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A RADIATING UHF SATELLITE SIMULATOR.(U)
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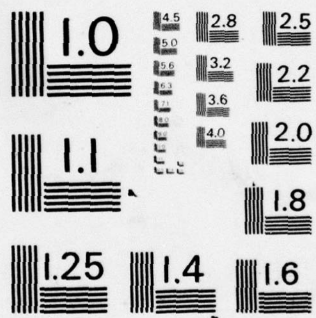

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AFAL-TR-76-174

A RADIATING UHF SATELLITE SIMULATOR

SYSTEM AVIONICS DIVISION
SYSTEM DEVELOPMENT BRANCH

JULY 1976

TECHNICAL REPORT AFAL-TR-76-174
FINAL REPORT FOR PERIOD OCTOBER 1973 - JUNE 1976

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James J. Foshee

JAMES J. FOSHEE
Project Engineer

FOR THE COMMANDER

James D. Everett

JAMES D. EVERETT, Col, USAF
Chief, System Avionics Division
Air Force Avionics Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This technical report contains a description of a Radiating UHF Satellite Simulator. This Radiating Simulator is a simplified version of the FLEETSATCOM satellite and was designed to augment the flight test program of the Air Force Satellite Communications System (AFSCS).

FOREWORD

This technical report was prepared by personnel of the System Avionics Division (AA), of the Air Force Avionics Laboratory, Wright-Patterson AFB, Ohio. This work was accomplished under Project No. 1205, "Air Force Satellite Communication Systems (AFSATCOM)," and Task No. 0103, "UHF Satellite Transponder."

This effort was accomplished during the period of October 1973 through June 1976.

The Project Engineers for this effort were Lowell R. Nawman and James J. Foshee. James J. Foshee designed the simulator and directed the fabrication and test of the simulator. Wayne Fischbach was responsible for the simulator layout, including most of the mechanical design, and was responsible for the construction effort. Harvey Bennett was the electro-mechanical technician.

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SECTION I

INTRODUCTION

The cost and availability of satellite time are important considerations in the design of a satellite communications system. Due to the normal ordering of priorities and the limited channel capacity of the space transponder satellite (the satellite), operational traffic generally consumes the bulk of available satellite time. Many functions which need to be performed, including terminal checkout just prior to moving into the operational environment and lower-priority communications, have to be performed off-line or on an alternate communications system. Quite often, these off-line checks are inadequate to fully evaluate the terminal performance, and the shift to the alternate communications system normally requires additional equipments but does not necessarily fully utilize the equipments which are readily available.

With satellite time at a premium the use of a radiating satellite simulator (the simulator) could greatly improve the efficiency of the satellite communications system and more fully utilize equipments normally dedicated to satellite communications. The simulator need not be an exact replica of the operational satellite. In fact, the simulator could well perform some functions not available on the operational satellite.

SECTION II

PHILOSOPHY OF THE RADIATING SATELLITE SIMULATOR

Prior to the use of the satellite in communications systems, communications with airborne mobile terminals were quite often performed on a first-come first-served basis. Analog voice communications was not only the primary mode of communications but essentially the only mode of communications. Channel availability was generally not a severe constraint in the communications system. The ultra-high frequency (UHF) band or the very-high frequency (VHF) band was used for line-of-sight communications and the high frequency (HF) band was used when line-of-sight communications was not available. The radio operator would select a frequency band and a specific frequency, and initiate communications when the channel was available.

Technology has tended to change the communications procedures. Digital data communications now complements analog voice communications and the trend is toward still more digital communications. The satellite has changed the use of UHF communications from line-of-sight to basically hemispherical coverage of the earth's surface. In addition, the satellite is tending to change the mode of communications from a first-come first-served basis to a well-ordered form of automatic digital reporting. In this type of system specific digital information would be automatically transmitted through the satellite, at a specific time and the quality of the data at the receiving end of the system would be determined through digital processing and without the aid of man.

Due to the nature of the design of such automated digital communications systems utilizing the satellite, it is quite often difficult, if not impossible, to fully check any portion of the total system without the use of the satellite and some other portion of the system. Since the cost of satellite time is at a premium this is normally accomplished under operational conditions. An alternative would be to utilize a simulator specifically designed to perform the checkout function. The level of checkout could vary from comprehensive to a very simple checkout.

The Radiating UHF Satellite Simulator (the Radiating Simulator) described in this report is a simplified model of the FLEETSATCOM military UHF repeater satellite.[1] This Radiating Simulator was designed to augment the Air Force Satellite Communications System[2] flight test program by allowing functions to be performed through the Radiating Simulator that would normally require the actual satellite. The Radiating Simulator has a three channel capability. There is one non-regenerative 500 kilohertz (kHz) bandwidth channel (wideband) and two 5 kHz bandwidth channels (narrowband). Each of the two narrowband channels can be connected for either regenerative or non-regenerative operation. The characteristics of the Radiating Simulator are contained in Table 1. The Radiating Simulator was designed to operate in the 225-400 megahertz (MHz) frequency band with the specific frequency of operation determined by the local oscillator and associated bandpass filter selection.

TABLE 1

CHARACTERISTICS OF THE RADIATING UHF SATELLITE SIMULATOR

Number of Continuous Channels	Three
Frequency Range (Discrete Crystal Oscillators):	
Receiving Section	290-315 MHz
Transmitting Section	230-260 MHz
Interface:	
Data	TTL, 75 b/sec
Receiving Section	70 MHz, -80 to 0 dBm
Transmitting Section	70 MHz, -50 to 0 dBm
Transmitter Power Output:	
Single Channel	Variable from 10 microwatts to 1 watt maximum (-20 to +30 dBm)
Three Channels Combined	1 watt maximum
Receiver Front-End Noise Figure:	
Each Channel	4 dB, maximum
Weight	140 pounds
Size:	
Transmitting Section	21 1/2" x 12" x 21"
Receiving Section	21 1/2" x 12" x 21"
Power Requirements	115 Volts, 60 Hertz, 400 VA
Receiver Input Signal Levels (UHF):	
Wideband Channel (500 kHz)	0 to -105 dBm
Narrowband Channel (5 kHz)	0 to -125 dBm
Expected Simulator Receive Signal Levels:	
Aircraft 100 miles from simulator	-80 dBm
Aircraft 2 miles from simulator	-50 dBm
Expected Aircraft Receive Signal Levels with 1/3 watt per Channel Transmitted:	
Aircraft 100 miles from simulator	-100 dBm
Aircraft 2 miles from simulator	-70 dBm

SECTION III

THE RADIATING SIMULATOR

GENERAL DESCRIPTION

The Radiating Simulator is housed in two cabinets. One cabinet contains essentially the receiving portion of the system and the other cabinet contains the transmitting portion. A photograph of the Radiating Simulator transmitter section is shown in Figure 1 and a photograph of the Radiating Simulator receiver section is shown in Figure 2. The cabinets are of equal size and portable. Each section contains its own power supplies to allow for independent operation. The simulator is designed to operate on commercial 115-volt 60 Hertz power. The connections on the front panels of each of the two units are located to facilitate the interconnection of the two units when the transmitter section sets on top of the receiver section as shown in Figure 3. The Radiating Simulator is designed to receive three channels and transmit three channels simultaneously. A maximum of six coaxial interconnections are required between the two units and the two units can share a common antenna.

DETAILED DESCRIPTION

A simplified block diagram of the Radiating Simulator is shown in Figure 4. This block diagram shows the essential sections of the Radiating Simulator. Each of the three channels is basically independent, with the exception of the power supplies and the antenna system including the power splitters and combiners. All signals

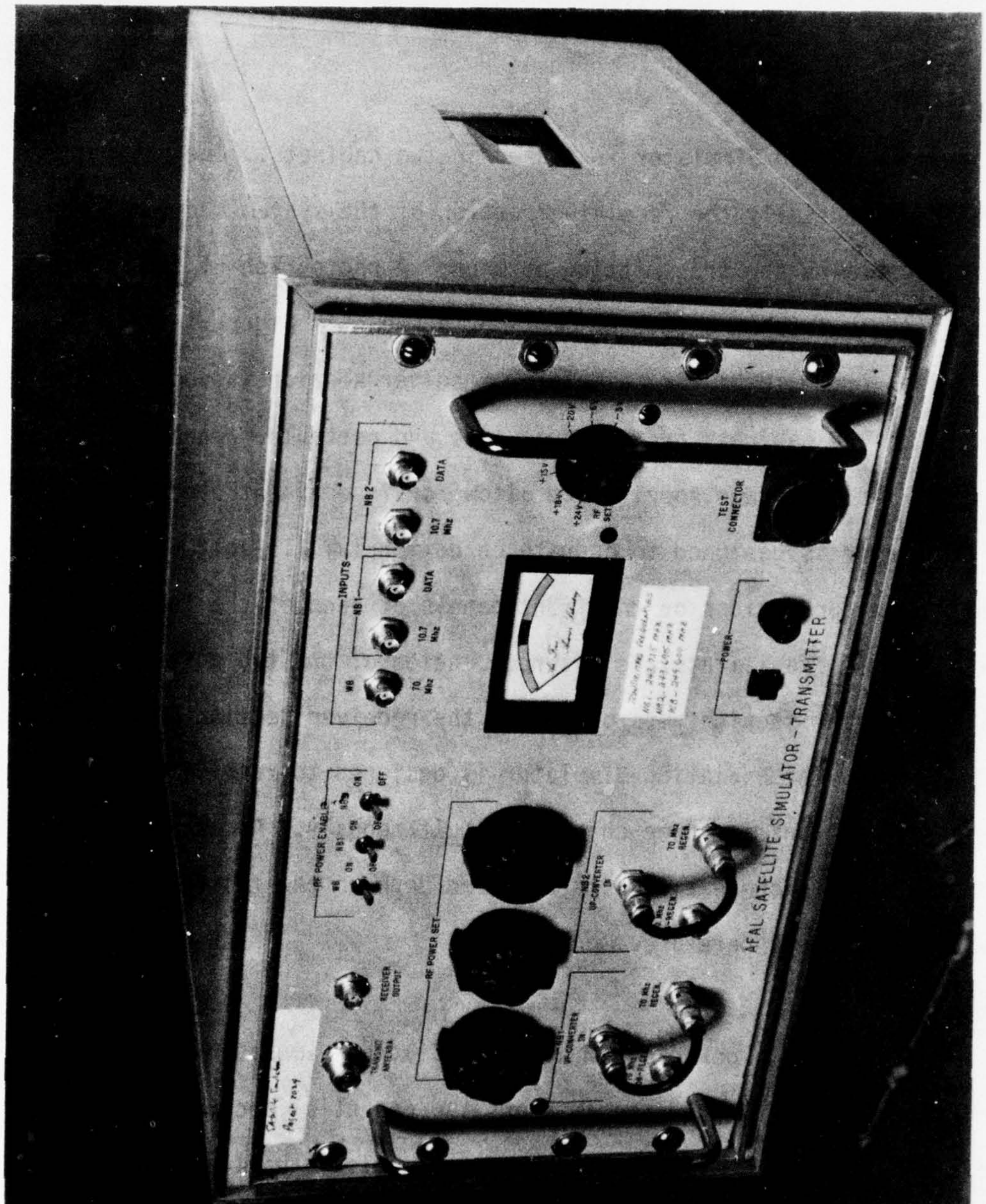

Figure 1 The Radiating Simulator Transmitter Section

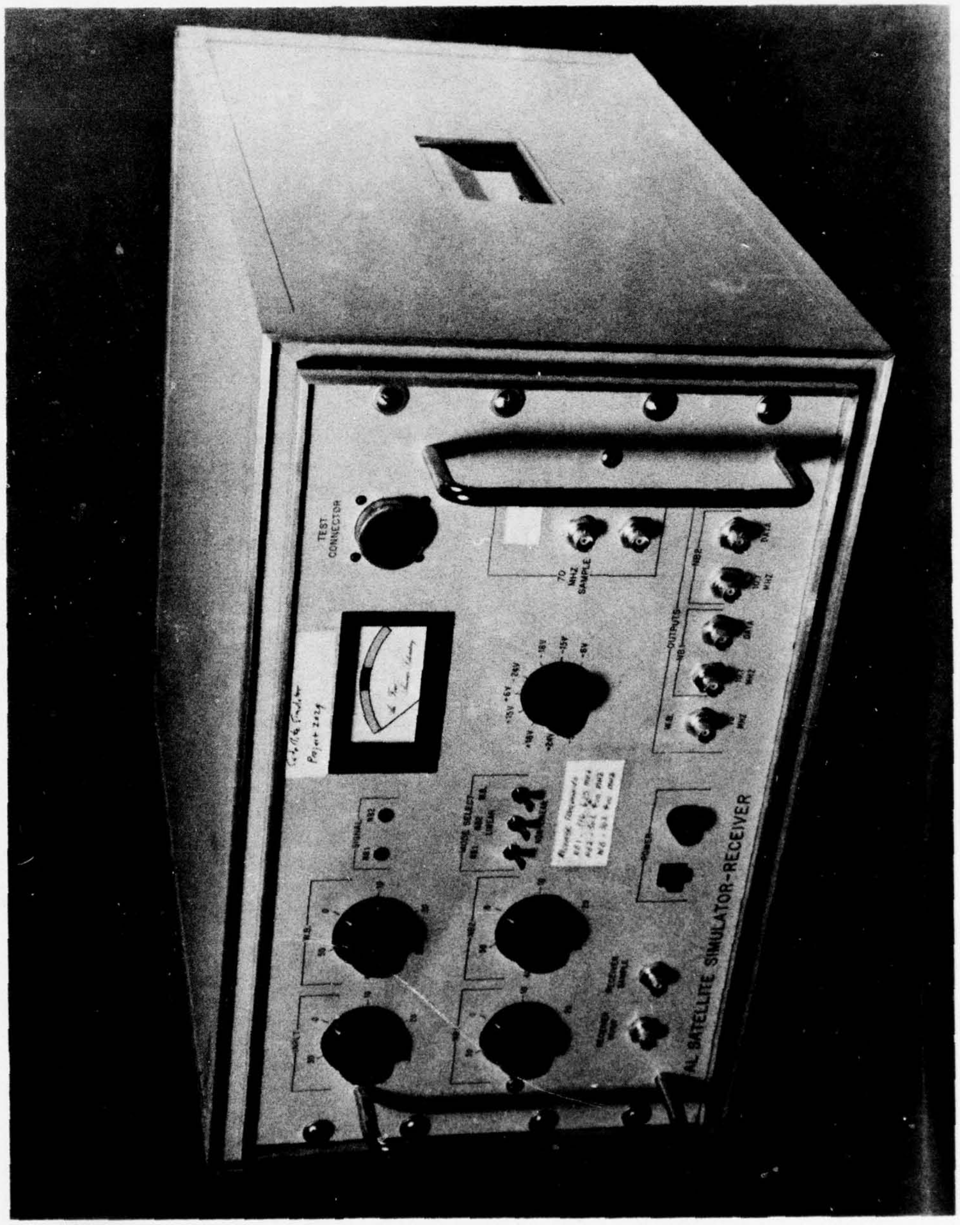

Figure 2 The Radiating Simulator Receiver Section

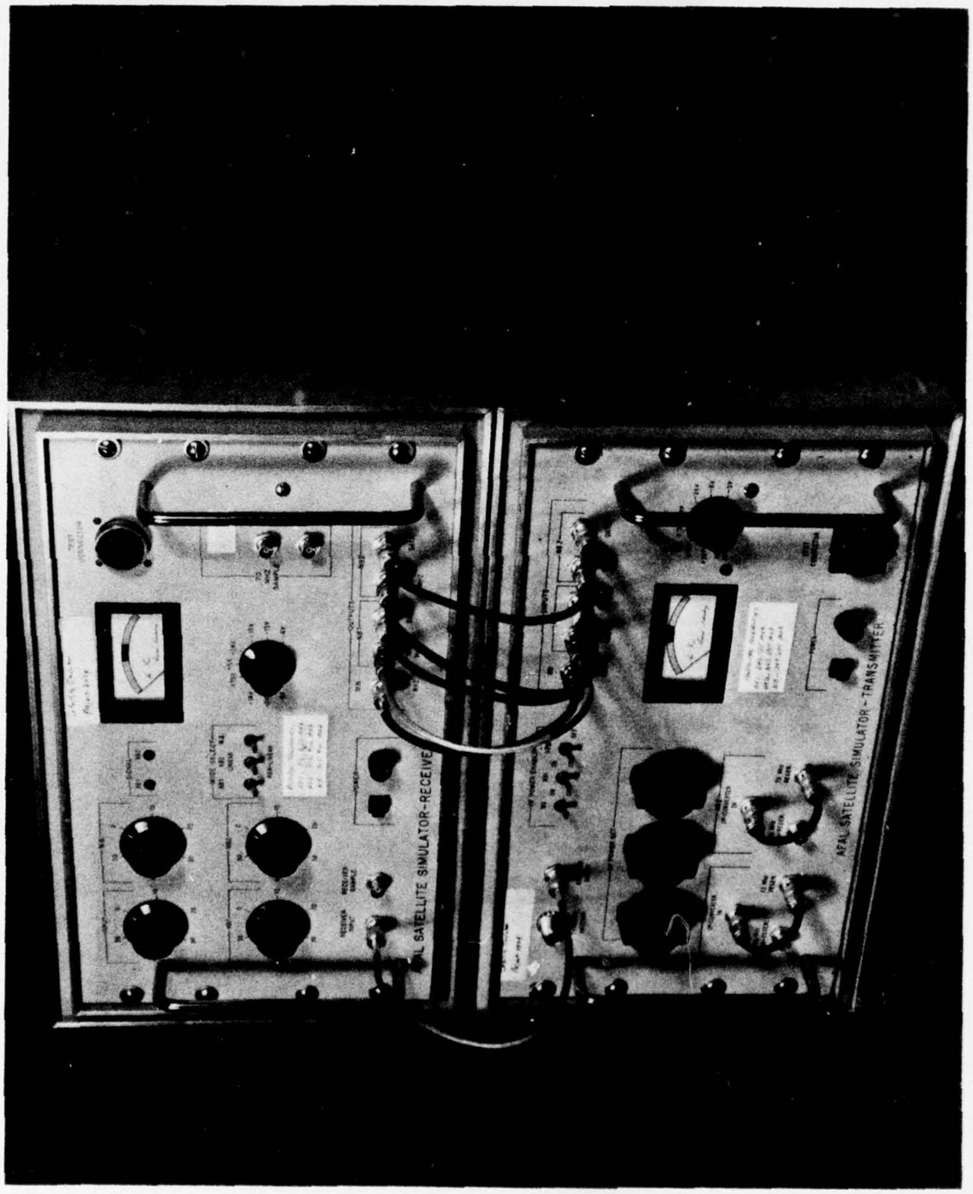

Figure 3 The Radiating Simulator

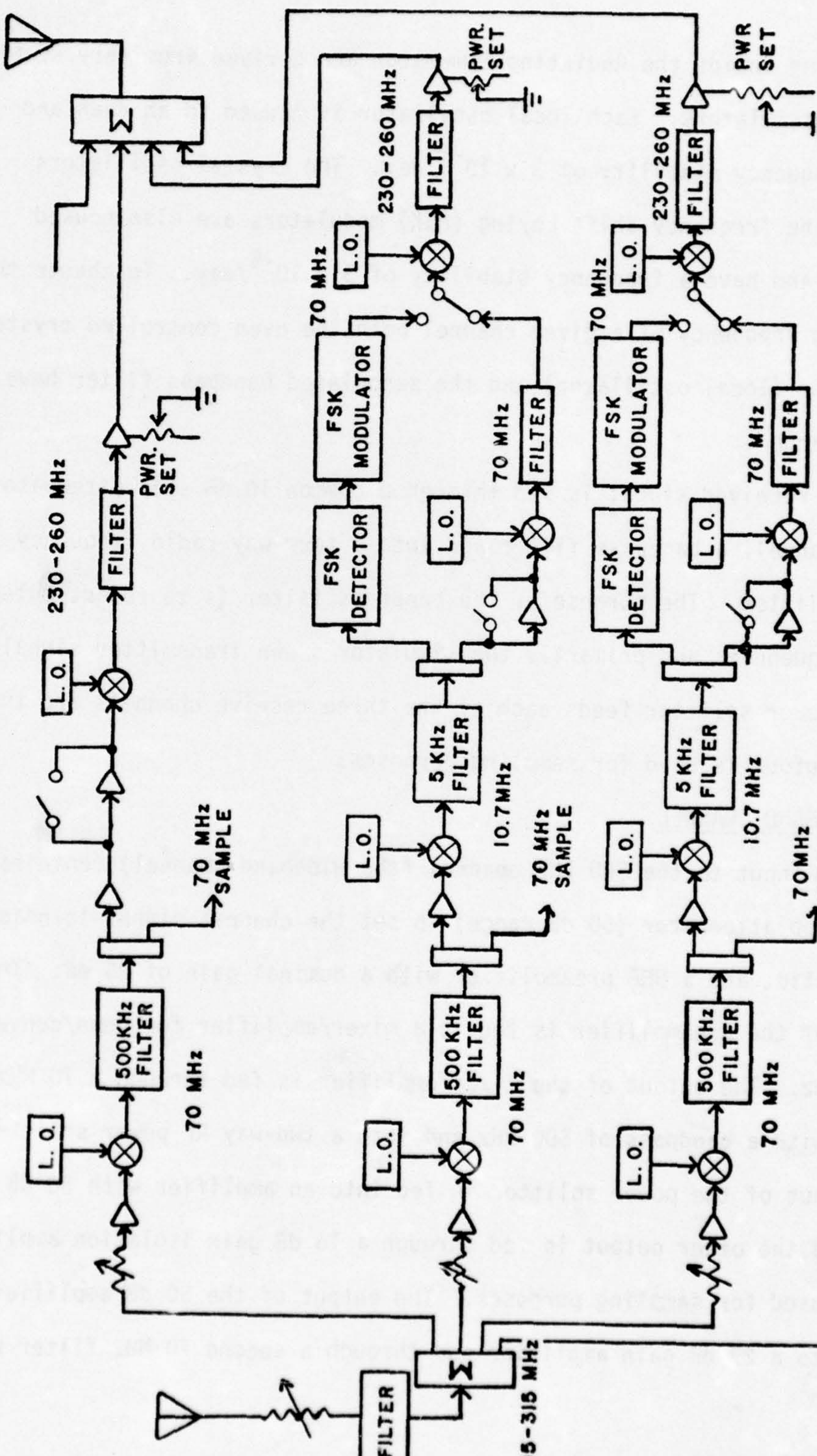

Figure 4 Block Diagram of the Radiating Simulator

originating inside the Radiating Simulator are derived from very stable crystal oscillators. Each local oscillator is housed in an oven and has a frequency stability of 3×10^{-8}/day. The crystal oscillators used in the frequency-shift keying (FSK) modulators are also housed in ovens and have a frequency stability of 3×10^{-8}/day. To change the operating frequency of a given channel both the oven controlled crystal oscillator (local oscillator) and the associated bandpass filter have to be changed.

The received signal is fed through a common 10 dB step attenuator (50 dB range), a bandpass filter and into a four-way radio frequency (RF) power splitter. The purpose of the bandpass filter is to reject out-of-band frequencies and primarily the simulator's own transmitted signals. The RF power splitter feeds each of the three receive channels and the fourth output is used for sampling purposes.

THE WIDEBAND CHANNEL

The input to the 500 kHz channel (the wideband channel) contains a 10 dB step attenuator (50 dB range) to set the channel signal-to-noise (S/N) ratio, and a UHF preamplifier with a nominal gain of 25 dB. The output of the preamplifier is fed to a mixer/amplifier for down/conversion to 70 MHz. The output of the mixer/amplifier is fed through a 70 MHz filter with a bandpass of 500 kHz and into a two-way RF power splitter. One output of the power splitter is fed into an amplifier with 50 dB gain and the other output is fed through a 10 dB gain isolation amplifier and is used for sampling purposes. The output of the 50 dB amplifier is fed to a 27 dB gain amplifier and through a second 70 MHz filter with a bandpass of 500 kHz. The output of the bandpass filter feeds a limiting amplifier. The RF power output of the limiting amplifier is a nominal 0 dBm. The 70 MHz output of the limiting amplifier can be used to interface with a compatible 70 MHz modem or it can be fed to a mixer/amplifier for up/conversion to UHF for retransmission. If the signal is to be retransmitted the 70 MHz signal is fed to a mixer/amplifier and through a filter to remove the unwanted mixer outputs. The output of the filter is fed to an RF power amplifier with a nominal gain of 35 dB and a maximum RF power output of one watt. The output RF power level of the power amplifier can be controlled by adjusting the input drive level to the mixer with a 1 dB step attenuator (with 60 dB of range). The output of the RF power amplifier is combined with the other two simulator channels for retransmission on one antenna.

The 500 kHz channel can be operated linearly by reducing the amount of amplification in the 70 MHz amplifier section of the simulator. This is achieved by bypassing some of the amplifiers in the 70 MHz section of the simulator.

THE NARROWBAND CHANNEL

The two 5 kHz channels (narrowband) are identical except for the local oscillator frequency and the associated bandpass filter selected for use in the 70 MHz up/converter and the 70 MHz down/converter sections. The received signal from the RF power splitter is fed through a 10 dB step attenuator (50 dB range), through a preamplifier with a nominal 25 dB gain and into a mixer/amplifier for down/conversion to 70 MHz.

The output of the mixer/amplifier is fed through a 70 MHz filter with a 500 kHz bandpass and into a two-way RF power splitter. One of the power splitter outputs is fed through an isolation amplifier with a nominal 10 dB gain and is used for sampling purposes. The other output is fed to an amplifier with a nominal gain of 50 dB. The output of the amplifier is fed to a mixer for down/conversion to 10.7 MHz. The output of the mixer is fed to a 10.7 MHz filter with a bandpass of 5 kHz. The output of the filter is fed to a two-way RF power splitter. One output of the power splitter is fed to an amplifier/mixer for up/conversion to UHF and retransmission. This is the non-regenerative path. The other output of the power splitter is fed to an FSK demodulator. This is the regenerative path.

Figure 5 is a block diagram of the FSK demodulator. The FSK demodulator contains two 10.7 MHz filters each with a bandpass of 2 kHz. The center frequency of one filter is 1.25 kHz above 10.7 MHz and the center frequency of the other filter is 1.25 kHz below 10.7 MHz. The energy in the outputs of each of the two filters is detected, integrated and compared to determine mark/space information. The integration following each of the detectors improves system performance since the bandwidth of each of the filters is 2 kHz and the digital data rate is less than 2 kHz.

The mark/space information from the FSK demodulator can be fed to external input/output equipments or it can be fed to an FSK modulator for regeneration and retransmission. Figure 6 is a block diagram of the FSK modulator. The mark/space information merely switches either the

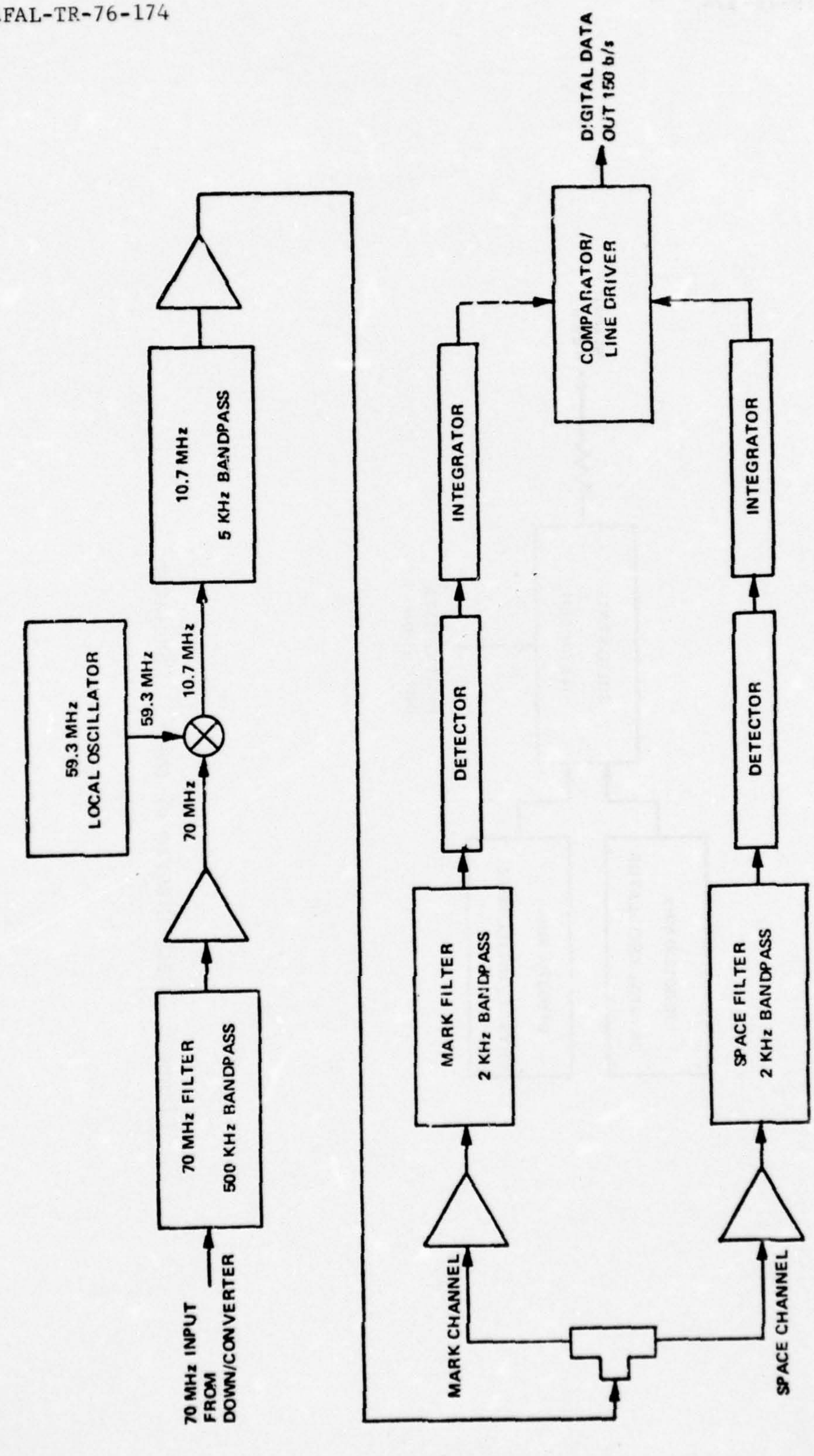

Figure 5 Block Diagram of the FSK Demodulator

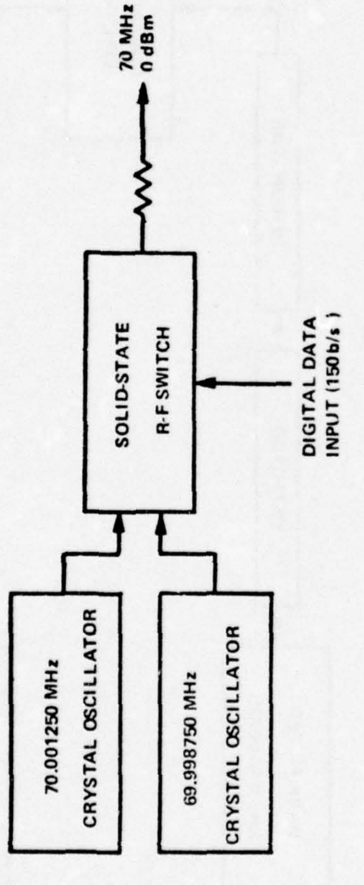

Figure 6 Block Diagram of the FSK Modulator

mark oscillator or the space oscillator to the output. The frequency of the space oscillator is 1.25 kHz above 70 MHz and the frequency of the mark oscillator is 1.25 kHz below 70 MHz.

Either the 70 MHz FSK modulator output or the 70 MHz non-regenerated signal spectrum can be selected for up/conversion to UHF and retransmission. The selected 70 MHz signal is fed to a mixer/amplifier and up/converted to UHF. The output of the mixer/amplifier is filtered to reject the unwanted frequency components and fed to an RF power amplifier similar to the one used in the 500 kHz wideband channel described previously. The RF power output of the power amplifier is controlled by controlling the drive level to the mixer. The non-regenerative section of either of the 5 kHz narrowband channels can be operated either linearly or non-linearly.

SECTION IV

RADIATING SIMULATOR OPERATION

GENERAL

The Radiating Simulator is designed to operate continuously and essentially unattended once initial adjustments are made. Photographs of the front panels of the simulator receiver and simulator transmitter are shown in Figure 7 and Figure 8, respectively. The following is a description of the function of each of the various front panel controls, the cable connections on the two units and general operating instructions.[3]

THE RECEIVER

Power is applied to the receiver by the "Power" switch. Associated with this switch is the power indicator lamp located as a part of the switch and the power fuse. The "Power" switch should remain off until all other controls on the unit have been set.

The four 10 dB step attenuators are used to set the level of the received signal levels in the simulator. Each attenuator is adjustable in 10 dB steps to a maximum of 50 dB for each attenuator. The "Input" attenuator is used to set the signal level from the antenna and affects all three channels. The "W.B." attenuator sets the received signal level in the 500 kHz channel. The "NB1" and the "NB2" attenuators are used to set the received signal level in the narrowband channels. The setting of each of these four attenuators is determined by the desired operating signal-to-noise ratio.

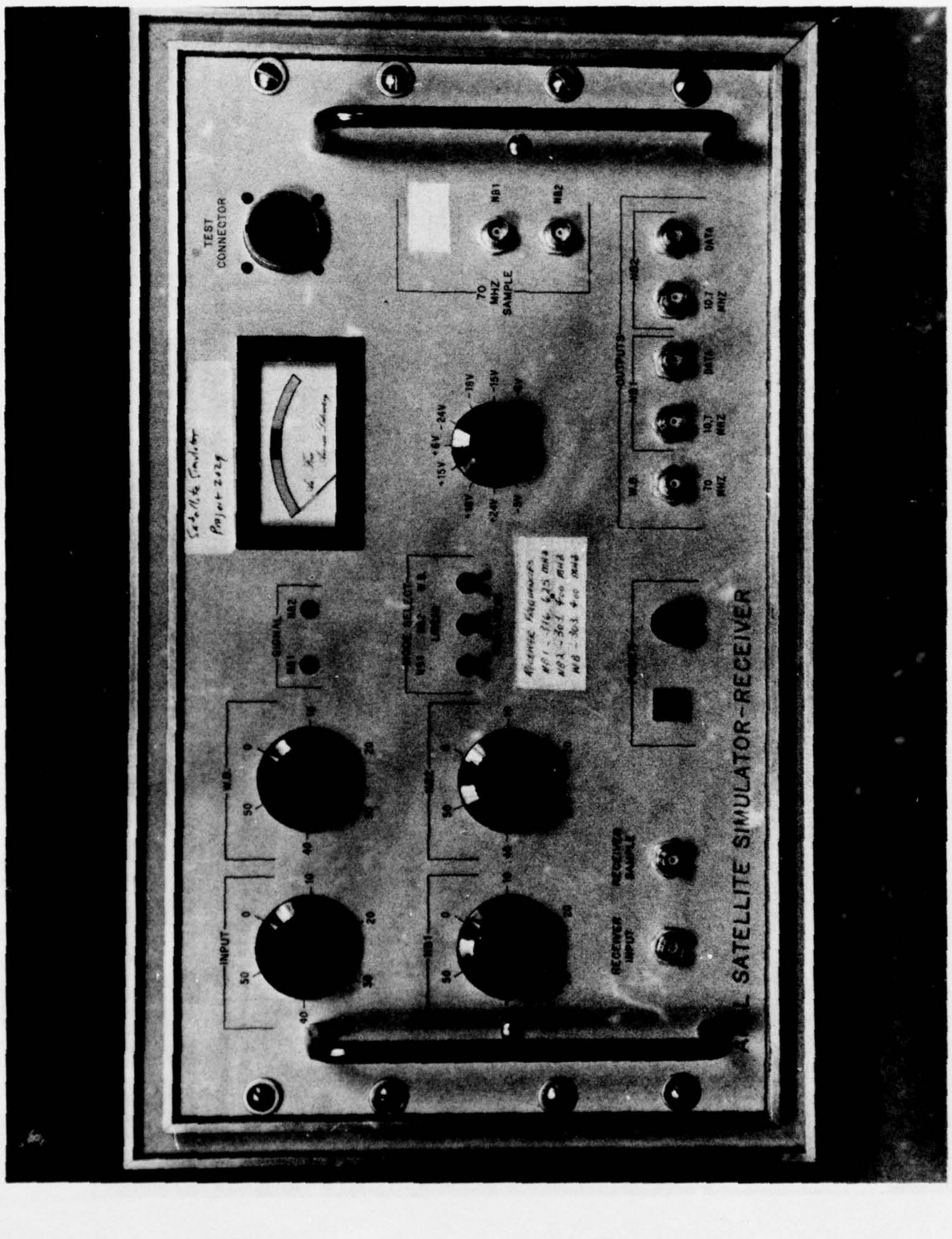

Figure 7 Front Panel of Simulator Receiver Section

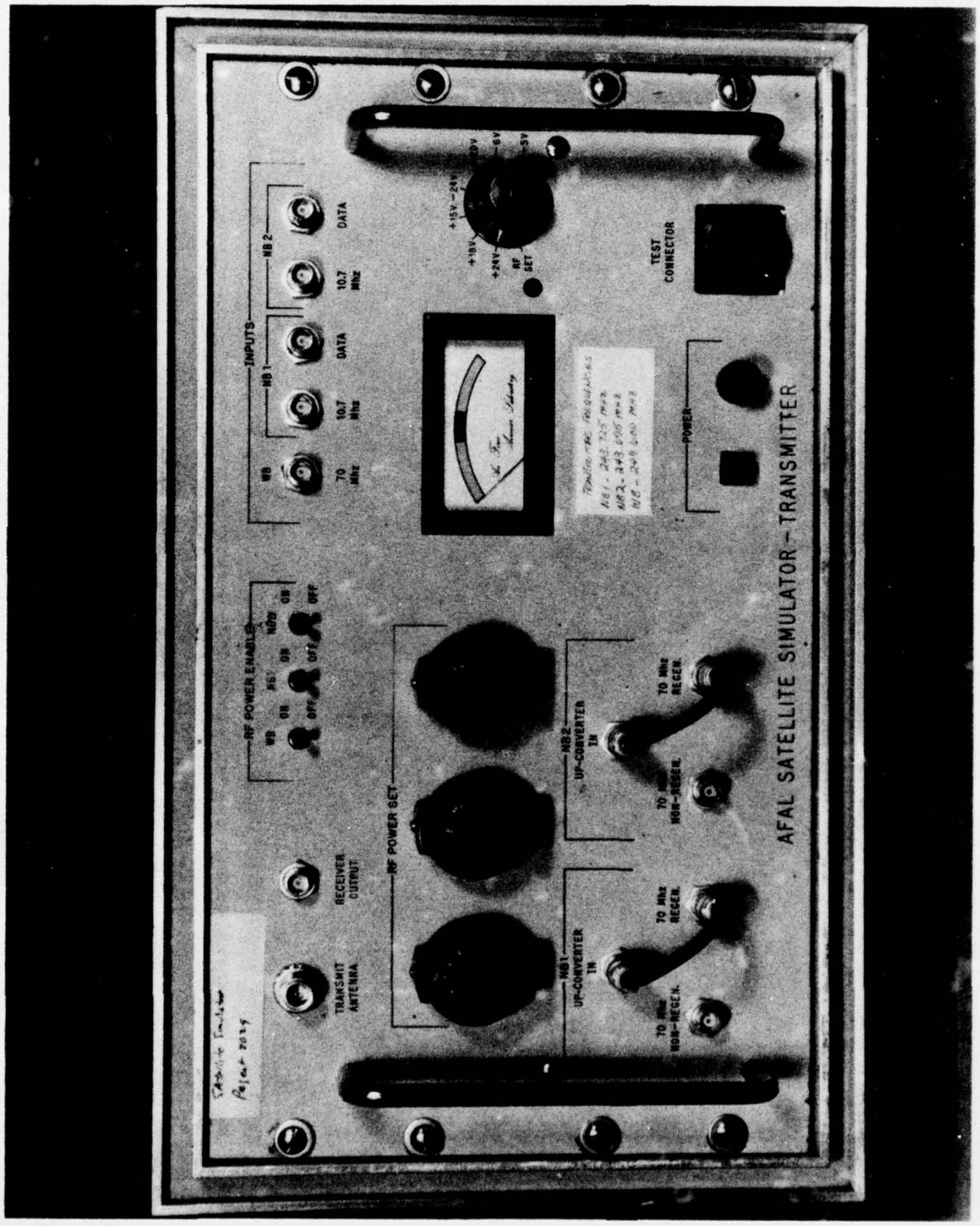

Figure 8 Front Panel of Simulator Transmitter Section

Each of the three non-regenerative channels can be operated either linearly or non-linearly. The mode of operation for each channel is determined by the settings of three toggle switches labeled "Mode Select." As discussed previously, the gain of the 70 MHz amplifier section is reduced to operate in the linear mode.

Each of the two narrowband channels contains an FSK detector. These detectors are operative in both the regenerative and the non-regenerative modes. Signal presence in each of two narrowband channels is indicated by the lamps labeled "Signal," "NB1," and "NB2."

The outputs of the three channels are brought to the front panel and are labeled "Outputs." The output of the 500 kHz channel is a high level 70 MHz signal and is labeled "W.B." Each of the two 5 kHz channels has two outputs; "10.7 MHz" is the output used in the non-regenerative mode and "Data" is the detected data from the FSK detector, and is used in the regenerative mode. Each of these five outputs should be connected to the transmitting section of the simulator with 50 ohm double-shielded (RG-223) type coaxial cable.

Three "70 MHz Sample" outputs are brought to the front panel. These three are samples of the 70 MHz signals in each channel following the 500 kHz filter. These outputs are low level (25 dB gain).

The input from the antenna should be connected to the coaxial connector labeled "Receiver Input." If operation on one antenna is desired the receiving section can share the antenna with the transmitting section. In this case the "Receiver Input" on the receiving section should be connected to the coaxial input on the transmitting section labeled "Receiver Output." Although this does allow the simulator to be operated on one antenna it causes approximately a 6 dB loss between the antenna and the input to the receiving section. This can be compensated for by the attenuator settings. If additional receiver sensitivity is required a 10 dB amplifier can be inserted between the front-end filter and the "Input" attenuator. This amplifier is permanently wired inside the receiver but is normally bypassed.

The coaxial output labeled "Receiver Sample" can be used to monitor the signal input to the receiving section. This output should be terminated in 50 ohms when not in use.

The front panel "Data" outputs are ± 6 volts. Located on the back of the receiver are TTL data outputs which can be used for monitoring.

The front panel of the receiver contains a meter to allow various functions inside the unit to be monitored. In addition, a multi-pin "Test Connector" is used to bring functions of interest to the front panel.

THE TRANSMITTER

Power is applied to the transmitter by the "Power" switch. Associated with this switch is the power indicator located as a part of the switch and the fuse. The "Power" switch should remain off until all other controls on the front panel have been set.

The coaxial input labeled "Transmitter Antenna" should be connected either to the antenna or terminated in 50 ohms before power is applied.

The maximum RF power output is one watt. The coaxial connection labeled "Receiver Output" should be terminated with a 50 ohm termination or connected to the receiving section of the simulator.

The RF power amplifier in each of the three channels is enabled by the toggle switches labeled "RF Power Enable." Each of these switches enable the drive to a power amplifier. The three "RF Power Set" adjustments are used to set power in each of the three channels. The RF power set adjustment is accomplished by enabling one channel at a time.

To interface with the receiver a series of five coaxial connections labeled "Input" are located on the front panel. The 500 kHz channel input is labeled "W.B." Each of the two 5 kHz channels has two inputs; "10.7 MHz" is the input used in the non-regenerative mode and "Data" is the input used in the regenerative mode. These coaxial connections do not determine the mode of operation and all five should be connected during normal operation.

The mode of operation, regenerative or non-regenerative, selected for each of the 5 kHz channels is determined by the coaxial patching on the front panel. The 10.7 MHz signal from each of the 5 kHz channels is up/converted to 70 MHz inside the transmitter section and brought to coaxial connections on the front panel "70 MHz Non-Regen." The 70 MHz outputs of each of the two FSK modulators are also brought to the front panel and are labeled "70 MHz Regen." The mode of operation is determined by the coaxial patch to the up/converter. The inputs to the up/converters are labeled "Up-Converter In." The up/converter inputs are designed to interface with 70 MHz modems at 0 dBm.

The front panel of the transmitter contains a meter to allow various functions inside the unit to be monitored. In addition, a multi-pin "Test Connector" is used to bring functions of interest to the front panel.

OPERATING PROCEDURES

A typical physical equipment configuration for the Radiating UHF Satellite Simulator is shown in Figure 3. This figure shows the basic cable interconnections required to operate the simulator with full capability.

Presets -

Receiver:

"Power" switch - Off

Input Signal Attenuators (4) - 0 dB

Mode Select Switches (3) - for linear or non-linear operation as desired

Function Switch - -5V

Channel Select - The center frequency for each channel is determined by the frequency of the local oscillator used in that particular channel. To change the channel center frequency the local oscillator and filter associated with that channel must be physically replaced. The center frequency associated with a given oscillator can be determined by adding 70 MHz to the frequency printed on the label of the oscillator. To change a channel center frequency, remove the receiver from the carrying case, locate the local oscillator and the bandpass filter associated with that channel, and replace the oscillator and filter.

Transmitter:

"Power" switch - Off

RF Power Set Attenuators (3) - 10 dB in each

Transmitter: (cont'd)

RF Power Enable Switches (3) - Off

Function Switch - -5V

Channel Select - The operating channel center frequencies of the transmitter are selected in a manner similar to the selection of channels in the receiver (see Receiver section above).

Cable Interconnections -

Input Power:

Each of the two units is designed to operate on commercial 115-volt, 60 Hertz power.

Interconnects:

The five outputs of the receiver should be connected to the five inputs of the transmitter ("WB 70 MHz," "NB1 10.7 MHz," "NB1 Data," "NB2 10.7 MHz," and "NB2 Data.") Use RG-223 or equivalent.

If the simulator is to be operated with one antenna the "Receiver Output" on the transmitter should be connected to the "Receiver Input" on the receiver. Otherwise, terminate the "Receiver Output" with 50 ohms and connect the "Receiver Input" to an antenna. Use RG-223 or equivalent.

Other Connections:

The "Transmit Antenna" connection on the transmitter should be connected to the antenna with RG-223 or equivalent.

The "NB1 Up-Converter In" should be patched to "70 MHz Regen" for regenerative operation or "70 MHz Non-Regen" for non-regenerative operation as desired.

The "NB2 Up-Converter In" should be patched to "70 MHz Regen" for regnerative operation or "70 MHz Non-Regen" for non-regenerative operation as desired.

Turn-On Procedures and Preliminary Checks -

Turn-On:

To turn-on either of the two units depress the power switch.

Preliminary Checks:

Using the Function Switch and meter in each unit check the internal voltages. The meter should read in the green in each setting (except the RF SET position on the transmitter).

Set the Function Switch on the transmitter to the "RF SET" position. Enable each of the three channels one at a time with the RF power enable switches. Reduce the attenuation in the RF power set attenuator associated with the particular enabled channel until the meter reads mid-scale. This calibrates that channel for +10 dBm at that attenuator setting. Reset the Function Switch to -5V.

Operation -

Receiver:

By using the input attenuators set each of the three channels to the desired operating received signal-to-noise ratio. If more than 50 dB attenuation is required the "Input" attenuator can be used for additional attenuation. The received signal-to-noise ratio of each channel can be measured by connecting the appropriate test equipment to the "70 MHz Sample" connections.

The presence of signal in the NB1 channel is indicated by the "Signal NB1" lamp. The presence of signal in the NB2 channel is indicated by the "Signal NB2" lamp.

Transmitter:

Using the RF power enable switches, enable each of the channels to be used. Using the +10 dBm attenuator setting set the RF power to the desired level for each channel.

Typical Operation - Table 2 contains the typical front panel attenuator settings for various distances between the aircraft and the simulator when operating with a 100 watt (ARC-171 type) transceiver. These settings should give adequate performance without an extremely high signal-to-noise ratio. Omni-directional antennas are assumed for each terminal.

TABLE 2

TYPICAL FRONT PANEL ATTENUATOR SETTINGS

DISTANCE BETWEEN TERMINALS	INPUT* ATTENUATION SETTING	NB1, NB2 ATTENUATION SETTING	WB ATTENUATION SETTING	RF POWER ATTENUATION SETTING
2 miles	30 dB	40 dB	20 dB	50 dB
10 miles	20 dB	40 dB	20 dB	30 dB
50 miles	10 dB	40 dB	20 dB	20 dB
100 miles	10 dB	30 dB	10 dB	10 dB
200 miles	10 dB	20 dB	0 dB	10 dB

*Increase input attenuator 10 dB when operating against a 1000 watt transmitter.

SECTION V

APPLICATIONS OF THE RADIATING UHF SATELLITE SIMULATOR

As discussed previously the Radiating Simulator was designed to augment the Air Force Satellite Communications System (AFSCS) flight test program. A variety of new concepts for use in the AFSCS satellite communications system were being implemented and an intensive evaluation of these subsystems prior to operational deployment was essential to the success of the AFSCS program. In many cases unlimited continuous use of the satellite with a minimum of interference from other variables is necessary to properly evaluate a system or subsystem. In general, a Radiating Simulator would more readily meet these requirements than the actual satellite.

Since the Radiating Simulator has been built it has been used in support of a variety of test programs. The first extensive use of the Radiating Simulator as a part of a test system was in a test program designed to evaluate the interface of an existing operational system with equipments developed as a part of the AFSCS program. In this particular test program the Radiating Simulator would be required to reliably transfer signals, and thus minimize the effects of any problems associated with propagation, and be available for continuous use. In this manner the actual satellite could be used when required, if available, and the Radiating Simulator could be used any time. This would allow flexibility in scheduling the specific tests.

The test program was designed to extensively utilize the Radiating Simulator and to be completed within a 60-day interval. If the test program had to rely only on the actual satellite it would have been virtually impossible to complete the program within the 60-day interval. The satellite was only available for a few hours per day and only at specific times. With the Radiating Simulator the test program was completed within the 60-day interval and the program was considered successful.

The Radiating Simulator has also been used to demonstrate and evaluate specific system operational modes and to demonstrate the adequacy of modifications to correct identified deficiencies.[4]

The Radiating Simulator has been used in a variety of other applications. For example, it has been used in support of the UHF Dual Modem test program[5]. In this test program, which involves the flight test of airborne equipments, the initial part of the test utilizes the simulator and not the satellite. In this manner the test procedures and techniques can be checked prior to the tests with the actual satellite.

The transmit and receive functions of the simulator can also be interchanged to allow the simulator to be used with the actual satellite. By utilizing a novel bit-timing extraction technique[6] and a full-duplex convolutional encoder/feedback decoder with data interleaving[7] the simulator has been used in support of the Fade-Resistant Modem program.[8] In this configuration the simulator with the additional equipments is a full-duplex terminal which can operate through a fading propagation environment.

SECTION VI
CONCLUSIONS

The Radiating Simulator described herein has proven to be a useful asset in support of the Air Force Satellite Communications System program. Due to the availability of the Radiating Simulator, as compared to the actual satellite, much time has been saved in the test program. In addition, because the cost of the Radiating Simulator was much less than the cost of an actual satellite there was a cost savings. This Radiating Simulator demonstrated the usefulness of a Radiating Simulator as a part of a satellite communications system. The exact configuration of a given radiating simulator would depend on the particular system requirements.

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