Solar Phys (2007) 245: 327–343
DOI 10.1007/s11207-007-9036-0

On Solar Intermediate Drift Radio Bursts at Decimeter and Meter Wavelength

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Received: 20 March 2007 / Accepted: 22 August 2007 / Published online: 4 October 2007

Abstract Fiber – or intermediate drift – bursts are a continuum fine structure in some complex solar radio events. We present the analysis of such bursts in the X17 flare on 28 Oct. 2003. Based on the whistler wave model of fiber bursts we derive the 3D magnetic field structures that carry the radio sources in different stages of the event and obtain insight into the energy release evolution in the main flare phase, the related paths of nonthermal particle propagation in the corona, and the involved magnetic field structures. Additionally, we test the whistler wave model of fiber bursts for the meter and the decimeter wave range. Radio spectral data (Astrophysikalisches Institut Potsdam, Astronomical Observatory Ondřejov) show a continuum with fibers for ≈ 6 min during the main flare phase. Radio imaging data (Nançay Radio Heliograph) yield source centroid positions of the fibers at three frequencies in the spectrometer band. We compare the radio positions with the potential coronal magnetic field extrapolated from SOHO/MDI data. Given the detected source site configuration and evolution, and the change of the fiber burst frequency range with time, we can also extract those coronal flux tubes where the high-frequency fiber bursts are situated even without decimeter imaging data. To this aim we use a kinetic simulation of whistler wave growth in sample flux tubes modeled by selected potential field lines and a barometric density model. The whistler wave model of fiber bursts accurately explains the observations on 28 Oct. 2003. A laterally extended system of low coronal loops is found to guide the whistler waves. It connects several neighboring active regions including the flaring AR 10486. For varying source sites the fiber bursts are emitted at the fundamental mode of the plasma frequency over the whole range (1200 – 300 MHz). The present event can be understood without assuming two different generation mechanisms for meter and decimeter wave fiber bursts. It gives new insight into particle acceleration and propagation in the low flare and post-CME corona.

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Keywords Sun: magnetic fields · Sun: radio emission · Sun: flares · CMEs · Particle acceleration

1. Introduction

The radio burst emission of the Sun in the meter – decimeter waveband is known to be rather varied (see Melrose, 1985, for a general reference) and reflects the presence of nonthermal electrons in the lower corona. It often reveals spectral fine structures (FS) on dynamic spectra, that is, narrowband features and fast temporal changes. Studying such specific signatures can give information about physical processes leading to the observed radio emission, as well as about plasma and magnetic field parameters in the coronal emission sources. Because of the various FS the type IV continuum can only be explained as broadband plasma wave emission from flux tubes with a certain density and magnetic field profile. Low-energy (≈10 keV) nonthermal electrons are the source of solar radio radiation from the plasma emission mechanism (Melrose, 1985). This electron population is studied by using radio spectral data, which are provided by the Astrophysikalisches Institut Potsdam (AIP) Radio Spectrograph, covering the range 40 – 800 MHz with a time resolution of 0.1 s (Mann *et al.*, 1992). This is completed by information on decimeter and microwave spectra (0.8 – 4.5 GHz) from the Astronomical Observatory Ondřejov (AOO). Electrons from a few tens of keV up to many MeV produce hard X-ray (HXR) and γ-ray radiation via thick-target bremsstrahlung. Spectral (from 3 keV to 18 MeV) as well as imaging observations in this range are available from the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI; Lin *et al.*, 2002; courtesy the RHESSI Team).

Here, we use the sweep spectrograph data for the spectral identification of fiber bursts. The fiber burst source sites are obtained from the Nançay Radio Heliograph (NRH; Kerdraon and Delouis, 1997, and courtesy A. Kerdraon and K.-L. Klein), which provides radio heliograms at a cadence of 8 images/second at six frequencies between 450 and 150 MHz, with a beam size of ≈ 1 arcmin at 327 MHz. In this paper we use only the NRH data at 432, 410.5, and 327 MHz. In all figures the source centroids are shown assuming Gaussian source profiles. Radio imaging data reveal the radio source sites of fiber bursts in projection on the disk. These can be compared to solar images in other spectral ranges and to the projection of the extrapolated magnetic field line pattern on the disk.

Fiber bursts may allow one to measure the strength of the coronal magnetic field in the radio burst source volume (Kuijpers, 1975; Mann, Karlický, and Motschmann, 1987; Mann *et al.*, 1989; Aurass *et al.*, 2005). From its timing during flares, and from the frequency range of the occurrence of fibers (between 150 and 3000 MHz), we expect that fiber burst sources are situated either in the evolving system of flare loops or in surrounding, stable magnetic field structures filled by flare-energized particles. Fiber bursts are interpreted as the radio signature of whistler waves excited after their coalescence with Langmuir waves in loops with an unstable distribution of nonthermal electrons. Bernold and Treumann (1983) and Treumann, Güdel, and Benz (1990) invoked Alfvén solitons to explain fiber bursts. Benz and Mann (1998) summarized earlier work and compared the existing models. Kuznetsov (2006) discussed fiber burst excitation by flux rope oscillations in an inhomogeneous corona.

In the present paper we use the whistler wave model for consistently interpreting fiber burst observations in the meter and the decimeter wave range during the X17 flare in AR 10486 and the surrounding complex of active regions on 28 Oct. 2003. By knowing that