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NEW MEASUREMENTS OF THE GALACTIC RADIATION SPECTRUM BETWEEN 200 KHz AND 2.6 MHz

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NEW MEASUREMENTS OF THE GALACTIC RADIATION SPECTRUM BETWEEN 200 KHz and 2.6 MHz

by

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The Goddard Space Flight Center Radio Astronomy experiment aboard the IMP-6 satellite has provided new data on the absolute spectrum of the galactic background radiation at frequencies between 0.2 and 2.6 MHz. The measurements have been obtained both in the terrestrial magnetosphere and in interplanetary space.

IMP-6 was launched on March 13, 1971 into a highly eccentric orbit whose apogee is about 32.5 earth radii and whose perigee is 9000 kilometers. The orbital period is about four (4) days. The satellite carried twelve (12) experiments for the study of cosmic rays, electrical and magnetic fields, plasma, and radio astronomy.

The spacecraft is a sixteen-sided (16) drum approximately six (6) feet in height -- four and one half (4½) feet in diameter. It is spin stabilized about the axis of the drum at a speed of five (5) revolutions per minute. The spin axis is oriented perpendicular to the ecliptic plane. Among the numerous booms extending from the spacecraft are two monopole antennas, 150 feet in length, lying in the spin plane (see figure 1).

Figure 2 shows a block diagram of the radio astronomy receiver system. The signal from each of the monopole antennas is amplified separately in one channel of a four (4) channel R.F. pre-amplifier. A 300-foot dipole antenna is electronically formed by combining the pre-amplifier outputs through differential amplifiers, which further act as power splitters to send the signal to two (2) receivers. Each is a step frequency radiometer consisting of thirty-two (32) discrete frequencies sampled over a five (5) second period. Receiver one has a frequency range of 30 kHz to 9.9 MHz with a bandwidth of 3 kHz and a time constant to 30 milliseconds. Receiver two has a frequency range of 30 kHz to 4.9 MHz with a bandwidth of 10 kHz and a time constant of 10 milliseconds.

The experiment carries an internal calibration system so that the long and short term changes of the receivers can be measured. This system activates automatically every three (3) hours.

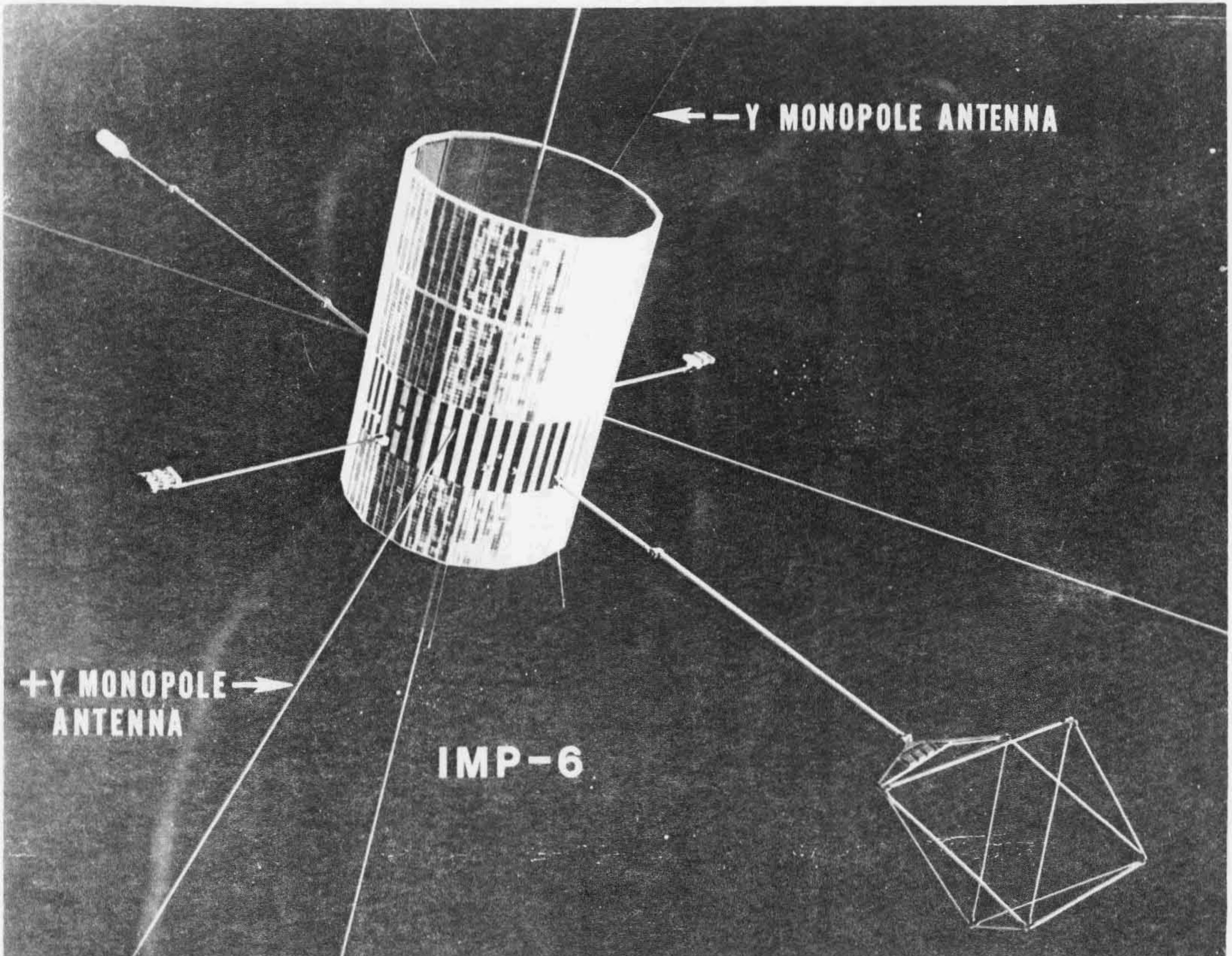

FIGURE 1. IMP–6 SPACECRAFT SHOWING 300-FOOT DIPOLE ANTENNA OF GSFC RADIO ASTRONOMY EXPERIMENT

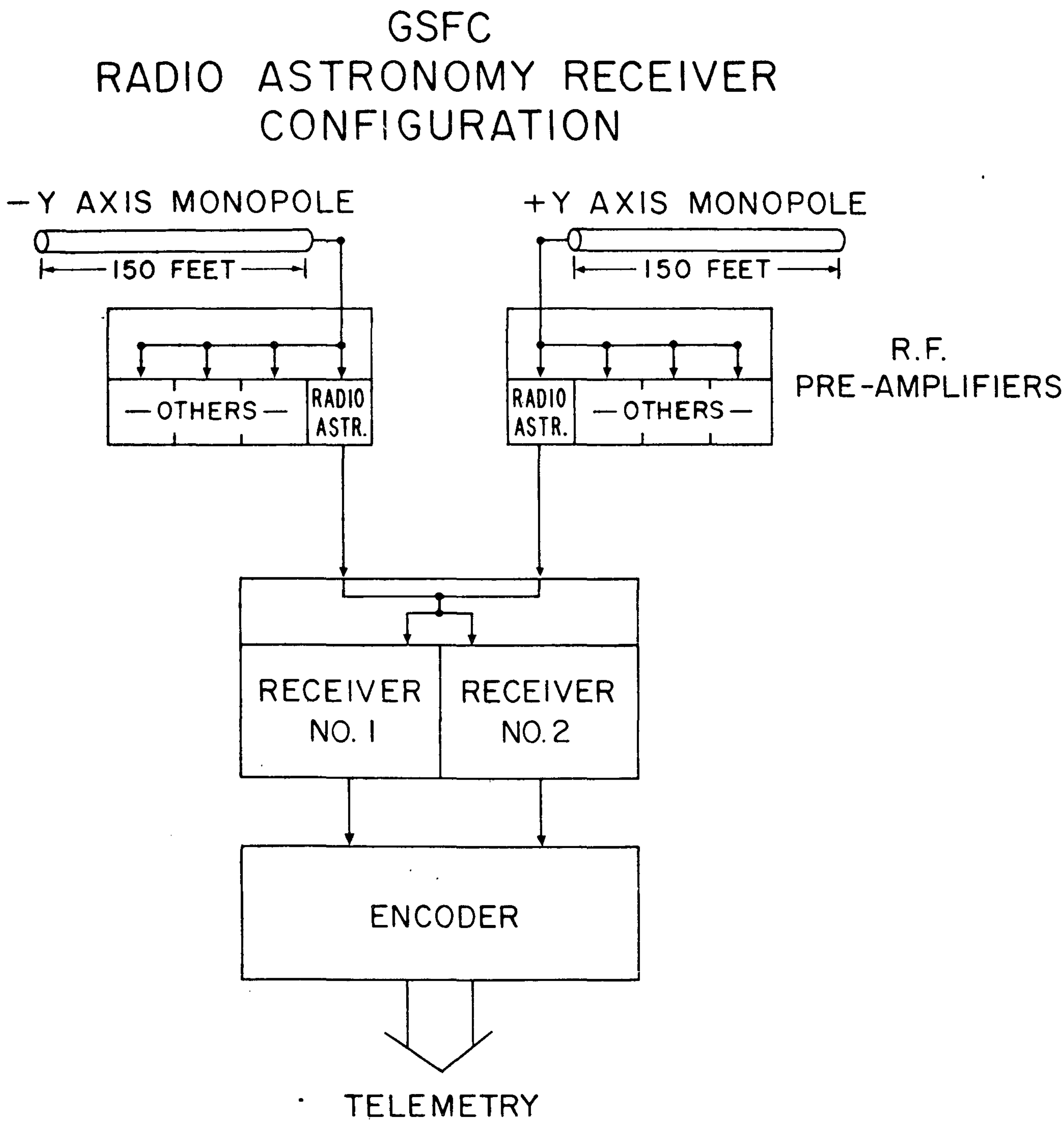

FIGURE 2. BLOCK DIAGRAM OF THE GODDARD RADIO ASTRONOMY RECEIVER ON IMP–6

Figure 3 shows the calibration levels which have been evaluated for the first thirty-six orbits. Over this period there has been a detectable long term drift in the mean calibration values of each orbit. However, the long term standard deviation has amounted to only 4%. The short term standard deviation over a single orbit has been the predictable 10% and has remained constant over all orbits.

One of the primary investigations of this experiment was the measurement of the low frequency component of the galactic radiation.

Figure 4 represents the progress which has been made to this point. The galactic radiation has been observed at eighteen (18) frequencies between 3 MHz and 200 kHz with an error of less than one (1) db.

This error arises from three (3) main sources. The first resides in the rms noise fluctuations of the receiver and the digitization of the receiver output by the spacecraft encoder. This effect accounts for a probable error of 10%. The second source of error is the measurement of the dipole antenna impedance. Pre-flight measurements made under laboratory conditions were accurate to the 5% level. However, the failure of the flight impedance probe early in the spacecraft's life increases the uncertainty in the flight antenna impedance to near 10%.

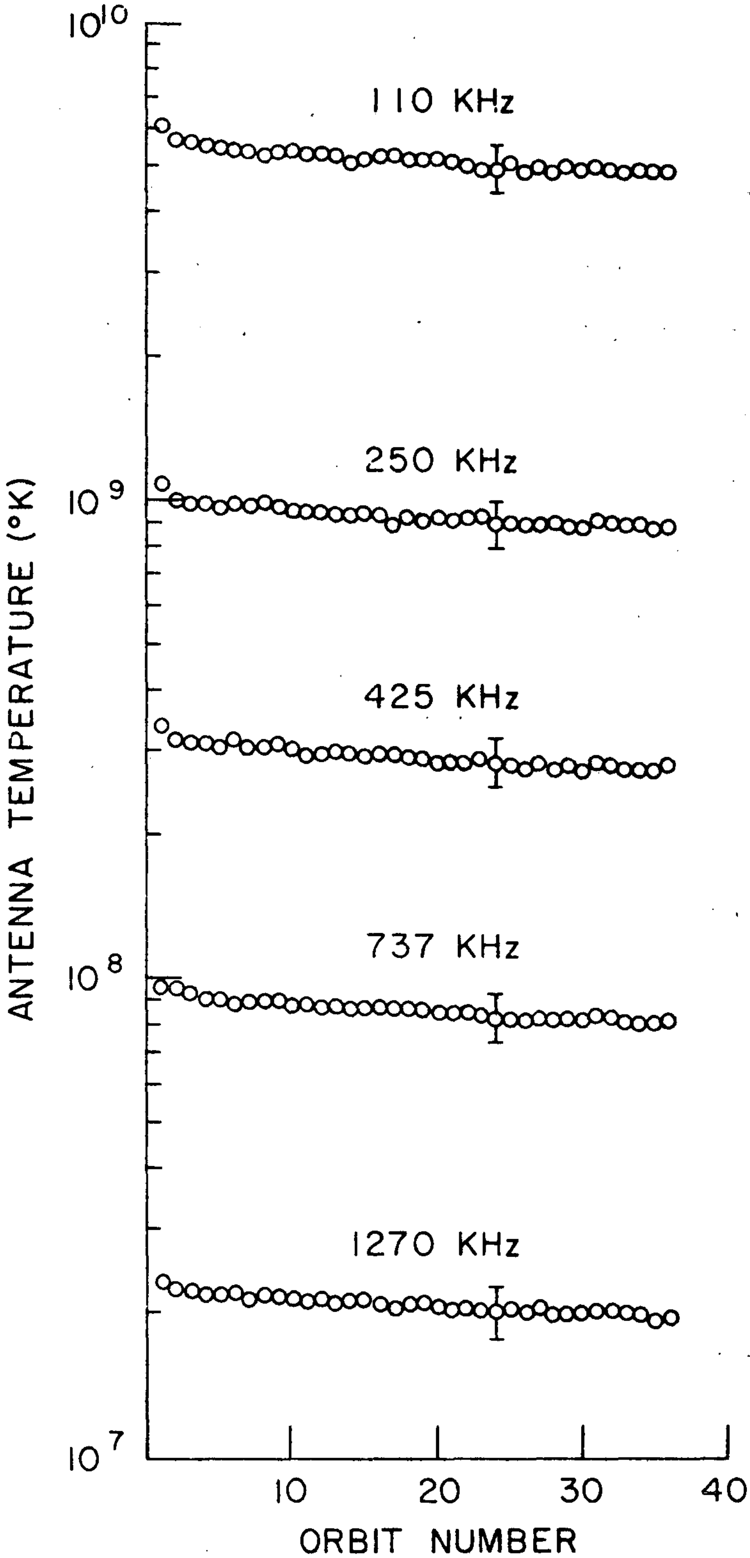

FIGURE 3. ORBITAL AVERAGES OF THE CALIBRATION SIGNAL LEVELS FOR SELECTED FREQUENCIES

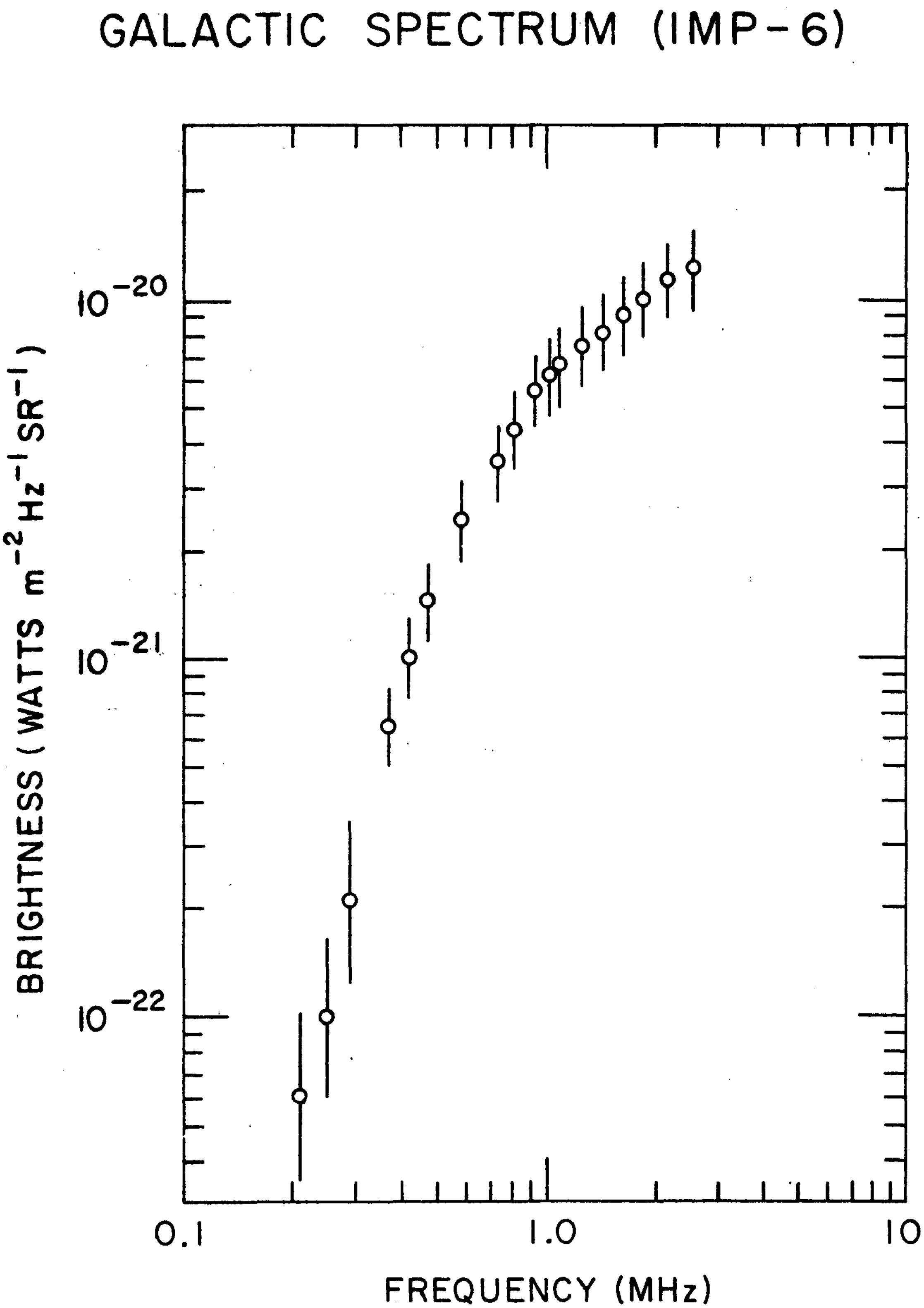

FIGURE 4. SPECTRUM OF THE GALACTIC BACKGROUND RADIATION AS MEASURED BY IMP-6

The major error occurs in the determination of the absolute power level of the noise source used in the pre-flight calibration of the receiver system. This measurement is subject to both random and systematic errors amounting to approximately 15%.

Recently, the noise source was remeasured by the National Bureau of Standards at Boulder, Colorado under laboratory conditions to an accuracy of 1%. This work indicates that any systematic error in the adopted power level is less than 10%. Hopefully, the removal of this systematic error will reduce the total probable error for the galactic spectrum to 15%.

Figure 5 shows that the IMP-6 results compare quite favorably with those made by the Radio Astronomy Explorer-1. The difference near 500 kHz results from the higher contamination of data by earth related noise due to the 6000 kilometer altitude of RAE. The earth noise is observed also by IMP-6, but due to its 210,000 kilometer apogee only the much lower frequencies are affected. Many of the early reports of high level galactic radiation were the result of such periods of extremely high earth noise.

GALACTIC RADIO SPECTRUM

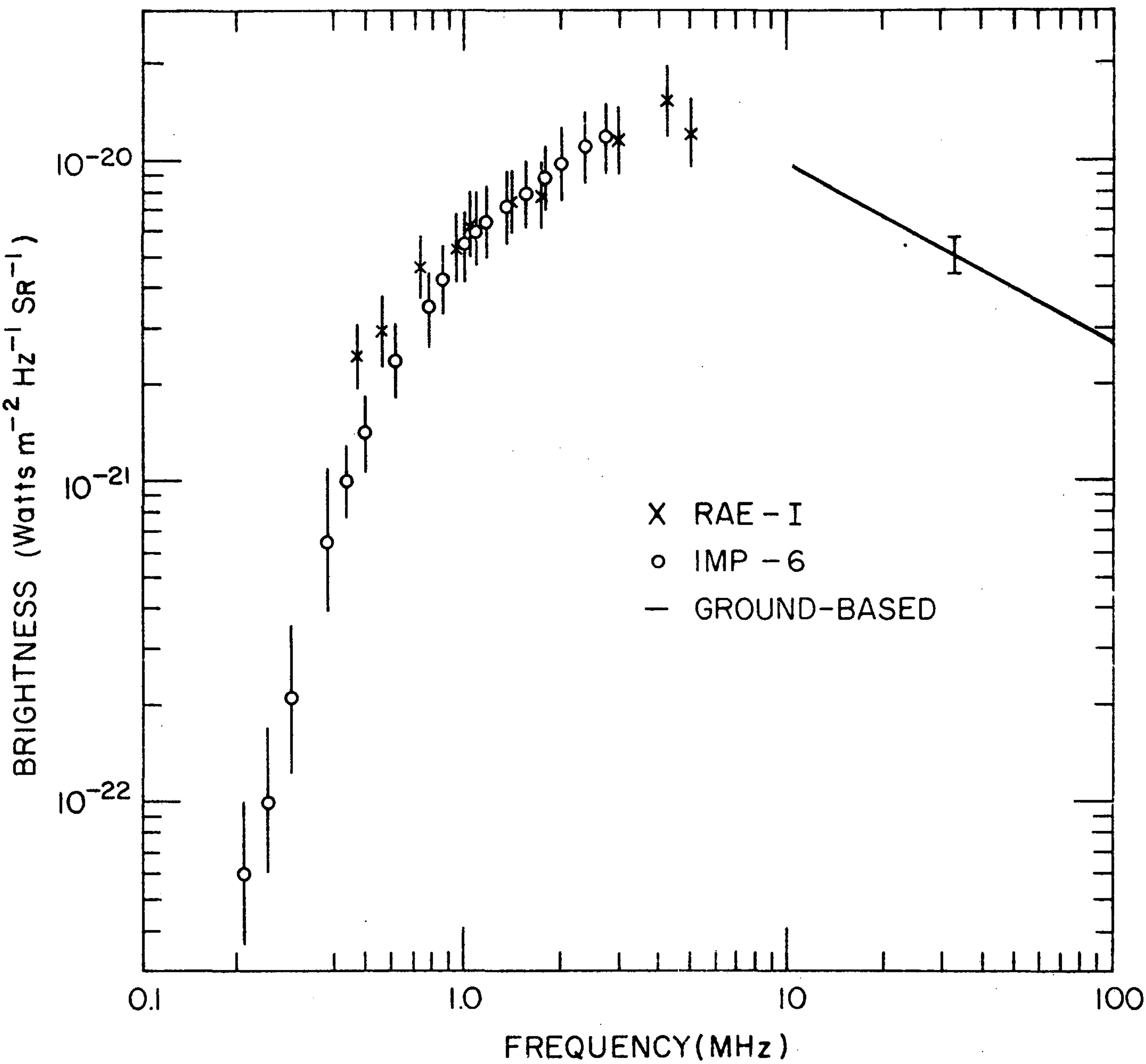

FIGURE 5. IMP–6 RADIO SPECTRUM AS COMPARED TO THE RADIO ASTRONOMY EXPLORER–1 MEASUREMENTS

Models of the galactic radiation based on RAE data have predicted that only two mechanisms, synchrotron emission and free-free absorption, were required to produce the observed spectrum. This seems to be contradicted by the IMP-6 data as the spectrum falls off much more rapidly than such models predict.

However, in these models the effect of the ambient plasma on the synchrotron emissivity was not taken into account. The ambient plasma with its low magnetic field will tend to suppress the synchrotron radiation of relativistic electrons at low frequencies.

If the effect of the ambient plasma is properly included in the models, then for acceptable interstellar densities and magnetic fields the suppression effect causes a moderate reduction in the synchrotron emissivity conforming to the observed IMP-6 spectrum. Future work is planned to construct the appropriate interstellar models.