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Study of solar radio spikes properties observed at frequencies 0.01-8.4 GHz

Gilberto A. Casillas-Pérez[1], **Solai Jeyakumar**[2], **Armando Carrillo-Vargas**[3], **Román Pérez-Enríquez**[4]

[1] *Instituto de Geofísica, Universidad Nacional Autónoma de México, gacp@geofisica.unam.mx*
[2] *Departamento de Astronomía, Universidad de Guanajuato, sjk@astro.ugto.mx*
[3] *Instituto de Geofísica, Unidad Michoacán, Universidad Nacional Autónoma de México, armando@geofisica.unam.mx*
[4] *Centro de Geociencias, Juriquilla, UNAM, roman@geociencias.unam.mx*

ABSTRACT

Fast transients in the form of spiky radio bursts have been observed in solar flares events, emitting at different ranges in frequency. These dynamical phenomena show up as high brightness temperature increments with short durations of the order of milliseconds. In this work we present results of the analysis of some properties of radio spike events observed at frequencies between 0.01 an 8.4 GHz, as reported in different studies. We analyze the relation of the duration, bandwidth, emitted flux, polarization and drift rate of the radio spikes with its observational frequency. Also, we analyze its correlation with other energetic solar events.

I. INTRODUCTION

Explosive events occurring frequently in the Sun produce radiation over a wide range of the electromagnetic spectrum. In the radio range these events involve energetic emissions with durations from milliseconds to several days (Hankins et al., 2003; Bhat, 2011) that far exceed the quiet solar radio emission (Benz, 2009). Among the different types of solar events, of particular interest are those related to radio spikes (RSs), which are identified as very short and intense fine structures that show up on top of the radio continuum of solar flares. The study of RSs has been of interest since they might reveal important information as regards physical processes involved during the production of energetic solar events such as solar flares, radio bursts or coronal mass ejections, where an important amount of energy is released. In the present work we compile observational studies relating to solar RSs previously reported in the literature. Using this compilation, we study the properties of RSs and their association with other solar events (Casillas-Pérez et al., 2019).

II. RESULTS OF THE ANALYSIS

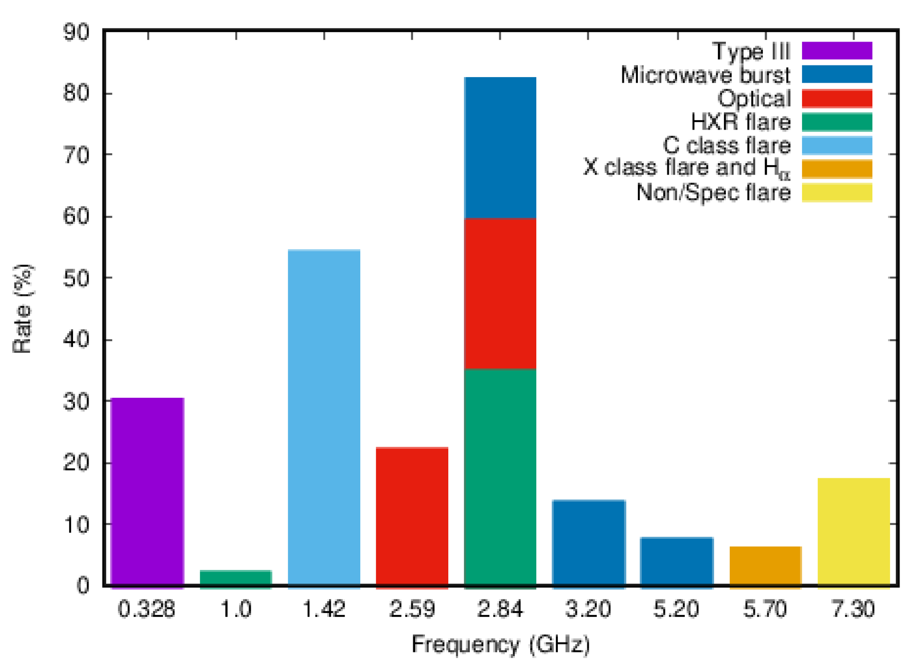

Figure 1. Rate of association of RSs with other solar events (%): Type III radio bursts (purple), HXR-flares (green), C-flares (light blue), X-flares and H_α (orange), non-specified flares (yellow), microwave bursts (dark blue) and optical flares (red).

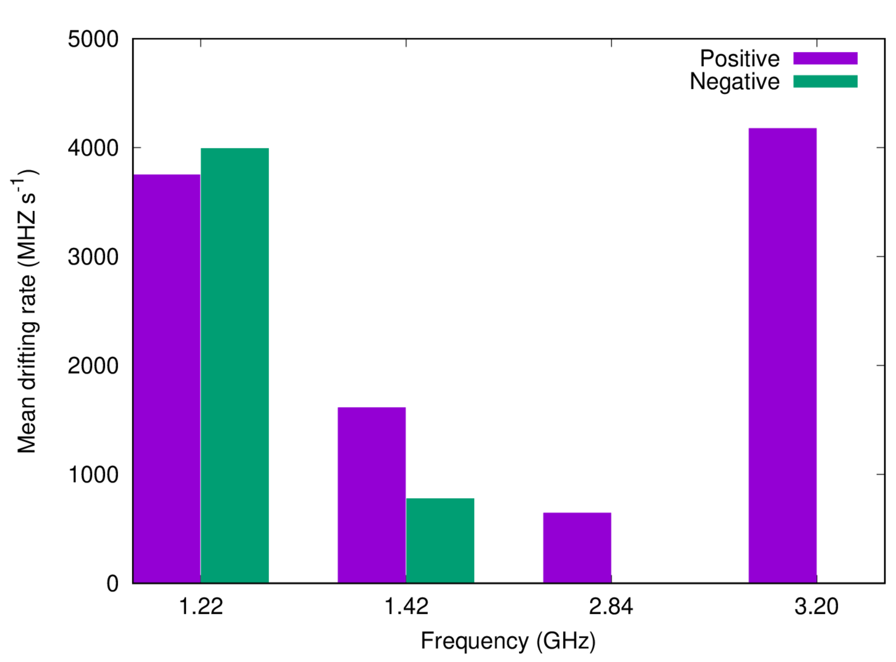

Figure 2. Mean positive (purple) and negative (green) frequency drift rate of RSs plotted against the frequency of observations.

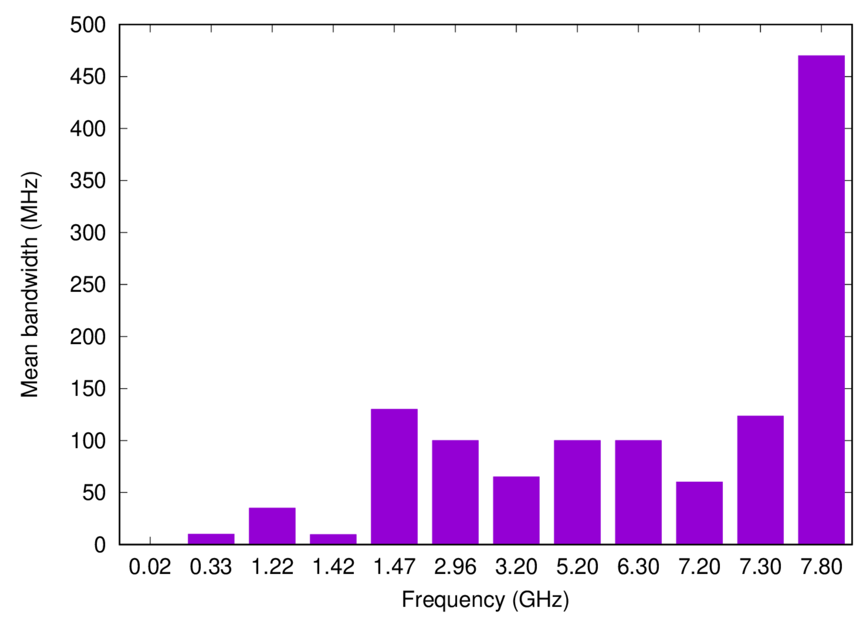

Figure 3. Mean bandwidth of RSs plotted against the frequency of observation. The minimum and maximum mean bandwidth correspond to 0.06 and 470 MHz

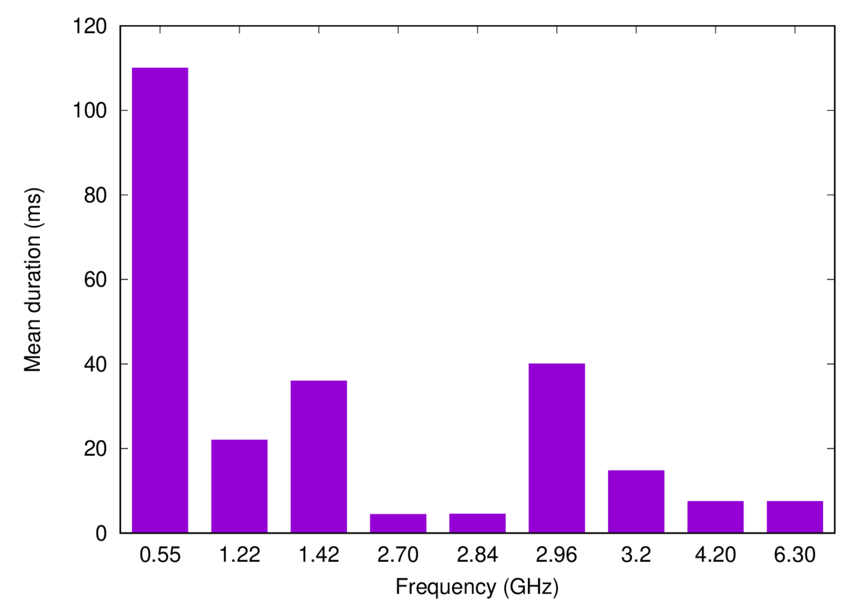

Figure 4. Mean duration of RSs plotted against the frequency of observation. The maximum duration of the RSs corresponds to 110 ms at a frequency of 550 MHz.

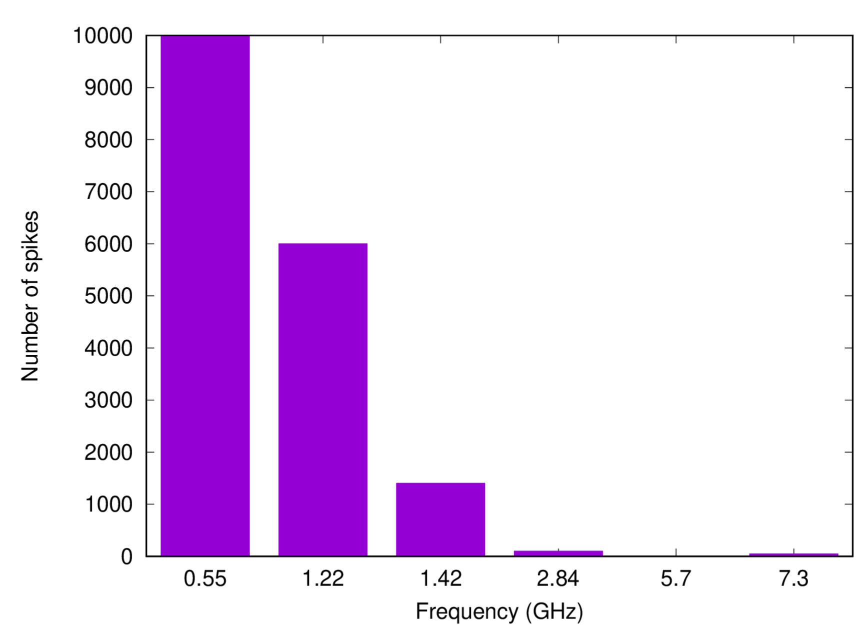

Figure 5. Maximum number of RSs per cluster plotted against the frequency of observation. The highest number of spikes per cluster value corresponds to 10^4 spikes observed at the averaged frequency of 550 MHz.

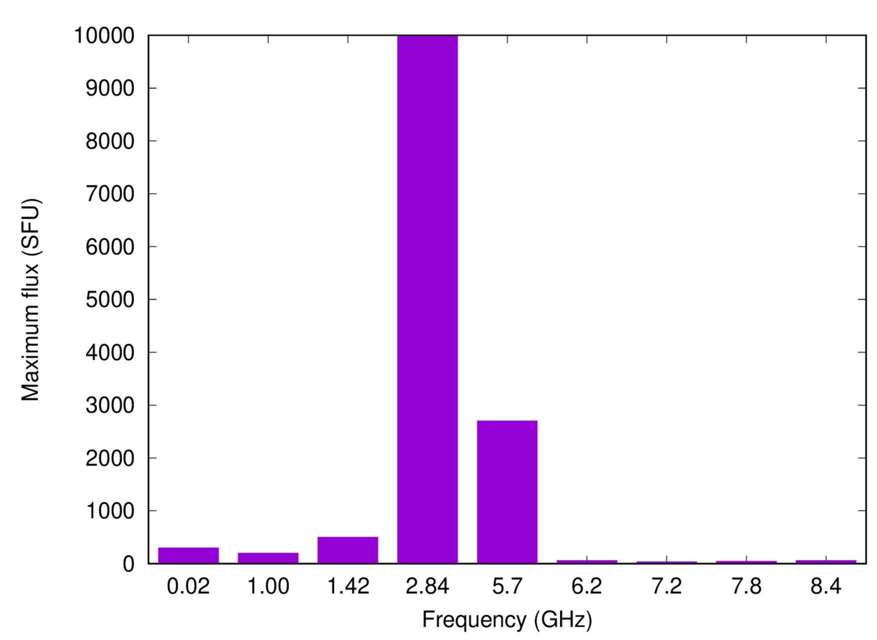

Figure 6. Maximum flux of RSs plotted against the frequency of observation. The maximum intensity of the RSs reported corresponds to 10^4 SFU at a frequency of 2.84 GHz.

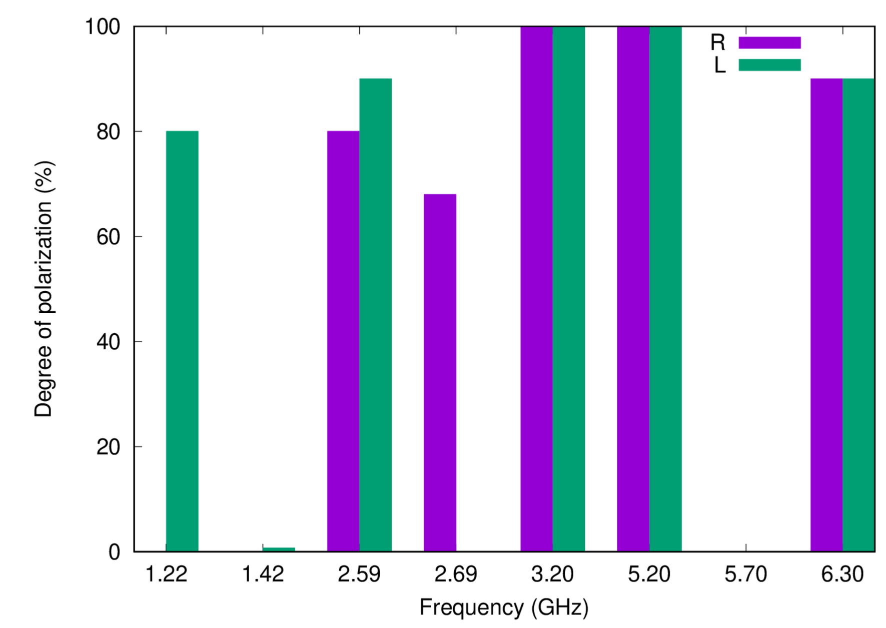

Figure 7. Polarization of RSs plotted against the frequency of observation. Except for the frequencies 1.42 and 5.70 GHz where an almost-null or null polarization was reported, the RSs exhibited an important degree of polarization.

III. DISCUSSION AND CONCLUSIONS

1) Depending on the distribution of the injected particles, and on the ambient density and magnetic field, different levels of turbulence may be produced. It is possible that a preferential electron density range may be present in combination with the ambient density and magnetic field, which allow for an efficient amplification of the waves in order to ensure the production of RS emission.

2) The short duration of RSs at larger frequencies may be explained considering that plasma densities have larger values at those frequencies. A large density may allow for wave–wave and particle–wave interactions that may result in the damping of the growth rate of the waves involved in the RS emission. A similar reasoning may be applied to interpret the smaller number of spikes obtained for high frequencies in comparison to those obtained for lower frequencies.

3) It can be noted that the coexistence of RSs together with microwave bursts, optical and HXR-flares is favored for the frequency centered at 2.84 GHz, and that at 1.4 GHz about half the events are associated with C-flares.

4)The drift rates are much smaller for metric spikes than for those observed at higher frequencies.

5) The polarization of the emission has been detected in both left and right circular modes, although no preference to any mode is found to occur.

6) Smaller values of negative in comparison with positive drift rates might indicate a higher density gradient in the direction toward the solar surface, or a faster interaction of electron beams with the environment near the solar surface, in order to produce instabilities that might induce radio emission.

7) The formation of RSs require the formation of instabilities and the subsequent amplification of waves in a coherent way. For this mechanism to occur, appropriate interactions between particles and waves should take place in agreement with the density and magnetic field of the environment. Both, ECM and plasma emission are acceptable mechanisms to support the generation of RSs and their intervention depends on the inhomogeneities in the medium and the onset of instabilities.

VI. REFERENCES

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