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Intensity Fluctuations of Solar Radio Emission, Scattered by Coronal Turbulence

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1. Introduction

Intensity fluctuations of the emission from a solar radio source are determined by two factors. One includes temporal fluctuations of physical parameters of the source itself (statistics of the source). The other involves fluctuations of parameters of the propagation medium (statistics of the medium). If the statistics of the source are known and if its true angular size is very small, the statistics of the medium can be studied. Such a problem is solved by, for example, probing the solar wind using cosmic radio sources or spacecraft. In the case of sources of solar origin the problem of transilluminating the solar corona is severely complicated: the statistics of source are unknown; the observed angular size of radio source is rather large.

This report presents some results of a theoretical analysis of the intensity fluctuations due to the scattering in the solar corona of the emission of a reasonably compact radio source. The intensity fluctuation spectrum is closely related to the angular spectrum of scattered emission. Therefore, experimental verification of some outcomes of such an analysis could also serve as a test of the idea itself of the substantial influence of the scattering of the emission upon the observed angular size of solar microwave sources (Bastian, 1994). Since spike burst sources are candidates for the role played by very compact objects, pertinent attention is given to these events.

2. Results

The properties of intensity fluctuations in an extended medium with a power spectrum of fluctuations of the refractive index depends virtually on a single parameter. In the case of a plane wave and statistically homogeneous media this parameter is represented by the value of a structure function of complex-phase fluctuations calculated on the size of the first Fresnel zone. In the real solar corona and the spherical wave case of concern to us the notion of this parameter should be corrected.

The main conclusions of this study are (Uralov, 1998):

a) The regime of strong scattering, in which scintillations saturate, is a candidate for a typical regime of solar decimetric and even centimetric emission. For a coherent (point) source, this signifies an approximate equality of the fluctuation dispersion and the mean value of the intensity.

b) Since the emission source co-rotates with the Sun, the corresponding diffraction pattern sweeps past the terrestrial observer with a velocity of about 400 km/s. This is the governing factor in the transition from a spatial to temporal spectrum of intensity fluctuations. And the same factor becomes decisive when explaining the large angular size of sub-second spike burst sources recorded at the Siberian Solar Radio Telescope (SSRT, wavelength 5.2 cm).

c) With the SSRT time resolution 14 ms, the long-exposure mode when it is impossible to identify the speckle-image of the presumed, nearly point source, corresponds to the observation of spike bursts, the apparent size of which exceeds 10 arcsec. This reasoning draws on a wide-spread belief that the main characteristics (a very short duration, the narrow-banded character, and a reasonably high intensity) of the spike bursts, are caused entirely by physical processes occurring in a small (by volume) impulsive emission source. It is likely that such is indeed the case on many occasions. But if there exists the scattering of the emission leaving such a source which leads to an appreciable growth in the angular size, then the influence of the propagation medium upon the temporal profile and the frequency spectrum of observed spike bursts can become important.

d) Moreover, spike bursts can also be associated with spatial spikes of a random intensity field of a sufficiently bright, compact (but not “operating” in the impulsive mode), broad-banded solar radio source. Since the intensity spike is caused by a random focusing of the emission by large-scale inhomogeneities, the angular size of the observed spike burst must correspond to the aperture (up to 10 arcsec) of the focusing "lens". Temporal characteristics of such (formed by the propagation medium) intensity spikes may correspond to observed spike bursts. Spike bursts that have formed in such a fashion, must also be narrow-banded. The only limitation in this case is on the true size of the radio source – not larger than a few tens of kilometers in the case of strong millisecond spikes if the observation wavelength is 5 cm. If the true size of the radio source is large, it is still possible to detect the low-frequency (a few seconds or longer) envelope of fast intensity variations.

e) It may be anticipated that the weak scattering regime is possible at short wavelengths (perhaps at about 1 cm or shorter). The exact and approximate solutions for the spectrum of temporal intensity fluctuations in this regime is found. The frequency, at which the spectrum shows a bend, is determined by the location of the effective scattering screen if the source size is not too large.

f) As the emission propagates through a turbulent medium, the spatial intensity distribution of scattered emission depends on frequency (and the role played by interference of the scattered waves arriving at the observation point is great). There is a good probability that the observed time and frequency fine structure of some solar broadband radio sources (type I noise storms, some type IY sources) is, on occasion, be tangibly determined by the statistics of the propagation medium rather than by the statistics of the source itself.

References

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