echnical Memorandum NESS 54

A METHOD OF CONVERTING THE SMS/GOES WEFAX FREQUENCY (1691 MHz) TO THE EXISTING APT/WEFAX FREQUENCY (137 MHz)

John J. Nagle
Ground Systems Group

Office of System Engineering
Suitland, Md.
April 1974

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NESS 28 Calculation of Clear-Column Radiances Using Airborne Infrared Temperature Profile Radiometer Measurements Over Partly Cloudy Areas. William L. Smith, March 1971. (COM-71-00556)

(Continued on inside back cover)

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CONTENTS

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Washington, D.C.

ABSTRACT. This report describes the modifications required to convert the 1691.0-MHz signal from the SMS/GOES satellite to the 137-MHz frequency used by current satellites so that existing receiving and facsimile equipment can be used to the maximum possible extent. It also describes system parameters in sufficient detail so that those wishing to design their own equipment will be able to do so. Theoretical calculations were verified by test transmissions of WEFAX photographs at various signal levels. Reproductions of these photographs are included.

INTRODUCTION

The SMS/GOES* spacecraft, to be operated by the National Environmental Satellite Service (NESS) beginning in 1974, will transmit weather facsimile (WEFAX) pictures on an S-band frequency of 1691.0 MHz instead of on very high frequencies in the 135- to 137-MHz region currently used for ATS-spacecraft WEFAX and polar-orbiting satellite APT.

This report describes the modifications required to convert the 1691.0-MHz frequency so that existing equipment can be used where possible. It also describes system parameters for those wishing to design their own equipment.

Although the transmission frequency from the SMS/GOES spacecraft will be 1691.0 MHz, the type of transmission (frequency modulation), the signal characteristics, and the image format of pre-SMS/GOES APT and WEFAX transmissions will not be changed. Current facsimile recording equipment may, therefore, continue to be used. With the relatively simple frequency conversion equipment described herein, current APT/WEFAX receivers also may still be used. Both the present APT/WEFAX pictures and those from SMS/GOES can be read out by simply connecting the present receiver to either a suitable VHF antenna or to the S-band conversion equipment described herein.

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*SMS stands for Synchronous Meteorological Satellite; GOES, for Geostationary Operational Environmental Satellite. Both names are used for the same spacecraft.

DESCRIPTION OF EQUIPMENT

A block diagram of the conversion equipment is shown in figure 1. Descriptions of the various components used in the experimental model are given below. These hardware items are identified by model and manufacturer, but any equipment having similar characteristics will be satisfactory.

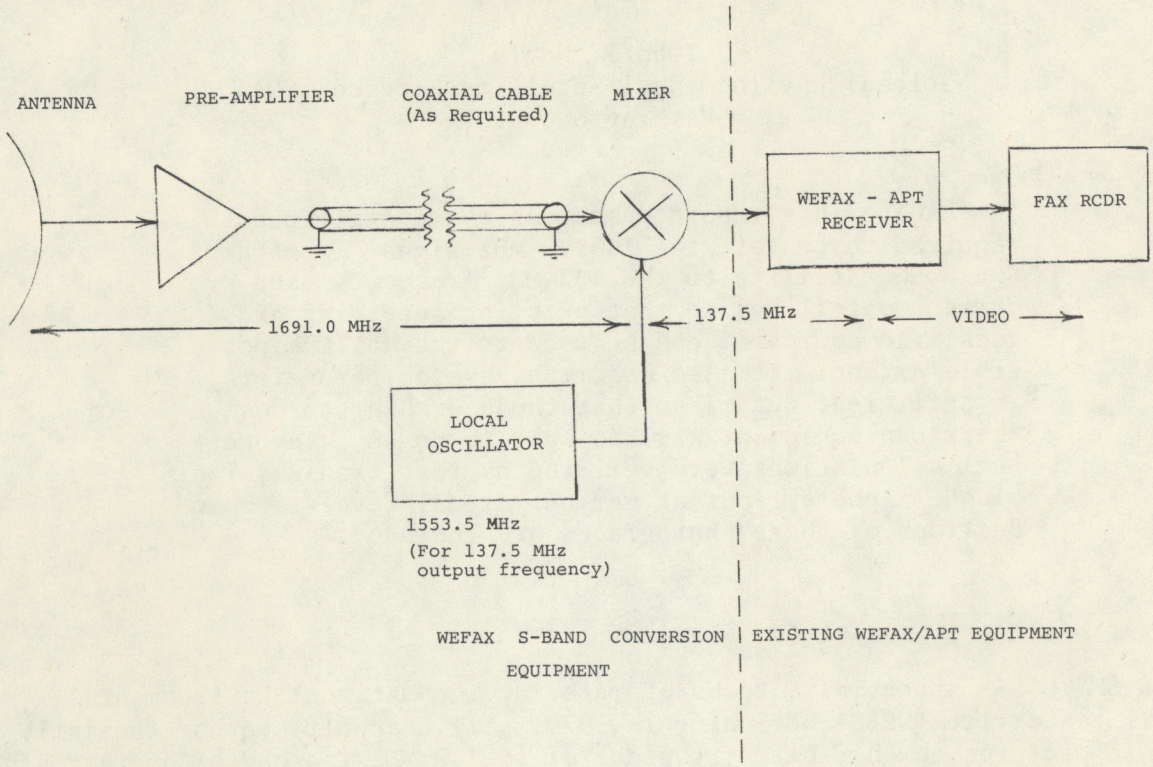


Figure 1.--Block diagram of S-band conversion equipment.

Antenna Assembly

The antenna assembly consists of a 3-m (10-ft) diameter, paraboloidal dish with a linearly polarized feed adjustable to any polarization angle. The gain is approximately 32 dB. The method of mounting the antenna to its supporting structure will be determined in part by the structure to which the antenna is attached and in part by the expected elevation angle of the satellite at the station.

Antenna and Feed

The antenna assembly shown in figures 2 and 3 consists of an antenna and feed, Type P-10-17C, supplied by the Andrew Corporation, 10500 W. 153rd St., Orland Park, Ill., 60462, U.S.A. Also shown is a vertical tilt mount type VT-10 and a type "N" adapter, Part #2260B, both available from Andrew. Approximate total cost of the assembly is $1500.

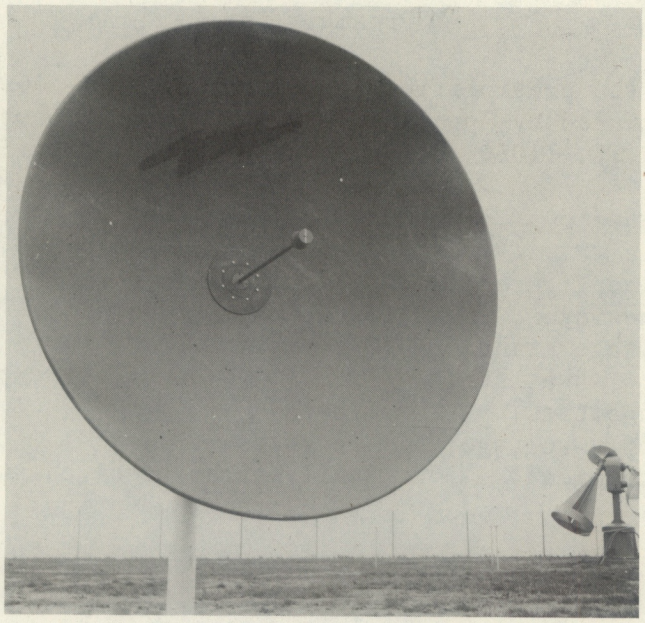
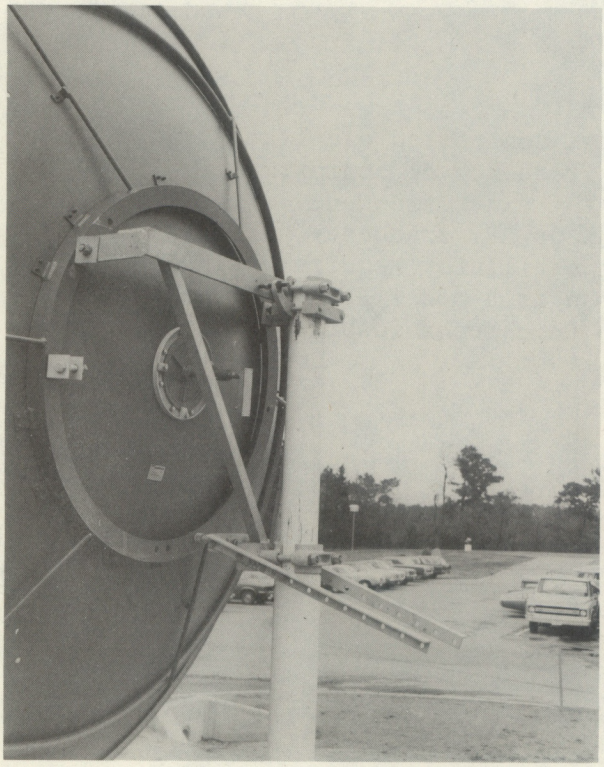


Figure 2.--Antenna and feed.



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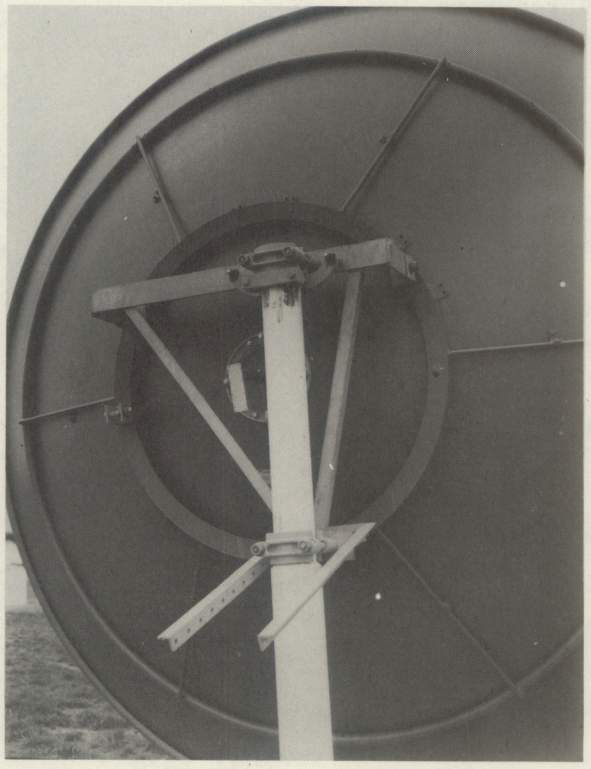


b

Figure 3.--The hardware for mounting the antenna to a 4-in (10-cm) pipe is shown in these photographs. The solid-state preamplifier may also be seen, attached directly to the antenna output terminal.

Preamplifier

Figure 4 shows the preamplifier, Model HFM-3 (TX) - 1690/50, approximate cost $900, manufactured by Applied Research, Inc., 76 South Bayles Ave., Port Washington, N.Y., 11050, U.S.A. The principal specifications are:

Frequency	1691.0 MHz
Gain	20 dB minimum
Noise figure	4.5 dB maximum
Bandwidth	30-50 MHz
Voltage standing wave ratio	2:1 maximum
Connectors	Type N
Supply voltage	-12 volts
Mechanical	Small weatherproof chassis for antenna mounting

Local Oscillator-Mixer Assembly

The oscillator and mixer (fig. 5) are mounted on the same chassis for convenience.

Local Oscillator

The local oscillator contains a crystal-controlled oscillator and a frequency multiplier to provide an output frequency of approximately 1553 MHz with an output power of 5 milliwatts. The exact frequency will be the difference between 1691.0 MHz and the WEFAX or APT frequency normally used by the individual receiving station. This oscillator requires a supply voltage of +12 volts. The local oscillator shown is a model EY-118BD, manufactured by Greenray Industries, 840 West Church Rd., Mechanicsburg, Pa., 17055, U.S.A. The cost is approximately $900.

Mixer

The mixer shown is a Relcom Model M1G wideband, low noise, double balanced mixer. The salient specifications are:

Conversion loss	7.5 dB maximum
Noise figure	7.5 dB maximum
Isolation	25 dB minimum

The cost is approximately $200. Relcom is located at 3333 Hillview Ave., Palo Alto, Calif., 94304, U.S.A.

Power Supplies

If the above components are used, two power supplies will be required, one for the preamplifier and one for the local oscillator. These are estimated at $100 each.

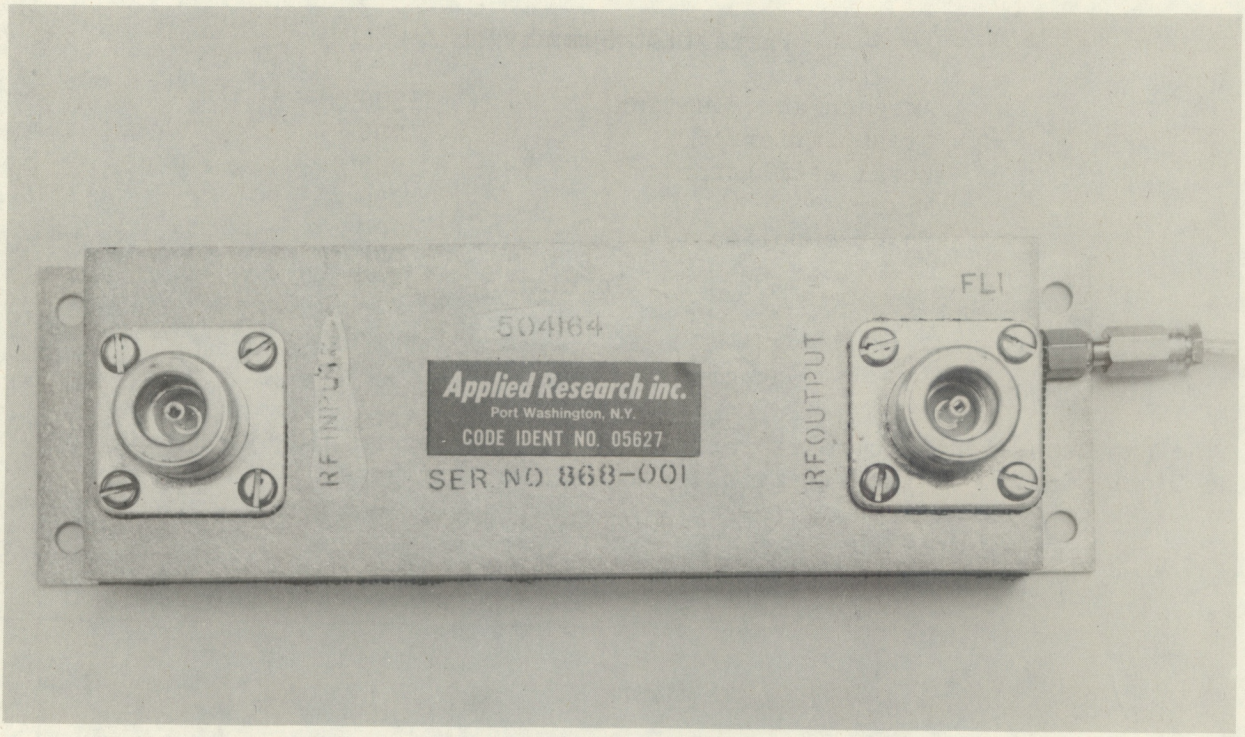


Figure 4.--S-band, solid-state preamplifier.

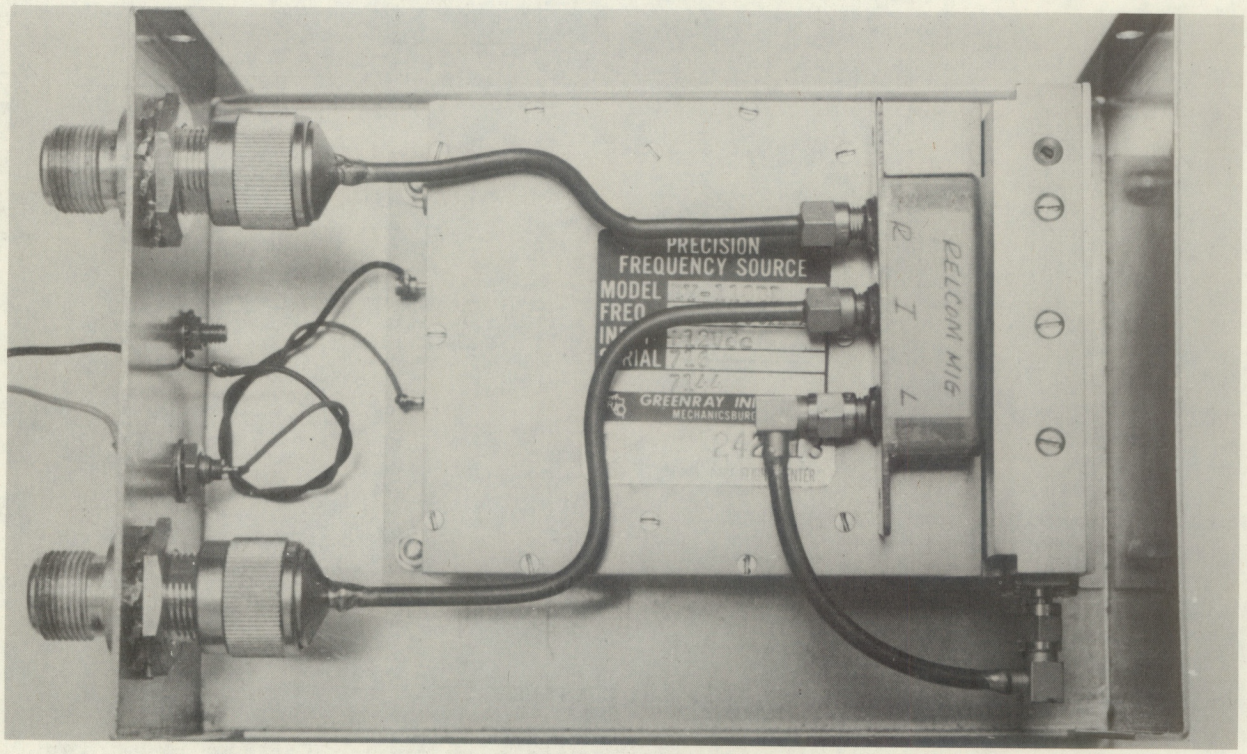


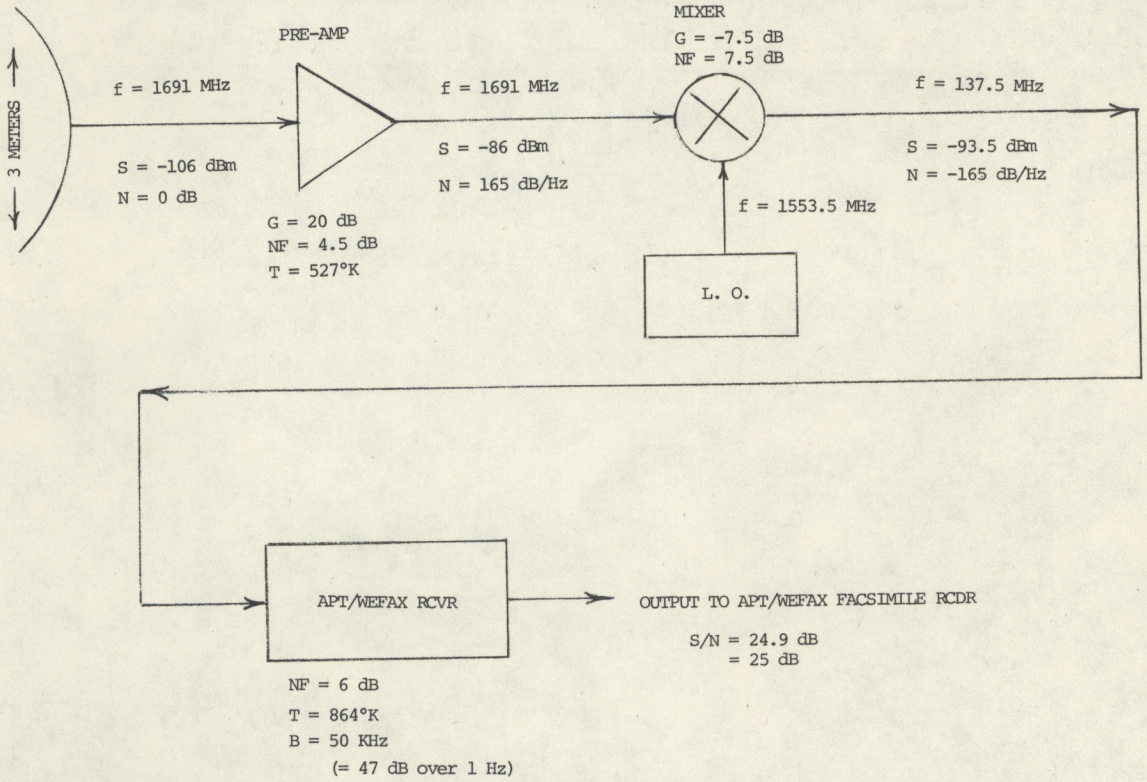
Figure 5.--Local oscillator and mixer assembly. The mixer has the three coaxial cables attached to it. This assembly courtesy of National Aeronautics and Space Administration (NASA).

Parts List Summary

Antenna and mounting	$1500
Preamplifier	900
Local oscillator	900
Mixer	200
Power supplies (2)	200
Total	$3700

SYSTEM ANALYSIS

The expected signal-to-noise ratio (SNR) can be determined by considering the block diagram of the receiving system shown in figure 6.



NOTE: All parameters taken from manufacturers' published data.

Figure 6.--Block diagram of the S-band WEFAX converter.

The analysis is based on the following assumptions:

1. The antenna is at an elevation angle high enough for the sky noise temperature to be considered negligible compared with that of the preamplifier. Elevation angles greater than 5° to 10° should fulfill this requirement.

2. The noise temperature of the antenna is negligible compared with that of the preamplifier.

3. The preamplifier and mixer are located at, or sufficiently close to, the antenna so transmission line losses can be neglected.

4. The signal level at the ground will be -106 dBm.

These assumptions should be valid in most cases. The major exception will be for the first assumption (high look angle) for a satellite near the horizon. In this situation the link margin will be reduced, but the signal should still be easily usable.

SIGNAL-TO-NOISE RATIO

The noise figure (NF) of the overall system can be calculated using the parameters given in figure 6.

$$NF = \underbrace{NF_1}_{\text{Preamplifier}} + \underbrace{\frac{(NF_2-1)}{G_1}}_{\text{Mixer}} + \underbrace{\frac{(NF_3-1)}{G_1\,G_2}}_{\text{APT receiver}}$$

where

$$NF_1 = 4.5 \text{ dB} = 2.82$$

$$NF_2 = 7.5 \text{ dB} = 5.62$$

$$NF_3 = 6 \text{ dB} = 3.98$$

$$G_1 = 20 \text{ dB} = 100$$

$$G_2 = -7.5 \text{ dB} = \frac{1}{5.62} = 0.1775$$

Hence

$$NF = 2.82 + \frac{(5.62-1)}{100} + \frac{(3.98-1)}{100 \times 0.1775}$$

$$= 2.82 + 0.0462 + 0.168 = 3.034,$$

$$= \text{approximately } 5.0 \text{ dB.}$$

The theoretical minimum thermal noise density is -174 dBm/Hz for a noise-free receiver. Hence for a receiver with a 5-dB noise figure the noise density becomes -174-{-log (3.034-1)} = -171 dBm/Hz. The receiver used in these tests had a bandwidth of 50 kHz (= 47 dB above 1 Hz). Hence the noise level at the input is equivalent to N = -171 + 47 = -124 dBm. A signal level of -106 dBm is expected so that the signal-to-noise ratio is SNR = -106-(-124) = 18 dB.

Since a SNR of 12 to 14 dB is required to give essentially noise-free pictures, these calculations show that a 4- to 6-dB margin exists. Actually an additional 3-dB improvement can be obtained by reducing the receiver bandwidth from 50 kHz to the 26 kHz actually required.

The above analysis indicates it should be possible to use a 2.5-m (8-ft) diameter antenna reflector, with a 2-dB gain reduction, and still receive "clean" copy in most cases.

Since the preamplifier is an expensive item it is of interest to calculate the expected system performance without it. Using the parameters given in figure 6, the overall noise figure for this case is given by:

$$NF = 5.61 + \frac{3.98 - 1}{1/5.61}$$

$$= 5.61 + 16.72 = 22.23 \ (= 13.5 \text{ dB})$$

The noise power input is given by:

$$N = -174 \text{ dBm/1 Hz} + \underbrace{47 \text{ dB}}_{\substack{50 \text{ kHz} \\ \text{bandwidth}}} + \underbrace{10 \log (22.33-1)}_{NF} = -113.7 \text{ dBm}$$

As the expected signal strength from the satellite is -106 dBm the signal-to-noise ratio is given by:

$$SNR = -106 \text{ dBm} - (-113.7 \text{ dBm}) = 7.7 \text{ dB}$$

This signal-to-noise ratio is insufficient for noise-free images although usable pictures may be obtained under some conditions.

These results were verified by tests described in the next section of this report.

PERFORMANCE OF SYSTEM

The equipment was connected as shown in the block diagram of figure 6; figure 7 is a photograph of the equipment.

The system was calibrated by connecting the output of a calibrated signal generator with an output of -106 dBm to the receiver and noting the reading on the receiver signal strength meter. The receiver was then connected to the antenna and the transmitter output adjusted to obtain the same reading. This level was then used as a reference, and precision attenuators were inserted or removed from the transmitter to adjust the signal level above and below this value.

The tests consisted of transmitting WEFAX or APT pictures at various signal levels and comparing the resulting pictures with the theoretical calculations.

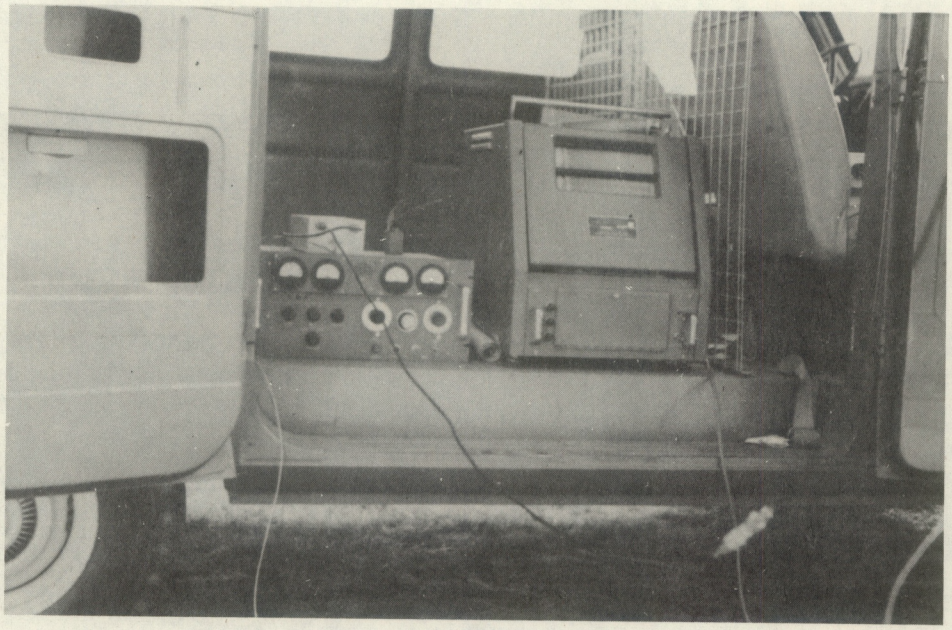


Figure 7.--The WEFAX receiver and recorder. The S-Band converter local oscillator and mixer assembly can be seen on top of the receiver.

The results are shown in figures 8 to 15. In comparing the pictures, allowances should be made for degradation in reproduction as well as for differences in picture content. Figure 8 was received at a level of 10 dB above the expected level and is intended to be used as a reference. Figure 9 was received at the expected signal level (-106 dBm) and is essentially of the same quality as figure 8. Figures 10 and 11 show the effect of a reduction in signal strength of 3 and 6 dB, respectively, with no apparent loss in detail. The effect of a 9-dB reduction in signal level is shown in figure 12; this picture is of doubtful value. The results of these tests agree closely with theoretical predictions.

A second series of pictures was run without the preamplifier; the antenna output was connected directly to the mixer. Figure 13 was received at the reference level (-106 dBm) and, although some noise is present, the picture appears usable. A 3-dB reduction in signal strength was made for figure 14, and the picture quality is marginal. With a 6-dB reduction in signal level (fig. 15) the picture is unusable.

In summary, test results show that the use of a 3-m diameter antenna and a low-noise preamplifier gives a 4- to 6-dB margin. This margin should be ample to ensure reception of essentially noise-free pictures from satellites close to the horizon. If only high altitude satellites are to be received, a smaller antenna with a low noise preamplifier should be acceptable. Operation without a preamplifier is not recommended unless an antenna larger than 3 m is used, and then only for high altitude satellites. Even then, little, if any, gain margin exists.

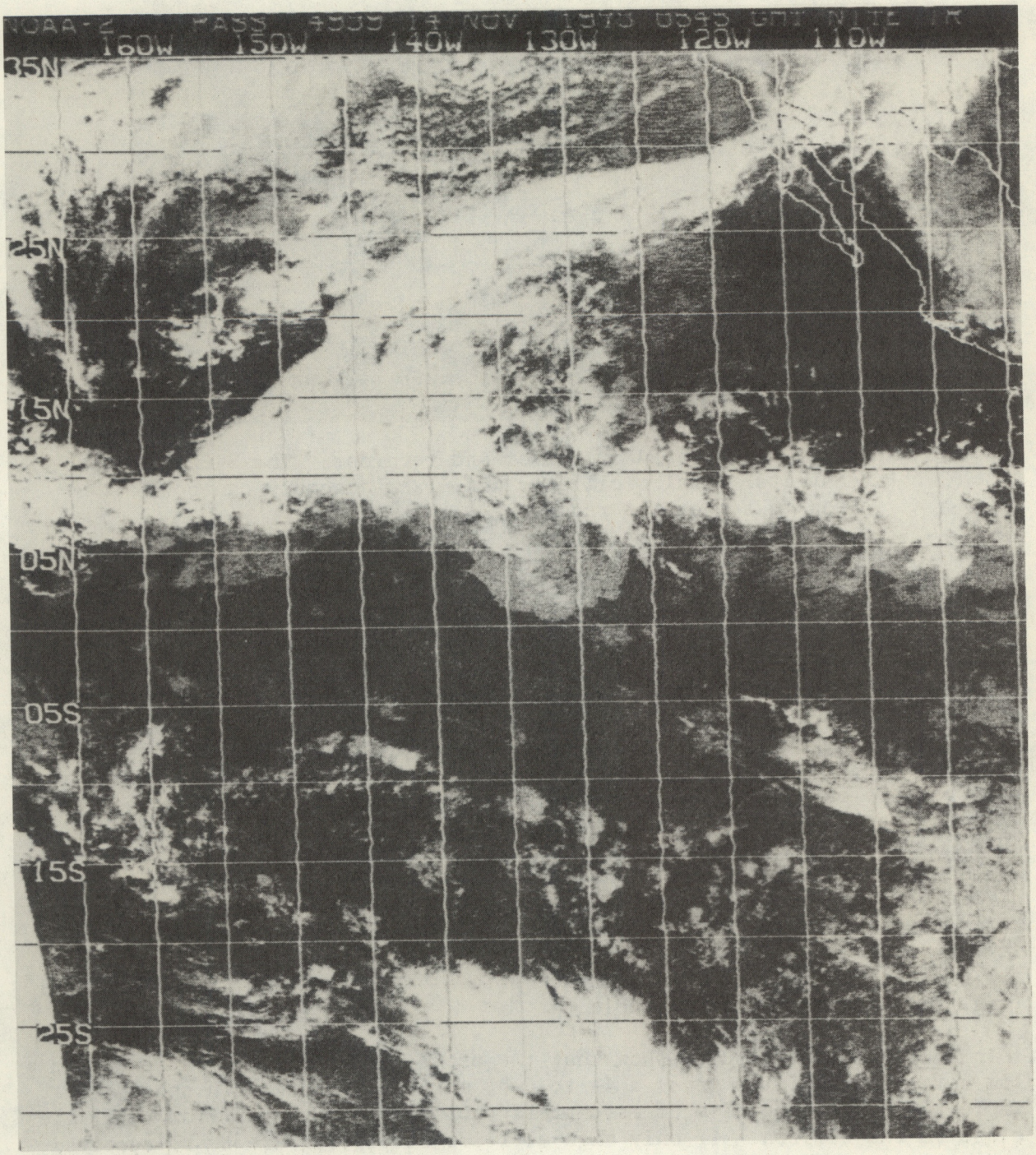


Figure 8.--Reference photograph received at a level of 10 dB above the expected signal level.

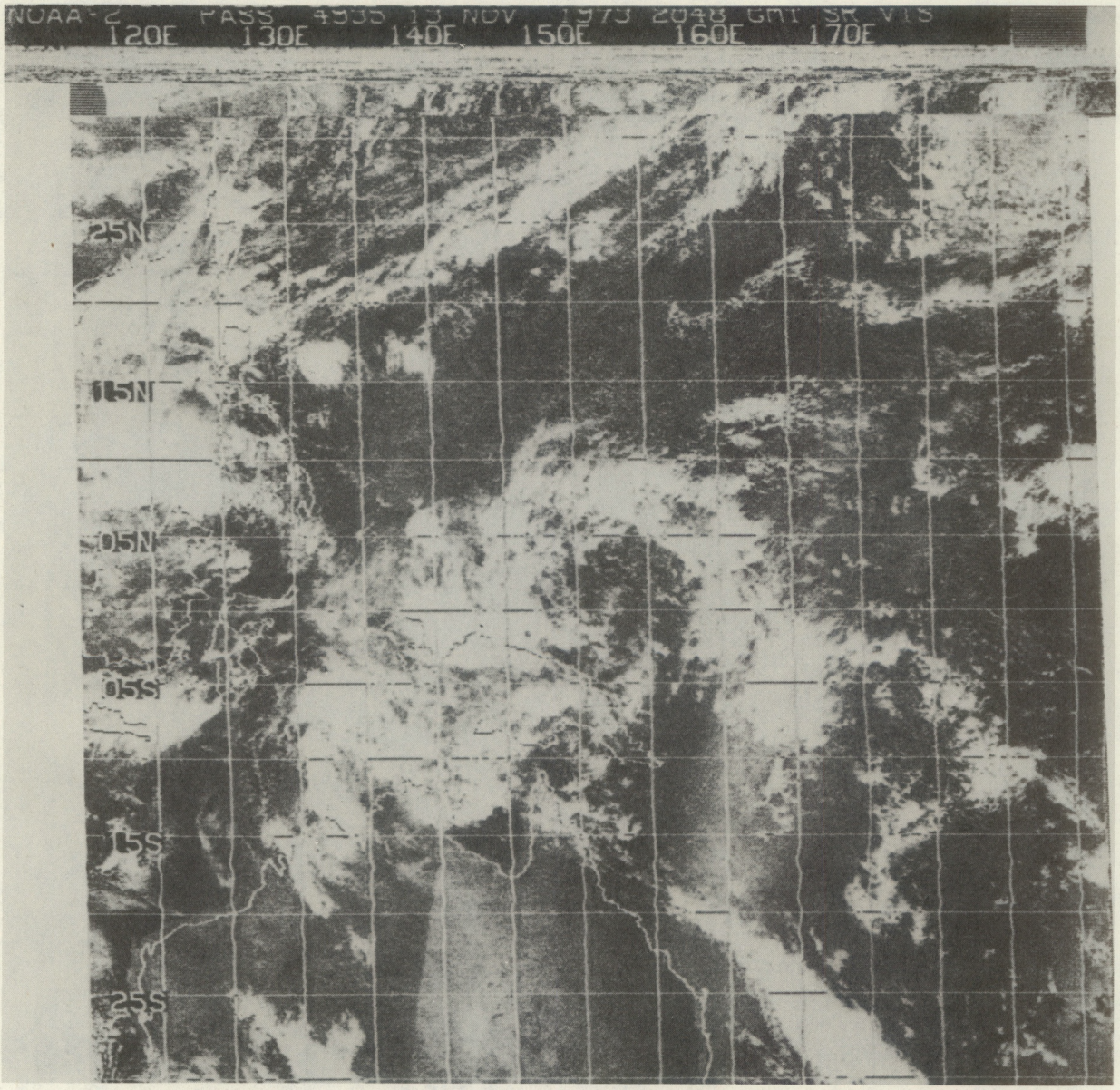


Figure 9.--Photograph received at expected signal level of -106 dBm.

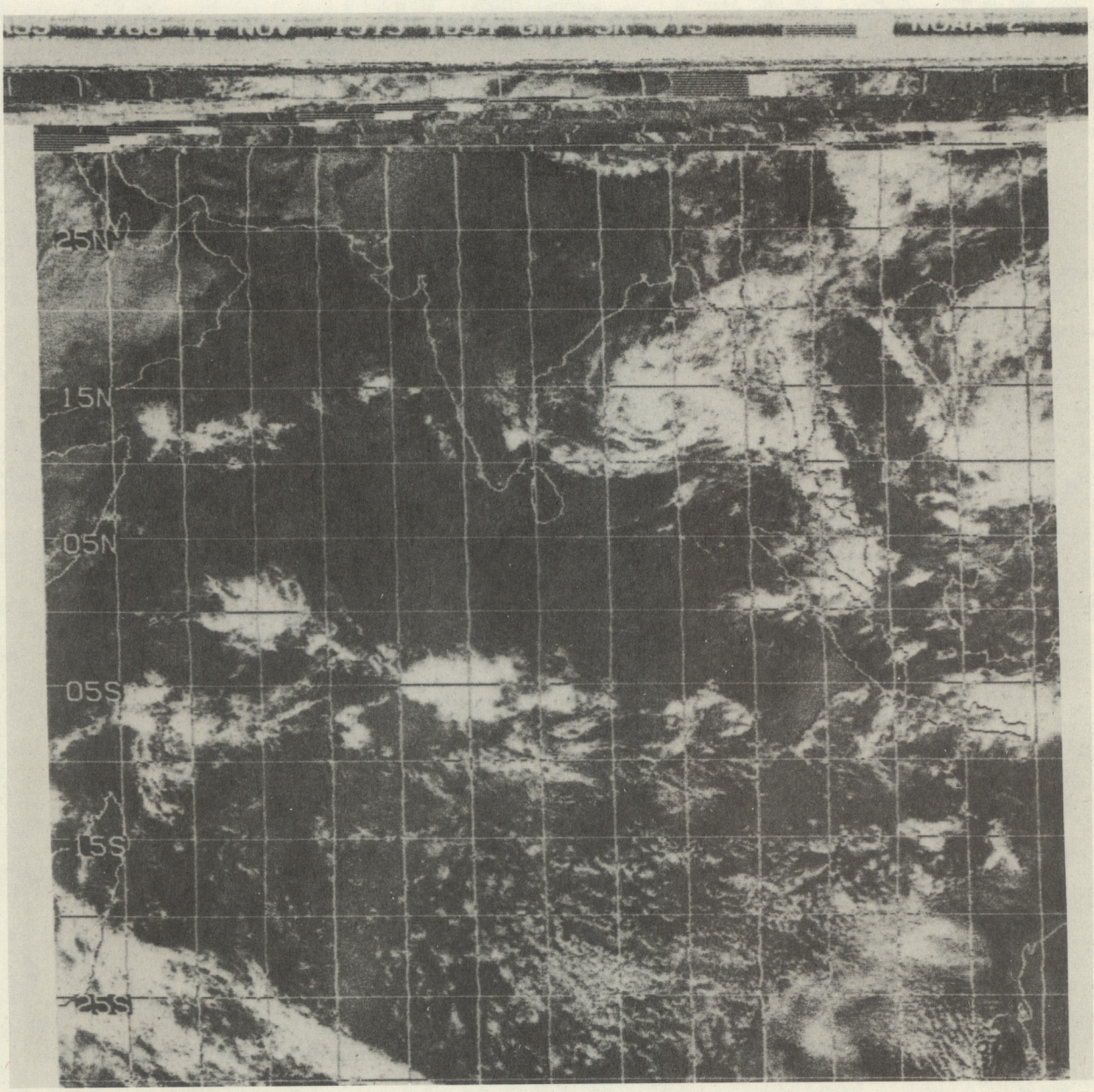


Figure 10.--This picture was received at a signal level of -103 dBm, 3 dB less than the expected level.

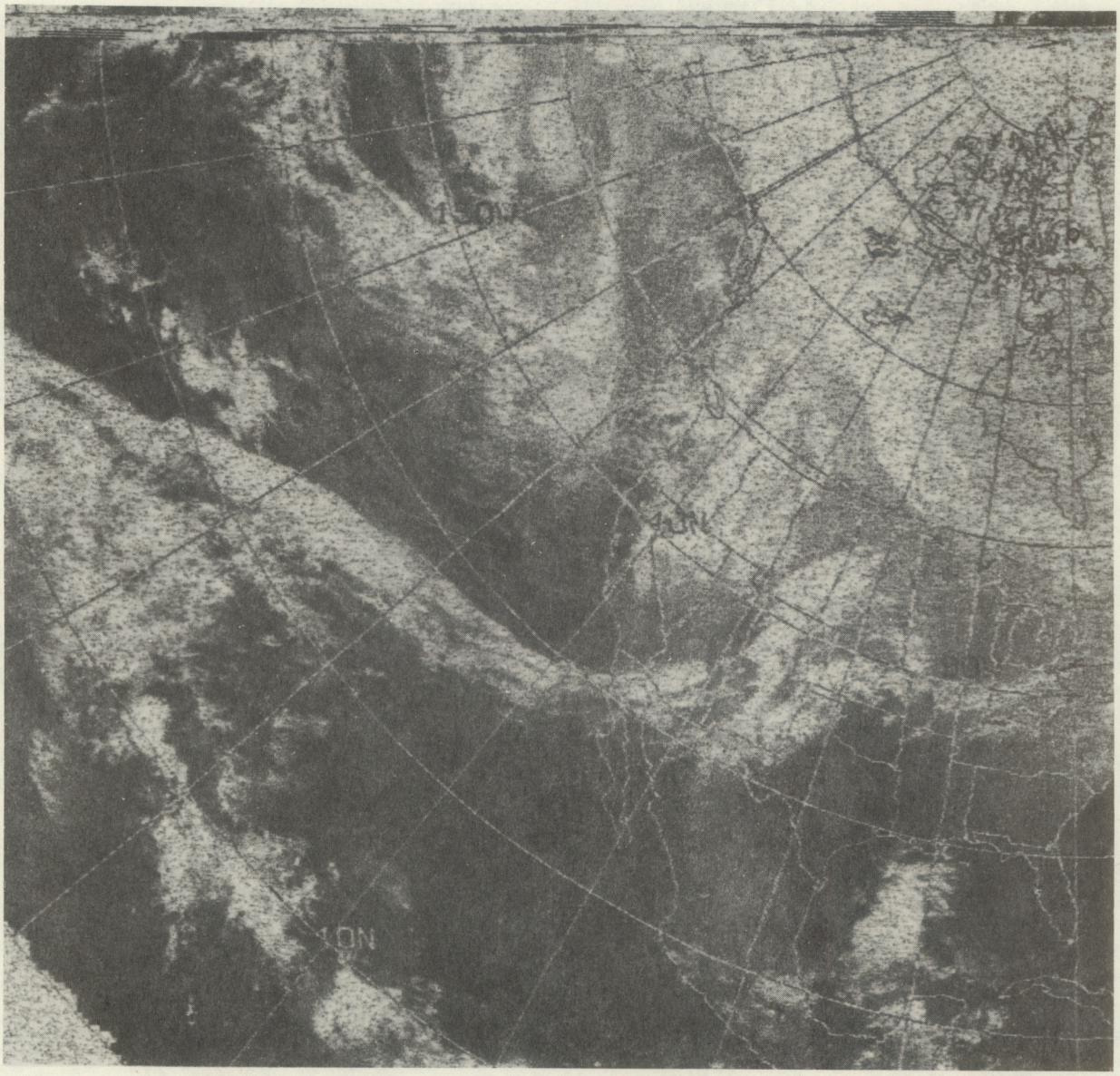


Figure 11.--A signal level of 6 dB below the expected level was used to transmit this picture. Noise is clearly evident.

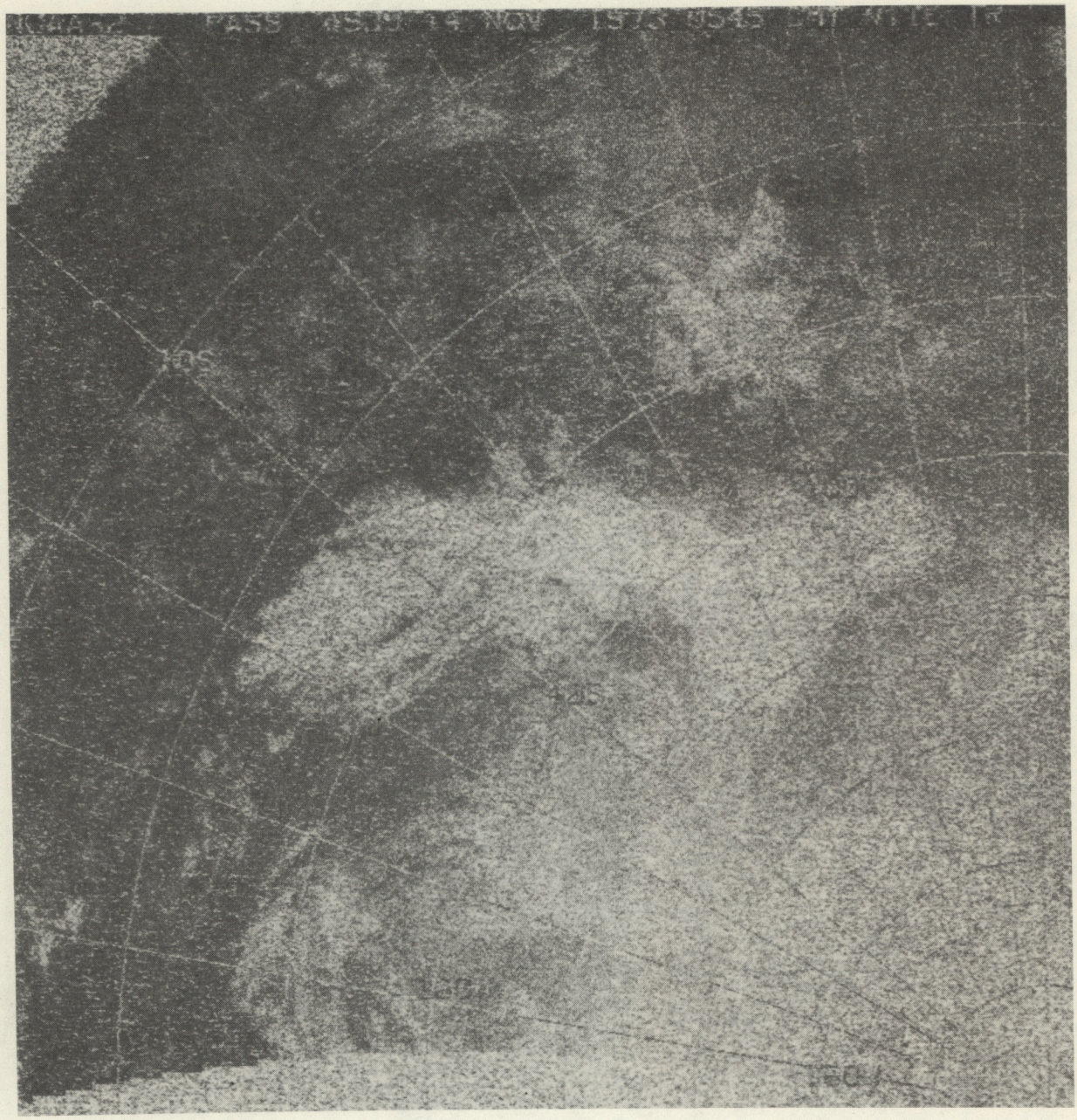


Figure 12.--Reducing the strength to -115 dBm, 9 dB below the expected level, results in a photograph that is nearly useless.

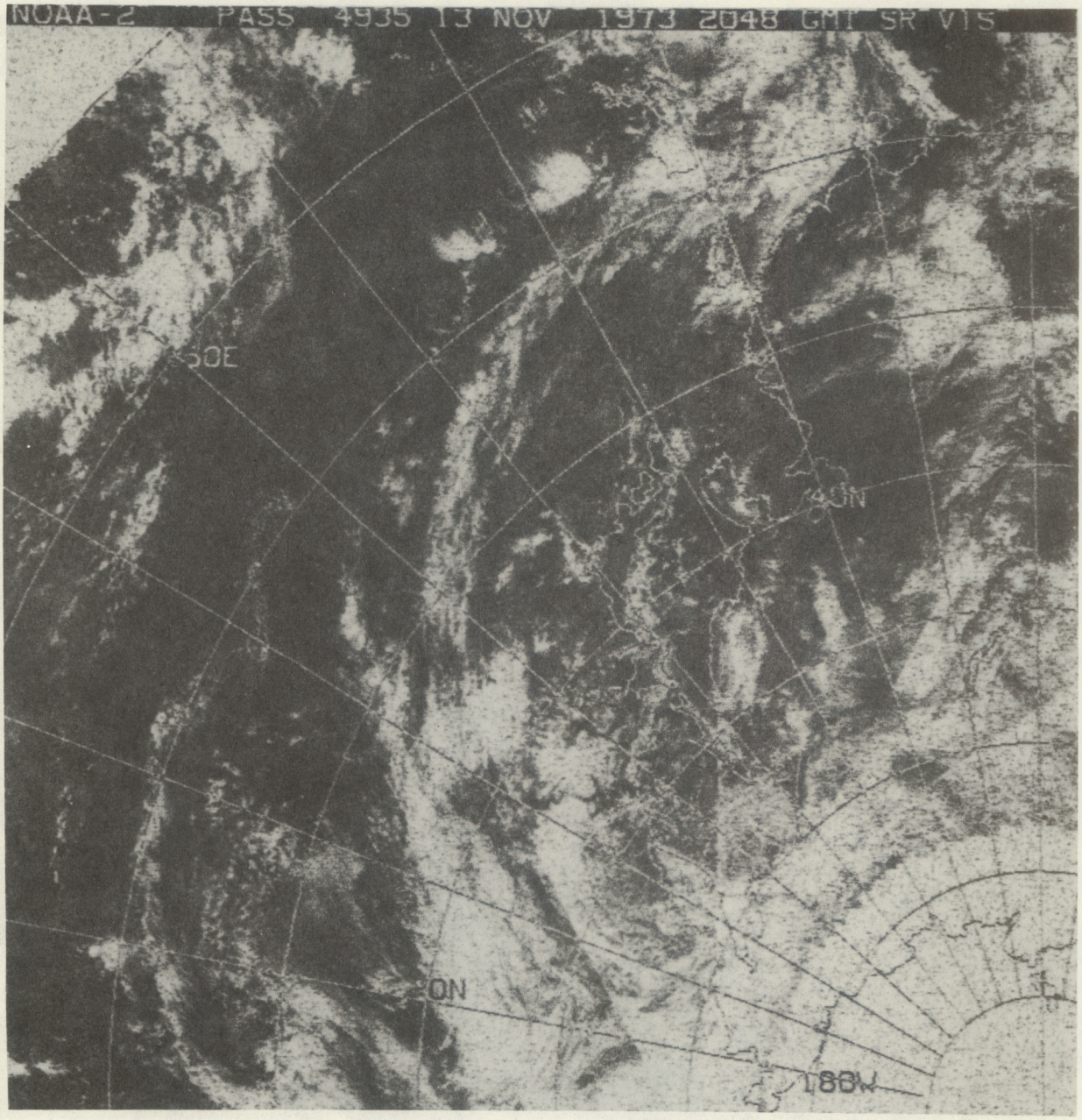


Figure 13.--This is an image received at the expected signal level of -106 dBm but without a preamplifier. Noise is evident, but the image appears useful for some applications.

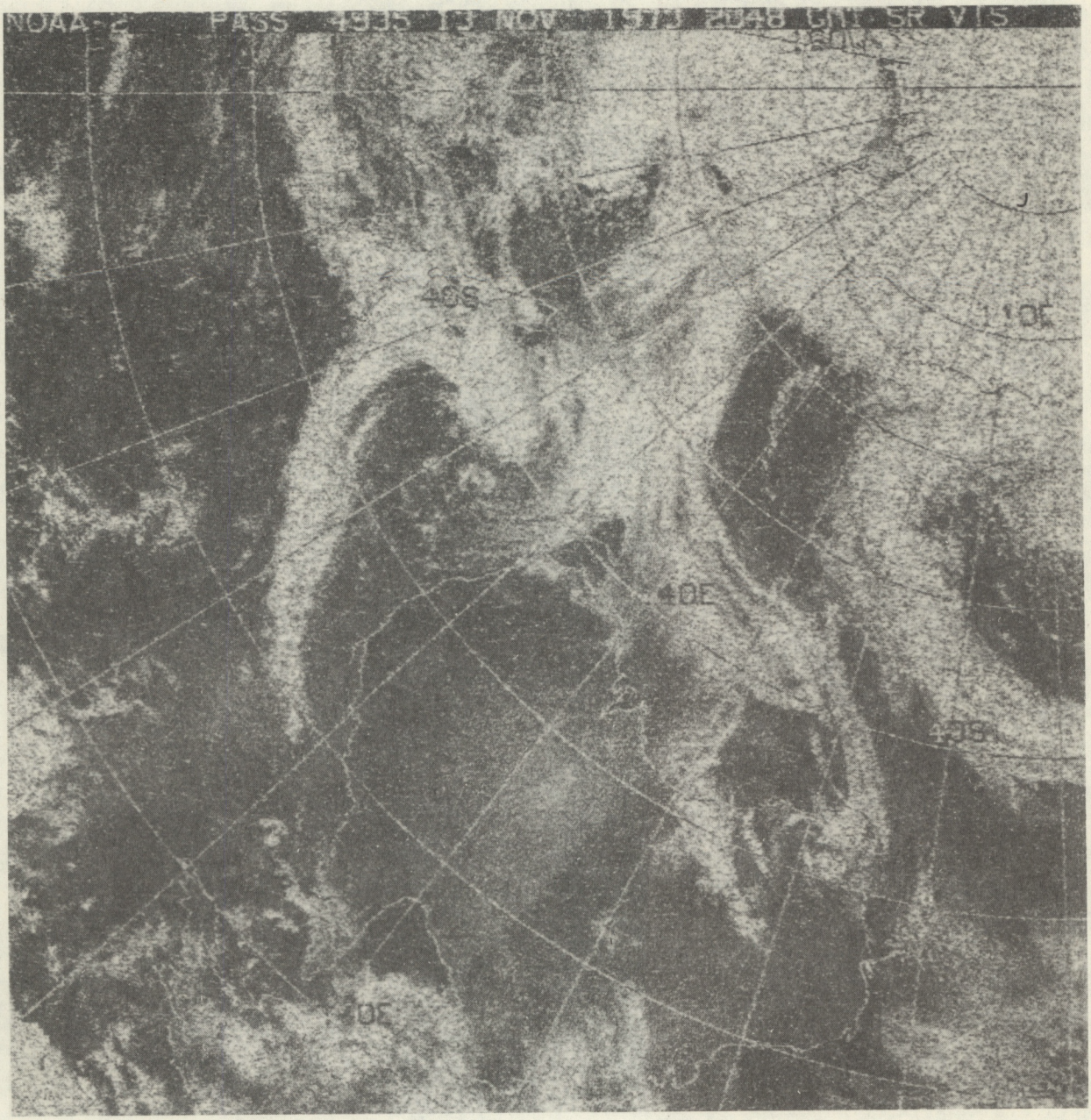


Figure 14.--As seen above, a 3-dB reduction in signal level, without a preamplifier, results in an image of marginal value.

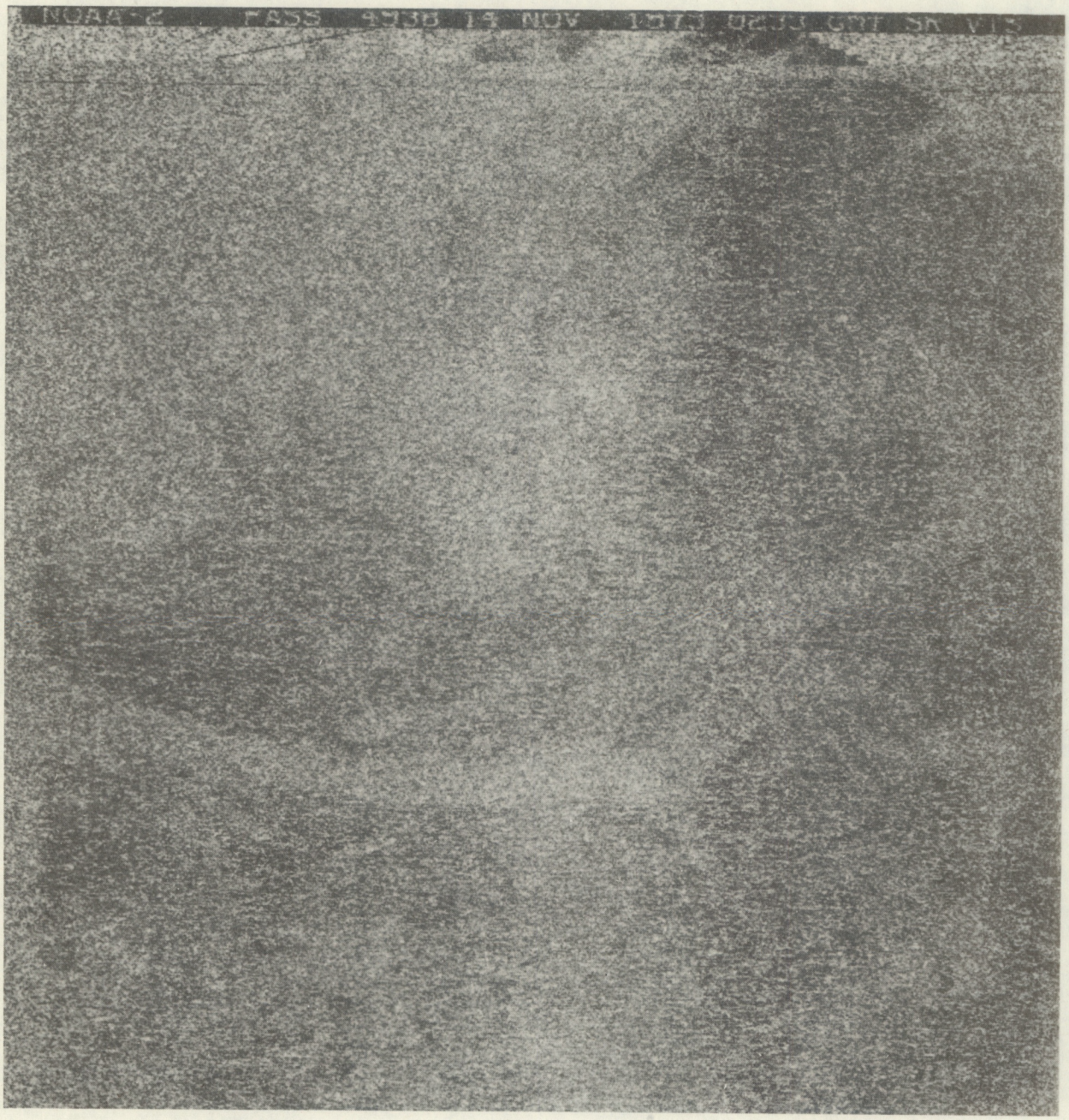


Figure 15.--Without a preamplifier, a 6-dB loss of signal gives a picture that is worthless.

ADDITIONAL INFORMATION

This report has described the equipment needed to receive future WEFAX signals at 1691 MHz. Additional information may be obtained by writing to:

The Director
National Environmental Satellite Service
National Oceanic and Atmospheric Administration
Washington, D.C. 20233
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(Continued from inside front cover)

NESS 29 The Operational Processing of Solar Proton Monitor and Flat Plate Radiometer Data. Henry L. Phillips and Louis Rubin, May 1972. (COM-72-10719)

NESS 30 Limits on the Accuracy of Infrared Radiation Measurements of Sea-Surface Temperature From a Satellite. Charles Braun, December 1971. (COM-72-10898)

NESS 31 Publications and Final Reports on Contracts and Grants, 1970--NESS. December 1971. (COM-72-10303)

NESS 32 On Reference Levels for Determining Height Profiles From Satellite-Measured Temperature Profiles. Christopher M. Hayden, December 1971. (COM-72-50393)

NESS 33 Use of Satellite Data in East Coast Snowstorm Forecasting. Frances C. Parmenter, February 1972. (COM-72-10482)

NESS 34 Chromium Dioxide Recording--Its Characteristics and Potential for Telemetry. Florence Nesh, March 1972. (COM-72-10644)

NESS 35 Modified Version of the Improved TIROS Operational Satellite (ITOS D-G). A. Schwalb, April 1972. (COM-72-10547)

NESS 36 A Technique for the Analysis and Forecasting of Tropical Cyclone Intensities From Satellite Pictures. Vernon F. Dvorak, June 1972. (COM-72-10840)

NESS 37 Some Preliminary Results of 1971 Aircraft Microwave Measurements of Ice in the Beaufort Sea. Richard J. DeRycke and Alan E. Strong, June 1972. (COM-72-10847)

NESS 38 Publications and Final Reports on Contracts and Grants, 1971--NESS. June 1972. (COM-72-11115)

NESS 39 Operational Procedures for Estimating Wind Vectors From Geostationary Satellite Data. Michael T. Young, Russell C. Doolittle, and Lee M. Mace, July 1972. (COM-72-10910)

NESS 40 Convective Clouds as Tracers of Air Motion. Lester F. Hubert and Andrew Timchalk, August 1972. (COM-72-11421)

NESS 41 Effect of Orbital Inclination and Spin Axis Attitude on Wind Estimates From Photographs by Geosynchronous Satellites. Linwood F. Whitney, Jr., September 1972. (COM-72-11499)

NESS 42 Evaluation of a Technique for the Analysis and Forecasting of Tropical Cyclone Intensities From Satellite Pictures. Carl O. Erickson, September 1972. (COM-72-11472)

NESS 43 Cloud Motions in Baroclinic Zones. Linwood F. Whitney, Jr., October 1972. (COM-73-10029)

NESS 44 Estimation of Average Daily Rainfall From Satellite Cloud Photographs. Walton A. Follansbee, January 1973. (COM-73-10539)

NESS 45 A Technique for the Analysis and Forecasting of Tropical Cyclone Intensities From Satellite Pictures. (Revision of NESS 36) Vernon F. Dvorak, February 1973. (COM-73-10675)

NESS 46 Publications and Final Reports on Contracts and Grants, 1972--NESS. April 1973.

NESS 47 Stratospheric Photochemistry of Ozone and SST Pollution: An Introduction and Survey of Selected Developments Since 1965. Martin S. Longmire, March 1973. (COM-73-10786)

NESS 48 Review of Satellite Measurements of Albedo and Outgoing Long-Wave Radiation. Arnold Gruber, July 1973. (COM-73-11443)

NESS 49 Operational Processing of Solar Proton Monitor Data. Louis Rubin, Henry L. Phillips, and Stanley R. Brown, August 1973. (COM-73-11647-AS)

NESS 50 An Examination of Tropical Cloud Clusters Using Simultaneously Observed Brightness and High Resolution Infrared Data From Satellites. Arnold Gruber, September 1973. (COM-73-11941/4AS)

NESS 51 SKYLAB Earth Resources Experiment Package Experiments in Oceanography and Marine Science. A. L. Grabham and John W. Sherman, III, September 1973.

NESS 52 Operational Products From ITOS Scanning Radiometer Data. Edward F. Conlan, October 1973.

NESS 53 Catalog of Operational Satellite Products. Eugene R. Hoppe and Abraham L. Ruiz (Editors). In press, 1974.