UPITER´S SYNCHROTRON RADIATION AT 50 MHZ MEASURED BY THE LARGE 50MHZ JICAMARCA ARRAY

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1. Introduction

Jupiter radiates electromagnetic radiation in a broad spectrum. We are concerned here with the center part, usually referred as the decimetric radiation, a relatively flat part of the spectrum going from about 39.5 MHz merging into the thermal radiation at about 4GHz (See Fig. 1). The source of this radiation is synchrotron radiation emitted by energetic electrons, trapped in Jupiter´s Van Allen radiation belt, gyrating around its magnetic field. The flux density of this radiation has been measured at many frequencies, the lowest being at around 80 MHZ. Here we present measurements made at 50 MHZ—closer to the Magnetic Cut-off at 39.5 MHz (highest electron gyro frequency)— with the large collective area of the Jicamarca observatory. Its antenna is about an order of magnitude larger ($8.4x10^4$ m^2 , See Fig. 2) than those used to measure at the neighboring frequency of 80MHZ.

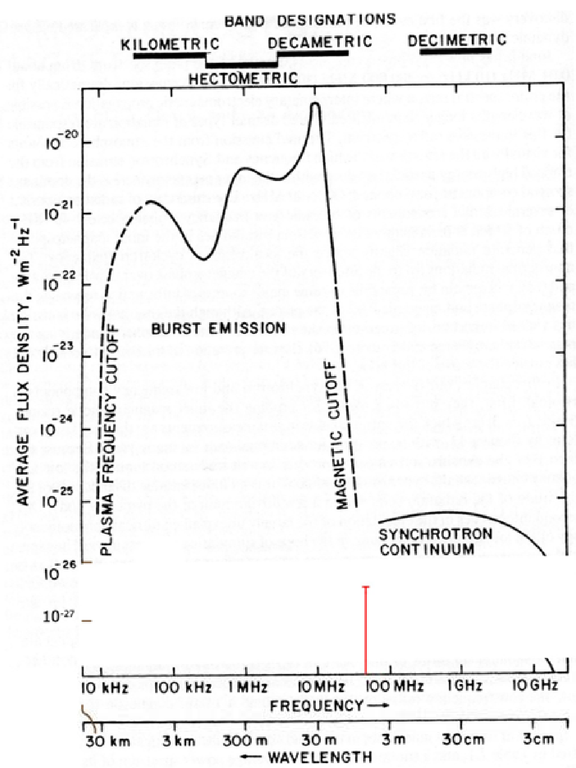

Figure 1. Frquency spectrum of Jupiter´s radiation

2. Experimental set up

The experimental set up is shown in Fig. 3**)**. Two receiver channels were set up connected to the two available linear polarizations of the antenna, one in the NW and the other in the SW direction, each cannel had a calibrating switch that allowed the receiver to switch sequentially to the antenna, a 50 Ohm load and a 10mA calibrated noise source for 60, 10 and 10 seconds respectively. The front end and the noise source were in an ice cooled environment (0°C) for stability. Re-ceiver bandwidth was set to 1 MHz and complex samples were taken at 10^6 per second.

3.Observations

We took data in several occasions during the last 20 years when the declination of Jupiter was within the observable range (12±3° S) of the Jicamarca antenna. We did not publish before because we were unhappy with the results: There were noisy power fluctuations much larger than those expected from statistical considerations: 0.1 mA of equivalent current versus an expected 0.001 mA. We suspected and excluded many possible causes for these discrepancy, among them receiver gain stability, external interference and scintillations to finally conclude that they were due to undesirable changes in the gain and performance of the antenna. A change in the gain of the antenna with characteristic time scales of a few minutes of only 1% is enough to explain a deterioration of the order of 100 in the level of detectability. Changes of this order are not hard to accept considering that the antenna has close to 20,000 connections and was build 50 years ago. Never the less, with this limitation, we are still in the position to make and important contribution to the radiation properties of Jupiter in the 50MHz range.

Here we present the best records taken in the last ~20 years. Figure 3a) shows several records of Jupiter transits around mid June of 2009. For each day, there are two records, blue and red, one for each linear polarization. Any non correlated differences between the two are attributable to changes in the gain of the antenna, and, since they have significant deviations in the same time scale as the transit of Jupiter or a radio star, they define the limit of detectability of any object. The multiple records of the same sky allows us to estimate the r.m.s of the deviations, for any one record, to be about 0.1 mA.

Figure 3b) shows two records corresponding to the average of the two polarizations of a few control days taken when Jupiter was no longer in the beam, and Figure 3c) the difference between the transit records and the control day. Had we the sensitivity to detect Jupiter radiation, it would have shown in this figure as a bell shape bump above the random

Figure 2. Panoramic view of the Jicamarca Radio Observatory showing the 300mx300m antenna array

fluctuations with a 4 minute width as depicted with a dotted line . It is clear from Figure 3c) than the actual radiation level of Jupiter could not be larger than 0.05mA, at the most.

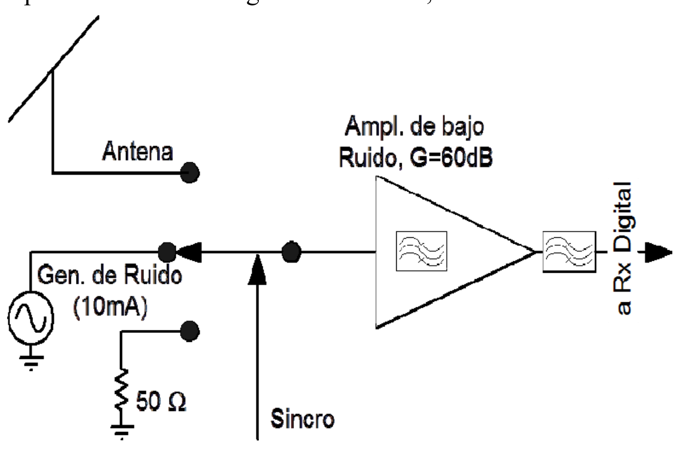

Figure 3. One of the two calibrating swotching scheme

Figure 4) shows a similar set of plots taken on a older occasion when Jupiter had a declination observable by the Jicamarca antenna (-12.13°). Figure 4a) shows passes taken on July 16 (solid) and August 4 (dashed), 1994. Since the passes were taken sufficiently separated in time, we can use them as control passes for each other. This passes were not calibrated using the switching sequence as described. The 50 Ohm and 10 mA source were switched manually, and only at the beginning and end of the transit. We have recalibrate them comparing them with a recent control experiment that did use it. In Figure 4b) we see their difference. This graph should show only the contributions of Jupiter. The dotted line shows an ideal situation, with Jupiter emitting the expected flux of 0.65 mA. (see discussion). Again, it shows that Jupiter´s contribution is smaller than the 0.05 mA. system fluctuations.

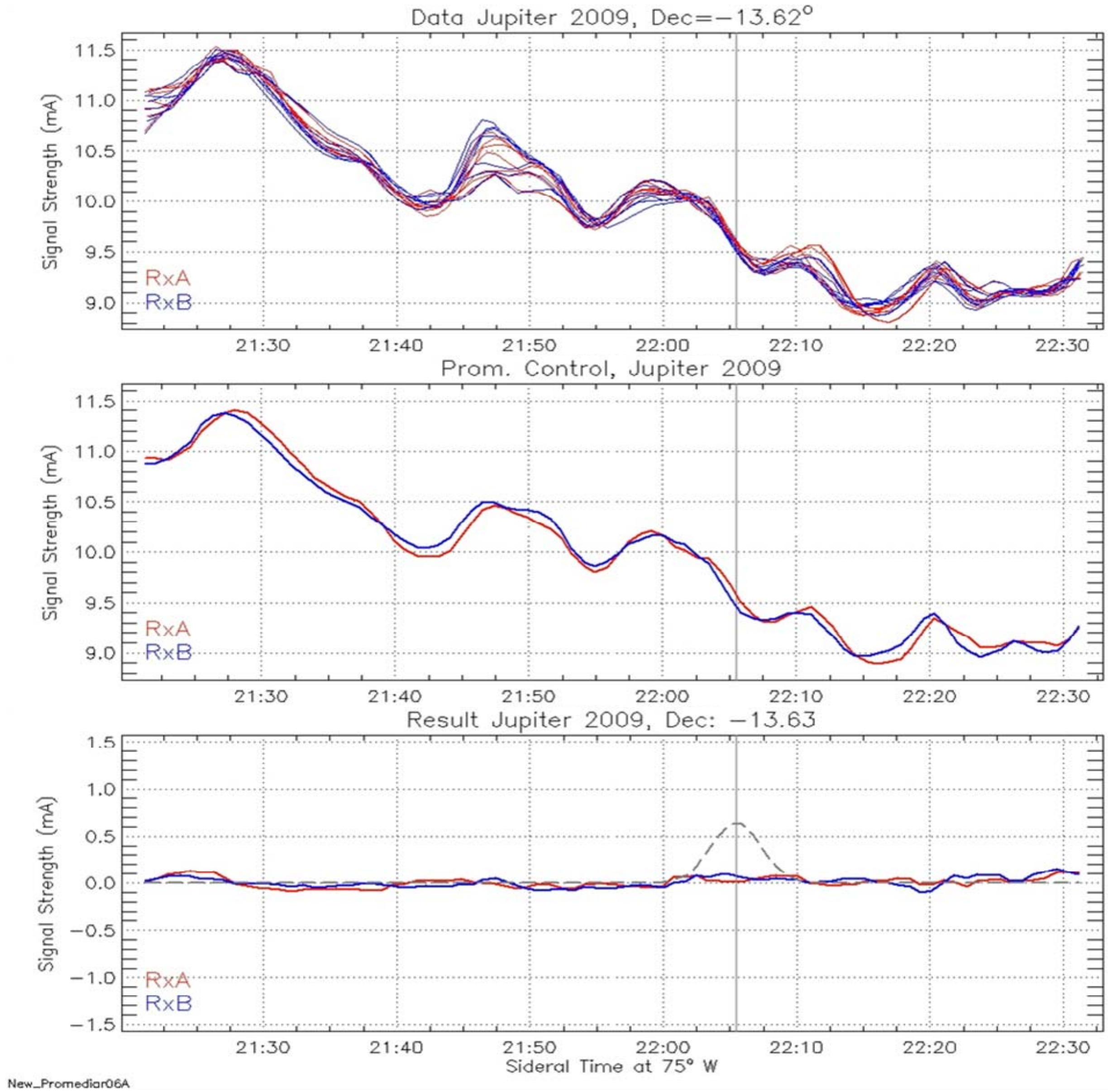

Figure 4. a) Composite of observations made on December 2009. b) control day. c) difference between observations and control. The dotted line is the expected signature of Jupiter

4. Discussion.

The previously reported levels for Jupiter synchrotron radiation flux (normalized at 4.04 AU) are $6x10^{-26}$ [2] and $4.5x10^{-26}$ [3] f.u. at 80 and 81.5 Mhz respectively (f.u.= $Wm^{-2}(c/s)^{-1}$). If we take 5 f.u. as a good average estimate for 50 MHz, we would expect -- considering an antenna aperture of 8.4x104 m2 and a efficiency of 0.63 [4]--an equivalent system temperature increase of 188K. To this temperature, it corresponds and equivalent excess noise generator current of 0.65 mA, i.e. an order of magnitude larger than the upper limit of 0.05 mA that we have observed. Expressing the same in f.u.´s,, we can claim that the maximum flux from Jupiter at 50 MHZ is only 0.38×10^{-26} f.u., at least an order of magnitude smaller than one extrapolated from previous 80 MHz measurements**.** We have plotted our results, in the context of previous observations, as a red line in Figure 1**.**

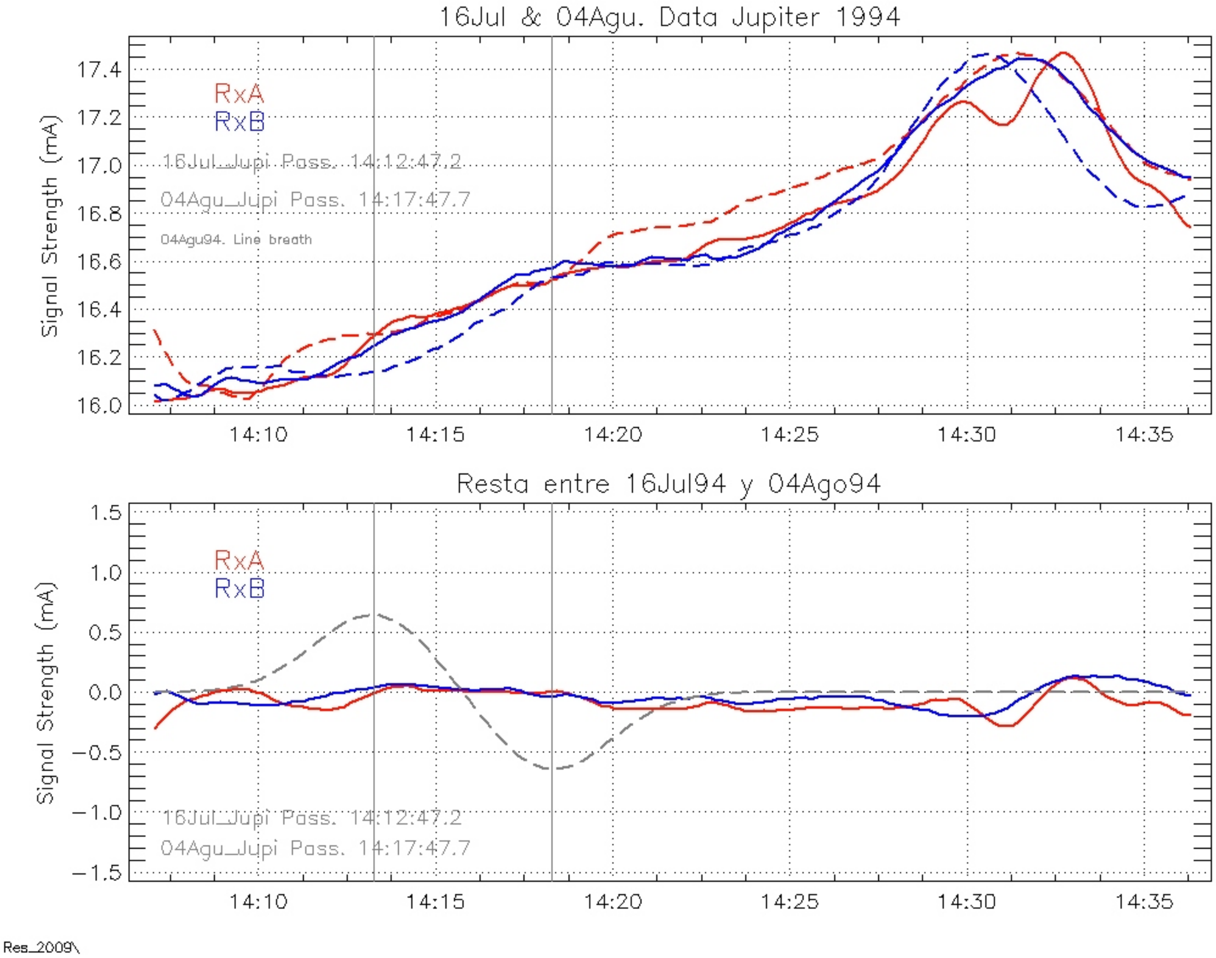

Figure 5. a) Records of expected Jupiter transits onJuly and August of 1994, two polarizations. b) Difference between the two transits. The dotted line shows the expected signature of Jupiter

5. Acknowledgement.

We would like to thank and acknowledge all the help received from the Jicamarca personnel in conducting the observations.

6. References

1.-Physics of the Magnetospher, A.J. Dessler (Editor), Cambridege University Press, 1983.

2.-Slee O. B., and G. A. Dulk, 80 MHZ measurement of Jupiter´s Synchrotron emission. *Austr. J. Phys*. 25:103-105, 1972.

3.- Gower. F. R., The flux density of Jupiter at 81.5 Mc/s. *Observatory* 88:264-267, 1968.

4.– Ochs, G.R., The large 50 Mc/s Dipole Array at Jicamarca Radar Observatory, *National Bureau of Standards, Report No 8772*, March 5, 1965.

SkyMap II software was used to compute the R.A. and Declination of Jupiter on the days of observation.