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# TEST AND EVALUATION OF A BROADBAND VHF ISOLATOR

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INTERIM REPORT

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16. Abstract

This report describes a prototype broadband VHF ferrite isolator device that can be used to reduce transmitter intermodulation in air traffic control air/ground communication equipments. The isolator was developed for the Systems Research and Development Service through an Inter-Agency Agreement with the United States Air Force. The isolator was tested at the National Aviation Facilities Experimental Center and was found to reduce T-1108/GRT-21 transmitter intermodulation approximately 30 dB. Test results fell short of design goals for weight, insertion loss, and intermodulation product reduction.

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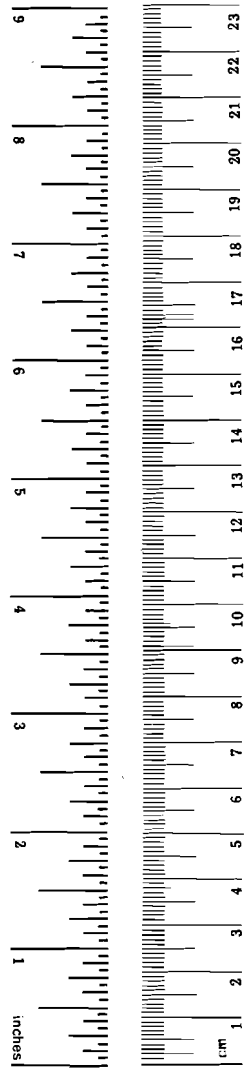
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

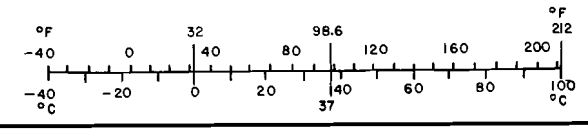
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 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 |



# PREFACE

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# INTRODUCTION

## PURPOSE.

The purpose of this activity was to test and evaluate a prototype broadband very high frequency Isolator/Intermodulation Reduction Device, and determine its ability to reduce transmitter intermodulation products at the Federal Aviation Administration air/ground communication facilities.

## BACKGROUND.

An Inter-Agency Agreement (DOT-FA74WAI-413), was established between the Federal Aviation Administration (FAA) Systems Research and Development Service and the United States Air Force, Rome Air Development Center (RADC) to have RADC develop a production prototype broadband very high frequency (VHF) Isolator/Intermodulation Reduction Device (IRD). This agreement was a follow on to a prior agreement where the feasibility for use of this type device was established.

Twelve production prototype IRDs were built for RADC by Addington Laboratories, Incorporated, 1043 Di Giulio Avenue, Santa Clara, California, 95050. Six of these IRDs were sent to the National Aviation Facilities Experimental Center (NAFEC) for test and evaluation.

# DISCUSSION

## GENERAL.

Many FAA Air/Ground Communication Facilities have VHF transmitters operating with their antennas in close proximity to other transmitting antennas. When two or more of these transmitters radiate simultaneously, the output signal of one transmitter can be coupled into the other transmitter through its antenna, and cause spurious signals including third-order intermodulation products to be radiated. If the carrier frequency of one transmitter is A and the carrier frequency of the other transmitter is B, then a third-order intermodulation product can be generated at frequencies 2A-B and 2B-A. Other odd order intermodulation products are also generated but at a lower and usually insignificant level.

The broadband VHF Isolator/IRD was designed to permit a transmitter output signal to flow into its antenna with little attenuation while greatly reducing the level of other signals flowing into the transmitter from its antenna.

## DESCRIPTION OF EQUIPMENT.

A ferrite isolator is essentially a three-port TEE circulator with one port internally terminated into a matched load. A signal entering port one will flow to port two and a signal entering port two will flow into the termination in port three. The IRDs tested at NAFEC contained three or four ferrite isolators integrated into a package with two 90° hybrids.

The prototype VHF broadband IRD shown in figure 1 is 14.7 inches long, 6.7 inches wide, 1.5 inches high and weighs approximately 7 pounds. All six IRDs sent to NAFEC for evaluation were designated by the manufacturer, as model number 103600010, however, the IRD with serial number 6099H was in a four module configuration as shown in figure 2, while the IRDs with serial numbers 6103H, 6104H, 6105H, 6109H, and 6110H were in a three-module configuration as shown in figure 3.

### DESIGN GOALS

| | |
|---|---|
| Frequency Band | 118-136 MHz |
| Power Capability | 50 watts in either direction |
| Maximum Size | 250 cubic inches |
| Maximum Weight | 4 pounds |
| Input/Output Impedance | 50 ohms |
| VSWR | 1.5 max at input |
| Insertion Loss | 3 dB max. |
| Isolation | 45 dB min. |
| Intermodulation Products | -45 dBm with +47 dBm forward power and +20 dBm of reverse power |

## TESTS CONDUCTED AND RESULTS.

The IRDs were tested at the NAFEC Experimental Peripheral Communication Facility. Measurements were made of (1) insertion loss, (2) isolation, (3)power handling capabilities, (4) voltage standing wave ratio (VSWR), and (5) the reduction of transmitter third-order intermodulation products. Two of the six IRDs tested at NAFEC were also sent to the Northwest Region for field evaluation and the results of their tests are included in an ANW-422 memorandum, dated March 27, 1975. Following are the results of the NAFEC measurements.

1. Insertion loss is a measure of the signal attenuation in an IRD when a signal flows through the IRD in a forward direction. Insertion loss

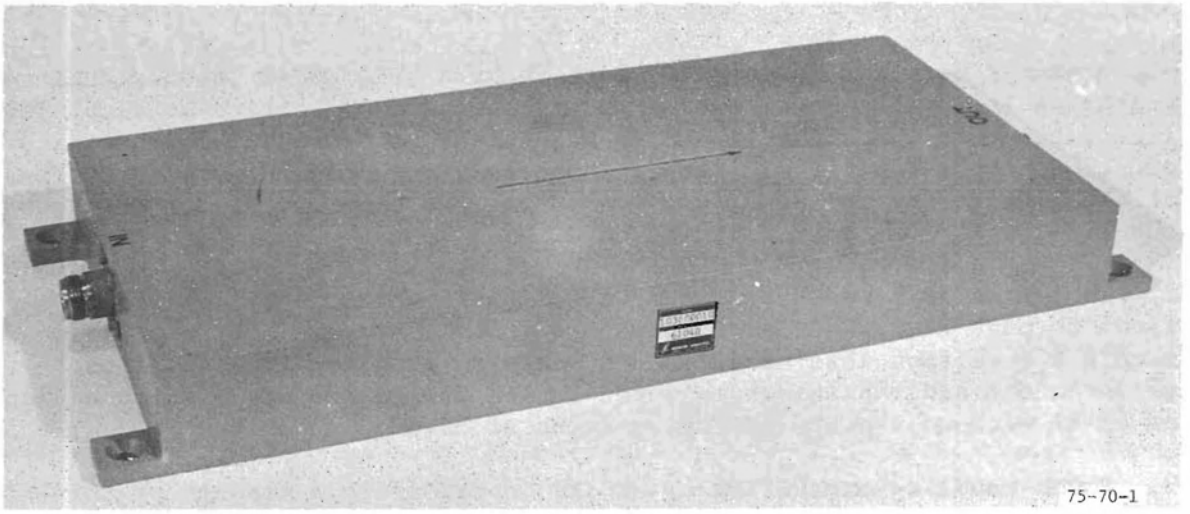


FIGURE 1. BROADBAND VHF ISOLATOR

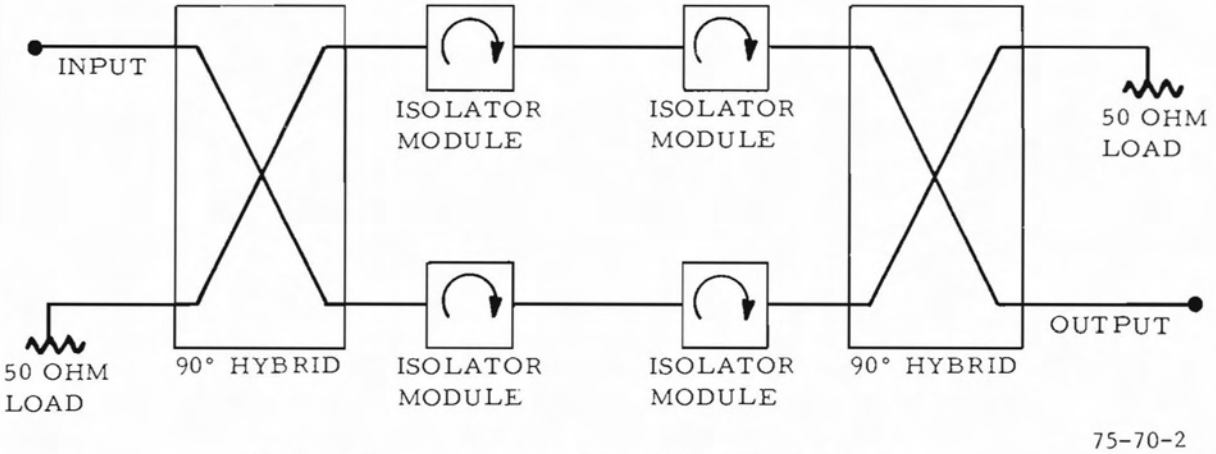


FIGURE 2. FOUR-MODULE CONFIGURATION IRD

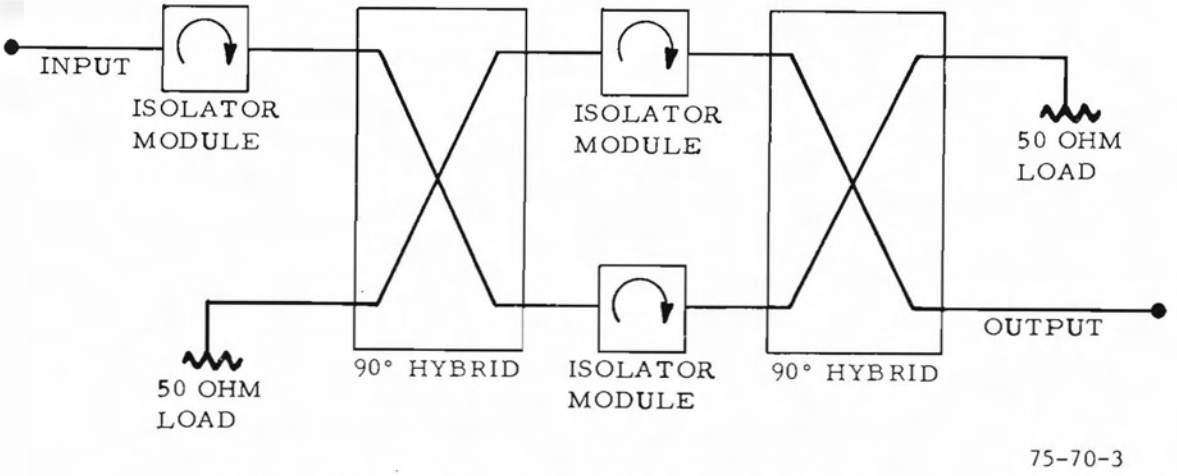


FIGURE 3. THREE-MODULE CONFIGURATION IRD

measurements were made using a Hewlett-Packard (HP) Model 8640B signal generator, a Ballantine Model 340 RF Millivoltmeter, and a Bird Model 61 Termaline wattmeter. The insertion loss values varied from a minimum attenuation of 2.7 decibels (dB) at mid-band frequencies, to a high of 3.4 dB attenuation at the high end of the band, with an average attenuation of 3.1 dB across the 118-136 MHz VHF communication band.

2. Isolation is a measure of the signal attenuation in an IRD when a signal flows through the IRD in a reverse direction. The same instrumentation used for insertion loss measurements was also used for the isolation measurements and the values measured varied from a low of 48 dB to a high of 62 dB with an average isolation value of 52 dB.

3. Power handling capability of an IRD is primarily a measure of the IRD ability to dissipate heat out of and away from the ferrite elements. Each IRD was installed on a T-1108/GRT-21 transmitter (see figure 4) and operated with a continuous 50 watts of forward power and 0.5 watts of reverse power for over 1 hour in a 74° F room environment. A Simpson Model 388 Therm-o-meter was used to measure the IRD temperatures. The hottest IRD area was measured at 104° F, which is within the operating range.

4. VSWR measurements were used to define the impedance match of the IRD to a nominal 50 ohm transmission system. Measurements were made using the HP 8604B signal generator, an Alford type 1026C-6 VHF slotted line, an HP Model 415B standing wave indicator and a Bird Model 81, 50 ohm load. The highest VSWR measurement was 1.4:1 with average VSWR values measuring approximately 1.2:1.

5. The reduction of transmitter third-order intermodulation products was measured under transmitter radiating conditions. Two T-1108/GRT-21 transmitters were operated in the 10-watt configuration. Transmitter A was tuned to frequency 133.125 MHz and transmitter B to frequency 134.7 MHz. Transmitter A was 90 percent modulated with a 1000 Hz tone while transmitter B was 90 percent modulated with a 400 Hz tone for identification purposes. The transmitters were then connected to type FA-5301 circularly polarized antennas which were installed on the peripheral communications site north tower. Horizontal spacing between the antennas was adjusted so that a signal from transmitter A was attenuated 20 dB when it reached the antenna terminal of transmitter B.

Signal level measurements were made using a Texscan Model AL-40 spectrum analyzer which was installed in the site screen room and connected to an antenna on the south tower. An Adams Russell Model 100 multistage filter cavity was installed in the spectrum analyzer antenna input circuit to eliminate the possibility of intermodulation developing within the analyzer. The received signal levels were read on the spectrum analyzer and their values were verified with a substitute signal from the HP-8640B signal generator.

With both transmitters radiating simultaneously the transmitter third-order intermodulation products were measured at 42 dB below the received transmitter carrier signal level. When IRDs were installed in the transmitter output

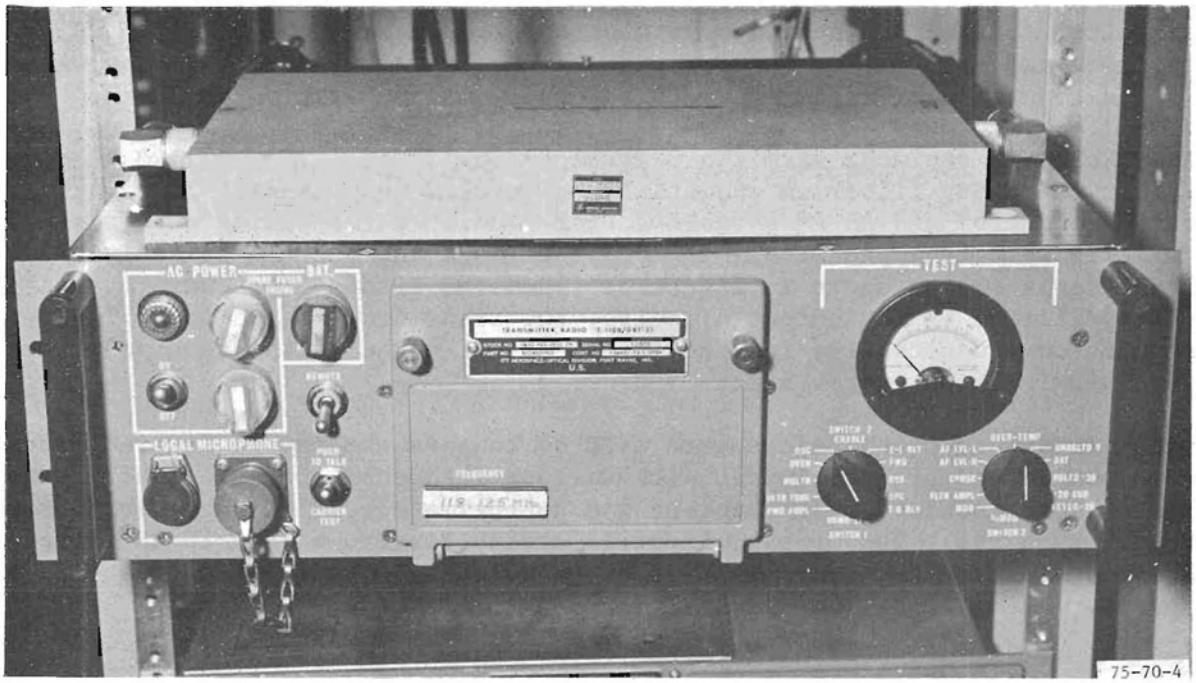


FIGURE 4. IRD INSTALLED ON T-1108/GRT-21

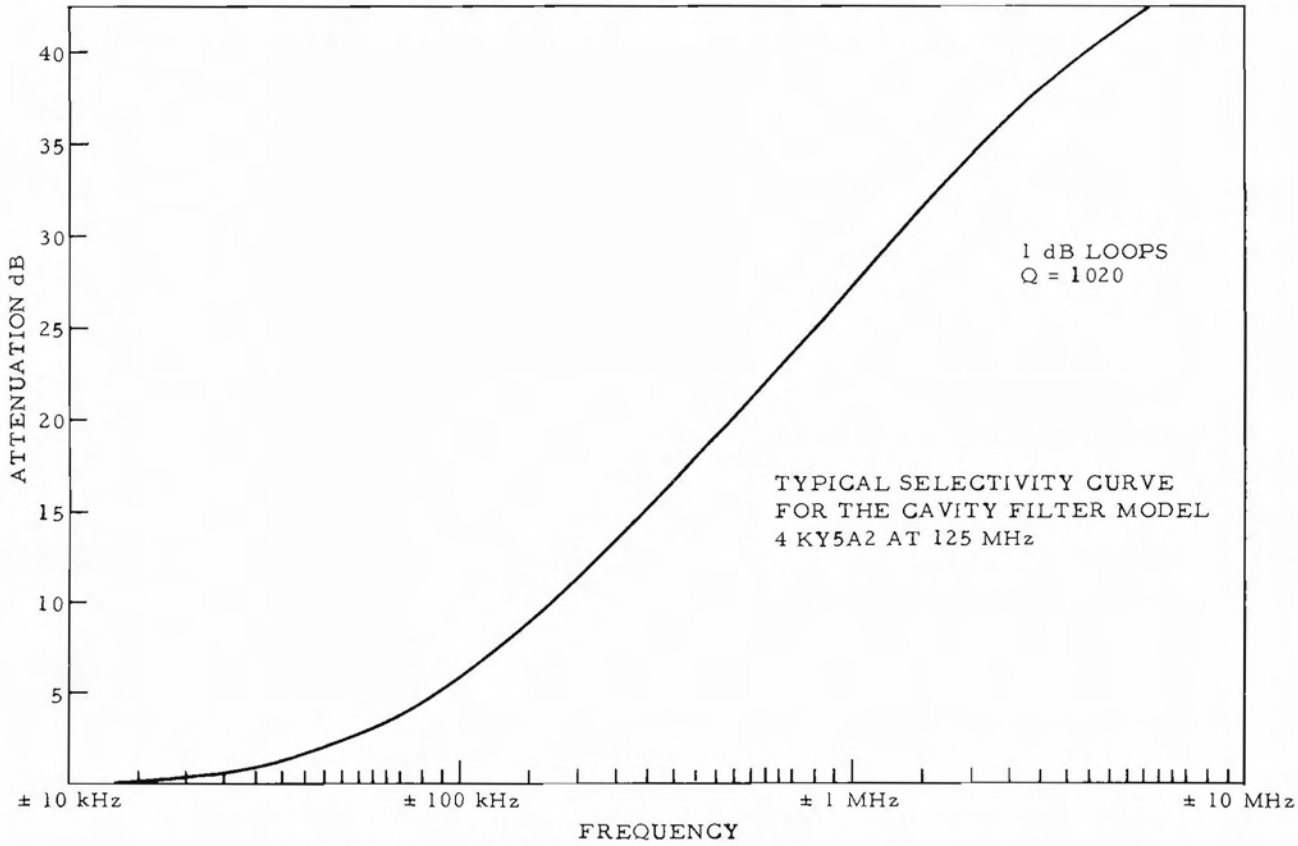


FIGURE 5. GE CAVITY SELECTIVITY CURVE

circuits, the third-order intermodulation products were measured 71 dB below the received transmitter carrier signal level. The IRDs improvement was 29 dB in the reduction of transmitter third-order intermodulation products.

The IRDs were replaced with two General Electric Model-4KY5A2 cavity filters. This type cavity filter is essentially a quarter wave coaxial line with a fixed outer conductor and an adjustable center conductor for tuning purposes. The cavities were equipped with 1 dB coupling loops and had the selectivity characteristics as shown in figure 5. When the transmitters were operated with cavity filters in the output circuits, the transmitter third-order intermodulation products were reduced to a level 72 dB below the received carrier level for a 30 dB improvement.

Other frequency combinations were used to compare the change in transmitter intermodulation product levels with various frequency spacing. The IRD transmitter intermodulation improvement was approximately 30 dB regardless of frequency spacings. The General Electric cavity filters made a 20 dB improvement at 0.5 MHz frequency spacing, a 30 dB improvement with 1.5 MHz frequency spacing, and a 40 dB improvement with a 4 MHz frequency spacing.

## CONCLUSIONS

Based on the data collected and presented in this report, it is concluded that:

1. The broadband VHF isolator built by Addington Laboratories Incorporated, and designated as model number 103600010, will reduce T-1108/GRT-21 transmitter third-order intermodulation products by approximately 30 dB regardless of frequency spacings.

2. The Addington Laboratories Incorporated broadband VHF isolator will reduce transmitter intermodulation products better than a General Electric Model-4K5A2 cavity filter when transmitter frequency spacing is less than 1.5 MHz.

3. The broadband VHF isolator tested did not meet the design goals for weight, insertion loss, and intermodulation product reduction.

## RECOMMENDATIONS

It is recommended that:

1. The broadband VHF isolator be considered acceptable for limited field use at locations where interfering transmitted signals are spaced less than 1.5 MHz from each other.

2. A study be undertaken to determine the problem of intermodulation product generation within the ferrite isolator, as the IRDs tested at NAFEC did not reduce transmitter intermodulation products by a level equal to its isolation value.

3. Additional ferrite isolator devices be obtained and tested at NAFEC. Field reports from RADC and ANW-422 indicate that other isolators are available with better operating characteristics than those tested at NAFEC.