POLARIZATION OF FUNDAMENTAL TYPE III RADIO BURSTS

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Abstract. The fundamental of type III bursts is only partially polarized, yet all theory for emission near the plasma frequency predicts pure o-mode emission. I argue depolarization is inherent in the burst itself. The o-mode radiation is intensely scattered and mode-converted when it temporarily falls behind its own source and finds itself in the medium that is already disturbed by the electron beam. In particular, mode conversion is very efficient and yet causes only modest angular scattering at the height were \( \omega \approx \omega_p + 0.5\Omega \).

The predicted minimum polarization nearly equals the polarization of the harmonic, as observed. 'Spike polarization' is naturally explained by the earlier arrival of the scattered o-mode. Additional residual polarization depends on the refraction at the site of emission; larger beam velocities imply higher polarization, as observed, because a larger fraction of the radiation escapes without mode-conversion. The polarization at the frequencies where U-bursts reverse is of particular interest.

1. Introduction

The fundamental of type III solar radio bursts is normally polarized in the o-mode, commonly by 30\%, occasionally up to 60\%, but it is rarely if ever observed fully polarized (Benz and Zlobec, 1978; Dulk and Suzuki, 1980; Hanasz et al., 1980). Yet all theory for fundamental emission in the ambient corona predicts emission so close to the plasma frequency that only the o-mode can exist (Melrose, 1980; see discussion in Benz and Zlobec, 1983). The main goal of this paper is to seek a cause for the depolarization of the fundamental.

1.1. Observational Considerations

Several observations argue that the depolarization must be inherent in the burst. It is not caused by the ambient corona. First, type I bursts at similar frequencies escape the corona fully polarized. Second, polarization reversal at coronal QT regions is uncommon at high frequencies (Benz et al., 1979) and sufficiently ordered when it occurs (Suzuki and Sheridan, 1980) so as not to depolarize by the admixture of two polarizations. Third, the polarizations of fundamental and harmonic in pairs are well correlated, yet the harmonic polarization is thought to be inherent in the emission process; thus the fundamental polarization is also inherent in the source. Fourth, the practical absence of bursts with very high polarization implies the depolarizer is always present during a type III burst, whereas the scattering sources that cause the observed strong radar echoes are probably as variable as are the radar echoes themselves (Wentzel, 1982a). No radar echoes were observed during type I storms from heights where scattering waves might have been expected (Fitze and Benz, 1981).

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Dulk and Suzuki (1980) found the fundamental to be typically three times as polarized as the harmonic. I wish to emphasize another feature of their data. Their Figure 4 shows a striking boundary such that the fundamental is at least as polarized as the harmonic. Indeed, mode conversion by low-frequency waves naturally explains a minimum fundamental polarization approximately equal to that of the harmonic (Section 3.1). After mode conversion, the o-mode travels faster and reaches us first; this naturally results in 'spike polarization', that is, a polarization maximum before intensity maximum (Slottje, 1974; Santin, 1976; Benz and Zlobec, 1978), but results in no additional net time-integrated polarization. Any additional residual fundamental polarization, larger than that of the harmonic, must be assigned to incomplete mode conversion.

Fundamental polarization larger than that of the harmonic is to be associated with incomplete mode-conversion. In this connection, refraction in a density gradient not parallel to the magnetic field will be important, theoretically. The more refraction, the more thorough the depolarization, thus the lower the residual observable polarization. The polarizations of ascending and descending legs of U-bursts without polarization-reversal should be least polarized at the frequency where the drift reverses, since refraction generally is greatest there. I shall argue that faster bursts tend to be more polarized (Dulk and Suzuki, 1980; Benz and Zlobec, 1978; Hanasz et al., 1980) because faster bursts radiate into a wider range of directions and refraction is less effective in assuring complete mode-conversion.

The observed durations of type III bursts give important clues to the essential phenomena in the bursts. Aubier and Boischot (1971) found that burst durations fit well to a model in which collisions dissipate the radiating plasma waves. Their result is likely to refer to harmonic bursts. In contrast, type IIIb bursts show rather more abrupt time changes, and fundamentals are in many ways similar to type IIIb (Dulk and Suzuki, 1980). This suggests a fundamentally different source for fundamental and harmonic radiation. Closely related, Stewart and Magun (1980) note that the fundamental of type II herring bone is less diffuse than the harmonic.

The high directivity of the fundamental in space (Caroubalos et al., 1974; Dulk and Suzuki, 1980; Suzuki and Sheridan, 1982) is best explained by refraction if mode-conversion occurs rather near to the plasma level and/or by mode-conversion which involves scattering by only relatively small angles. Both explanations apply for mode-conversion and scattering at the lowest level where o- and x-modes both occur, near the level where $\omega - \omega_p = 0.5\Omega$, $\Omega < \omega_p$. (These are the radiation, plasma, and electron gyro-frequencies, respectively.)

The type III bursts in the frequency ranges 100–400 MHz and 20–100 MHz (sometimes referred to as the high and low frequencies) are observed with different instruments, but many of the observed distinctions between the two regimes represent true physical differences in the arriving radiation. For example, spike radiation is observed at the high frequencies, and fundamental and harmonic are indistinguishable at these frequencies, except that high polarization is taken to imply fundamental; relatively steady polarization is observed at the lower frequencies, where F and H components can be distinguished. In general, more temporal structure is observed at the higher frequencies, perhaps