AD-A083 027 NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER ATL--ETC F/G 17/2
RADAR MICROWAVE LINK (RML) ELECTROMAGNETIC COMPATIBILITY MEASUR--ETC(U)
MAR 80 J G DONG
UNCLASSIFIED FAA-NA-80-2 FAA-RD-80-15 NL

1 OF 1
AD
A083027

END
DATE
FILMED
5-80
DTIC

Report No. FAA-RD-80-15

LEVEL II

RADAR MICROWAVE LINK (RML) ELECTROMAGNETIC COMPATIBILITY MEASUREMENTS

James G. Dong

FINAL REPORT

MARCH 1980

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D. C. 20590

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-80-15		

4. Title and Subtitle	5. Report Date
RADAR MICROWAVE LINK (RML) ELECTROMAGNETIC COMPATIBILITY MEASUREMENTS	Mar[redacted]80
	6. Performing Organization Code
7. Author(s): James G. Dong	8. Performing Organization Report No.: FAA-NA-80-2
9. Performing Organization Name and Address: Federal Aviation Administration, National Aviation Facilities Experimental Center, Atlantic City, New Jersey 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.: 213-062-890
12. Sponsoring Agency Name and Address: U.S. Department of Transportation, Federal Aviation Administration, Systems Research and Development Service, Washington, D.C. 20590	13. Type of Report and Period Covered: Final, Feb[redacted]-Jul[redacted]79
	14. Sponsoring Agency Code: SRDS, ARD-450

15. Supplementary Notes

16. Abstract

Tests were accomplished on two different Microwave Relay Transmitter and Receiver combinations operating in the frequency ranges of 7.125 to 8.4 GHz and 14.4 to 15.25 GHz. Measurements to determine interference characteristics included: receiver off-channel rejection, receiver intermodulation, transmitter spectrums, transmitter intermodulation, and second harmonics. Based on the test results, the adjacent frequency spacing should be at least 20 MHz and 50 MHz for RML-4 and TerraCom equipment, respectively. Additional measurements are recommended on new equipment in the 14.4 to 15.25 GHz range for valid criteria for the handbook in preparation.

17. Key Words	18. Distribution Statement
RML Transmitter and Receiver Off-Channel Rejection Spurious Responses	Document is available to the U.S. public through the National Technical Information Service. Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	22	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

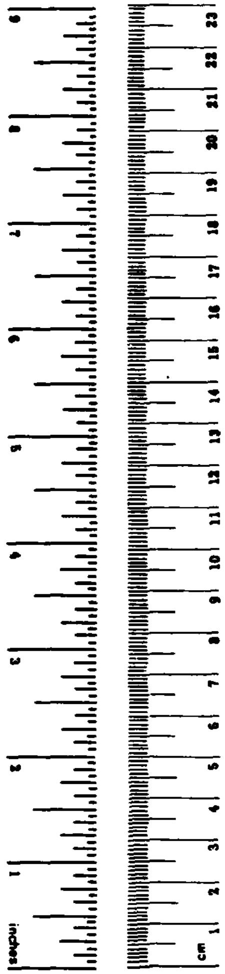
240550

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

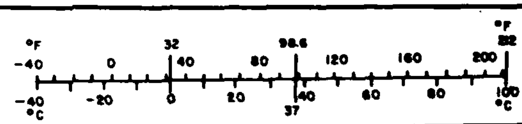


TABLE OF CONTENTS

	Page
INTRODUCTION	1
Purpose	1
Background	1
Description of Equipment	1
DISCUSSION	2
Test Procedure and Results	2
CONCLUSIONS	4
RECOMMENDATION	5
APPENDIX	

LIST OF ILLUSTRATIONS

Figure		Page
1	RML-4 Transmitter and Receiver Rack	6
2	TerraCom Transmitter and Receiver	7
3	Basic Test Configuration for RML-4 System	8
4	Basic Test Configuration for TerraCom Transmitter and Receiver	9
5	RML-4 Receiver Off-Channel Rejection	10
6	TerraCom Receiver Off-Channel Rejection	11
7	TerraCom Receiver Image Frequency Rejection Response	12
8	RML-4 Transmitter Spectrums	13
9	TerraCom Transmitter Spectrums	14

INTRODUCTION

PURPOSE.

The purpose of this project was to measure radar microwave link (RML) transmitter and receiver performance characteristics pertinent to interference in the frequency bands of 7.125 to 8.4 gigahertz (GHz) and 14.4 to 15.25 GHz. The Collins Radio RML-4 and TerraCom (TCM)-608 transmitter and receiver combinations were to be used in the tests.

BACKGROUND.

The installation of new RML equipment at Federal Aviation Administration (FAA) facilities operating at higher frequencies than existing links necessitates new criteria for analyzing improved electromagnetic compatibility. With new frequency assignments and considerations for band sharing with high power satellite systems, current information on existing and new equipment is necessary for the Very High Frequency/Ultra-High Frequency (VHF/UHF)/ Microwave Link Engineering Handbook, 6050.17A, in the process of revisions.

DESCRIPTION OF EQUIPMENT.

COLLINS RML-4 TRANSMITTER AND RECEIVER. The transmitter had a reflex klystron generator which produced the microwave carrier frequency, and the klystron was frequency modulated by varying the voltage applied to the repeller. The modulating voltage was supplied by the video modulator which is a plug-in module and can be easily removed from the transmitter. Other components in the transmitter include a load isolater and waveguide line filter. No automatic frequency control (AFC) was used with the transmitter.

The receiver had a reflex klystron generating the oscillator signal which is mixed with the microwave carrier received from the distant transmitter. Different klystron oscillator tubes are required to cover two different frequency ranges of 7125 to 7750 megahertz (MHz) and 7750 to 8400 MHz, respectively. The receiver klystron was approximately 70 MHz below the frequency of the received signal, thus produced the 70 MHz intermediate frequency (IF) required by the IF amplfier. Automatic frequency control for the receiver was provided by changing the voltage applied to the klystron repeller in response to error signals developed in the IF amplifier. These changes in repeller voltage raised and lowered the operating frequency to match small changes in the frequency of the received microwave carrier. Other components in the receiver include: local oscillator filter, load isolator, and a preselector filter which functioned as an eight-cell (3 band reject and 5 bandpass) filter.

The transmitter and receiver, which are a part of the RML-4 system, are shown in figure 1.

TCM-608 TRANSMITTER AND RECEIVER. The TCM-608 transmitter and receiver, shown in figure 2, was designed to operate in the 14.4 to 15.25 GHz frequency range. Both transmitter and receiver had built-in test equipment (BITE) for self-checking. Both transmitter and receiver had the following modules: power supply, control/monitor, baseband-audio module, AFC module, and an RF head module which are designed for specific microwave frequency bands. In addition, the transmitter had a synthesizer module and the receiver had an IF demodulator module.

In the transmitter, all microwave components were located in the radiofrequency (RF) head which included the cavity oscillator, multipliers, filters, etc. The cavity oscillator was stabilized by a sample of the fundamental frequency, mixing with a reference frequency derived from a crystal oscillator, resulting in an IF frequency of 70 MHz. The AFC module utilized the 70 MHz signal after processing in combination with the low frequency circuitry. This provided the frequency error information which was amplified, integrated, and returned to the AFC control terminal on the cavity oscillator. The output of the cavity oscillator was applied to a wide band power amplifier which raised the level of the carrier to 5 watts maximum. Options for two program channels are provided, a 10 hertz (Hz) to 6 MHz band and signal into the video input (75 ohm) or 10 Hz to 15 kilohertz (kHz) subcarrier input (600 ohm).

In the receiver, the RF input was selected by a preselector bandpass filter which couples the input to the receiver mixer via a terminated circulator. The solid-state local oscillator was voltage controlled with frequency maintained by an internal AFC control circuit. The mixer output was amplified by a low noise preamplifier and coupled to a bandpass filter 70 ±15 MHz which determines the noise bandwidth of the system.

The IF amplifier had a 52 dB dynamic range and a frequency response flat to within 0.1 dB from 60 to 80 MHz. The demodulator accepts the 70 MHz signal from the IF amplifier coupled into a balanced discriminator network via splitting network and high gain amplifiers. Each amplifier drives a low Q circuit with one tuned above 70 MHz and the other below. The outputs were selected by opposite polarity and combined to give an optimum noise figure.

DISCUSSION

TEST PROCEDURE AND RESULTS.

GENERAL. Tests were accomplished at the National Aviation Facilities Experimental Center (NAFEC) using the Collins RML-4 system in building 189. The transmitter and receivers in the system provided performance characteristics in the 7.125 to 8.4 GHz frequency range. In the 14.4 to 15.25 GHz frequency range, a TCM transmitter and receiver from their microwave relay system, TCM-608, which included power supplies, were tested in the NAFEC measurement laboratory. The IMC-1415 equipment from International Microwave Corporation (IMC) scheduled for test were cancelled because of equipment unavailability. An abridged description of this equipment and a selectivity curve supplied by IMC is in the appendix.

The tests completed included: receiver off-channel rejection, image frequency rejection, receiver intermodulation, transmitter spectrums, transmitter intermodulation, and second harmonics.

BASIC TEST CONFIGURATIONS. The basic test configuration employing the RML-4 system is shown in figure 3. Disconnecting the elbow at the coupler main waveguide permitted the use of the coupler ports for sampling or inserting signals. Waveguide to "N" adapters were used for coaxial cable attachment.

Figure 4 depicts the basic test configuration employing TCM-608 transmitter and receiver. A coupler was used to isolate the output of the signal source because of the unavailability of a circulator. Isolation between signals using a coupler, limited the signal level that could be applied to the receiver and the level used in transmitter intermodulation test because of coupling loss.

RECEIVER OFF-CHANNEL REJECTION. Utilizing the Collins RML-4 receiver, the desired signal was adjusted to a level of 24 dB above noise (-88 dBm) or 21 dB greater than the sensitivity of the receiver with 3 dB quieting. Discrete frequency increments were selected and their corresponding amplitudes were recorded when the off-channel signal interferred with the desired level by 3 dB. The test results are shown in figure 5, which includes the off-channel rejection characteristics when the off-channel signal was unmodulated, ±0.5 MHz modulation, and ±5.0 MHz modulation.

In the off-channel rejection test with the TCM-608 receiver, the 15 GHz desired signal was at a level of 24 dB above noise (-86 dBm) or 21 dB above the sensitivity at 3 dB quieting. Results are shown in figure 6.

IMAGE FREQUENCY REJECTION. With a desired signal of 8.605 GHz applied to the RML-4 receiver, the image frequency was not noticeable using the Hewlett Packard Model 8555A Spectrum Analyzer. RML-4 image rejection is at least 115 dB. The TCM-608 receiver image frequency rejection response curve was obtained with the receiver tuned to 15 GHz, the frequency of 14.860 GHz was used as the desired signal which is 70 MHz below the local oscillator frequency (14.930 GHz). TMC-608 image rejection is approximately 40 dB. Results are shown in figure 7.

RECEIVER INTERMODULATION. In the test employing a receiver in the RML-4 system, a T-connector was used at the waveguide adapter attached to the main waveguide of the coupler for inserting equally spaced frequencies from two signal generators and 30 MHz from the receiver tuned frequency (Receiver = 8.065 GHz, signal generator 1 = 8.095 GHz and signal generator 2 = 8.125 GHz) at amplitudes of 0 dBm. Monitoring the audio output of the receiver, no third order intermodulation product was detected. Sensitivity to interference producing third order intermodulation is down at least 88 dB relative to the on-channel signal level.

The TCM-608 receiver intermodulation measurements were accomplished with the receiver tuned to 15 GHz and two signals applied to the receiver. At frequencies of 15.090 and 15.045 GHz, the third order intermodulation was -59 dBm, with signal generator outputs of 0 dBm. With signal generator outputs of -5 dBm, the intermodulation level was -70 dBm. Sensitivity to interference producing third order intermodulation is down 73 dB relative to the on-channel signal level.

TRANSMITTER INTERMODULATION. Two transmitters in the RML-4 system were adjusted to frequencies 8.095 GHz and 8.125 GHz and tuned to their maximum output which was about 15 dBm at these frequencies. No intermodulation effects were observed at the receiver tuned frequency of 8.065 GHz. Intermodulation products are down at least 110 dB.

With the TCM-608 transmitter adjusted for 0 dBm output at 15.090 GHz and a signal generator adjusted for 0 dBm at a frequency of 15.045 GHz, transmitter intermodulation was not detected. Intermodulation products are down at least 100 dB.

TRANSMITTER SPECTRUMS. The RML-4 transmitter spectrums are shown in figure 8. When the transmitter is unmodulated with the modulator connected, the upper and lower sidebands of the pilot signal were present. If the modulator was disconnected from the transmitter, only the carrier signal was evident. To obtain the spectrum with modulation, a 1000 Hz signal at a level for ±5 MHz deviation was applied to the transmitter.

The TCM-608 transmitter spectrums are shown in figure 9. Similarly, unmodulated and modulated carrier are depicted.

SECOND HARMONICS. The second harmonic of the RML-4 transmitter could not be detected at a level 75 dB down from the carrier. The second harmonic frequency of the TCM-608 transmitter exceeded the frequency range of the spectrum analyzer. It was also considered of little consequence because the second harmonic frequency was beyond the frequency range that would cause interference in other facilities.

CONCLUSIONS

Based on the tests accomplished, it is concluded that:

1. The RML-4 off-channel rejection curve indicates adjacent channel frequency should be spaced more than 20 MHz apart to avoid interference. This applies to equipment using a common waveguide; less separation is possible with the use of separate waveguides.

2. From observation of the transmitter spectrum and second harmonic measurements, the RML-4 transmitter should not cause any interference from spurious emissions.

3. The TerraCom off-channel rejection curve indicates adjacent channel frequency should be spaced more than 50 MHz apart to avoid interference. This applies to equipment using a common waveguide; less separation is possible with the use of separate waveguides.

4. From the TerraCom transmitter test results, spurious emission levels should not cause interference because of low level.

RECOMMENDATION

It is recommended that measurements be accomplished with the IMC-1415 or other microwave relay transmitters and receivers in the 14.4 to 15.25 GHz to assure valid criteria in this frequency range. Site measurements may be required where more than one transmitter is available for transmitter intermodulation.

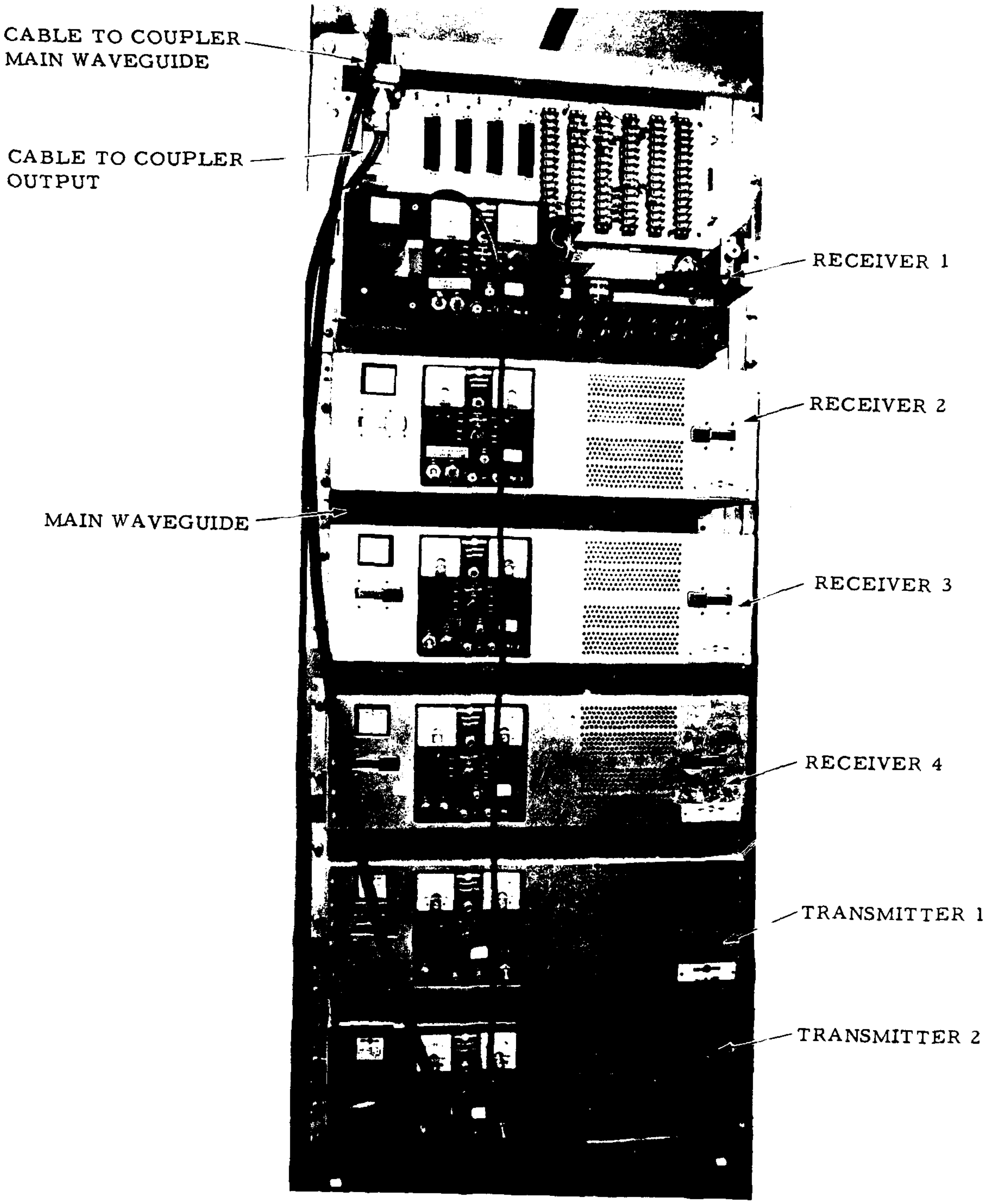


FIGURE 1. RML-4 TRANSMITTER AND RECEIVER RACK

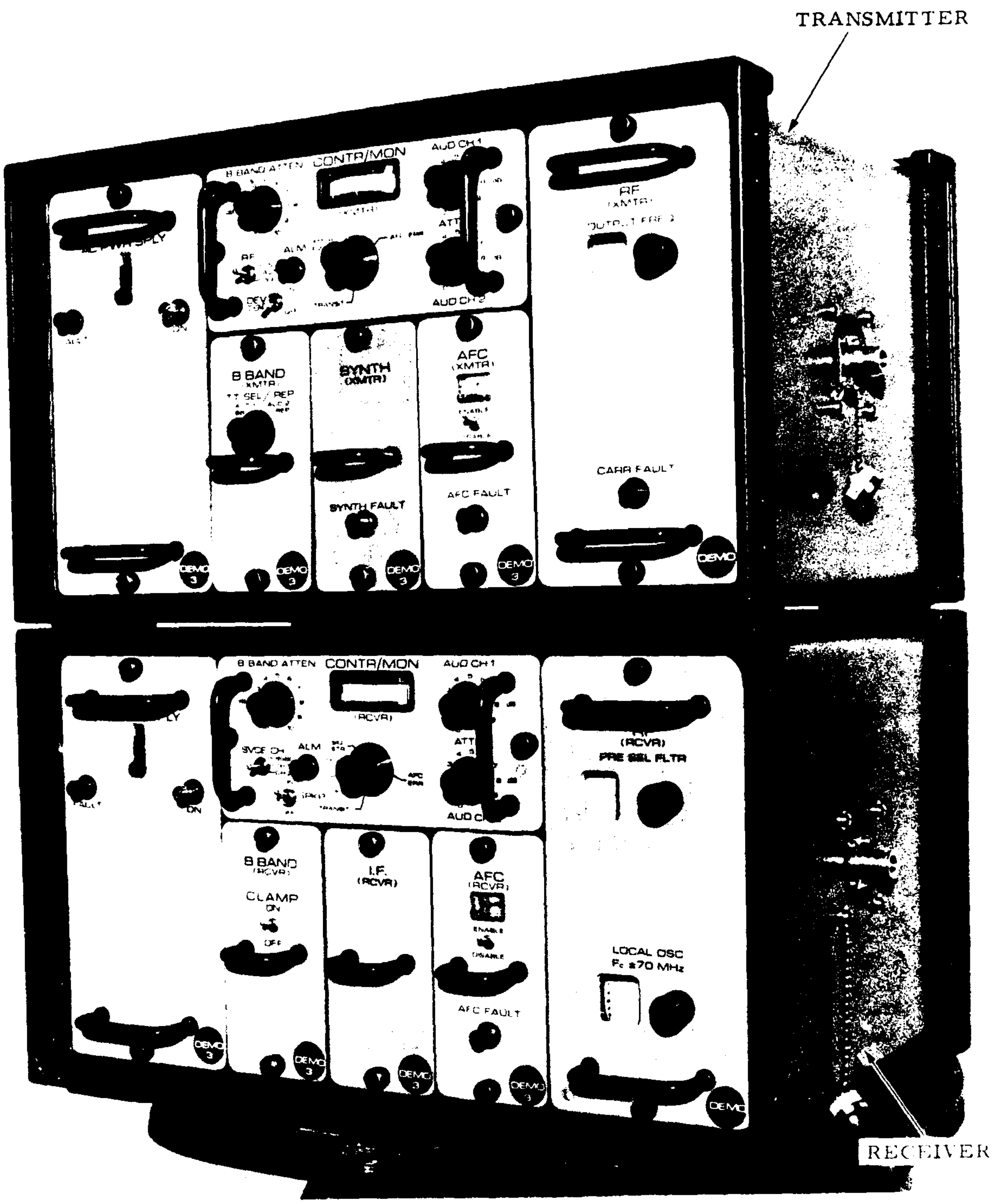


FIGURE 2. TERRACOM TRANSMITTER AND RECEIVER

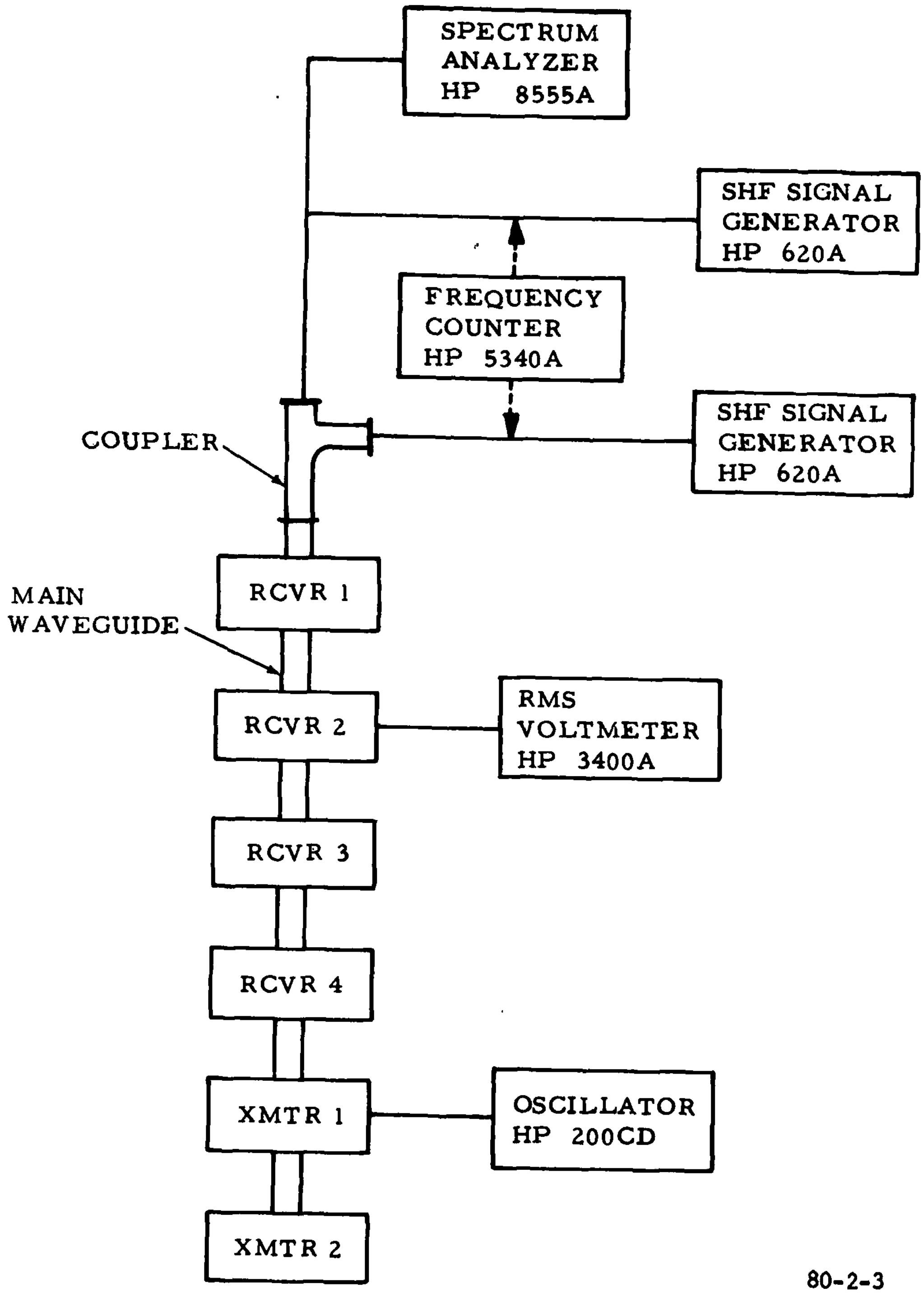


FIGURE 3. BASIC TEST CONFIGURATION FOR RML-4 SYSTEM

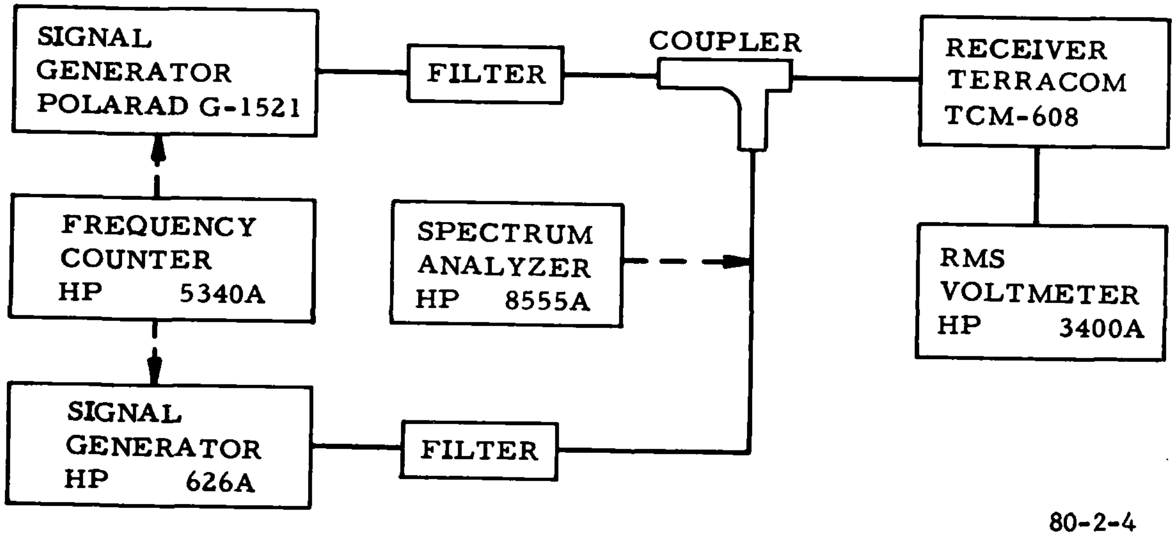


FIGURE 4. BASIC TEST CONFIGURATION FOR TERRACOM TRANSMITTER AND RECEIVER

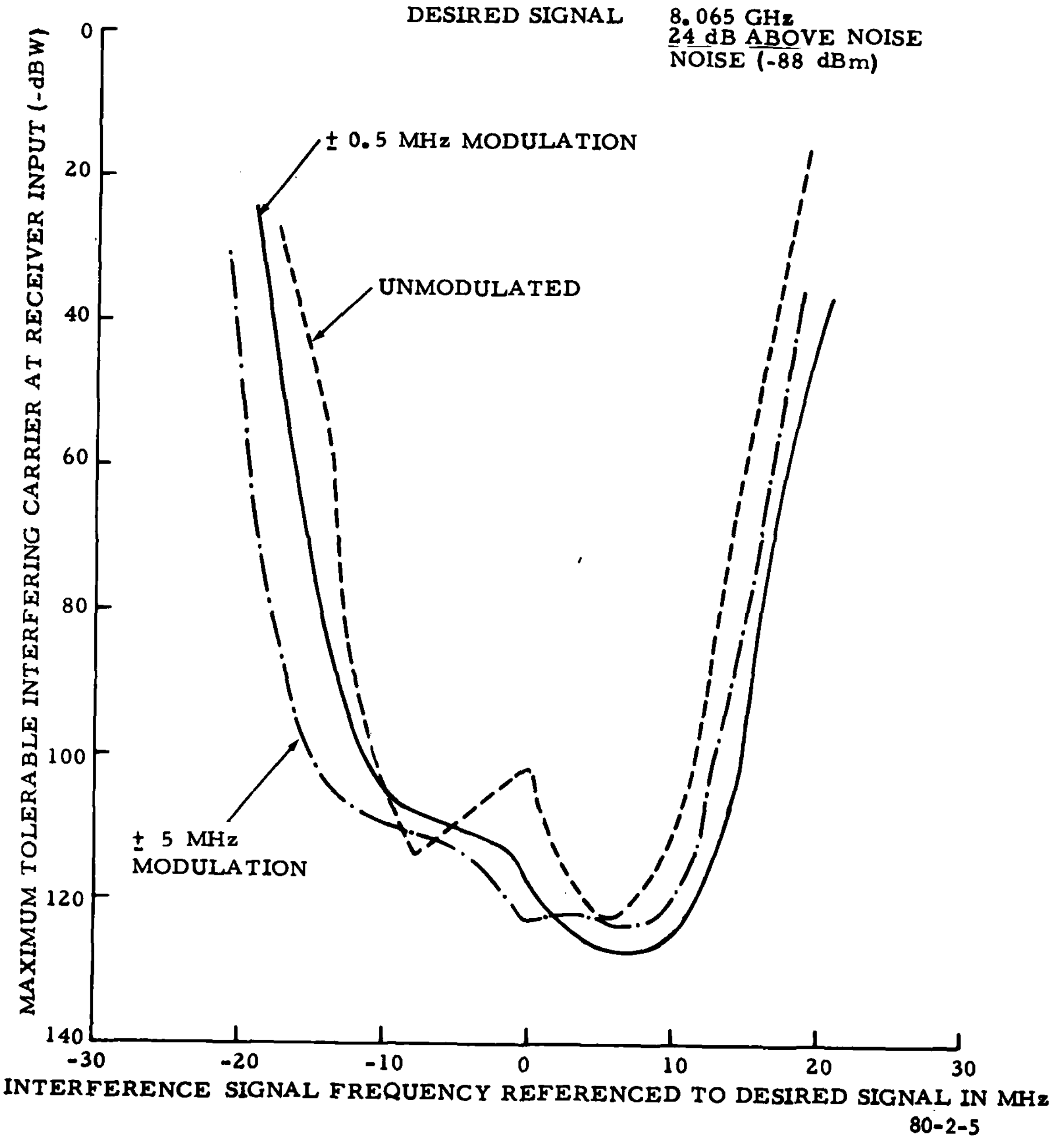


FIGURE 5. RML-4 RECEIVER OFF-CHANNEL REJECTION

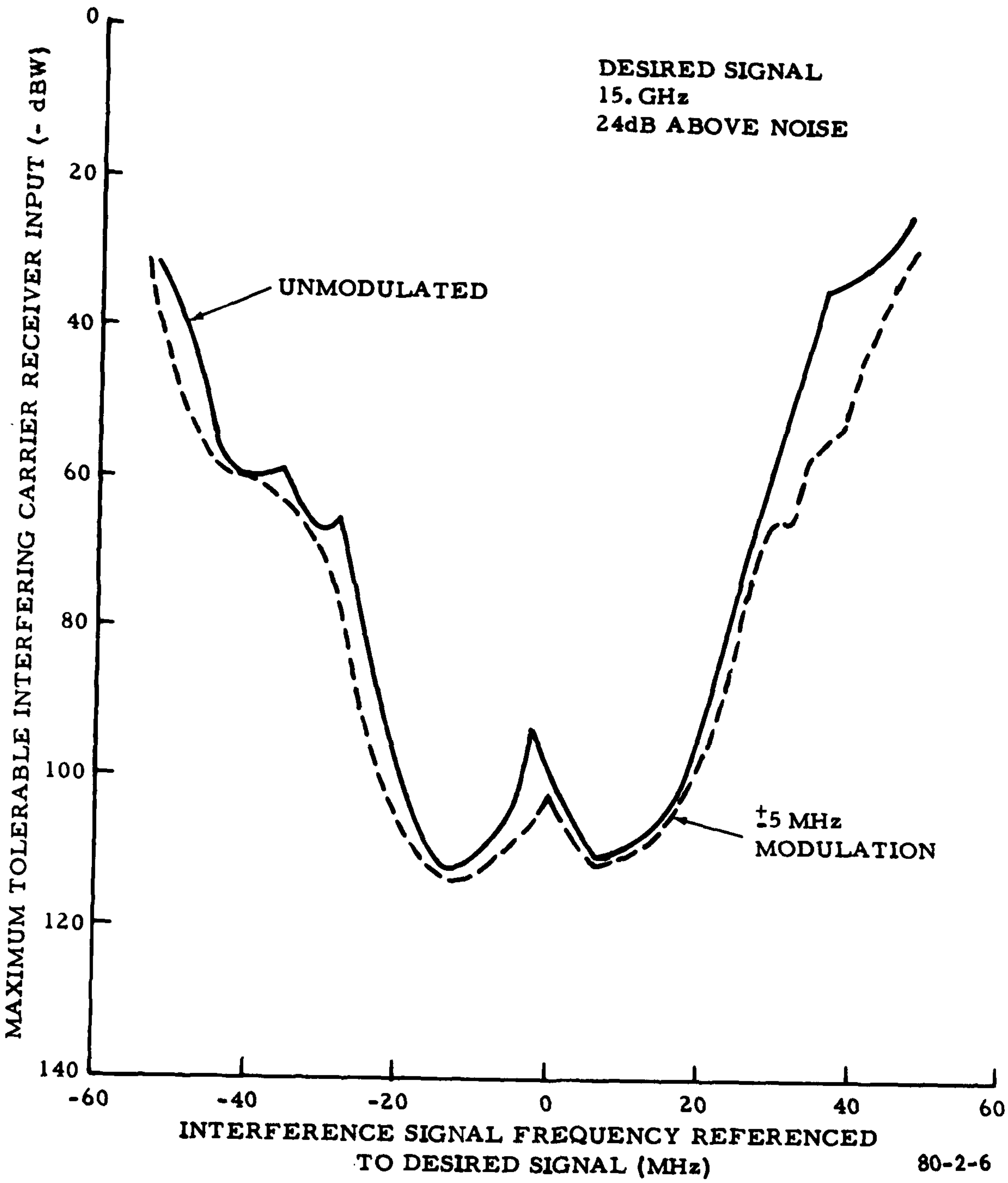


FIGURE 6. TERRACOM RECEIVER OFF-CHANNEL REJECTION

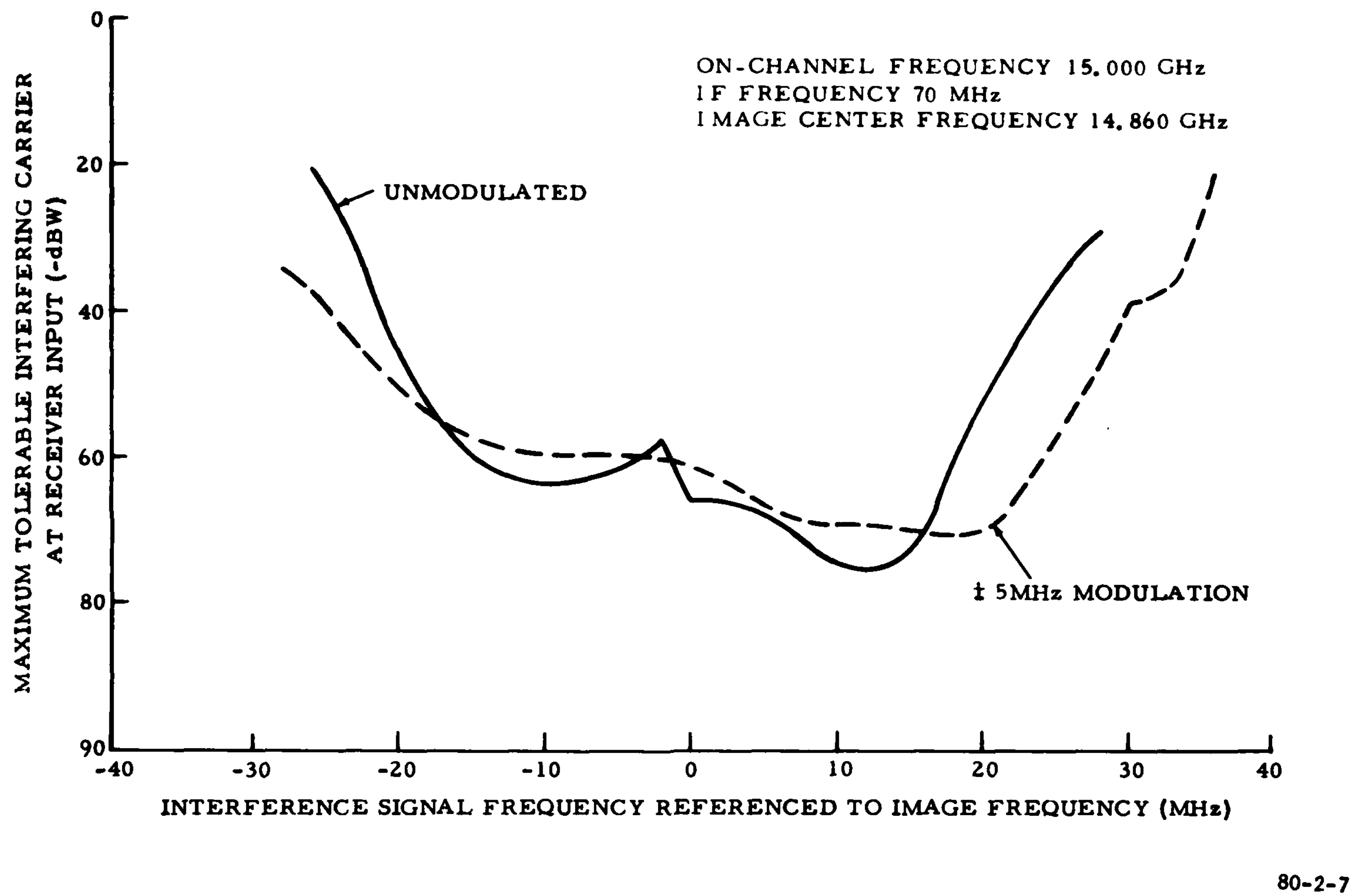
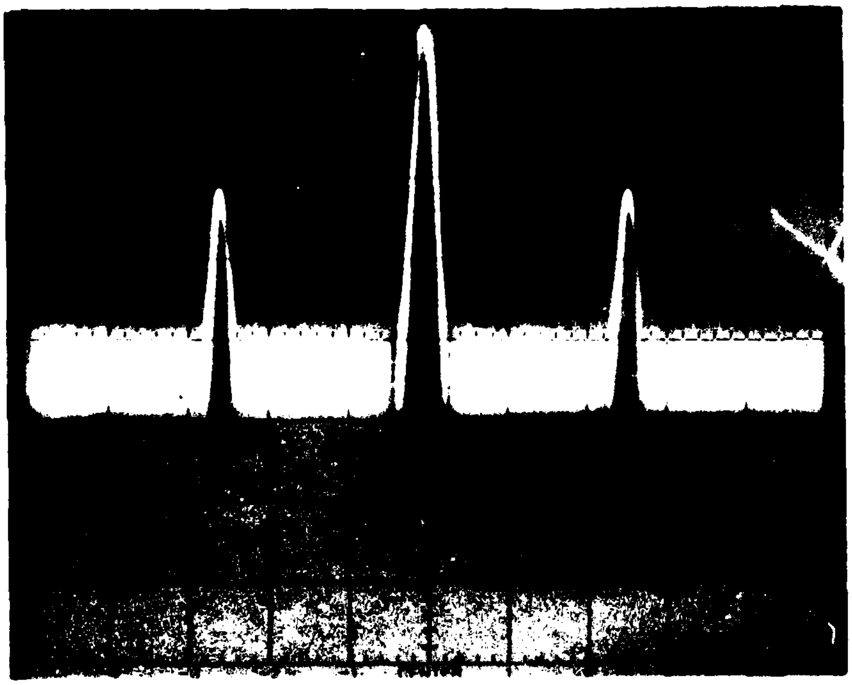
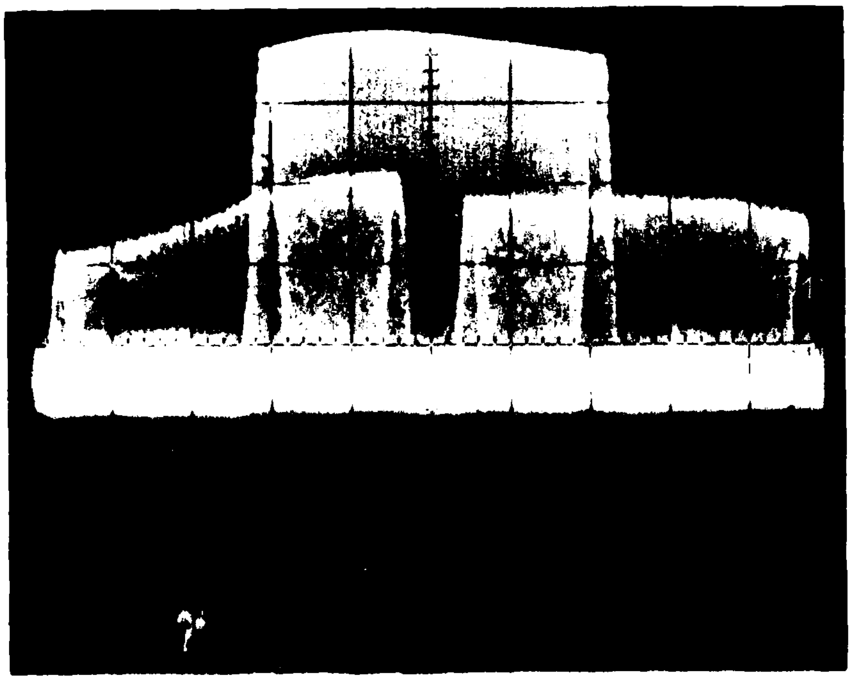


FIGURE 7. TERRACOM RECEIVER IMAGE FREQUENCY REJECTION RESPONSE

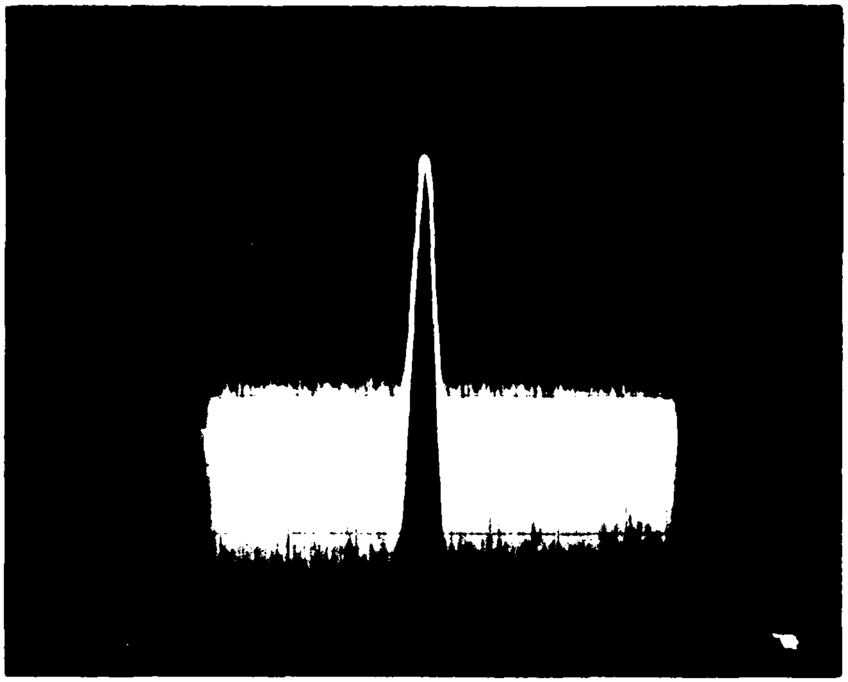


(a) UNMODULATED CARRIER

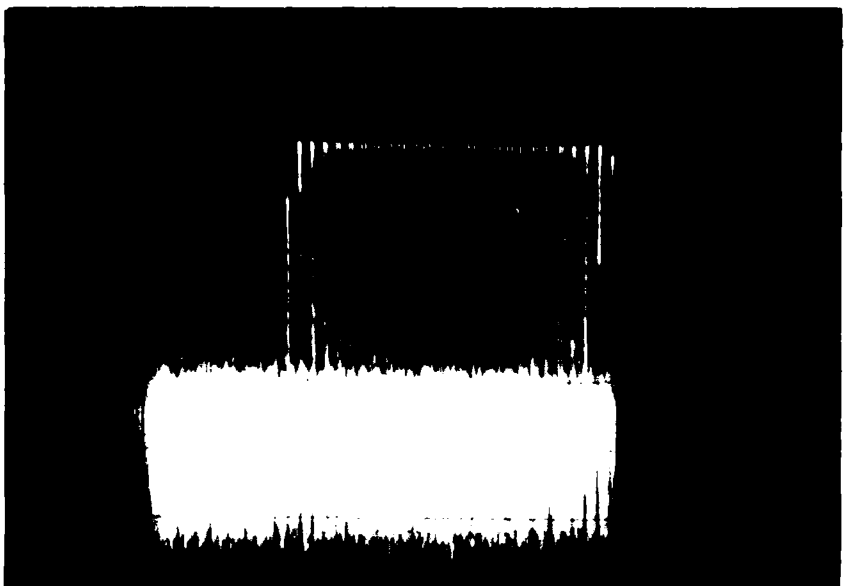


(b) ± 5 MHz MODULATED CARRIER

FIGURE 8. RML-4 TRANSMITTER SPECTRUMS



(a) UNMODULATED CARRIER



(b) ± 5 MHz MODULATED CARRIER

FIGURE 9. TERRACOM TRANSMITTER SPECTRUMS

APPENDIX

INTERNATIONAL MICROWAVE CORPORATION (IMC-1415) TML-3 SYSTEM

The operating frequency of the transmitter and receiver is within the 14.4 to 15.25 GHz band. Transmitter power is a minimum of 1/8 watt (21.7 dBm) with a frequency stability of 0.005 percent. Baseband frequency response is in the range of 10 kHz to 16 MHz signal.

The transmitter receives a video signal through a 75 ohm unbalanced line and the signal is fed to the very high frequency-frequency modulation (VHF-FM) oscillator assembly which is comprised of three major subassemblies: (1) a video preamplifier, filter, and attenuator adjustment of the level of the incoming signal for proper deviation of the FM oscillator; (2) broadband video amplifier to increase the signal gain to 20 dB; and (3) VHF oscillator and amplifier which is comprised of a 250 MHz oscillator and a three stage VHF amplifier up-converter. The second input to the VHF amplifier up-converter is the isolated output signal of the phase locked low frequency crystal oscillator to a high Q cavity oscillator. Only the upper sideband from the up-converter's output (transmitter frequency) is allowed to pass to the IMPact Ionization Avalanche Transit Time (IMPATT) amplifier for amplification of the signal to the 1/8 watt minimum output.

The microwave receiver includes four sections: receiver head, receiver, patch panel, and power supply. Input signal to the receiver head processes the signal by dual down conversion to the receiver IF frequency. The receiver processes the IF frequency and the baseband video signal which is fed to the receiver patch panel for local monitoring or retransmission.

A receiver selectivity curve, supplied by the manufacturer, is shown in figure A-1. Note that the curve is not the true selectivity, since an off-channel signal was not present.

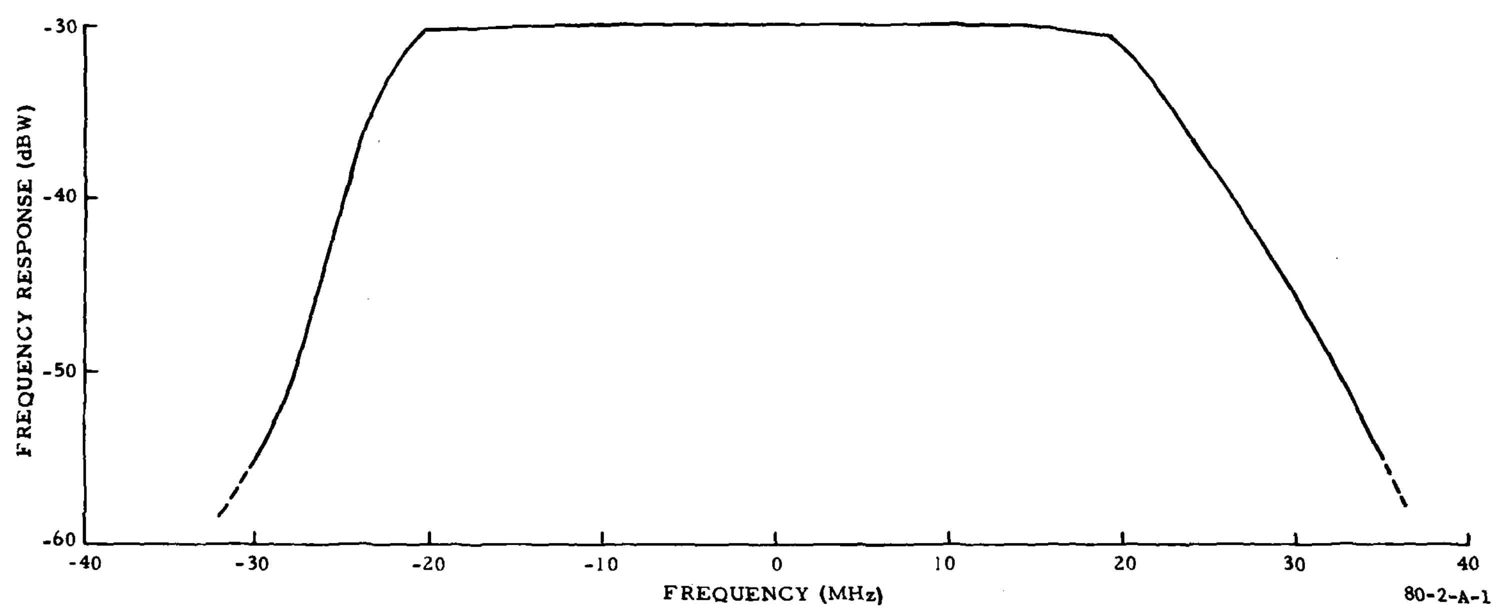


FIGURE A-1. RECEIVER SELECTIVITY IMC-1415