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Periodicities in Fine Structure of Type IV Radio Solar Bursts

P. Tsitsipis[*], A. Kontogeorgos[*], X. Moussas[†], P. Preka–Papadema[†], A. Hillaris[†,**], V. Petoussis[*], C. Caroubalos[†], C. E. Alissandrakis[‡], J.-L. Bougeret[§] and G. Dumas[§]

[*]*Technological Education Institute of Lamia, Lamia, Greece*
[†]*University of Athens, 15783 Athens, Greece*
[**]*Hellenic Naval Academy, Piraeus 18503, GREECE*
[‡]*University of Ioannina, 45110 Ioannina, Greece*
[§]*Observatoire de Paris, CNRS UA 264, 92195 Meudon Cedex, France*

Abstract. A study of periodicities appearing in the type–IV bursts fine structure (fibers and pulsations in particular) is presented. Our data set includes recordings by ARTEMIS IV with high time resolution; this facilitates the detection of lower than 1 sec periodicities. We introduce a method which employs directional filtering for the separation of intertwined fibers and pulsations for independent analysis of different events within complex radio bursts. For further analysis we use Short Time Fourier and Wavelet transforms which enable the study of the evolution of periodicities with time over specified periods of solar radio activity. Since, according to existing theoretical models, periodicities depend on basic parameters of active regions, this methodology provides the appropriate diagnostic tools.

Keywords: Solar activity; Corona; Radio; Radiation and spectra; Solar electromagnetic emission
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INTRODUCTION

The type–IV solar radio bursts originate from energetic electron populations confined within magnetic structures such as coronal loops etc. On the dynamic spectra they have the form of continua yet, they are, often, rich in *fine structure* (fibers or intermediate drift bursts, pulsations, etc.). The fibers and pulsations, frequently exhibit quasi–periodic behaviour which is thought to be the effect of the magnetic structure oscillations, and of the corresponding variations of the magnetic field on the emission mechanism.
A study of periodicities appearing in the type–IV bursts fine structure (fibers and pulsations in particular) appears promising in revealing the variations of the basic parameters of active regions during this type of activity.
A study of this type of periodic behavior and the appropriate methodology is presented in this report.

DATA ANALYSIS

For the analysis of periodicities in the type–IV fine structure Short Time Fourier Transform wavelet transform are applied on radiospectrograph recordings. These have been

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TABLE 1. Periodicities of Fibers and Pulsations Within Selected Type–IV radio events

Date	Time (UT)	Pulsation Freq. (Hz)	Pulsation Power (minutes)	Fiber Freq. (Hz)	Fiber Power (minutes)
14–07–2000	10:30–11:25	0.31; 0.45	1.4; 2.7; 4.7; 14.4	0.32; 0.45 0.80; 1.2	4.7; 10.4 14.7
11–07–2000	13:00–14:00	0.35; 0.38; 0.47; 0.65; 0.73; 1.22 2.5; 2.8; 3.3	2.8; 8.6		2.7; 3.4; 4.4; 6.4; 11.6; 15.5
17–04–2002	08:40–09:10		3.6; 5.7; 7.9	0.44	4.12; 8.3; 16.3
17–04–2002	09:00–10:00		13.5; 18		
17–01–2005	09:30–10:30		2.0; 4.1; 6.6; 13.8	0.4	14.2
15–01–2005	07:00–08:00		2.4; 3.3; 4.8; 6.4; 22		1.7; 4.3 6.7; 14.2

obtained from the Solar Radio-spectrograph ARTEMIS-IV[1] (cf. [1], [4]) with a frequency coverage 650–20 MHz and time resolution 1/10-1/100 sec.
This type of analysis presents a particular difficulty, since the spectra of interest are quite complex comprising different groups of fibers and pulsating structures within the same period.
The separation of intertwined structures for individual analysis is attained by means of an algorithm outlined in [7] and [8]; this algorithm has been used for the detection of different groups of fine structure based on their *frequency drift rate*, these have been separated, in turn, with directional filtering. The groups of fibers or pulsations thus isolated have been further analysed with Short Time Fourier and wavelet methods. The parameters of interest in this study were firstly, the characteristic frequencies of the recorded time–series and the characteristic periodicities of the power of the recorded signal. Examples of this analysis for a pulsating structure and for fibers are in figures 1 and 2.

RESULTS

For this work, a number of selected periods of type–IV activity recorded by ARTEMIS–IV were used; characteristic frequencies and periodicities were calculated and the results are summarized in the table. The period of the pulsations power varies in the range 1.4–22.0 minutes, while for the fibers was in the range 1.7–16.3 minutes. As regards the characteristic frequencies detected, they are in the range of 0.3–3.5 Hz for the pulsating structures and 0.3–0.8 Hz for fibers.
We note, at this point, that certain characteristic periodicities appear to be of particular interest. A periodicity of ≈ 3 minutes may be identified with the 3 min sunspot oscillation and another of ≈ 5 minutes with the global modes of solar oscillations (cf. [5],

[1] Appareil de Routine pour le Traitement et l' Enregistrement Magnetique de l' Information Spectral

[6]).

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REFERENCES

1. C. Caroubalos, D. Maroulis, N. Patavalis, J. L. Bougeret, G. Dumas, C. Perche, C. Alissandrakis, A. Hillaris, X. Moussas, P. Preka–Papadema, A. Kontogeorgos, P. Tsitsipis and G. Kanellakis, *Experimental Astronomy* **11**, 23–32, (2001).
2. C. Caroubalos, C. E. Alissandrakis, A. Hillaris, A. Nindos, P. Tsitsipis, X. Moussas, J. L. Bougeret, C. Bouratzis, G. Dumas, G. Kanellakis, A. Kontogeorgos, D. Maroulis, N. Patavalis, C. Perche, J. Polygiannakis and P. Preka–Papadema, *Solar Physics* **204**, 167–179, (2001).
3. C. Caroubalos, A. Hillaris, C. Bouratzis, C. E. Alissandrakis, P. Preka-Papadema, J. Polygiannakis, P. Tsitsipis, A. Kontogeorgos, X. Moussas, J. L. Bougeret, G. Dumas, C. Perche, *A&A* **413** 1125-1133 (2004).
4. C., Caroubalos, C. E., Alissandrakis, A., Hillaris, P., Preka–Papadema, J., Polygiannakis, X., Moussas, P., Tsitsipis, A., Kontogeorgos, V., Petoussis, C., Bouratzis, J. L., Bougeret, G., Dumas and A., Nindos, *These Proceedings* (2006).
5. I. De Moortel, A. W. Hood, and J. Ireland, *A&A* **381**, 311-323 (2002).
6. I. De Moortel, A. W. Hood, J. Ireland and R.W. Walsh, *Solar Physics* **209**, 89-108 (2002).
7. P. Tsitsipis, A. Kontogeorgos, A. Hillaris, X. Moussas, C. Caroubalos, P. Preka–Papadema, *Pattern Recognition* (submitted)(2005).
8. P. Tsitsipis, A. Kontogeorgos, X. Moussas, P. Preka–Papadema, A. Hillaris, V. Petoussis, C. Caroubalos, C. E. Alissandrakis, J.-L. Bougeret and G. Dumas , *These Proceedings* (2006).

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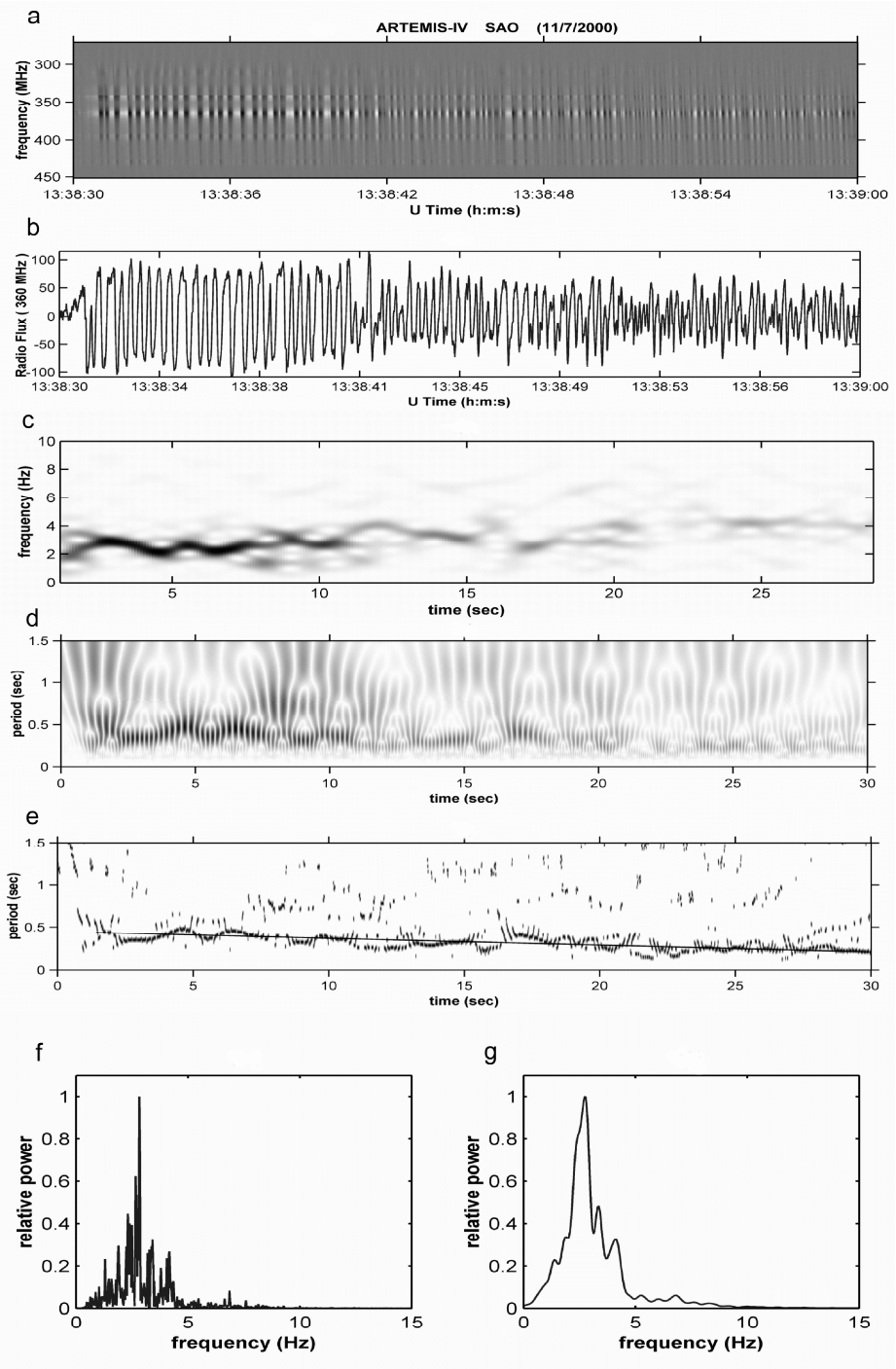

FIGURE 1. Periodicity Detection on a Pulsating Structure (2000 July 07 13:38:30–13:39:00); it is part of a type–IV event from the 1998–2000 ARTEMIS–IV Catalogue [3]. Top: The ARTEMIS–IV Dynamic Spectrum; the type–IV continuum background has been suppressed by means of a high pass filter. Second panel from top: Time profile of a single ARTEMIS–IV channel recording (360 MHz). Third panel: Short Fourier Transform of the time profile in the second panel. Fourth panel: Wavelet Transform of the same time profile and (Fifth panel) skeleton of the corresponding scalogram. Bottom: Comparison of the total Fourier Spectrum (left) and average wavelet spectrum (right).

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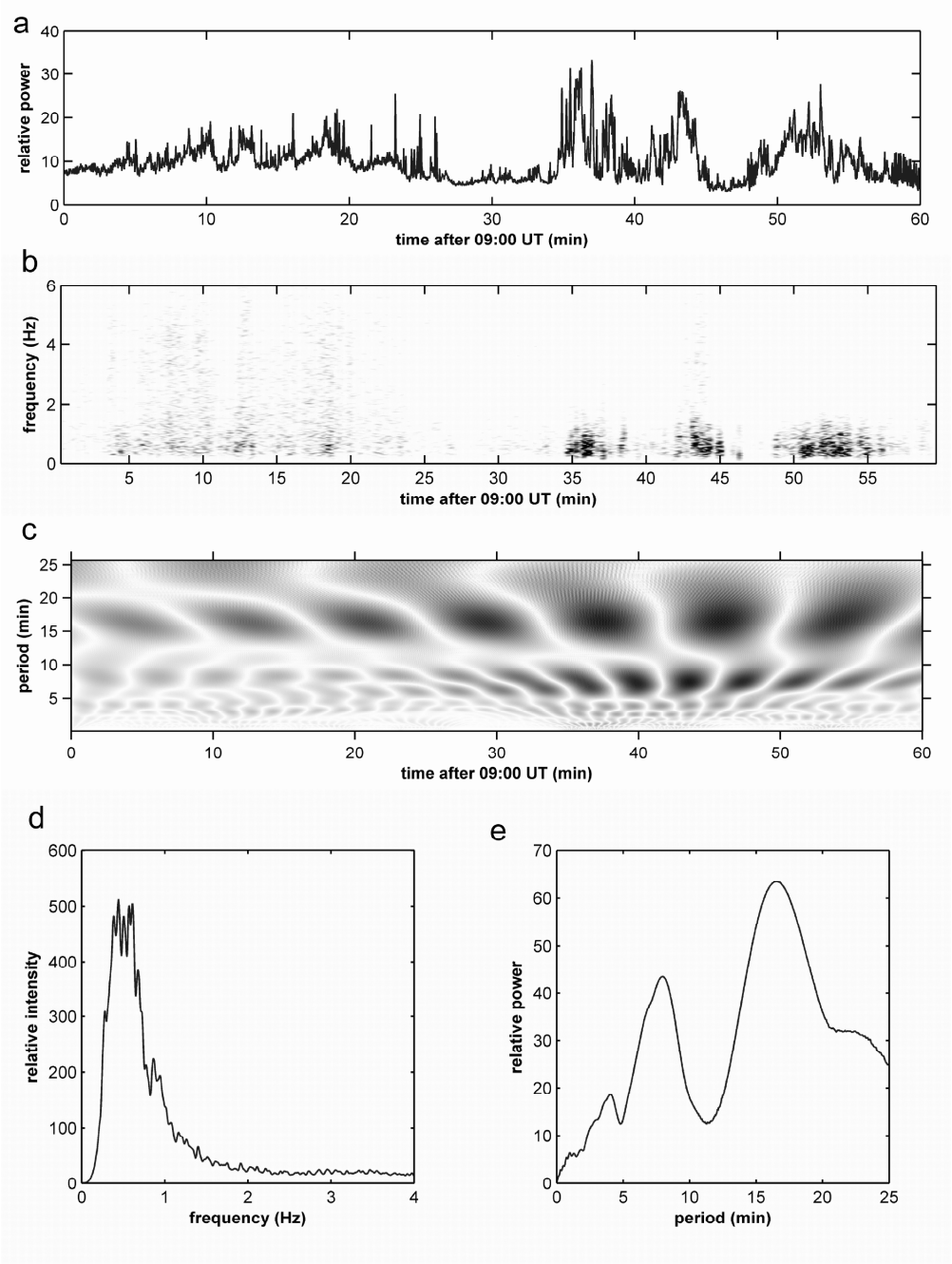

FIGURE 2. Periodicity Detection on fiber groups (2002 April 17 09:00:00–10:00:00 UT) recorded by ARTEMIS–IV; (a) Time evolution of the power of fibers. A single channel is used (channel 75, 376 MHz). (b) Time - frequency analysis with STFT of the signal of channel 75 (376 MHz). (c) Wavelet Transform of the same time profile. (d) Averaging of spectra of the second panel. Quasi-periodic character of fibers is obvious with a mean frequency of about 0.5Hz. (e) Averaging spectra of the third panel. Three dominant periods 4.1 min, 8.0min and 16.3min are detected.