].

We do not understand the relevance of the statement by D'Angelo that 'a frosted piece of glass does, after all, appear opaque whether we shine a light through it from above or from below.' The electrojet region is neither frosted nor opaque; it is almost completely transparent to VHF radiation. The 'optical depth' σh is, as we have pointed out, far smaller than 10^{-1} (a value which, incidentally, implies an 'absorption' of at most 0.4 dB, but more likely about 0.2 dB since scattering is not the same as absorption or reflection, not 1 dB as stated by D'Angelo), even at 20-30 MHz. Our estimate of 5×10^{-5} or less for σh corresponds to an 'attenuation' of $<2 \times 10^{-4}$ dB. Furthermore, if the electrojet region really were 'frosted,' as D'Angelo suggests, all daytime equatorial ionograms would show a horizontal band of strong echoes extending in range from 100 km to 200 km or more (oblique echoes) at all frequencies from f_oE to the maximum transmitted frequency. Such echoes are not seen.

The corresponding analysis for the auroral zone is less clear cut, perhaps, but we believe the available evidence indicates convincingly that scattering will have a negligible effect on riometer records. In his commentary D'Angelo [1981] argues that the 'optical depth' for auroral scattering might be as much as 10^4 times larger than the corresponding equatorial value. Several of D'Angelo's assumptions are at best questionable. For example, the scattering certainly will not increase as the square of the layer thickness, and it is dangerous to infer radar cross sections from rocket data. It is far safer to rely on actual radar observations when discussing scattering phenomena, even if the data are rather sparse.

For the sake of argument, however, let us for the moment accept D'Angelo's result that the 'optical depth' for scattering at 50 MHz in the auroral zone might be as large as 0.1; i.e., about 10% of the power directed perpendicular to the magnetic field and incident on a unit area of auroral irregularities might be isotropically scattered (the scatter is not isotropic of course, but σ is defined as though it were). It is then easy to show that a simple radar consisting of a few dipoles and a 1-W transmitter would receive signals well above the noise level from a moderate sized patch of such irregularities. Auroral scatter is strong, but not that strong. The largest quoted value for the auroral scattering cross section that we are aware of is about 2×10^{-7} m^{-1} at 50 MHz [Chesnut et al., 1968; Chesnut, 1972], corresponding to $\sigma h < 5 \times 10^{-3}$, at least 20 times weaker than D'Angelo's value.

Furthermore, there remains the problem of the auroral geometry. We do not understand the arguments associated with Figure 1 of the preceding commentary [D'Angelo, 1981]. Scattering is not the same as absorption, and it is perhaps dangerous to use the term 'optical depth' without putting it in quotation marks. D'Angelo's Figure 1 correctly shows almost no cosmic noise being scattered back into space from the ionosphere. If the noise is not scattered back into space and is not absorbed, it must reach the ground, even if the scatter is very strong (which it is not).

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