connected to the receiver input for a full revolution. The shadow inhibit circuit is called "holding circuit" in FIG. 2.

(2) COMMAND 217 (high pass filter out). Because of attenuator switching the receivers do not behave well in the presence of a very large low frequency signal because the signal is chopped by the input attenuators and can make spurious signals appear in the high frequency channels. In order to guard against possible strong low frequency signals from the solar array, (1 Hz and 16 Hz), particularly at 1 Hz, we have built a filter which strongly attenuates a one hertz signal. However, again this has a bad effect since we would also like to measure, (if possible), the 1 Hz signal in order to measure the DC electric fields in solar wind. Therefore, this filter is removable by command. The command "high pass filter out" bypasses this filter. The position of the filter is shown in FIG. 3.

(3) COMMAND 370 (impedance measurement and calibrate). This command causes the antenna impedance to be measured, and then a standard calibration signal to be applied to the receiver inputs. The antenna impedance is measured by switching on an oscillator which oscillates at the same frequencies that the receivers are tuned to, and applying its signal through a small (3-pf) capacitor to the antennas. After the oscillator has gone through one measurement cycle, it is turned off, and a signal consisting of filtered square waves derived from the spacecraft clock is applied to the receiver inputs in order to check their calibration. This calibration also lasts one measurement cycle, making a total of 2 measurement cycles. One measurement cycle takes 48 frames in formats 1, 2 and 3 and 96 frames in format 5.
In addition to being commandable, this impedance measurement and calibration sequence is performed every 2^{13} sec on the appropriate spacecraft clock pulse.

(4) COMMAND 305 (Reference oscillator calibrate).
The reference oscillator whose signal is applied to the antenna in order to measure its impedance can be calibrated by switching it directly to the receiver input. This command turns the oscillator on, switches it directly to the receiver input for one measurement cycle and then turns the oscillators off and disconnects it.

(5) COMMAND 160 (Reset). This command erases the effect of all foregoing commands and puts the experiment in a standard mode, which is as follows: high pass filter in, shadow inhibit in, no impedance measurement, and no reference oscillator calibrate. When the experiment is turned on, it automatically goes into the same mode except that it begins with a reference oscillator calibrate.

The Radio Astronomy Experiment on Helios A and B (E 5c)

Richard R. WEBER, Goddard Space Flight Center, Greenbelt/Md., USA

The NASA Goddard Space Flight Center radio astronomy experiment on HELIOS, identified as Experiment 5C, has sixteen observing frequencies over the range of 26.5 to 3000 kHz. The antenna consists of two extendible 15-m booms, forming an electric dipole, two high-impedance preamplifiers located at the root of the booms, and the 16-channel radiometer. Important informations about propagation conditions mportant information about propagation conditions,such as absorption, scattering and refraction, are ex pected from observations of radio emission regionsat distances between 1 and 0,3 AU.

Das Radioastronomie-Experiment des NASA Goddard Space Flight Center ist für verschiedene Meßfrequenzen im Bereich von 26,5 bis 3000 kHz ausgelegt. Die Antenne besteht aus zwei ausfahrbaren 15 m-Booms als elektrischen Dipol, zwei Vorverstärkern hoher Impedanz direkt an den Antennenwurzeln und dem 16-Kanal-Radiometer. Wichtige Informationen über die Ausbreitungsbedingungen von Radiowellen wie Absorption, Verteilung und Veränderungen werden von den Meßergebnissen über den Bereich von 1,0 bis 0,3 AE erwartet.

1. PHYSICAL ASPECTS OF THE OBSERVATIONS

Radio astronomy experiments conducted in space, beyond the plasmapause, have extended the observations of solar radio bursts from 10 MHz down to near 10 kHz. These observations have shown that type III (fast-drift) traveling disturbances occur in large numbers over this frequency range. According to present understanding of the process responsible for type III emission, a packet of superthermal electrons, ejected for example during a solar flare, travels out through the corona and interplanetary space along magnetic field lines. These "exciter" electrons produce Cerenkov waves, which in part are converted into electromagnetic radiation at twice the local pasma frequency. This radiation thereby provides a measure of the local plasma density. As the exciter moves outward to regions of lower density, the radiation occurs at progressively lower frequencies and later times. The difference in emission times for two frequencies is then equal to the time for the exciter to

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[*] **Radio Astronomy Branch, Laboratory for Extraterrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.**

pass between the two coronal levels, and allows a determination of the velocity of the exciter. Average emission frequencies are 280 kHz at 0.3 AU and 55 kHz at 1 AU.

The rise time of a burst can be related to the length of the exciter and the size of the emission region. As the exciter moves outward, its dimensions grow due to its dispersion of velocities. The increase in rise time at lower frequencies provides a measure of this dispersion. The intensity of the burst yields information on the number of particles in the exciter and the volume of the interacting region. The decay time of the burst is longer than the rise time and has been related to various damping processes in the solar wind. The smoothness of the burst at a given frequency gives some indication of coronal inhomogeneities. A small emission region with large scale scatterers can produce scintillations during a burst.

Observations already conducted in space [Fainberg and Stone, 1974] have revealed a surprisingly large number of type III solar bursts during the years of maximum solar activity. They arise not only as individual bursts associated with large flares, but also as storms of bursts observed during the entire transit of an active region across the disk of the Sun. These storms, composed of thousands of drifting bursts and continuum, are well correlated with active regions on the Sun. During one year of hectometer wavelength observations by RAE-1, more than 10^5 storm type III bursts have been observed in addition to over 10^3 individual or complex groups of type III events.

Analysis of these data has:

1) found that the exciter electrons have energies of 5 to 200 keV,
2) established an average density scale out past 1 AU,
3) provided an estimate of solar wind bulk speed at a distance of 0.4 AU,
4) shown the existence of magnetic loop structure extending out to 30 solar radii, and
5) shown the occurrence of long-lasting streams of superthermal electrons arising in active regions on the Sun and moving outward through interplanetary space along open field lines.

It is anticipated that HELIOS will observe not only solar bursts, but also radiation from some of the planets. Earth and Jupiter have been observed at low frequencies from spacecraft near Earth. [Kaiser and Stone, 1975; Brown, 1974]. It is possible that the characteristics of the Earth will look more like those of Jupiter when the observations are made from a great distance. Mercury may be detected when HELIOS is relatively close.

Observations of solar radio sources from a spinning spacecraft such as HELIOS display a modulation pattern which allows a determination of source direction and size to be made. When this is done over a range of frequencies from a few MHz to tens of kHz, the path of a solar exciter as it travels out from the Sun to 1 A.U. is outlined by the resulting radio radiation very much as the droplets in a cloud chamber describe the path of charged particles. Since the exciter is constrained to move along the interplanetary magnetic field which has a direction set by the solar wind, the radio observations of the exciter paths lead to determination of gross structure in the solar wind.

Another powerful method to be employed with HELIOS is time-of-flight measurements of radiation received by two or more separated spacecraft. The data to be used are from HELIOS A and B and RAE-2. Observations from two spacecraft can be correlated on the ground to find the difference in received time. This time difference will define a hyperboloid on which the source is located. Spin modulation and other means will then locate the source on the surface. Both time-of-flight and spin modulation measurements will be applicable to solar bursts and planetary radiation.

The HELIOS radio experiment is very well suited to these tasks. The good sampling rate and sixteen observing frequencies will permit detailed observations to be made over almost the entire path of the burst out to 1 A.U. Moreover, when the spacecraft is near the Sun, valuable data on the directivity of the bursts and the size of the emission region will be obtained. Important information about propagation conditions – absorption, scattering, and refraction – should result from observations of radio emission regions at progressively shorter distances.

In addition to solar bursts, there are other phenomena which will yield significant information. Observations of enhanced radio noise near the local plasma frequency lead to a measure of the plasma density in the vicinity of the spacecraft. As HELIOS moves in its orbit, a measure of the bulk density made in this manner will complement other measurements. More rapid changes in local plasma frequency with time will yield information on solar wind inhomogeneities.

Other spacecraft observations have indicated large amounts of radio noise taking place in processes within the Earth's magnetosphere and tail regions. HELIOS, with its direction-finding capability and large dynamic range, should give much information about these effects, especially if they are related to solar phenomena occurring at earlier times.

2. DESCRIPTION OF THE EXPERIMENT

The radio astronomy experiment consists of two extendible 15-m antenna booms forming an electric dipole, two high-impedance preamplifiers located at the root of the booms, and a dual 16-channel radiometer. Similar instrumentation has been used on previous spacecraft [Weber et al., 1971]. Figure 1 is a block diagram of the system. The preamplifiers contain gain switching for three 30-dB dynamic ranges covering approximately 2 μ v to 60 mv. The preamplifier outputs are combined in a transformer balun located in the main radiometer box. The balun secondary winding feeds both sides of the dual radiometer. Following the balun a lowpass filter attenuates frequencies above 3 MHz. A mixer combines the incoming signal with the output of one of the 16 programmed crystal-controlled oscillators. The crystal filter has a 10-kHz bandwidth centered on the 21.4-MHz intermediate frequency (IF). After the IF amplification, the signal is detected and passes through a logarithmic amplifier having an output slope of about 6 dB/volt and an output time constant of 8 ms. This logarithmic amplifier also has an output which is compared with preset range switching limits; when the output exceeds the limits, the preamplifier gain is changed to the next range.

Each half of the redundant radiometer system operates at the following frequencies:

FREQ	kHz	FREQ	kHz
0	26.5	8	340
1	50	9	445
2	65	10	585
3	85	11	765
4	115	12	1010
5	150	13	1320
6	195	14	2280
7	255	15	3000

The four frequency sequences are:

Mode A	$f_0, f_8, f_1, f_9, f_2, f_{10} \ldots f_7, f_{15}, f_0, f_8$, etc., staying on each frequency for 16 samples (one-half spin).
Mode B	Same as A but always on one commanded pair of f_i, f_{i+8}.
Mode C	Single frequency operation at any commanded frequency.
Mode D	Staircase $f_0, f_1, f_2 \ldots f_{15}$ staying on each frequency for 2 of 32 sectors.

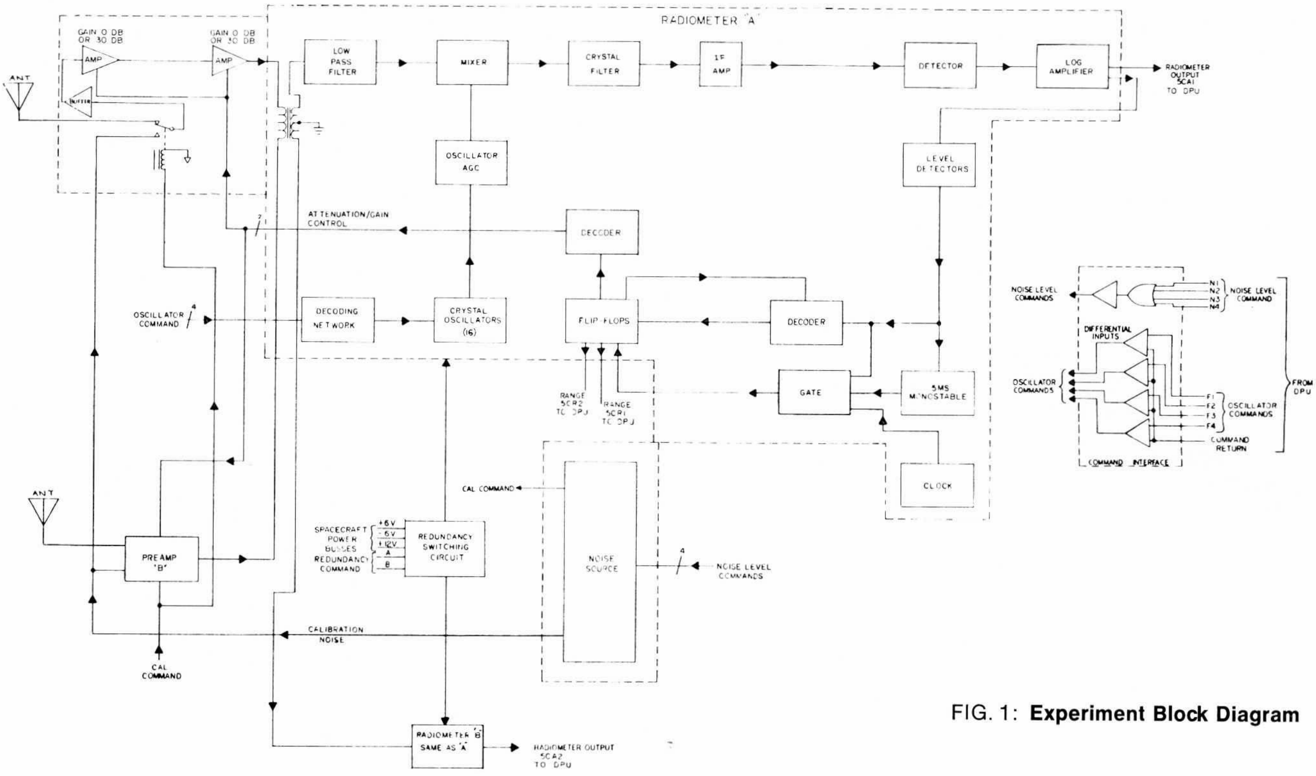

FIG. 1: **Experiment Block Diagram**

In all cases, data are spin synchronous and are divided into 32 sectors. Each data word contains 7 bits of analog data and 2 bits for the dynamic range. Data are always collected for one complete spin.

A data-processing unit (DPU) supplies power and pogramming signals to the radiometer. It accepts the radiometer analog output of 0-5.08 volts and converts it to seven-bit words. It also accepts the two radiometer range bits. These data are processed by the DPU for transfer to the telemetry system.

During in-flight calibration, the Expriment 5 C preamps are switched off the antennas and are connected to an internal noise source which steps through four levels, beginning with the highest level and ending with the lowest level. This calibration cycle occurs automatically each 2^{16} seconds (about once per 18 hours) and can be commanded at any time.

3. POST-LAUNCH ADDENDUM

HELIOS A was successfully launched on December 10, 1974. The launch vehicle and most spacecraft systems performed nominally. The GSFC radiometer is working well. However all the electric field experiments are experiencing interference arising from two problems. First, one of the two booms forming the dipole did not deploy properly and is shorted to spacecraft ground. This short has caused RFI levels of 3-30 dB above expected levels. A second problem is unexpected interference from the high-gain telemetry antenna. This adds about 60 dB of RFI at 27.5 kHz, decreasing with increasing frequency, so that above 200 kHz it adds no additional RFI. Because of this problem, the spacecraft telemetry is being sent via the medium gain antenna when possible, supported by unprecedented coverage by 64-m and 100-m ground-based antennas.

REFERENCES

[1] BROWN, L. W., Spectral behavior of Jupiter near 1 MHz, Astrophys. J. Lett., **194,** L159, 1974.

[2] FAINBERG, J., and R. G. STONE, Satellite observations of type III solar radio bursts at low frequencies, Space Sci. Rev., **16,** 145, 1974.

[3] KAISER, M. L., and R. G. STONE, Earth as an intense planetary radio source: similarities to Jupiter and Saturn, Science, **189,** 285, 1975.

[4] WEBER, R. R., J. K. ALEXANDER, and R. G. STONE, The radio astronomy explorer satellite, a low-frequency observatory, Radio Sci., **6,** 1085, 1971.