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SATURN RADIO EMISSION NEAR 1 MHz

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SATURN RADIO EMISSION NEAR 1 MHz

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ABSTRACT

Emission from the direction of the planet Saturn has been observed by the IMP-6 spacecraft at 15 frequencies between 375 and 2200 kHz during the period April 1971 to October 1972. The Saturnian radio bursts were identified in the IMP-6 data through an analysis of the phase of the observed modulated signal detected from the spinning dipole antenna. Initial data reduction has isolated approximately 12 storms whose occurrence corresponded to times in which the spacecraft had an unobstructed view in the direction of Saturn. These events persisted over periods between one and ten minutes. Over the span of 500 days of data another 10-20 Saturnian events may exist, but positive identification is confused by the presence of terrestrial noise as well as a geometric ambiguity with Jupiter. A power spectral analysis of the storm occurrence times indicates a weak periodicity at $10^h\ 30^m \pm 5^m$ at some of the observing frequencies. The spectral character of the radiation has been found analogous to that of Jupiter. The Saturnian emission most similar to the Jovian

decametric source appears to be strongest at 1100 kHz with a bandwidth of approximately 1000 kHz. The spectrum hints also of a secondary spectral peak at 400 kHz similar to that recently observed for the Earth and Jupiter.

Subject headings: Saturn - radio radiation, planetary

In two recent papers (Brown, 1974a, 1974b; hereafter papers I and II) the detection of radio emission from the planet Jupiter near 1 MHz has been reported. This emission was identified from data obtained with the radio astronomy experiment aboard the Interplanetary Monitoring Platform-6 (IMP-6) spacecraft. The IMP-6 is spin-stabilized about an axis perpendicular to the ecliptic plane with a 100-m dipole antenna situated in the spin plane. The direction of a radio source can be determined then from the phase of the modulated signal resulting from the passage of the maximum gain of the antenna pattern across the source twice per spin period. Since an analysis of these directions was successful in the detection of Jupiter radiation (paper I), the technique was applied to other planets in the solar system. Among them, Saturn was considered to be a logical candidate for detection due to its similarities with Jupiter.

Since the radiation received by the IMP-6 shows the effects of spin modulation at all times, the phase can be used to determine the direction of maximum emission for all the IMP-6 data. This determination was done for orbits 10 through 136 covering the period April 1971 to October 1972 by a crosscorrelation of the dipole antenna pattern over the observed data. The possible Saturnian storms were identified by sorting the directions for each frequency to find all the data which gave directions within $\pm 4^{\circ}$ (maximum probable variation due to low level sources) of the ecliptic longitude of the planet, and then accepting only that part of the data which had at least four semicontiguous frequencies showing the direction of radiation to be toward Saturn. The initial data reduction isolated a number of events which fitted the above criteria.

These events fell into three classes. The first class contained events with simultaneous directions at the lowest frequencies only. These events corresponded to times at which parts of the Earth's magnetosphere lay between the spacecraft and Saturn. This emission comes from the 'mid-frequency' (MF) source of Earth noise also identified in the IMP-6 data (Brown, 1973). During the 500 day span of data the relative motions of Saturn and Jupiter produced a geometrical ambiguity in directions for approximately half of the data (due to the 180° ambiguity in the dipole radiation pattern). Most of this second class of events detected during this period had the spectral behavior typical of Jovian events (paper II). Since the spectral behavior of the Saturnian bursts was unknown, this period of time had to be eliminated from the analysis. It is estimated that approximately 10-20 Saturnian events may have been detected during this time, but identification is confused by the presence of emission from Jupiter and the Earth. The remaining class of events occurred during a period of time in which the spacecraft had an unobstructed view in the direction of Saturn, and no ambiguity in direction existed between Saturn and the known sources of emission such as the Sun, Earth, and Jupiter. The initial data reduction has isolated at least 12 storms of this class which appear to radiate from the direction of Saturn. These events were observed to last over periods of approximately one to ten minutes.

Figure 1 illustrates the direction finding results for a possible Saturnian storm on December 16, 1971 for a frequency of 1030 kHz. Under the assumption that the modulation is caused by excess radiation in one direction, the phase of the signal (and thus the direction) relative to the solar direction as determined by spacecraft optical sensors is plotted. Prior to the storm of 16 December 1971 the phase is first directed toward the area of maximum Galactic emission (Brown, 1973). Then, as the Saturnian emission begins to dominate in intensity, the phase locks on to the direction of the planet. Toward the end of the Saturnian burst, the phase is pulled in the direction of the Earth as its emission becomes the dominant radiation observed. One of the difficulties of this method of detection is that two sources may combine in such a manner as to produce an erroneous direction. The observed direction is an intensity weighted mean of the sources. Fortunately the most intense source need be only slightly more intense (~ 50%) than the other sources to dominate the phase of the observed modulated signal. In general, the dozen storms identified with Saturn were observed at times when the only competing source was the low level and only slightly modulated emission from the galactic background.

From the depth of the modulation pattern (modulation index) an attempt can be made to reconstruct the events as they would be observed by a non-spinning antenna (paper I). For the Saturnian storm of figure 1, the modulation index was determined and the storm reconstructed from the observed antenna temperature. Figure 2 shows the result of this reconstruction for a number of IMP-6 frequencies. This particular storm consisted of two individual events. The early event (2^h 18^m U.T.) was observed over the frequency range 375 to 1270 kHz. The behavior below 375 kHz could not be determined due to reaching the detection limit of the receiving system; while the behavior above 1270 kHz was confused by other low intensity sources. The late event (2^h 25^m U.T.) was observed over the frequency range 600 to 2200 MHz. In this case the spectral behavior could not be determined below 600 kHz due to confusion with the Earth MF emission, and above 2200 kHz the intensity of the Saturnian emission was below the receiver detection limit.

The spectral characteristics of the Saturnian emission are typified by the behavior of the December 16 events. The spectra for these events appear in figure 3. The uncertainty in the data results from the errors in calibrating the IMP-6 radio astronomy experiment and from separating the Saturn emission from the background radiation. The total error ranges from $\pm$ 20% near 1 MHz to $\pm$ 42% near 0.3 MHz (approximately 2x the total error for the galactic spectrum given in Brown 1973). The emission from Saturn has been observed at 15 frequencies over the range 375 to 2200 kHz. The frequency range limit appears to be determined by the rapid decease in intensity of the emission to levels below the detection limit of the receiving system. The Saturnian emission which probably corresponds to the

Jovian decametric (or 'normal') component (paper II) is exemplified by the late event of December 16 (2^h 25^m U.T.). The maximum emission occurs at 1100 kHz with a bandwidth of 1000 kHz. Although the range of the observed flux density is very limited due to the detection sensitivity, the peak frequency and bandwidth appear to remain the same regardless of the intensity or length of a Saturnian storm. These features are also characteristic of the Jovian decametric radiation.

The early event of December 16 (2^h 18^m) hints also of a secondary spectral peak between 400 and 500 kHz. This secondary peak could correspond to the 'mid-frequency' (MF) source which exists in the Jovian emission spectrum (paper II) and which is the predominate source of Earth noise. Although the number of observed events is small, the peak frequency and bandwidth of the secondary emission appear to vary with intensity as do the Jovian and Earth MF components. The stronger emission has the lower peak frequency and the narrower bandwidth. The Saturnian MF component has not been observed without the presence of the normal component in contrast to the behavior found for the Jovian MF source. The normal spectrum has been observed in other storms to extend to 375 kHz with the same slope as the December 16 storm shows above 600 kHz. Most of the 12 promising Saturn storms show the normal spectra. Overall, the Saturnian emission has not been observed below 375 kHz nor above 2200 kHz.

A power spectral analysis technique developed to determine the rotational period of the Jovian decametric radiation (Kaiser and Alexander 1972) has been applied to the Saturn data. In the analysis all the data which might be connected with Saturn including the cases with some ambiguity were used due to the small number of positive detections of Saturnian storms available. The results were not over-credulous but suggest that a weak periodicity exists at $10^h\ 30^m \pm 5^m$ for some of the observing frequencies. The peak in the power spectrum is approximately three standard deviations above the noise limit of the surrounding portion of the spectrum. Although not convincing evidence it is comforting that this periodicity falls within the $10^h\ 14^m$ to $10^h\ 38^m$ rotational period most often quoted for optical features of Saturn. Figure 4 shows the power spectral analysis at the observing frequency of 1100 kHz over this range of periods. The periodicities (at two standard deviations) flanking the main peak are the inter-modulation between the rotation period and its first harmonic. This results from variations caused by the small number of observed bursts coupled with the finite length of the data sample crosscorrelated to obtain the direction of radiation.

In summary, tentative Saturnian emission has been observed by the IMP-6 spacecraft at 15 frequencies between 375 and 2200 kHz during the period April 1971 to October 1972. Initial data reduction has isolated 12 storms whose existence cannot be explained except in terms of radiation originating from the direction of Saturn. Another 10-20 storms are probably Saturnian emission but confusion with other sources, namely the Earth and Jupiter, is possible. The spectral behavior of these storms is identical to that of the initial group of 12 storms leading to a greater probability of their identification with Saturn. The spectral behavior of Saturn seems to be similar in shape to that of Jupiter. A Jovian-decametric-like Saturnian source peaks at 1100 kHz with spectral indices of -3 on the high and +2.5 on the low frequency side and a bandpass of 1000 kHz. The peak flux density found for the Saturnian emission spectrum (1 MHz) is nearly equal to that found for Jupiter (8 MHz, paper II) when the distance differential between the planets is considered. The difference in the frequency of the emission peak is probably related to the higher magnetic field strength of Jupiter which from these results is estimated to be a factor of 8 if linear scaling is appropriate as would be the case for cyclotron emission. The bandwidth difference would suggest a smaller emission region for Saturn. The occurrence probability of Saturnian storms is approximately 5% of the Jovian occurrence probability at these low spacecraft frequencies. There is a hint of a secondary peak at 400 kHz similar to the MF-type sources recently observed for the Earth and Jupiter. A power spectral analysis hints at a weak periodicity of $10^h\ 30^m \pm 5^m$ which could be the rotational period of the planet for sources emitting at low radio frequencies.

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REFERENCES

Brown, L.W., 1973 Ap.J., 180, 359.

__________., 1974a, Ap.J., 192, 547.

__________., 1974b, Ap.J. Letters, 194, L159.

Kaiser, M.L., and Alexander, J.K., 1972 Astrophys. Letters, 12, 215.

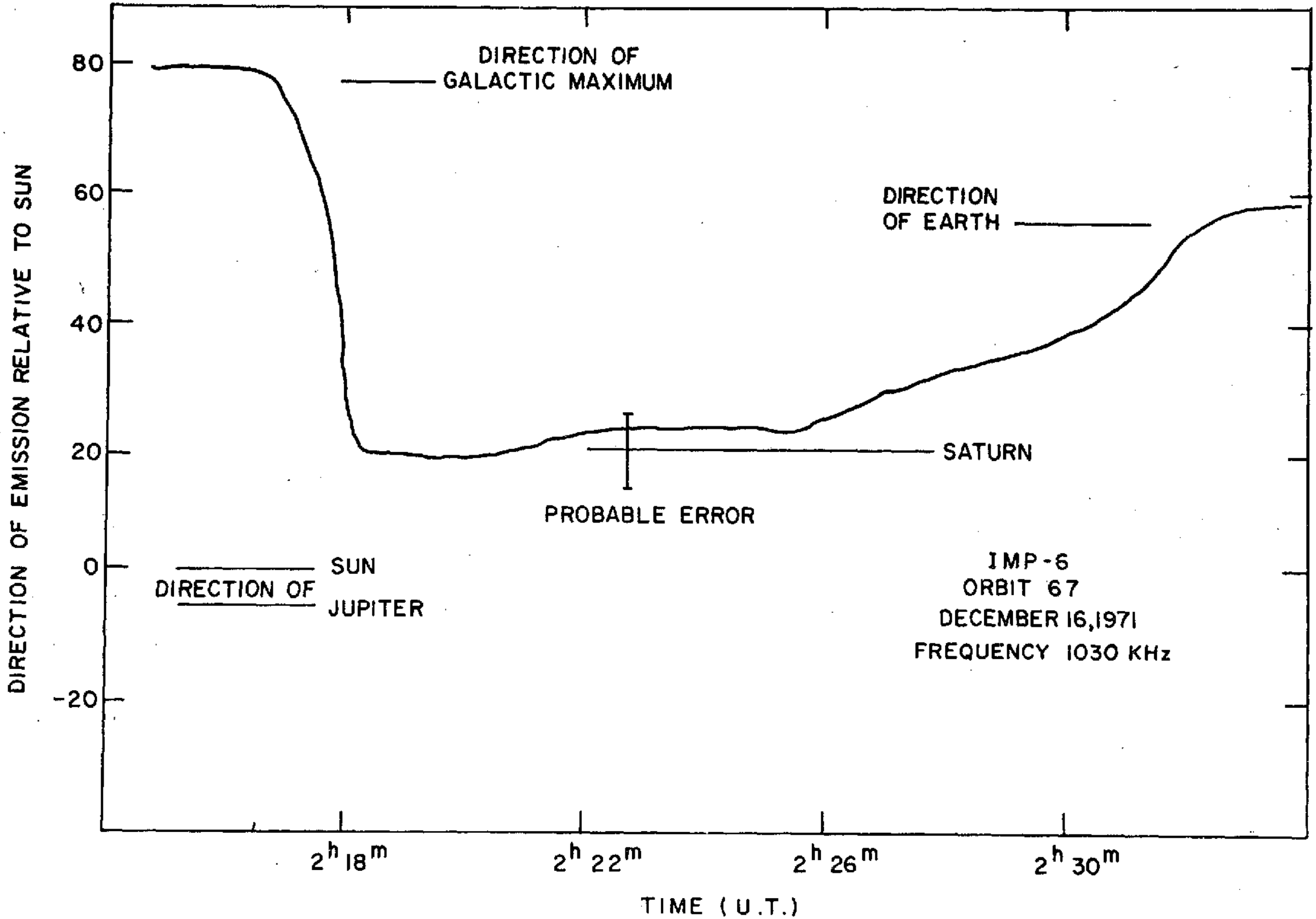
FIGURE CAPTIONS

FIGURE 1 - Direction of emission in degrees relative to solar direction determined from the phase of the modulated signal at 1030 kHz for the storm of December 16, 1971.

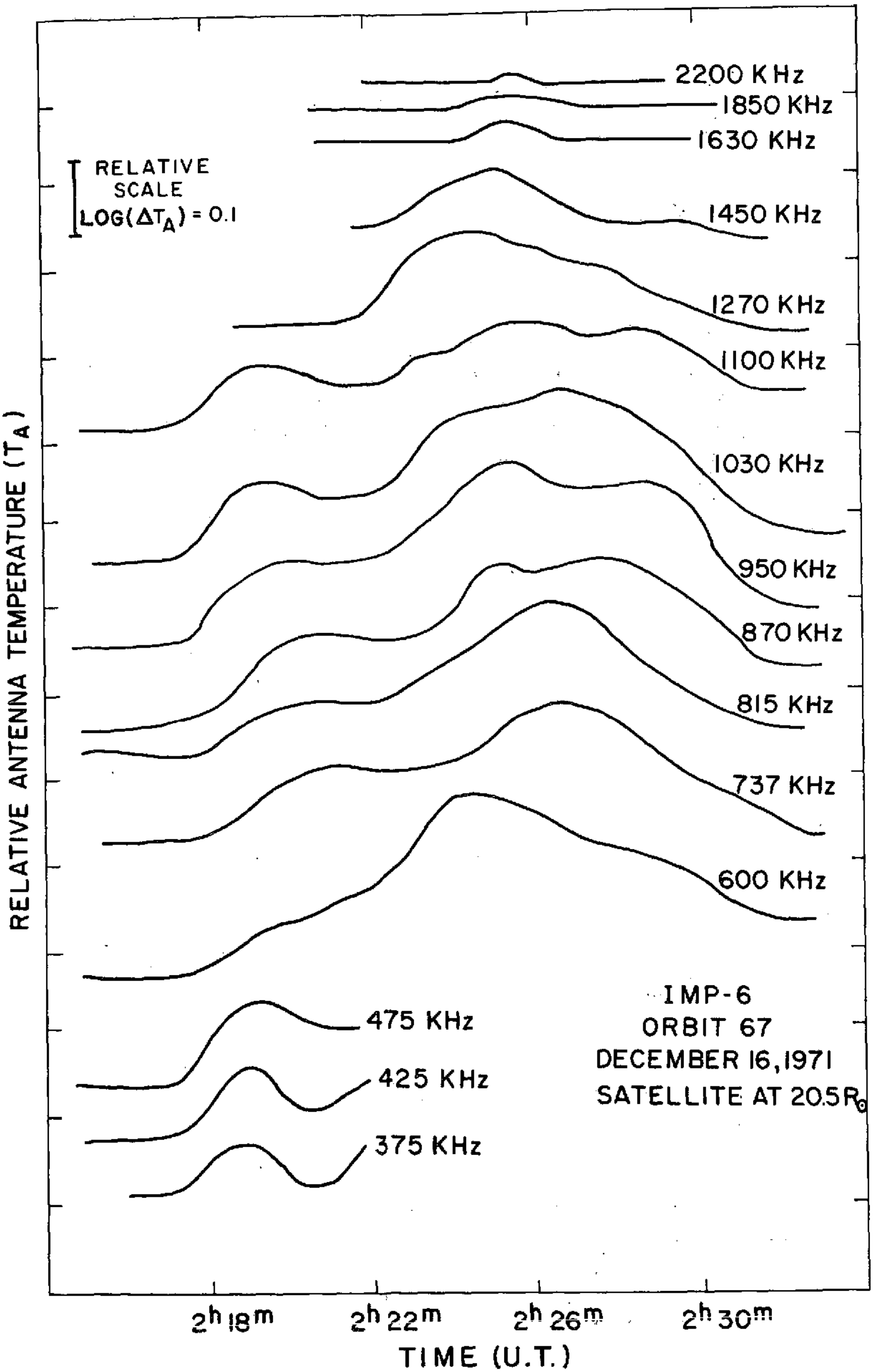
FIGURE 2 - Antenna temperature observed at a number of frequencies showing Saturnian emission with modulation effects removed. (Baseline shifted for display, relative scale refers to a change in antenna temperature of 1 db).

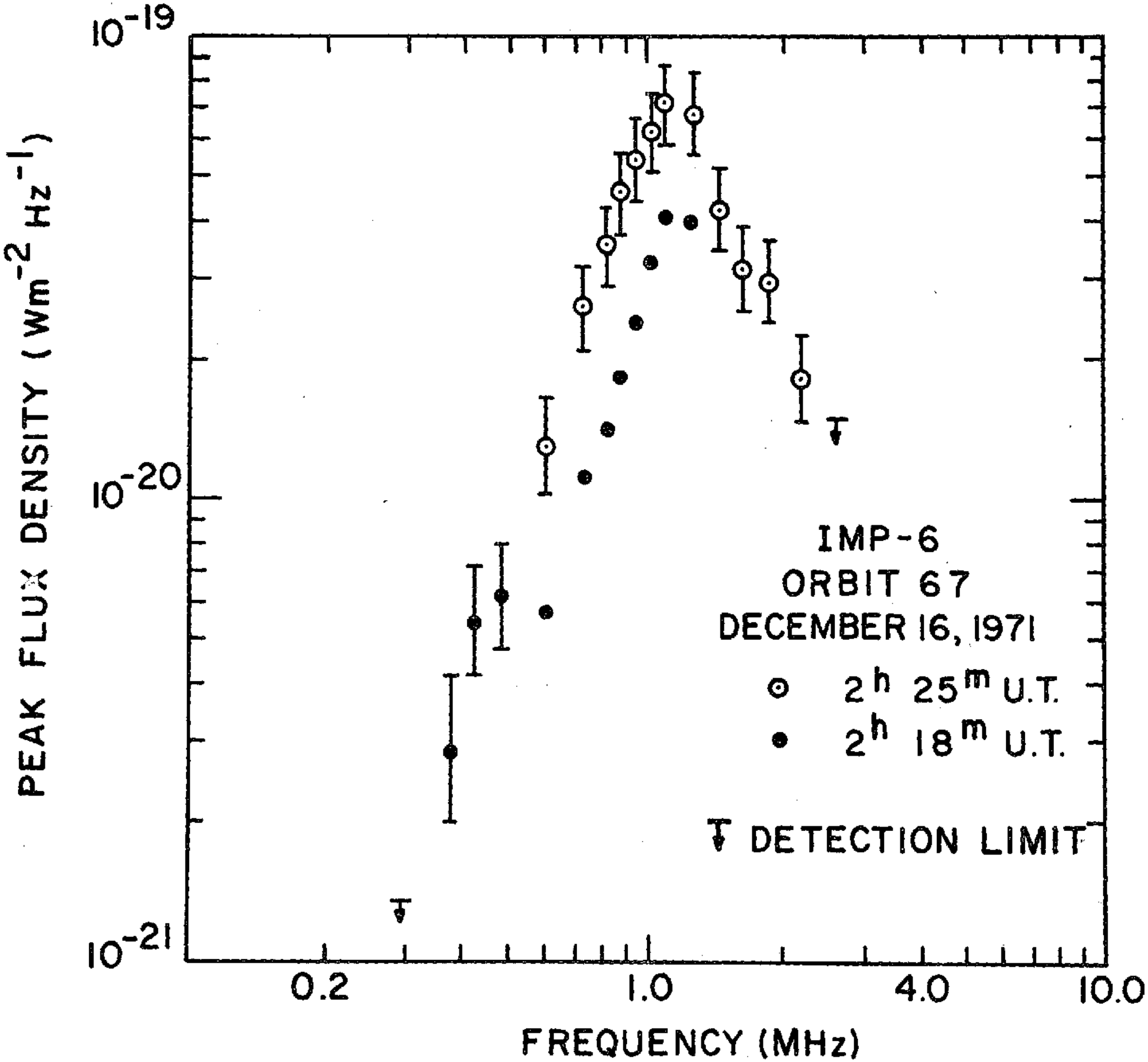
FIGURE 3 - Spectrum of Saturn emission for the intense storm of December 16, 1971 for an Earth-Saturn distance of 8.2 A.U.

FIGURE 4 - Power spectral analysis of Saturn detections at an observing frequency of 1100 kHz. (N is the noise level).

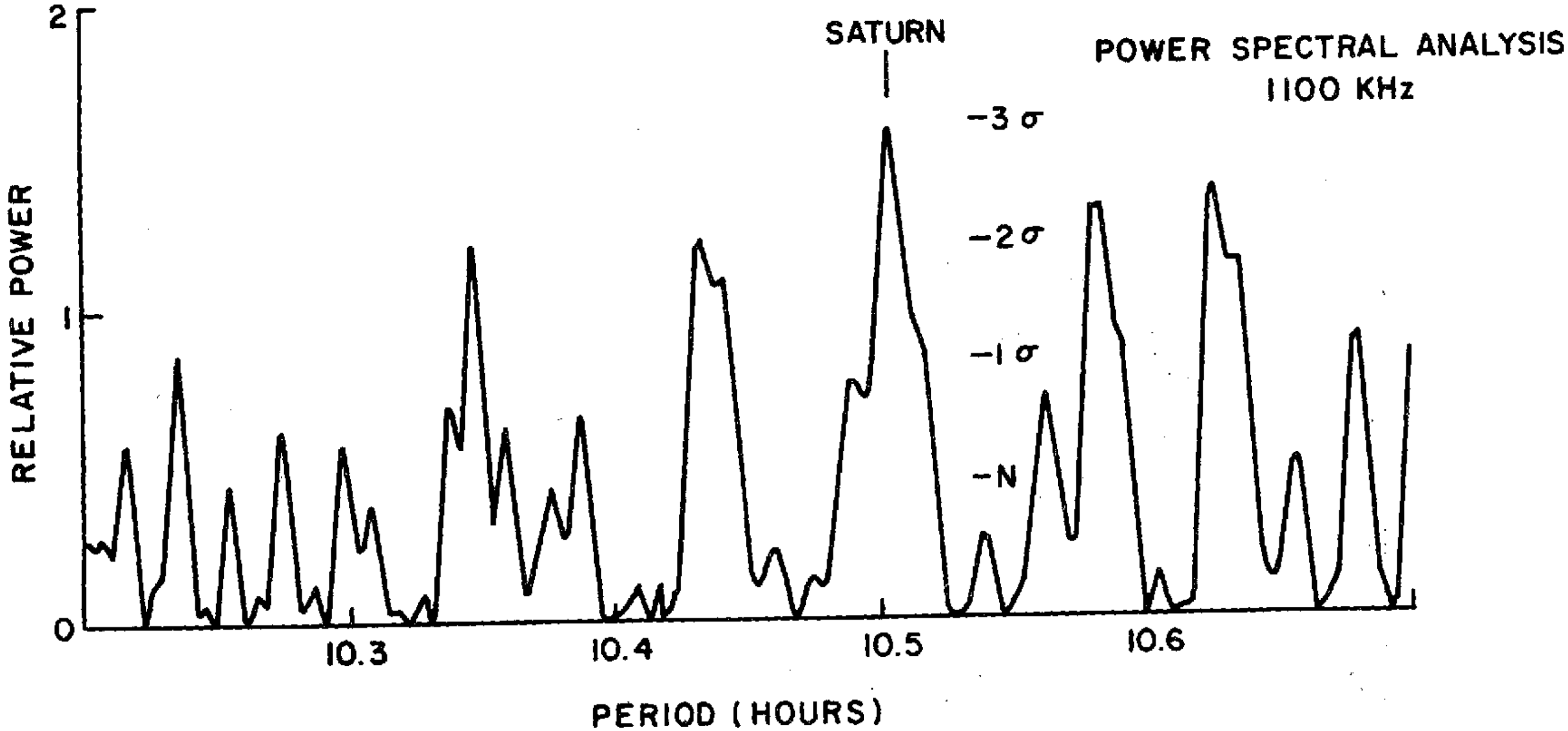


DIRECTION OF
GALACTIC MAXIMUM
DIRECTION
OF EARTH
SATURN
PROBABLE ERROR
SUN
DIRECTION OF
JUPITER
IMP-6
ORBIT 67
DECEMBER 16,1971
FREQUENCY 1030 KHz
DIRECTION OF EMISSION RELATIVE TO SUN
80
60
40
20
0
-20
2h 18m
2h 22m
2h 26m
2h 30m
TIME (U.T.)


2200 KHz
1850 KHz
1630 KHz
RELATIVE SCALE LOG(ΔT_A) = 0.1
1450 KHz
1270 KHz
1100 KHz
1030 KHz
950 KHz
870 KHz
815 KHz
737 KHz
600 KHz
475 KHz
425 KHz
375 KHz
IMP-6
ORBIT 67
DECEMBER 16, 1971
SATELLITE AT 20.5 R_0
RELATIVE ANTENNA TEMPERATURE (T_A)
$2^h 18^m$
$2^h 22^m$
$2^h 26^m$
$2^h 30^m$
TIME (U.T.)



10^{-19}
10^{-20}
10^{-21}
PEAK FLUX DENSITY (Wm^{-2} Hz^{-1})
0.2
1.0
4.0
10.0
FREQUENCY (MHz)
IMP-6
ORBIT 67
DECEMBER 16, 1971
2^h 25^m U.T.
2^h 18^m U.T.
DETECTION LIMIT



POWER SPECTRAL ANALYSIS
1100 KHz
SATURN
2
1
0
RELATIVE POWER
-3 σ
-2 σ
-1 σ
-N
10.3
10.4
10.5
10.6
PERIOD (HOURS)