TYPE-III RADIO BURSTS AND THEIR INTERPRETATION

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Abstract. The observations of type-III solar radio bursts are briefly reviewed to set requirements on a model for their interpretation. The most important of these requirements is that the source must be an electron stream which is in a state of continuous quasilinear relaxation and which initially must have a nearly monotonically decreasing velocity distribution. The problem of constructing a model is broken into three parts: (1) The plasma wave source which depends on the interaction of the electron stream with electron plasma waves. (2) The radiation source which depends on the interaction of plasma waves and transverse electromagnetic waves or in a magnetized plasma the ordinary and extraordinary modes of magnetoionic theory. (3) The propagation of radiation between the source and the observer which depends on the transmission of radiation through a scattering refracting absorbing magnetized plasma.

Progress on a model for the plasma wave source is reviewed and it is concluded that no existing models are adequate. The equations which would lead to an adequate model are written down, but not solved. These include, in addition to collisional damping, Landau damping both by the exciting stream and the background plasma, and spontaneous and induced processes for a three-dimensional distribution of plasma waves. Possible limitations to a quasilinear approach such as pile-up of plasma waves and nonlinear effects are considered. Processes which affect the gross structure of the source such as electron trajectories in coronal streamers and electron scattering by inhomogeneities are reviewed.

Progress on the radiation source is considered both in the absence and presence of a magnetic field. At high frequencies (e.g., 80 MHz) observations of radiation near the fundamental and second harmonic of the plasma frequency allow a unique determination of source size and the energy density in plasma waves within the uncertainties of geometry by source ray tracing. This determination is extremely critical because the fundamental must be amplified and thus production of the fundamental is effectively a much more highly nonlinear process than production of the second harmonic. At low frequencies (e.g., 500 kHz) the second harmonic is shown to be dominant because amplification of the fundamental becomes an inefficient process.

Calculations of scattering of radiation in a random medium are reviewed. It is concluded that these are adequate at high and low frequencies, but have not been carried out properly at intermediate frequencies where amplification of the fundamental may still be present. It is shown in particular that when scattering is taken into account at high frequencies all observations can be explained by isotropic emission near the second harmonic. At low frequencies the nature of the scatterers is determined by source occultations unlike the case at high frequencies where these are free parameters. This fact allows the possibility of determining true source sizes at low frequencies by subtracting out the contribution due to scattering. A mechanism for producing the possibly observed linear or highly elliptical polarization of type-III bursts, which must be imposed far from the source due to Faraday rotation, is reviewed.

Finally, the questions of what remains to be done and what we can hope to obtain upon completion of this work are briefly considered.

1. Introduction

1.1. Nature of the Phenomenon

One of the most characteristic features of solar activity is a type-III radio burst

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(Zheleznyakov, 1970; Kundu, 1965; Wild and Smerd, 1972; Fainberg and Stone, 1974) which consists of a radio brightening at one frequency which drifts rapidly from high to low frequencies as shown in Figure 1 and the figure of Fainberg and Stone (1974). The frequency range covers the remarkable extent of several hundred megahertz to a few tens of kilohertz. A harmonic structure which is often difficult to recognize is characteristically present at high frequencies as shown in Figure 1. The systematic frequency drift and the existence of a harmonic gave rise to the plasma hypothesis in which plasma waves are excited by a disturbance which moves rapidly outward through the corona (Wild et al., 1954). The most dramatic confirmation of this hypothesis has been made with the Imp-6 spacecraft which gives directional information via spin modulation (the figure of Fainberg and Stone, 1974). These and other observations constitute very convincing evidence for use of the plasma hypothesis.

The exciting disturbance was hypothesized to be streams of electrons (Wild et al.,