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OBSERVATIONS OF THE SMS-1 SATELLITE RADIATION IN THE BAND 1660-1670 MHz

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INTRODUCTION

This report describes the results of observations of the SMS-1 satellite with the NRAO 140-foot telescope in the band 1660-1670 MHz. The observations were made 8 and 9 February 1975.

Earlier observations of the SMS-1 satellite, made in August 1974, have been reported earlier (September 1974) in NRAO's Electronics Division Internal Report No. 147 by B. E. Turner, J. L. Dolan and C. R. Moore. These measurements were made using a scanning spectrum analyzer which measured the peak power levels, and an autocorrelation receiver which measured the time averaged spectrum. The autocorrelation output showed an enhanced signal at about 1664 MHz, exceeding the CCIR limit of 2.5×10^{-24} $Wm^{-2}Hz^{-1}$ (-236 $dBWm^{-2}Hz^{-1}$) by about 6 ± 1 dB. No explanation for this signal was found and the possibility that it could have been produced in the receiving system could not be excluded.

The purpose of the recent (February 1975) observations was to repeat the measurements of the SMS-1 satellite using a different receiver in order to resolve this question. Also the satellite reportedly changed its behavior in October 1974 and the power level had decreased by about 4 dB by the time the present observations were made. The February 1975 measurements would further be a check on the interference situation after the satellite had been in regular operation for several months.

The performance specifications for the SMS-1 satellite were described in detail in the report mentioned above, and will not be repeated here.

EQUIPMENT

The receiving system used for these tests was a dual-channel, cooled parametric amplifier connected to a dual linearly polarized feed. The receiver and feed were mounted in the prime focus of the NRAO 140-foot telescope. The system noise temperature was 60 K. Each receiver channel consisted of a cooled parametric amplifier followed by another parametric amplifier operated at room temperature. The combined bandwidth was 25 MHz between the 3 dB points. Following additional amplification in a transistor amplifier each channel was converted to the 150 MHz IF frequency. The local oscillator frequency was generated by a Hewlett Packard HP5105A frequency synthesizer with a times 6 multiplier. The synthesizer was locked to a 5 MHz reference frequency derived from a hydrogen maser frequency standard. The output of a broadband avalanche diode noise source was coupled into each receiver channel input to provide a calibration signal.

For this experiment one of the receiver channels was tuned to 1685 MHz and used for acquiring and peaking the antenna positioning on the SMS-1 satellite. In order to prevent overloading, the parametric amplifiers in this channel were turned off. The other receiver channel was tuned to 1665 MHz with a 20 MHz filter in the IF amplifier, and presented to a Hewlett Packard HP8554L spectrum analyzer with a frequency resolution of 300 kHz for signal processing. The spectrum analyzer sweep was driven externally with a Wavetek-model 111 function generator at 33.3 kHz/s. The vertical output from the spectrum analyzer was time averaged (both 1 s and 3 s integration times were available) and displayed on a Moseley 7035B X-Y recorder. Thus the average power spectrum in the 1660-1670 MHz band was recorded. The spectrum analyzer was equipped with both a voltage linear detector and a logarithmic detector, and records were made with both. The logarithmic display was calibrated in 1 dB steps with the attenuator in the spectrum analyzer and the 20 K noise source. The linear display was calibrated only with the 20 K noise source.

OBSERVATIONS

A total of 14 recordings of the SMS-1 satellite in the 1660-1670 MHz band were made with the 140-foot telescope pointed at the satellite and with the polarization angle adjusted for maximum response. Between each scan on the satellite, a baseline was obtained by pointing the telescope 2° off the satellite position. Frequency markers at 1600 MHz, 1665 MHz and 1670 MHz were superimposed on the baseline scans. A second baseline scan, with the 20 K calibration source on, was also made. Figures 1 and 2 show examples of the records on the X-Y plotter; Figure 1 shows the voltage linear condition, and Figure 2 shows the logarithmic output. Notice that Figure 2 includes a 1 dB step staircase calibration, and a second scan with the telescope pointed at the satellite and with the 20 K calibration on.

RESULTS

The results of the observations are shown in Figure 3. Here the observed power flux density represents the average of the scans. The peak occurring at about 1666 MHz has a power flux density of $(6.5 \pm 1.0) \times 10^{-24}$ $Wm^{-2}Hz^{-1}$ (-232 ± 1 $dBWm^{-2}Hz^{-1}$), which is 4 ± 1 dB above the CCIR limit for spectral-line frequency observations in this band. The satellite transmitter reportedly operated at a power level 4 dB below its nominal value during these experiments and, therefore, the potential power flux density might be 8 dB above the CCIR limit.

The predicted[(1)] radiation levels from the SMS-1 satellite are also shown on the graph. The cause of the discrepancy between the predicted and the observed values is not understood at the present time, although some clues to its origin might be found in the next paragraph.

TRANSMITTER SPECTRUM CHARACTERISTICS

A closer examination of the X-Y plots, for example Figure 1, shows a "sawtooth" modulation of the graph which is caused by the limited integration time (1 s) that allows the pulsed transmissions of the fast VISSR signal to "leak through" the integrator. The fact that this modulation is significantly weaker at the frequency where the observed radiation is strong suggests that the enhanced radiation is not caused by the fast VISSR, but that some other part of the transmission is responsible. Oscillograms of the transmissions (amplitude versus time) shown in Figure 4 confirm this. It appears that the slow, or stretched, VISSR could cause the peak at 1666 MHz. Although the instantaneous amplitude of the stretched signal is lower than that of the fast signal, the duty cycle of the slow signal is close to one and its average signal is stronger. The fact that the bandwidth of the 1666 MHz radiation is in the order of 1 MHz also agrees with the radiation bandwidth of the slow signal. The peak signal at 1666 MHz could, therefore, be caused by a higher order cross modulation product involving the slow VISSR signal.

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(1) From a memo to NASA Headquarters from C. Curtis Johnson, July 5, 1974, File No. 249.

APPENDIX

The calibration of the records was made using the 20 K calibration signal to determine the antenna temperature ΔT of the radiation from the SMS-1 satellite. The relation between the antenna temperature and the power flux density ΔP is determined in the following way:

$$\Delta p = \frac{k\Delta T}{\eta A_o} \qquad [Wm^{-2}Hz^{-1}] \quad ^{(1)}$$

where

ΔP	=	Power flux density	$[Wm^{-2}Hz^{-1}]$
k	=	Boltzmann's constant $1.38x10^{-23}$	$[Ws\ K^{-1}]$
ΔT	=	Antenna temperature	[K]
A_o	=	Geometrical aperture of the antenna	$[m^2]$
η	=	Aperture efficiency of the antenna	

In the case of the NRAO 140-foot antenna the geometrical aperture is 1430 m^2 and at 1665 MHz the aperture efficiency is 0.54. Then

$$\Delta p = \frac{1.38x10^{-23}}{0.54x1430} \Delta T = 1.79x10^{-26} \Delta T$$

$$\Delta p = 1.79x10^{-26} \Delta T \qquad [Wm^{-2}Hz^{-1}]$$

which is the conversion factor used to convert the observed antenna temperature to the power flux density. The antenna temperature ΔT is found by scaling the records, using the calibration signal of 20 K.

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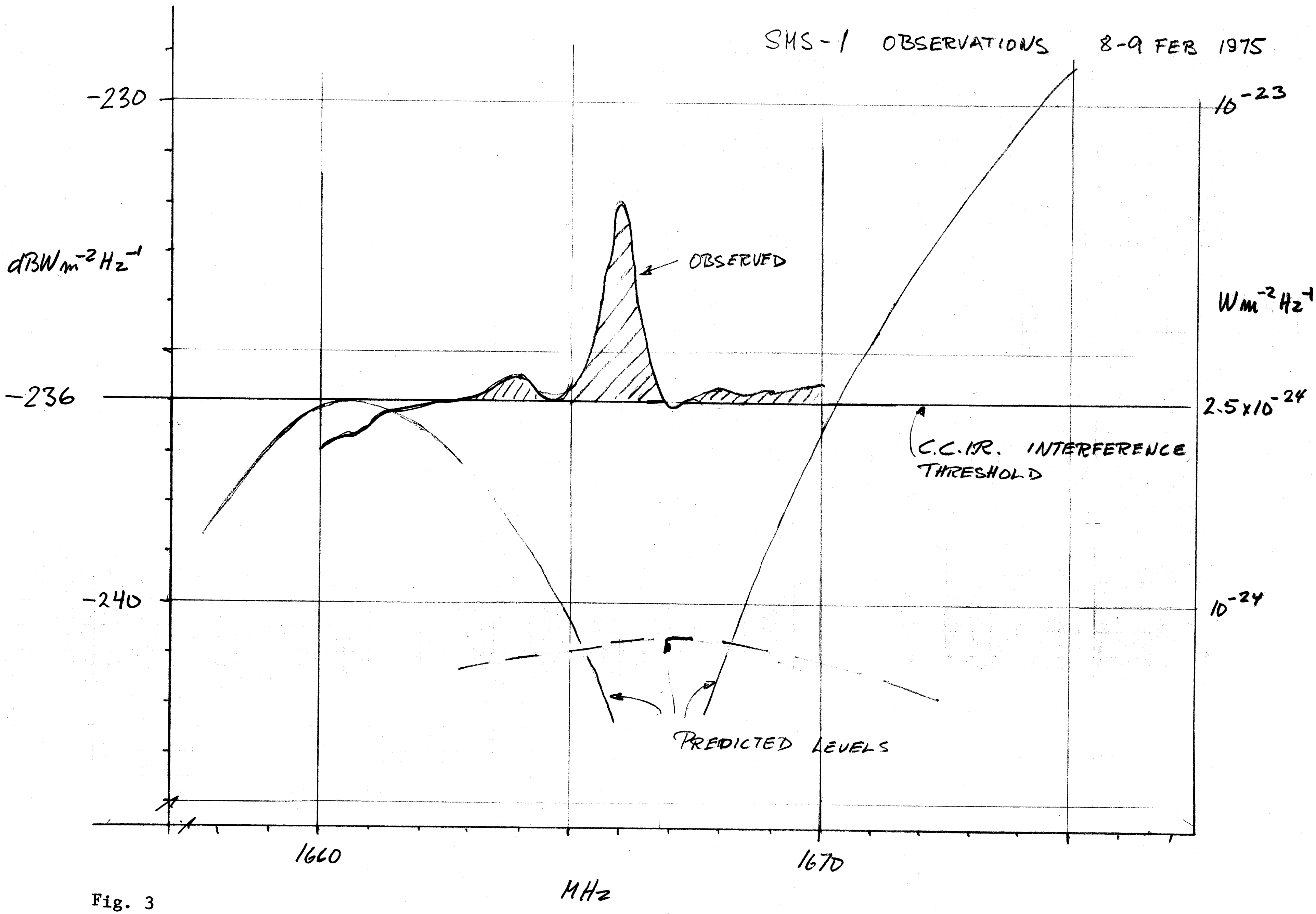
1) The equation assumes a linearly polarized source that is aligned with a linearly polarized antenna.

POSTSCRIPT

This report was discussed in a meeting on 14 March 1975 at NASA Headquarters in Washington, D. C. with representatives from NASA, NOAA and DOC. NASA confirmed that the measurements made by NRAO agree with their evaluation of the current emissions from SMS-1. The enhanced radiation near 1666 MHz seems to be caused by a 7th order product between the stretched VISSR and the telemetry signals. NASA estimates that SMS-2 has a lower radiation level in the 1660-1670 MHz band, and it was agreed that NRAO should make similar observations of SMS-2 as soon as possible.



SMS-1 OBSERVATIONS 8-9 FEB 1975
-230
-236
-240
dBWm-2Hz-1
10-23
Wm-2Hz-1
2.5x10-24
10-24
OBSERVED
C.C.I.R. INTERFERENCE THRESHOLD
PREDICTED LEVELS
1660
1670
MHz

Fig. 3

750224

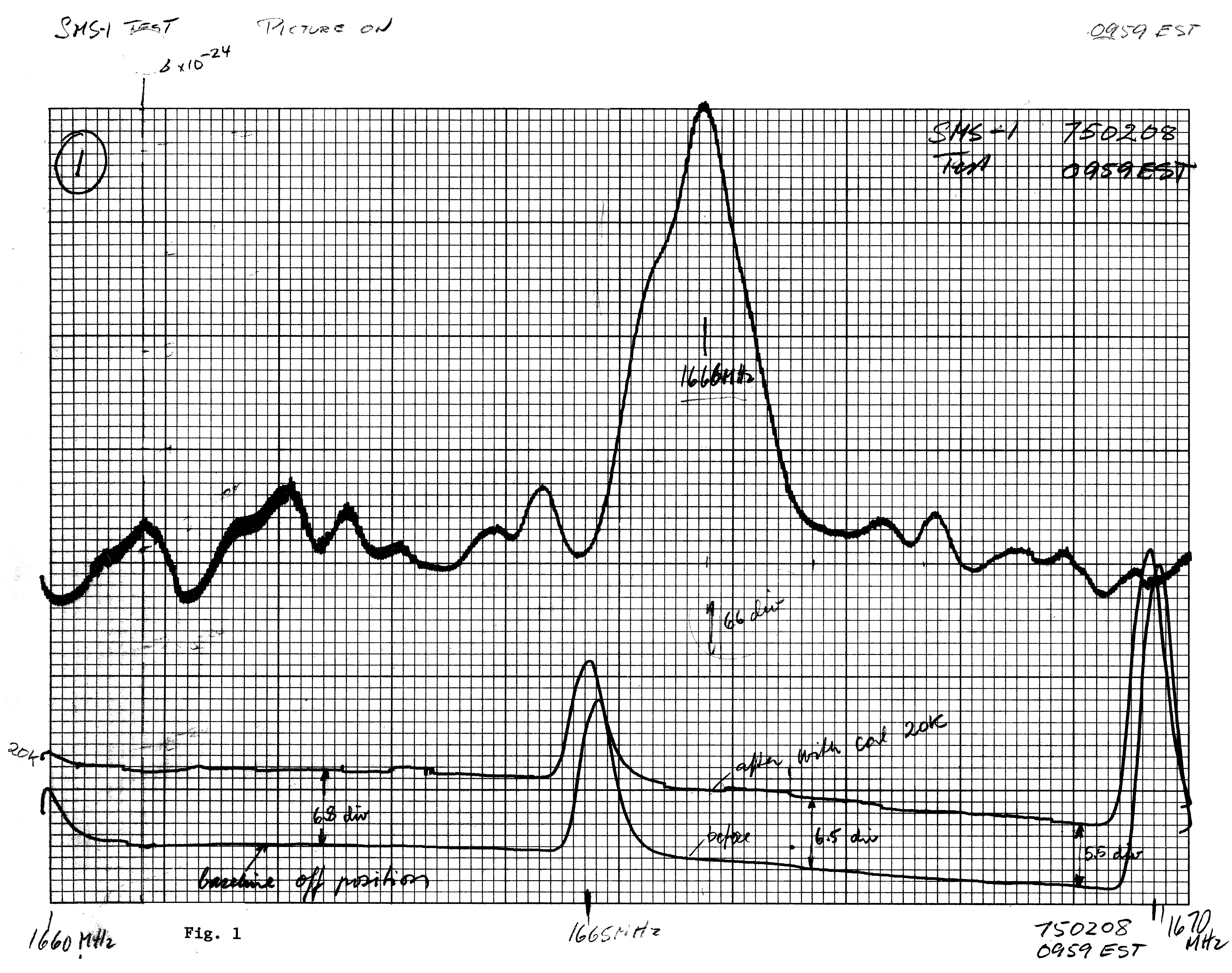

SMS-1 TEST
PICTURE ON
0959 EST
8 x10^-24
1
SMS-1 Test
750208
0959EST
1666MHz
66 div
204K
after with cal 20K
6.8 div
before
6.5 div
5.5 div
baseline off position
1660 MHz
1665MHz
750208
0959 EST
1670 MHz

Fig. 1

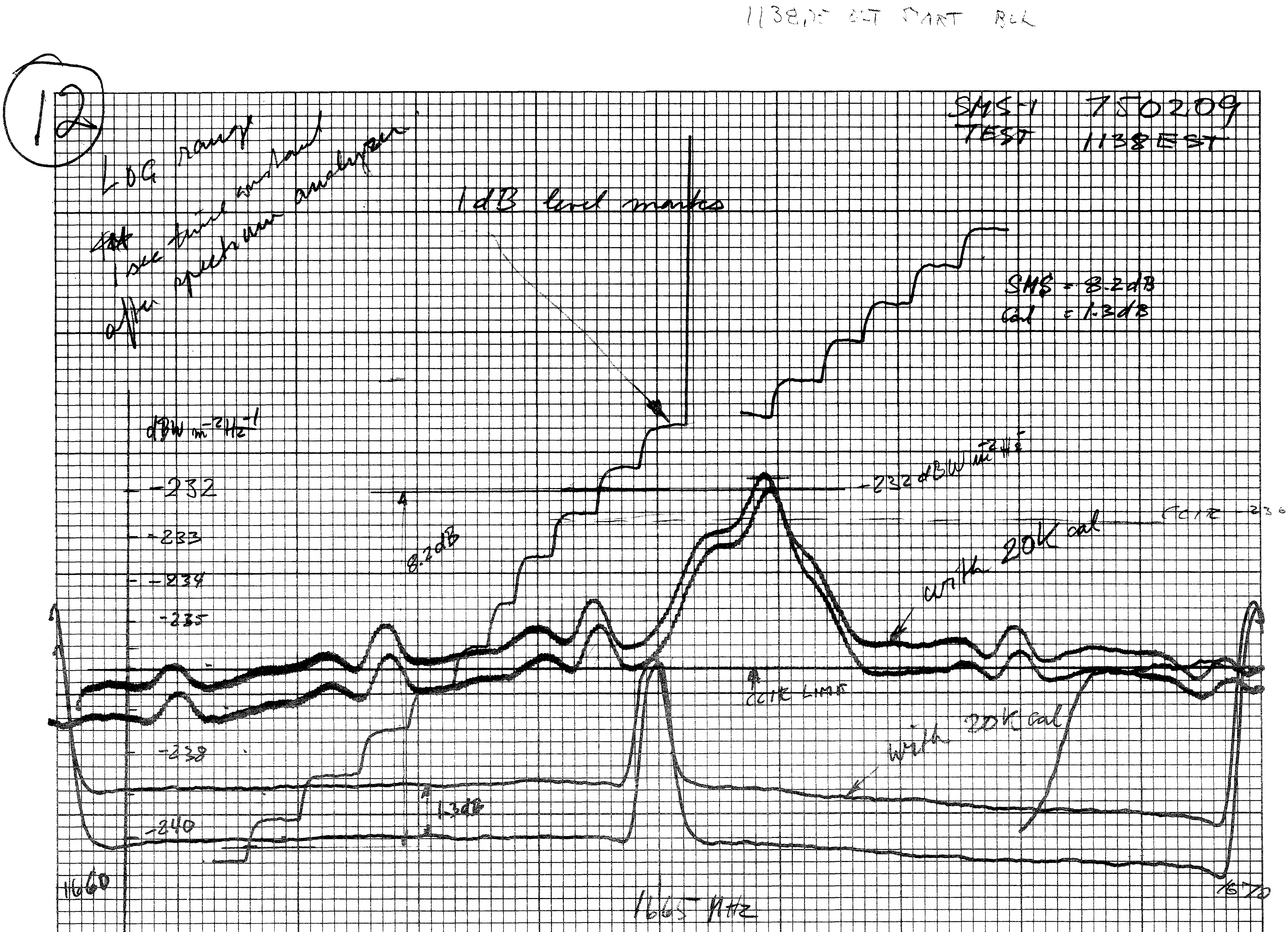
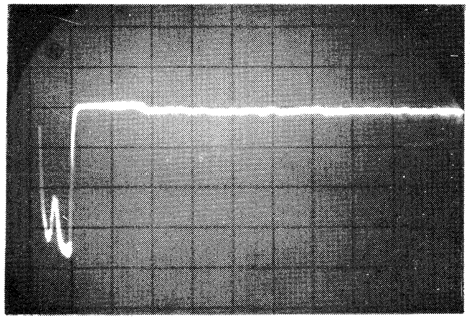
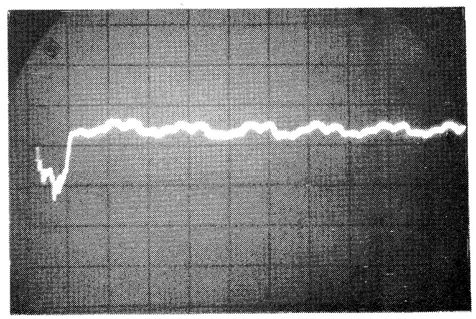

1138,5 EST START RLK
12
SMS-1 750209
TEST 1138EST
LOG ramp
1 sec time constant
after spectrum analyzer
1dB level marks
SMS = 8.2dB
Cal = 1.3dB
dBW m-2 Hz-1
-232
-233
-234
-235
-238
-240
8.2dB
1.3dB
-232 dBW m-2 Hz-1
with 20K cal
with 20K cal
1660
1665 MHz
1670

Fig. 2



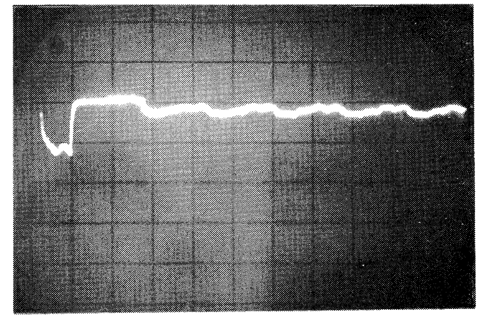
PICTURE ON

1660 MHz



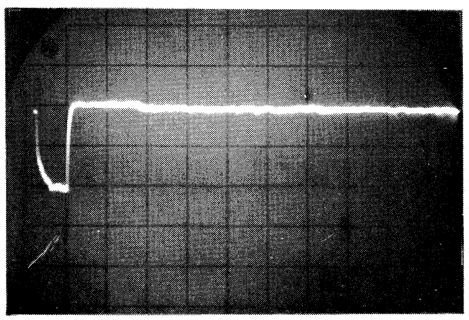
PICTURE ON

1666 MHz



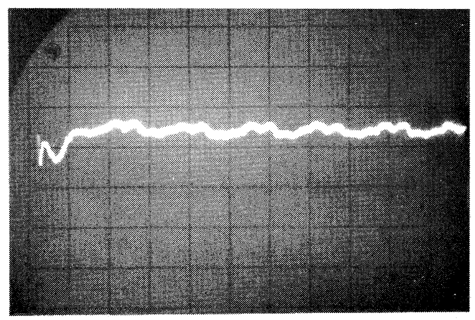
PICTURE ON

1670 MHz



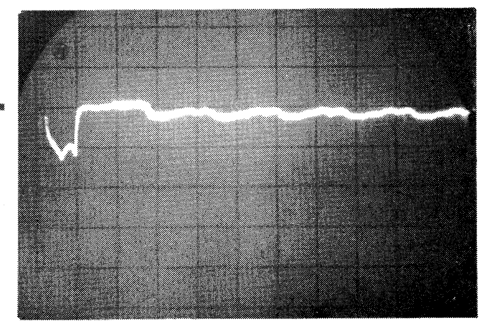
PICTURE OFF

1660 MHz



PICTURE OFF

1666 MHz



PICTURE OFF

1670 MHz 750208

FIGURE 4