MILLISECOND POLARIZED PULSES IN DECAMETRE-WAVE RADIATION FROM JUPITER AND SUN

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Abstract. A new approach is suggested to the problem of the theory of Jovian decametric radiation and physical conditions at the point of origin. This depends upon a comparison of the characteristics of fast pulse decametre-wave radio emission from both Jupiter and the Sun and invokes the deductive procedure which Sagan (1971) has called 'Propositional Calculus'.

Fast polarized pulses in radiation from Jupiter and the Sun have been studied at fixed frequencies in the range 18 to 26 MHz with time resolutions from one to five msec; a number of similarities between the pulses from both sources have been noted. A comparison of some of the pulse characteristics is being made in order to decide whether or not they are sufficiently alike to be regarded as having a common mechanism of origin at both Jupiter and the Sun. From this 'decision' it is proposed to establish boundary conditions for theoretical study. Fast pulses in the Jupiter radiation are generally supposed to be a source phenomenon although their actual mechanism is not understood. The reasons for this are to some extent inferred rather than proven and so, to check the possible (if unlikely) role of the interplanetary medium, observations are also being made using the large 26 MHz array at the University of Florida to search for possible fast pulses in the radiation from the more distant source Taurus A.

Several different types of burst structure have been recognized in the Jupiter radiation and various classifications have been proposed based upon typical burst durations. In this paper we confine attention to structures and pulses having durations of the order of 100 ms or less and we refer to these as 'millisecond pulses'. These have been studied in some detail by Olsson and Smith (1966), by Torgersen (1969), and by Baart *et al.* (1966). Typical examples are shown in Figures 1 and 2. The pulses can occur singly, in groups, or in prolonged sequences; they have narrow instantaneous bandwidths and they may display a characteristic polarization. Rapid polarization changes

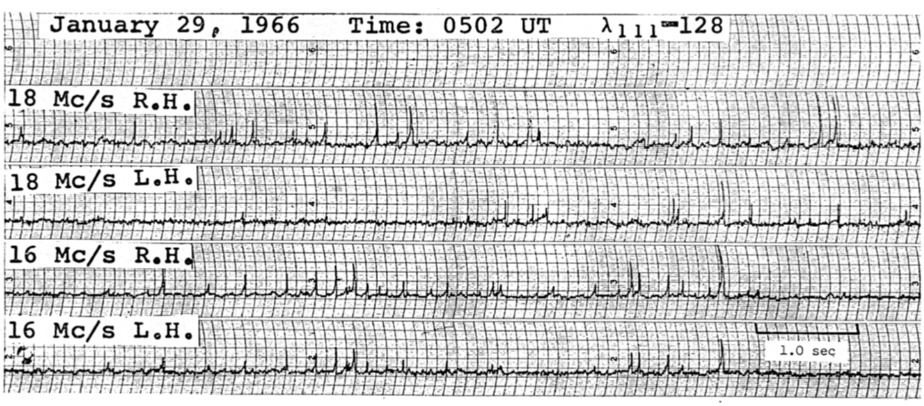

Fig. 1. Left- and right-hand components at 16 and 18 MHz showing isolated millisecond pulses from Jupiter.

Woszczyk and Iwaniszewska (eds.), Exploration of the Planetary System, 407–413.

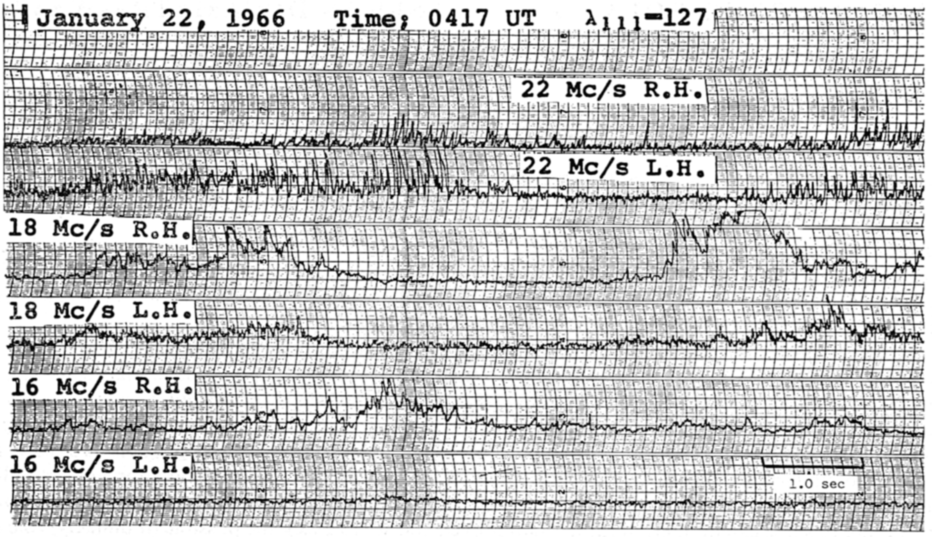

Fig. 2. High-speed record of groups of millisecond pulses from Jupiter at 22 MHz. In this case the pulses are not present simultaneously on the other channels.

Fig. 3. Unresolved solar millisecond pulses at 18 and 26 MHz. Some of the pulses recorded on the 26 MHz in-phase channel do not appear simultaneously on the other three channels.

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and reversals in sense sometimes occur. The pulses appear to be predominantly associated with the B and C 'sources' on Jupiter.

During the recent minimum in the Jupiter activity inverse sunspot cycle we attempted solar observations using the Jupiter receiving equipment. The radio site at the University of the West Indies, Jamaica (18° N, 77° W) is well shielded by mountains and it is often possible to observe under quite good conditions by day, even at 18 MHz. Solar millisecond pulses were first observed in the summer of 1970 and were reported by Barrow and Saunders (1972). Similar and related observations have been reported by various other workers, notably by Mosier and Fainberg (1972).

The receiving equipment consists of an 18 MHz crossed-Yagi polarimeter and two square corner-reflectors. These latter may be used either for 22 and 26 MHz total-power or as a simple interferometer providing in-phase and out-of-phase channels from a hybrid ring at 26 MHz. It is also possible to receive total-power frequencies separated by 100 to 500 KHz from divided antenna inputs. Magnetic tape and high-speed pen-recording are available for four channels of information. In addition, a swept-frequency receiver, built and operated by Mr A. Achong, covers the band 18–28 MHz with a time resolution of 50 ms.

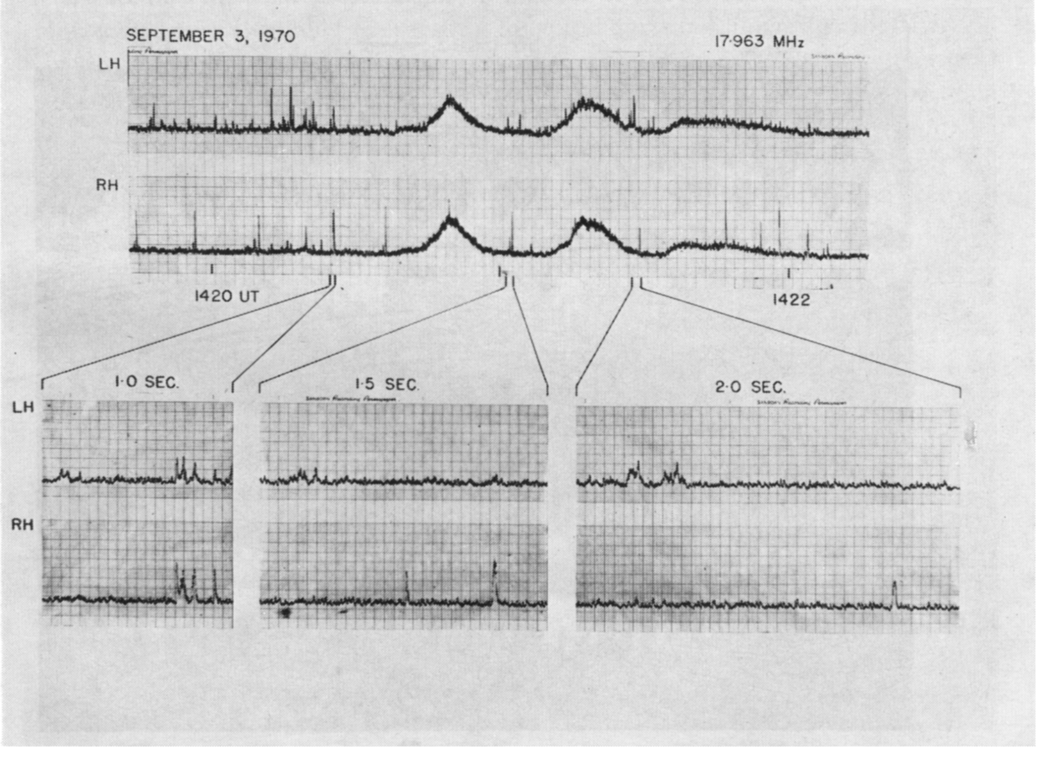

Fig. 4. Slowed playback sections taken during a type III event. Note the fast changes in polarization sense. Pulse durations at half-height range from about 5 to 30 ms with bandwidths less than 150 KHz.

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The problem of receiver bandwidth for the fixed frequencies has been discussed in some detail by Barrow and Saunders (1972). It is necessary, at decametric frequencies, to tune the receivers to operate in gaps between stations and so the bandwidth must be sufficiently narrow to achieve this while still being broad enough to give reasonable time resolution. 2.4 KHz is found to be an acceptable compromise as compared to about 5 KHz often used for Jupiter observations at night.

A general record of each observation is made with a slow-speed chart recorder and at the same time the observation is recorded on magnetic tape following the procedure used by Torgersen (1969) for Jupiter observations. Sections of interest are identified from the general record and then played back either to the high-speed pen recorder or to a CRO where they can be recorded photographically. By using a slower playback speed than recording speed the effective time resolution of the high-speed recorder can be improved. A small post-detection time constant is added to give resolutions of one and five milliseconds for the CRO and the high-speed pen recorder respectively.

Interference discrimination has already been described by Barrow and Saunders (1972). Briefly, the following considerations are involved:

(a) Response of the interferometer system.

(b) Narrow bandwidth and very short duration of the millisecond pulses.

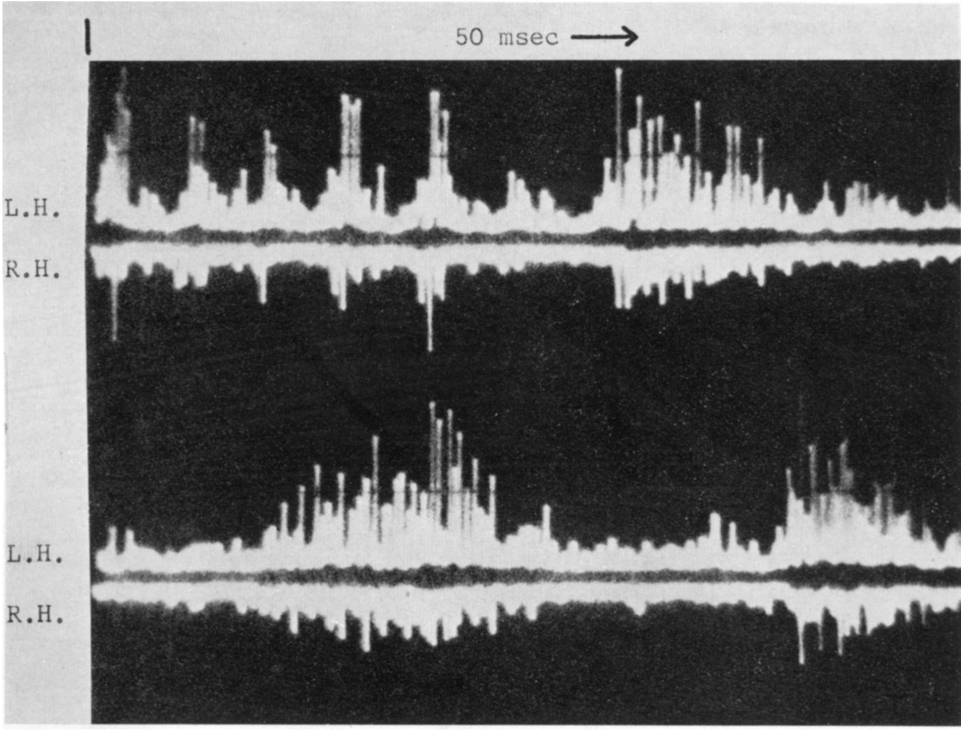

Fig. 5. CRO playback record showing two 50 ms sweeps taken at 18 MHz. The upper section of each trace is the left-hand polarized channel; the lower section of each trace (displacement downward) is right-hand polarized.

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(c) Characteristic polarization of the pulses.

(d) Confirmation of solar radio activity, at the time of the pulses, from *Solar-Geophysical Data* (Prompt Reports), ESSA, U.S. Department of Commerce.

(b) and (c) above distinguish the solar pulses from static pulses which are broad-banded, of longer duration and unpolarized. (d) is necessary as many pulses seem to occur at the onset and the decay of type III bursts as well as during noise storms. Only pulses occurring in association with confirmed solar phenomena are considered.

Some typical examples of solar millisecond pulses are shown in Figures 3, 4, and 5. In Figure 3 the pulses are unresolved but a number can be seen clearly on the 26 MHz in-phase channel that are not shown simultaneously on the other three channels. Figure 4 is a slowed playback record and shows good examples of polarization reversal. Figure 5, in the upper trace, shows a sequence of very fast left-hand polarized pulses each of duration about one millisecond. This sequence is similar to several reported for Jupiter by Torgersen (1969).

Note that in the records shown, we are only recording left- and right-hand components. We can, therefore, assess only the sense of polarization and not the degree of polarization apart from the special case of pure circular. This point has been discussed in detail by Barrow and Morrow (1968).

We see that the solar pulses display a number of similar characteristics to Jovian millisecond pulses, notably with respect to typical durations, intensities, polarization characteristics, bandwidths and short sequences. The solar pulses have not yet been observed in the prolonged, almost continuous sequences that sometimes occur in Jupiter radiation, however.

In Figure 6, half-height pulse durations are compared for some 1600 pulses and the distributions are seen to be similar for both Jupiter and the Sun. The majority of the pulses have durations between 10 and 20 ms. For comparison, Carr and Gulkis (1969) quote 16.0 ± 2.2 ms as a typical average duration for Jovian millisecond pulses.

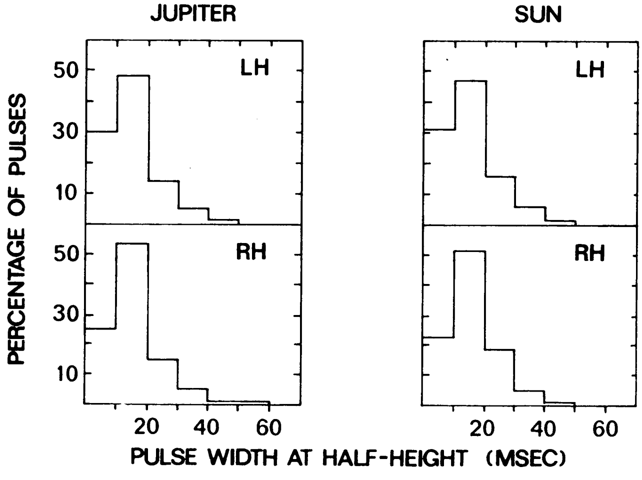

Fig. 6. Normalized distribution of half-height pulse durations for Jupiter and the Sun.

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Rise-and-fall rates and pulse-separation within groups are also being compared but in this respect it is often difficult to find pulses which can be measured unambiguously because of grouping, possible overlapping, and structured peaks. Also a pulse having very fast rise-and-fall rates may split in the manner of an unresolved square pulse [see, for example, Goodyear (1971)]. Thus one must be suspicious of what may appear to be a 'fast double-pulse'.

Millisecond pulses from Jupiter are generally accepted as being a source phenomenon rather than a superimposed effect of the interplanetary medium. The reasons for this are that the pulses do not appear to show drifts in time when observed from separated sites (Slee and Higgins, 1967) and that they are not seen in scintillation studies of radio stars (Warwick, 1967). These latter observations, however, are conducted at higher frequencies and on a longer time scale than Jovian millisecond pulse studies so they can hardly be regarded as conclusive proof. A check can be made (although probably with negative result) by using the same recording-playback technique on large array observations of a more distant source. Such observations are being attempted at the present time by Dr T. D. Carr who is kindly using the large 26 MHz array at the University of Florida to monitor Taurus A. Two sets of observations have been obtained at the time of writing both giving a negative result.

Eventually it is hoped to provide a reasonably objective answer to the question 'Are the millisecond pulses from Jupiter and the Sun sufficiently similar to be regarded as having a common mechanism of origin?' If we can make a decision regarding this question, we can apply the deductive process of propositional calculus to compare all the known characteristics of Jupiter and the Sun that are relative to radio emission and either eliminate or retain properties which might be common to both objects. By this means we may be able to obtain a few more definite starting points than are presently available for the would be theoretician. Conditions of local electron density and magnetic field are two obvious examples. Present estimates of these quantities in theoretical work cover ranges of some two orders of magnitude.

In conclusion four general thoughts are offered for the future:

(a) At the present time the millisecond pulses from Jupiter and the Sun appear to be more similar than dissimilar.

(b) The propositional calculus approach could (as pointed out by Dr S. Gulkis in discussion) obviously be directed towards obtaining solar information rather than Jovian information although at present it appears that solar radio emission is generally better understood than the Jovian emission.

(c) The propositional calculus approach could also be directed at a comparison of Jupiter and Saturn.

(d) Perhaps the time has arrived when we have sufficient grounds for a general study of solar-Jovian relationships.

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DISCUSSION

Gulkis: There is a good chance that we will understand the Jupiter emission process prior to the time we understand the solar emission mechanism. Hence a common mechanism should allow us to better understand the environmental conditions on the Sun.

Moore: What is your opinion about the correlation between the position of Io and the Jovian radio emission?

Barrow: The correlation is now well established and is, in fact, sometimes used as a means of
Torgersen, H.: 1969, *Physica Norvegica* **3**, 195.
predicting major periods of Jupiter activity.