NATIONAL RADIO ASTRONOMY OBSERVATORY
VERY LARGE ARRAY
SOCORRO, NM 87801

VLA ELECTRONICS MEMORANDUM NO. 210

MEASUREMENT OF POTENTIAL INTERFERENCE FROM THE IONDS TRANSMISSIONS OF THE NAVSTAR SERIES OF SATELLITES

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Navstar 8 and further satellites to be launched in this series (the Global Positioning Satellites) include a nuclear burst detector, data from which is transmitted to earth at 1381.05 MHz. The burst detector system is known as the Integrated Operational Nuclear Detection System (IONDS). Eventually there will be 18 satellites in 12-hour orbits carrying this system. The IONDS transmissions are of a broadband character using spread-spectrum modulation, and the spectrum resembles those of the navigational signals centered at 1227.6 and 1575.4 MHz from the satellites.

I. INTERFERENCE TO RADIO ASTRONOMY

The IONDS transmissions pose two potential problems for radio astronomy. First, the frequency is close enough to the 1400-1427 primary radio astronomy band that sideband radiation at harmful levels could occur within the band. This problem was recognized by the U.S. Air Force, which operates the satellites, and a 1400-1427 MHz band stop filter has been incorporated in the transmitter output. The second problem is the interference to observations of red-shifted hydrogen at frequencies within the range 1330-1400 MHz. The proposed solution to this problem has been to transmit the 1381 MHz signal only for very short time intervals.

In the band 1330-1400 MHz radio astronomy is protected by a footnote in the International Radio Regulations asking administrations to take "all practical steps" to protect spectral line observations.

These frequencies are, in fact, not allocated to space services, but in 1977 the use of the 1381 MHz frequency by the Air Force was approved by the Spectrum Planning Subcommittee of the IRAC[1]. At that time the Air Force stated that the estimated transmission time was five minutes per week for the entire constellation of satellites. In 1982 it was found, however, that the planned transmission time had been increased to something like 5-10 minutes per day for each of the 18 satellites, and included a data dump in addition to the false-trigger transmissions resulting mainly from lightening. The data dump transmissions were not considered when the 1381 MHz assignment was originally requested. As a result of this the Radio Astronomy Subcommittee of CORF[2] wrote a letter to the Air Force in February of this year requesting that they hold to their original estimate of transmission time.

The present situation is rather complicated. The IRAC is largely supportive of the radio astronomers' position. The Air Force has stated that they may be able to change the data-dump downlink frequency to S-band after the first four satellites with IONDS have been launched. The Air Force, however, requires that tests be made to verify that the IONDS transmissions cause a serious problem for radio astronomy. Tests were arranged on August 18 and 24 of this year and five radio observatories participated. These were Arecibo, Green Bank, VLA, Owens Valley and Hat Creek. The results will be collated by V. Pankonin of the N.S.F. There were two main aims of the tests: to measure the flux density of the radiation in the 1400-1427 MHz band and to determine the effect on measurements of red-shifted hydrogen at frequencies within a range of about 1360-1400 MHz.

II. MEASUREMENTS WITH THE VLA

Measurements with the VLA were aimed principally at checking the flux density in the band 1400-1427 MHz transmitted by the satellites.

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[1]Inter Department Radio Advisory Committee, which is part of the National Telecommunication and Information Administration.
[2]The Committee on Radio Frequencies of the National Academy of Sciences.

During each of the tests the 1381 MHz transmitter was switched on and off for alternate five-minute intervals over a two-hour period. This sequence was chosen to produce easily detectable effects in observations of the type used for red-shifted hydrogen. At the VLA the satellite was tracked using an OBSERVE file generated by the SATPOS program described in VLA Electronics Memorandum. No. 178. Reliable measurements were obtained in the test period 2030-2230 UT on August 24. The 25 MHz bandwidth filter was used at the antennas and the L6 frequency was 3590 MHz. The band of frequencies brought back from the antennas thus covered 1402.5 to 1427.5 MHz. The array was used in the continuum mode with a final IF bandwidth of either 25 MHz matched to the above range or a 12.5 MHz bandwidth centered at 1409 or 1421 MHz. The 20 dB solar attenuators were inserted to prevent overloading. The results showed a signal of average flux density about -259 dB Wm^{-2} Hz^{-1} was present within the 25 MHz band. The signal strength fluctuated randomly over several decibels, probably as a result of tracking errors, but showed no systematic 5-minute on-off sequence. It seems clear that the observed signal was attributable to the far sidebands of the L1 (1272 MHz) and L2 (1575 MHz) transmitters as well as 1381 MHz (L3) transmitter. The expected levels of the L1 and L2 signals in the 1400-1427 band, from most figures that I have seen, appear to be in the range -255 to -265 dB Wm^{-2} Hz^{-1}. The observations are consistent with the conclusion that the filter in the transmitter has reduced the L3 signal to about the same level as the L1 and L2 signals, and the fluctuations in the combined level due to tracking errors mask the 5-minute on-off sequence of the L3 signal.

Tracking errors result partly from the nature of the VLA control software in which the coordinates for a source with non-sidereal motion are interpolated from the rates in R.A. and Dec. at 10-sec intervals, between which the array tracks at the sidereal rate. To minimize this problem data taken at high elevation angles (the maximum elevation of the satellite was 86°) were not used. A second problem was the failure of the Air Force to supply orbital parameters for the satellites. Parameters used were obtained by Bill Brundage from the Naval Research Laboratory, and were dated August 7, 1983, and so were 17 days out of date by August 24. A rough estimate suggests tracking errors might be of order $\frac{1}{2}°$ to $1°$, and an allowance of 4 dB for pointing errors has been included in the flux density figures given below.

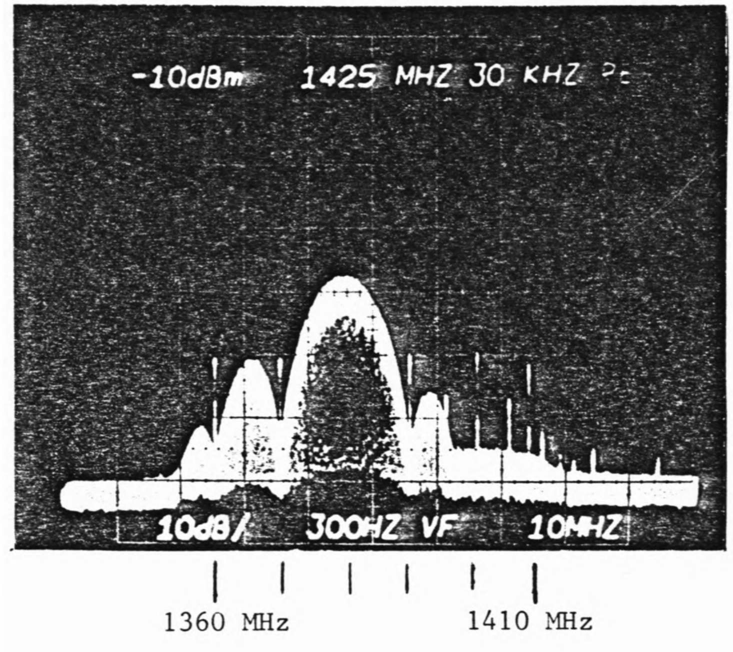
The final figures for the measurements are listed below. Their accuracy is difficult to estimate because of the tracking errors, and is unlikely to be better than ±3 dB. The source 3C286 was observed during the tests to provide a flux density standard.

Center Frequency	Bandwidth	Flux Density
1415 MHz	25 MHz	-259 dB Wm^{-2} Hz^{-1}
1409 MHz	12.5 MHz	-257 dB Wm^{-2} Hz^{-1}
1421 MHz	12.5 MHz	-265 dB Wm^{-2} Hz^{-1}

The figures indicate that on average the flux density within the band 1402.5-1427.5 MHz does not exceed the harmful limit for continuum radiation of -255 dB Wm^{-2} Hz^{-1} specified in CCIR Report No. 244-5. This does not preclude the flux density being higher in limited parts of the band, and it should be noted that the above figures clearly indicate higher levels towards the low end of the band. Note that the limits of the band measured, 1402.5 to 1427.5 MHz do not exactly match the 1400-1427 MHz radio astronomy band. This is the best match that could be obtained with the limited tunability of the local oscillators at the antennas. In preliminary measurements on August 18 a 50 MHz band extending from 1390 to 1440 MHz was brought back from the antennas, and the oscillators and later-stage filters set to give a precise match to the radio astronomy band. However the strong signal in the 1390-1400 MHz range was not sufficiently well rejected and the resulting measurements were discarded.

III. SPECTRUM-ANALYZER RECORD

Spectrum-analyzer pictures of the transmitted signal were taken using the 50 MHz IF bandwidth covering 1390 to 1410 MHz. Two examples are shown in Fig. 1. Narrow band signals, some of which coincide with the minima in the (sin x/x) spread spectrum, can be seen. It seems likely that these are radiated by the satellite, but it is also possible that they could arise from some intermodulation process in the receiving equipment. They were not seen on a similar record of the 1575 MHz signal.



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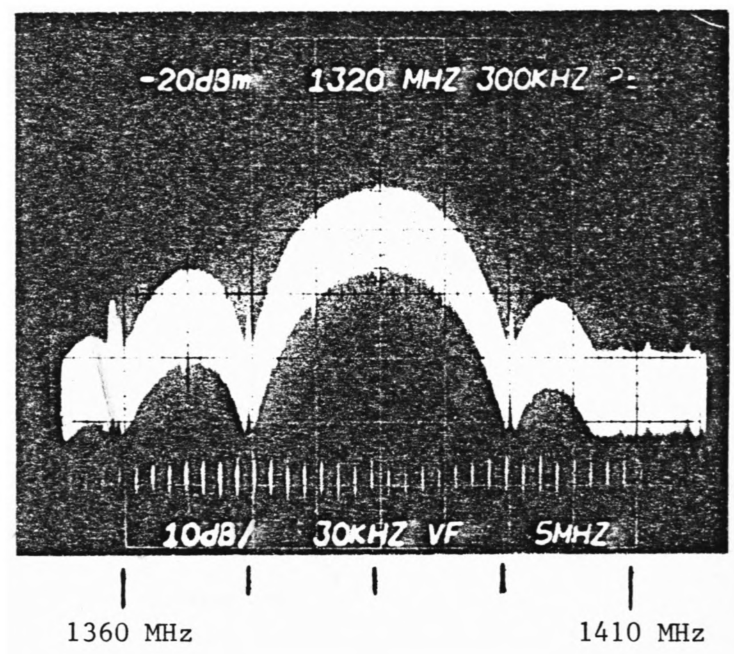

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Fig. 1. IF spectra taken with Tektronix 7603 spectrum analyzer.