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TACAN-DME FALSE DISTANCE LOCK-ON

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National Aviation Facilities Experimental Center
Atlantic City, New Jersey

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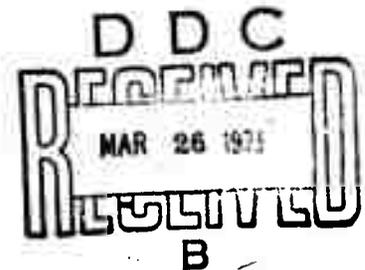
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## FINAL REPORT

Prepared for

# DEPARTMENT OF TRANSPORTATION

## FEDERAL AVIATION ADMINISTRATION

Systems Research & Development Service

Washington D. C., 20591

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16. Abstract

The report covers the results of laboratory and field tests of various TACAN ground station modifications designed to minimize the false DME problem. An airborne and ground data collection package was designed to record the percentage of false replies synchronous with an aircraft interrogation. The modifications tested included a modified GRN-9 TACAN receiver developed by ARINC, a tighter decoder tolerance modification (Tulsa modification) designed by Stanley Milner of the Tulsa VORTAC, a jittering dead time gate designed by LTV Electro Systems, Montek Division, and a retriggerable long dead time gate (Crazy Woman modification) designed by George Oltion of the Crazy Woman Wyoming VORTAC. Although all modifications were successful in reducing the percentage of false DME, the Crazy Woman modification was the most successful in eliminating all false DME caused by multipath air-to-ground interrogations.

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## PREFACE

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The assistance and cooperation of the site personnel at Tyrone, Pennsylvania; Salt Lake City, Utah; Delta, Utah; Crazy Woman, Wyoming; Sheridan, Wyoming; Albuquerque, New Mexico; and Tulsa, Oklahoma VORTACs, added greatly to the successful completion of this effort.

The assistance and comments of personnel from the LTV Electro Systems Montek Division and the ARINC Research Corporation were most appreciated by the authors.

The authors feel a special acknowledgement should be given to Mr. George Oltion, inventor of the Crazy Woman modification, for his clear and logical approach to the solution of the false DME problem.

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## TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

## LIST OF ILLUSTRATIONS (continued)

# INTRODUCTION

## Purpose

The purposes of this project are to evaluate the effectiveness of several techniques designed to prevent false distance lock-on of the RTB-2 and GRN-9 series transponders, and to identify the nature and extent of modifications to existing transponders which would be required to provide performance in accordance with operational standards.

## Background.

The history of the Federal Aviation Administration (FAA) involvement in the false Distance Measuring Equipment (DME) problem began in February 1964, a report from the Western Region Flight Inspection and two user airlines indicating the observance of false distance information. Several services of the FAA cooperated to develop a modification to alleviate the problem. This modification, AFP6780.1, Chapter 117, Change 50, dated April 14, 1965, was identified as an interim modification, and only facilities that had false distance replies, verified by flight inspection, were to implement the modification. At that time, the problem was identified as caused by two factors: air-to-ground reflections and bunching of squitter after receiver dead time. The interim modification was implemented as a sequential three-step process, stopping at that step which eliminated the false replies. The modification was identified as causing a reduction in traffic handling capability and each successive step of the modification further degraded the system.

In late 1965, General Dynamics Corporation, under contract FA65WA-1237 provided a false DME modification for the GRN-9 series transponders. Interim report RD-66-87, dated December 1966, which was an evaluation of the General Dynamics modification, concluded that: (1) the General Dynamics modification eliminated the false DME problem, but at a cost of 2 or 3 dBm in receiver sensitivity, and (2) the receivers with the FAA modification (Chapter 117, Change 50) produced better cancellation of false DME replies than the General Dynamics receiver for the same receiver sensitivity.

The next significant event from a review of false DME history is AFP6780.1, Chapter 182, Change 144, dated August 18, 1969. Chapter 182 is entitled "Modification of TACAN/DME Ground Station Receivers to Eliminate False DME Lock-On Error." This modification is essentially the same as Step 1 and 2 of the 1965 Chapter 117 modification with the addition of a reduced value of the coupling capacitor between the first and second video amplifiers. The cause of false DME errors is identified as reflections (multiple or discrete). This modification (Chapter 182) states that the suspected system degradation caused by increased echo suppression is not serious and that due to the unpredictable nature of the false DME lock-on problem, it is advantageous to modify all TACAN/DME receivers regardless of whether false lock-on has been experienced.

1

On December 11, 1970, Notice N6780.16 was issued by Systems Maintenance Service entitled, "Problems Associated with Implementation of AFP6780.1, Chapter 182." The notice suspends application of portions of the Chapter 182 modification on the GRN-9 equipment. The problems associated with Chapter 182 are close-in unlocks and erratic receiver operation. The notice also indicates submission of a Request for Research, Development and Engineering Effort, calling for improvements to eliminate the false DME lock-on and close-in unlock problems.

In March 1971, Systems Research and Development Service (SRDS) provided a work statement to the National Aviation Facilities Experimental Center (NAFEC), under Project 041-306-05X, entitled, "TACAN-DME False Distance and Unlock Problems." The work statement recognized the existing problems with the Chapter 182 modification and identified a Wilcox DME, Series 496, transponder developed under an FAA contract and a receiver drawer modification developed for the USAF by the ARINC Research Corporation as equipments having features which may be expected to prevent false distance lock-on.

Preliminary literature research at NAFEC identified various other modifications that warranted investigation as to their ability to reduce false distance lock-on. The modifications were a narrower decoding tolerance developed at the Tulsa VORTAC (Tulsa mod.), a unique modified dead time gate developed at the Crazy Woman, Wyoming VORTAC (Crazy Woman mod.) and a jittering dead time gate developed by LTV Electrosystems, Montek Division (Montek mod.).

Description of Equipment.

ARINC Modification - The ARINC modification, developed under an Air Force contract, is designed to improve the TACAN system by eliminating problems in the ground transponder that cause gross DME and azimuth errors. The modification consists of a slightly modified GRN-9 intermediate frequency (IF) amplifier, a new solid state video chassis, and redesigned receiver chassis power supplies. The modification is designed to provide improved receiver squitter, decoding processes, blanking characteristics, and alleviate interference problems.

Figure 1 is a functional block diagram of the ARINC modified receiver. The IF amplifier is essentially a fixed gain receiver. The gain is varied by an automatic gain control (AGC) only when continuous wave (CW) interference is detected or an interrogation overload exists. The output of the IF amplifier is passed through thresholding and decoding circuits. The output of these circuits is decoded DME interrogations and a few decoded noise pulses from the IF amplifier. The short-pulse inhibitor inhibits all decoded pulses of 1 microsecond ($\mu$s) or less. A separate squitter source supplies pulses to the video output circuitry to maintain the required 2,700 pulses to be fed to the encoder. The receiver dead time gate can be adjusted to a maximum of 150 $\mu$s. The blanking gate from the Frequency Multiplier Oscillator (FMO) has been extended an additional 10 $\mu$s from the normal GRN-9 system.

Note should be made that, although the ARINC modified receiver was designed to improve many aspects of the TACAN system, the NAFEC tests of this modification were directed toward its effects on false DME only.
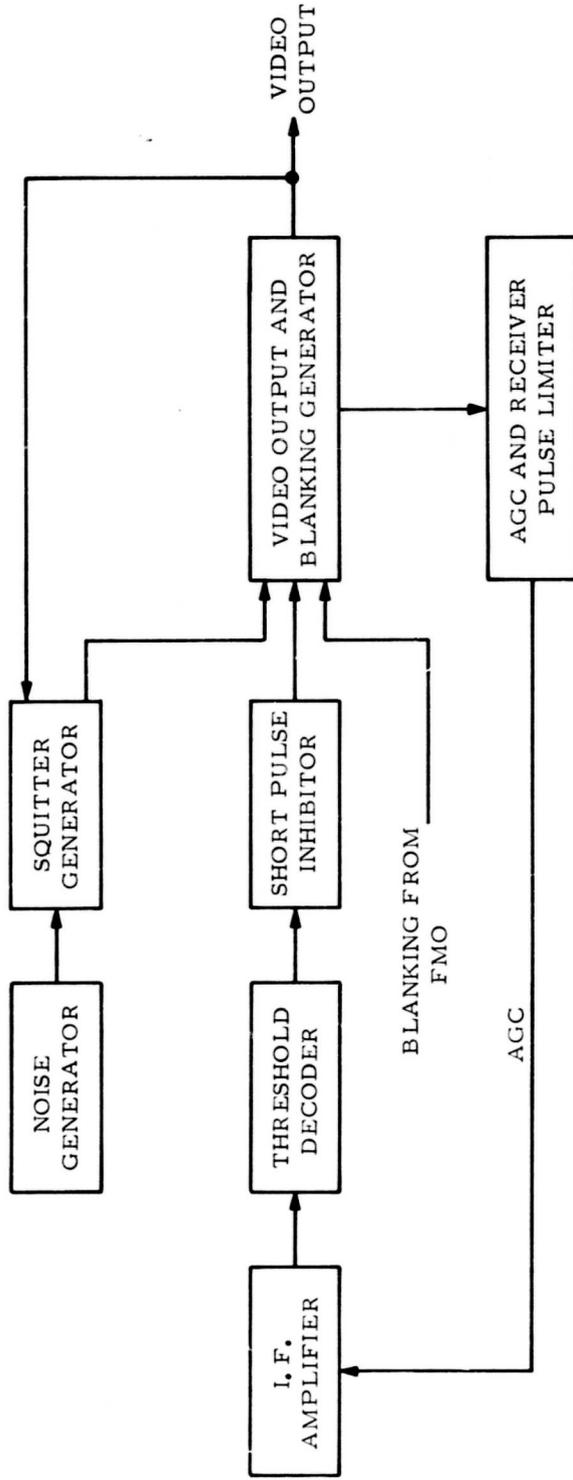
ARINC RECEIVER



FIGURE 1 - ARINC FUNCTIONAL BLOCK DIAGRAM

3

The reports of ARINC stated the principal problem, which causes false DME responses, is inadequate receiver blanking during transmission periods. The inadequate blanking problem was corrected, in the ARINC modification, by extending the blanking gate from the FMO an additional 10 µs.

ARINC also states that another problem, which contributes to the generation of false DME's, is a cross-modulation effect caused by insufficient decoupling of the various pulse circuits from the common receiver power supply. The problem was corrected in the modified receiver by using separate power supplies for receiver pulse circuits and receiver IF sections. During the receiver modification program, ARINC identified that the FAA modification (Chapter 182) was not compatible with TACAN system-performance specifications. The problem is that high interrogation levels are distorted by the FAA modification to such a degree as to cause pulse spacings outside the GRN-9 system decoding limits(close-in unlocks). ARINC did use the FAA fourth stage IF amplifier modification in their modified receiver.

FAA Modification (Chapter 182) - The FAA modification has identified the cause of the false DME problem as multipath reflections. The modification states: "These reflected signals generate what appear to be irregular amplitude, long duration pulses in the receiver video circuits after the dead time gate. Noise pulses riding on top of these long duration pulses have a high probability of decoding immediately following dead time."

The modification deals with the multipath signal by increasing the echo suppression time of the fourth and fifth stages of the IF amplifier. The echo suppression causes the instantaneous sensitivity of the receiver to be reduced for a given period following an interrogation signal level. Thus, the stronger the interrogation the longer the receiver will be desensitized.

The long duration pulses associated with the multipath signals are dealt with by a smaller coupling capacitor between the two video amplifiers preceding the decoder. The smaller coupling capacitor causes the low frequency components to be attenuated before decoding takes place. Thus, the noise pulses riding atop the long pulse are returned to a lower baseline, and the probability of decoding is less.

Tulsa Modification - The Tulsa modification identified the cause of the false DME problem as wide decoder tolerance allowing a high probability of decoding squitter after dead time. The problem is identified as always occurring at a distance of 5 miles and thus an association with the trailing edge of dead time was established.

The modification reduced the value of the coupling capacitor before the decoder. This change narrowed the pulses to the coincidence decoder and thus reduced the decoder tolerances of the GRN-9 equipment from $12^{+1}_{-2\frac{1}{2}}$ to $12^{+1}_{-1\frac{1}{2}}$. The modification also identified the effect of the FAA

4

modification on pulse spacing caused by pulse distortion in the IF amplifier. With the tighter decoder tolerance, it was necessary to reduce the echo suppression of the fifth IF stage so that pulse distortion did not occur with high interrogation levels.

Wilcox Receiver - The Wilcox DME, Series 496, is a complete DME ground station. The equipment includes transmitter and receiver and a full monitoring system. The instruction manual supplied with the equipment makes no particular mention of any false DME fixes designed into the equipment. The equipment does have a short echo suppression circuit that protects the second pulse of a pulse pair from short range multipath signals and thus will prevent DME unlocks caused by these multipath signals.

Figure 2 is a functional block diagram of the Wilcox 496 ground receiver. The 63 MHz output signal from the preamp is mixed with a local oscillator (LO) signal and the resultant 10 MHz signal is applied to the 10 MHz amplifier. The output of the 10 MHz amplifier is fed both a delay line and the AGC generator. The delay line delays the signal into the main IF amplifier until the AGC generator sets the gain of the receiver. This allows the gain of the receiver to be adjusted as a function of the input signal before application to the IF amplifier. The output of the decoder enables the blanking gate generator which inhibits the input to the decoder for the duration of the blanking generator function. Note that the blanking generator (receiver dead time) is enabled for DME interrogations and a few receiver noise pulses only. A separate squitter source supplies pulses to the video output circuitry to maintain the required 2,700 pulses fed to the encoder.

Montek Modification - The Montek modification was developed by Montek as a plug-in modification for the AN/TRN-26. Montek believes their modification is the most logical and effective approach for eliminating the false DME problem. Montek recognizes that no explanation of the exact mechanism by which the false DME problem arises has been advanced. They state that the false DME's occur just after the end of the dead time gate, which is generated by a previous interrogation, and that the phenomenon is most severe at sites having echo-producing obstructions in the vicinity. Montek's approach is to count down the echo generated DME reply, such that the reply is below the required reply efficiency of the airborne DME units.

The desired effect is realized by randomly jittering the trailing edge of the dead time gate. This is accomplished by adding an additional time interval to the existing dead time gate. The additional time interval is initiated by the trailing edge of the existing dead time gate and terminated by the first clock pulse, of a free running pulse generator, following the cessation of the original dead time gate. Since the dead time gate and the pulse generator are non-synchronous, the new dead time gate duration varies between two limits. The limit values are determined by the duration of the original dead time gate and the period of the pulse generator. For example, if the original dead time gate is 60 μs, and the clock period is 90 μs, the additional dead time interval will vary randomly between 60 and 150 μs.
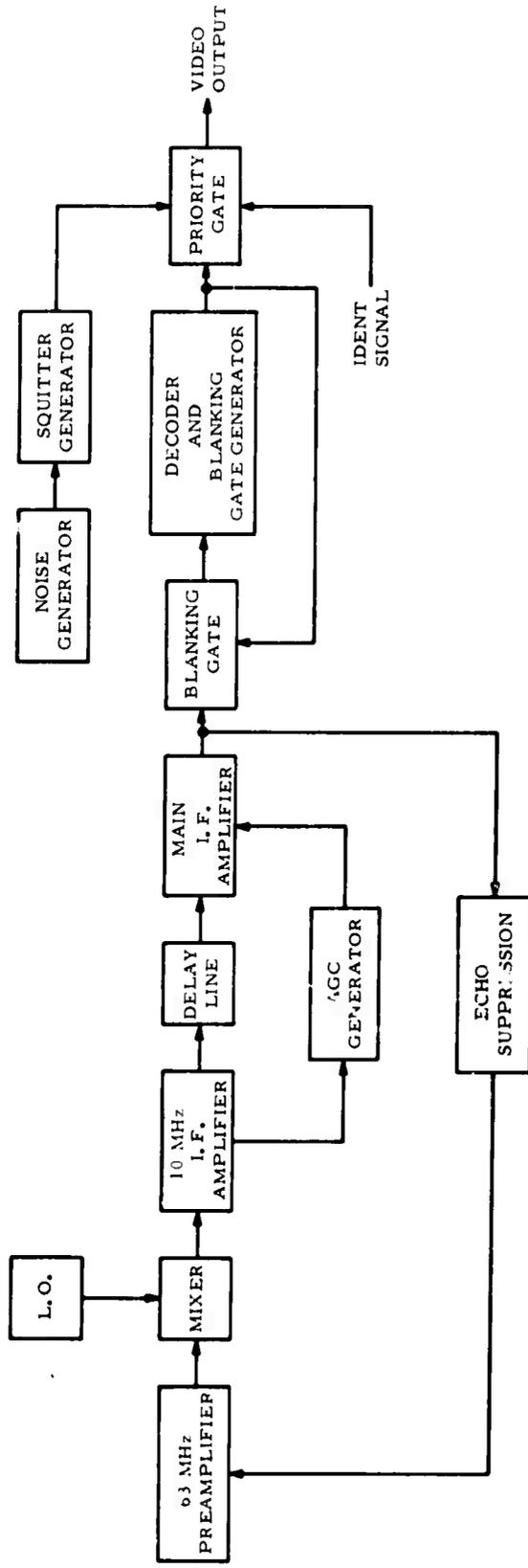
5

WILCOX 496 RECEIVER



FIGURE 2 - WILCOX FUNCTIONAL BLOCK DIAGRAM

General Dynamics Modification - The General Dynamics modification was a false DME modification to the GRN-9B receivers under an FAA contract. The modification is designed to minimize the reception of multipath air-to-ground interrogation signals which may become troublesome in the presence of relatively strong interrogation signals. Two additional means of controlling the receiver gain are provided. An adjustable fixed gain control permits a fixed reduction in receiver sensitivity and an adjustable AGC circuit will introduce various reductions in receiver sensitivity, depending upon the PRF and level of the interrogating signal and the AGC circuit adjustment. Both additional sources of receiver gain control are gated onto the existing squitter control bus in such a manner that the longest gain control voltage determines receiver gain. The additional gain control reduces the thermal noise from the IF amplifier and, hence the squitter rate at the receiver output. A separate squitter source is provided so that a given squitter rate can be maintained in the presence of a reduction in the IF amplifier gain.

A field evaluation of the modification was conducted by the FAA. An interim report of this evaluation entitled, "Evaluate TACAN Separate Squitter Source," concluded that the modification eliminates the DME false reply problem, but at a loss of 2 to 3 dBm receiver sensitivity.

Crazy Woman, Wyoming Modification - The Crazy Woman modification was submitted in the form of a technical paper to Systems Maintenance Service (SMS), by the inventor of the modification, Mr. George Oltion, Sector Chief from Casper Wyoming. Tests at the Crazy Woman Wyoming VORTAC determined that the cause of false distance lock-ons was reflections from mountains or other objects.

The modification is basically a retriggerable long dead time gate. The sensitivity of the gate is adjusted such that only interrogations enable the gate. The length of the gate is adjustable out to 500 s. The modification is based on the premise that multipath signals are substantially lower in amplitude than direct path signals. Thus, an interrogation occurring during the long dead time gate of a previous interrogation will be processed if its amplitude exceeds the threshold level of the retriggerable gate. As long as the amplitude of the multipath signals remains below the threshold of the retriggerable gate, no false DME signals, due to multipath signals will be processed.

## DISCUSSION

The background of the false DME fixes indicates an uncertainty as to the cause or causes of the problem. This being the case, one of the objectives of the project was to attempt an identification of the cause of the false DME problem. Various investigators have identified the problem as a system problem (inadequate blanking, leakage through power supplies, bunching of squitter after dead time, higher receiver sensitivity right after dead time, etc.). Other investigators have identified the cause of the problem to be multipath signals, while others have identified some combination of multipath and system errors to be the cause of false DME.

Since the ARINC modification was a contract item and the contractor identified a solution to the false DME problem, this modification was thoroughly investigated first. During the evaluation of the ARINC modification, knowledge as to the cause of the false DME problem was acquired. With this newly acquired knowledge a determination was made that the Wilcox DME receiver had no features different from the ARINC modification that warranted investigation as to their effect on false DME.

Various laboratory tests were conducted on the normal GRN-9 and RTB-2 series TACAN ground equipments to determine if the cause of the false DME problem was generated in the ground equipment. A series of field tests was conducted at various problem sites selected by SRDS. The ARINC modification and various other modifications were evaluated and flight tested at each of the problem sites to determine the degree to which the false DME problem was reduced.

Laboratory Tests.

Squitter Bunching Tests - The distribution of squitter after signal generator interrogation was determined by counting the squitter that falls after the interrogation signals dead time gate. Figure 3 is a block diagram of the test configuration for the squitter bunching tests. The test pulses from the test pulse generator are used in the normal system to generate signal generator interrogations. These same test pulses are used to trigger the delay generator and thus produce a gate out of the delay generator that is synchronous with the signal generator interrogation. The width of the gate and the time position of the gate relative to the signal generator interrogation are both variable by the controls of the delay generator. For our tests, the gate width was set at 40 μs and the gate position was adjusted to begin at the trailing edge of the normal receiver dead time gate. Therefore, any decoded pulse that was synchronous with the signal generator interrogation and arrived from 60 to 100 μs after the same interrogation would pass through the AND gate. The time base of the counter was set at 1 second and the output of the counter is fed to a printer. Thus, the printout of the printer contains the number of decoded pulses per second (pps) synchronous with, and arriving from 60 to 100 μs after a signal generator interrogation. The tests were performed at the NAFEC sites and each of the field sites. All of the false DME modifications were removed from the equipment while the test was conducted. Varying the signal generator interrogation level between -70 and -30 dBm had little effect on the percentage of replies falling in the 40 μs gate. The data presented in this report were collected using a -50 dBm signal generator interrogation level.

Receiver Sensitivity After Dead Time Tests - Figure 4 is the test configuration for measuring receiver sensitivity of an interrogation synchronous with and following the dead time of a previous interrogation. The test configuration allows the signal generator interrogation of Monitor #1 to be synchronous with Monitor #2 signal generator interrogation and delayed in time
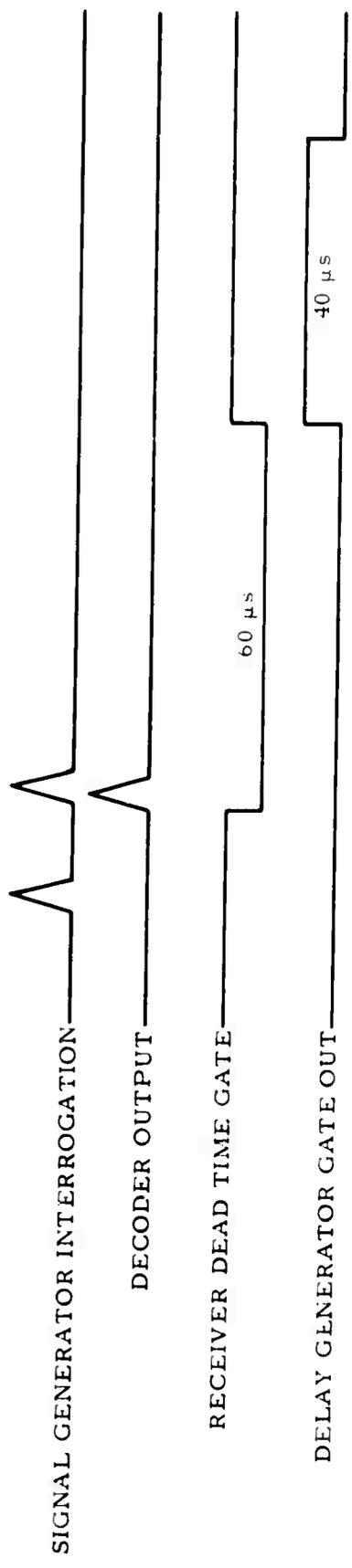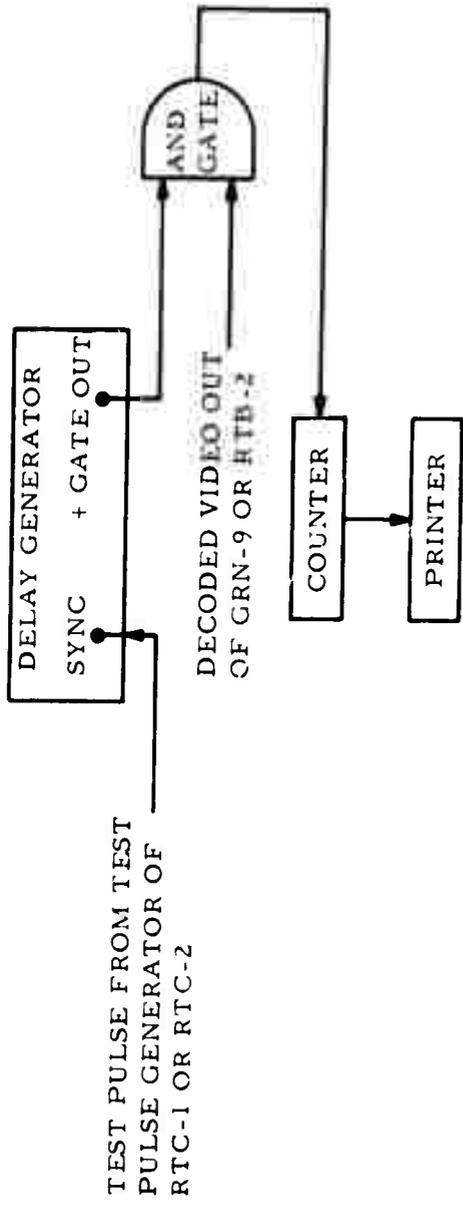
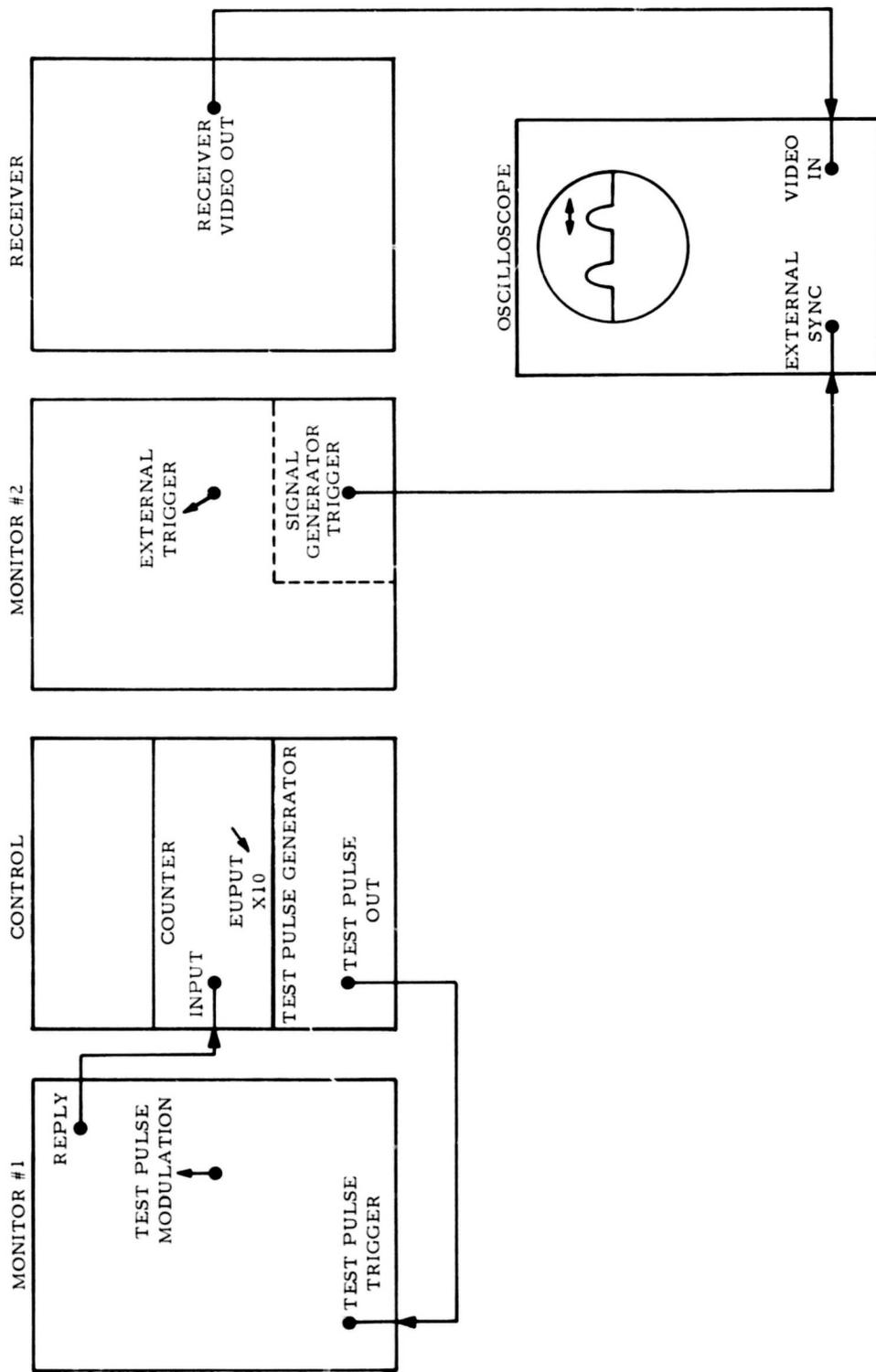FIGURE 3 - TEST CONFIGURATION FOR SQUITTER BUNCHING TESTS

FIGURE 4 - TEST CONFIGURATION FOR MEASURING RECEIVER SENSITIVITY AFTER DEAD TIME

10

from Monitor #2's interrogation by the delay control of the monitor's test pulse generator. The delayed pulse, test pulse out of the test pulse generator, modulates the signal generator of Monitor #1. The oscilloscope is synchronized by the signal generator trigger from Monitor #2. The receiver video output is displayed on the oscilloscope. The oscilloscope displays the decoded reply from Monitor #2 interrogation followed by the decoded reply from Monitor #1. The reply output of Monitor #1 is counted utilizing the system (Beckman Berkley Counter).

Signal Generator #2 is set at -75dBm in order that echo suppression would not be initiated and thus affect the reply from Signal Generator #1. The reply from Signal Generator #1 is set at the maximum delay and the Signal Generator attenuator is adjusted until the reply count on the counter is approximately 240 replies per 400 interrogations. An average of ten 10-second reply counts were recorded as the reply count for each delay position of the reply from Signal Generator #1 interrogation.

Test of Crazy Woman Modification - The dead time gate was adjusted to 300 s. The TACAN ground station was randomly interrogated and the effect on TACAN azimuth and receiver sensitivity was noted for various random interrogation rates. The azimuth calibrator was utilized as a source of random interrogations. Number 1 Signal Generator was operated in the test pulse modulation position and the azimuth calibrator provided the modulation pulses for the signal generator. The effect on azimuth was indicated by viewing the systems 135 Hz and 15 Hz azimuth error meters. The effect on receiver sensitivity was recorded using Signal Generator #2.

Laboratory Test Results

Squitter Bunching Test Results - Figure 5 shows the percentage of synchronous replies falling in a 40 µs count gate following the dead time gate of a signal generator interrogation. The data show that at all the sites tested, the percentage of synchronous replies was less than 15 percent. The data are an average of approximately 100 samples of the number of replies in the 40 µs gate divided by the signal generator interrogation rate (400 interrogations/second).

Receiver Sensitivity Test Results - Figure 6 shows the effect on reply count (receiver sensitivity) of a reply following a previous reply dead time gate. The microseconds delay is measured from the first reply to the second reply as viewed on the oscilloscope. The change in receiver sensitivity from a count of 250 to 300 is less than 2 dB.

Crazy Woman Modification Test Results - Randomly interrogating the receiver at a 2,500 pulse pair per second (ppps) rate had no measurable effect on the 15 or 135 Hz azimuth error indicators. This same condition showed a less than 2 dB decrease in receiver sensitivity.

11

PERCENT OF SYNCHRONOUS REPLIES FALLING
BETWEEN 60 TO 100 μs AFTER A SIGNAL
GENERATOR INTERROGATION.
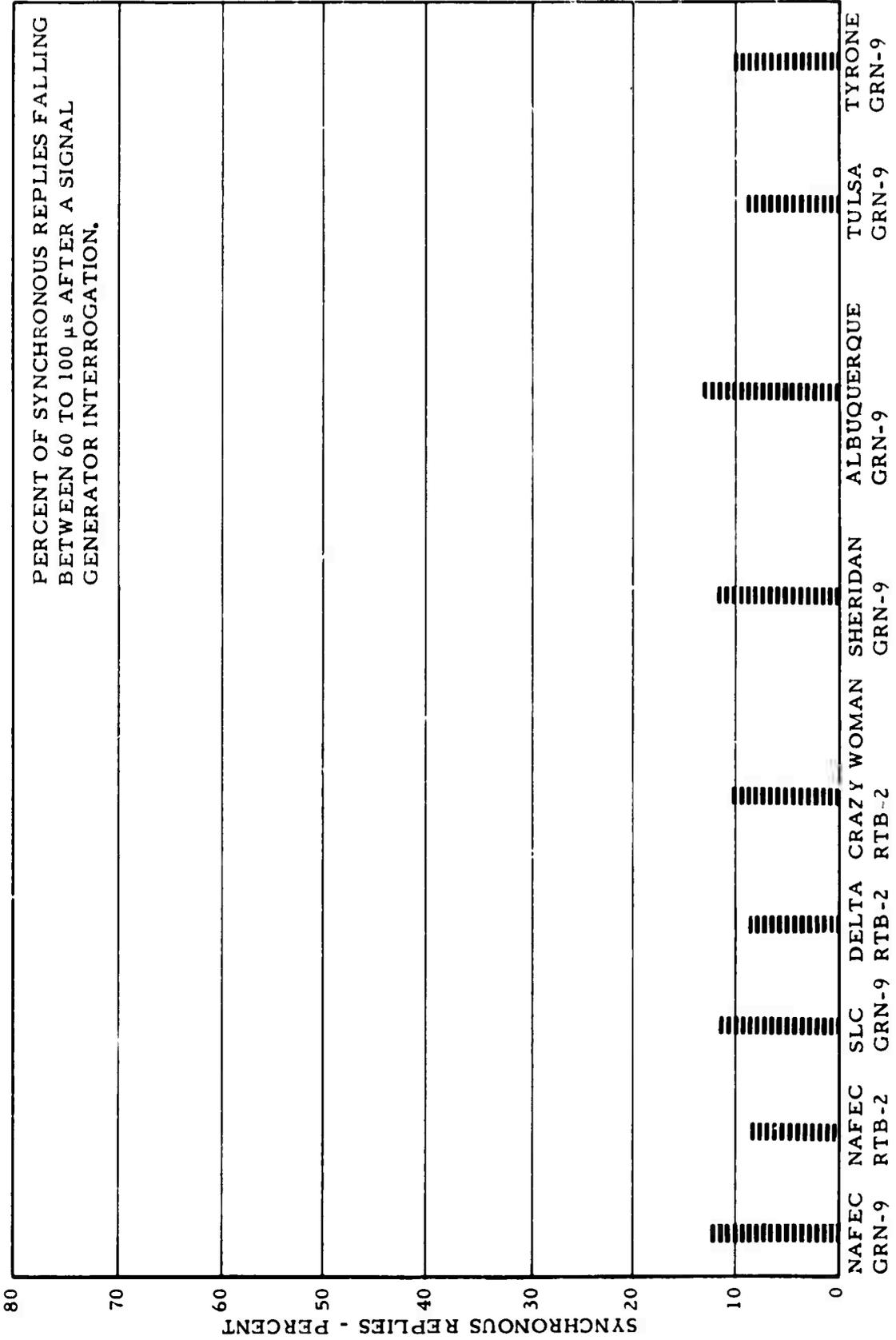
FIGURE 5 - PERCENT SYNCHRONOUS REPLIES AFTER A SIGNAL GENERATOR INTERROGATION

SYNCHRONOUS REPLIES - PERCENT

80

70

60

50

40

30

20

10

0

NAFEC
GRN-9

NAFEC
RTB-2

SLC
GRN-9

DELTA
RTB-2

CRAZY WOMAN
RTB-2

SHERIDAN
GRN-9

ALBUQUERQUE
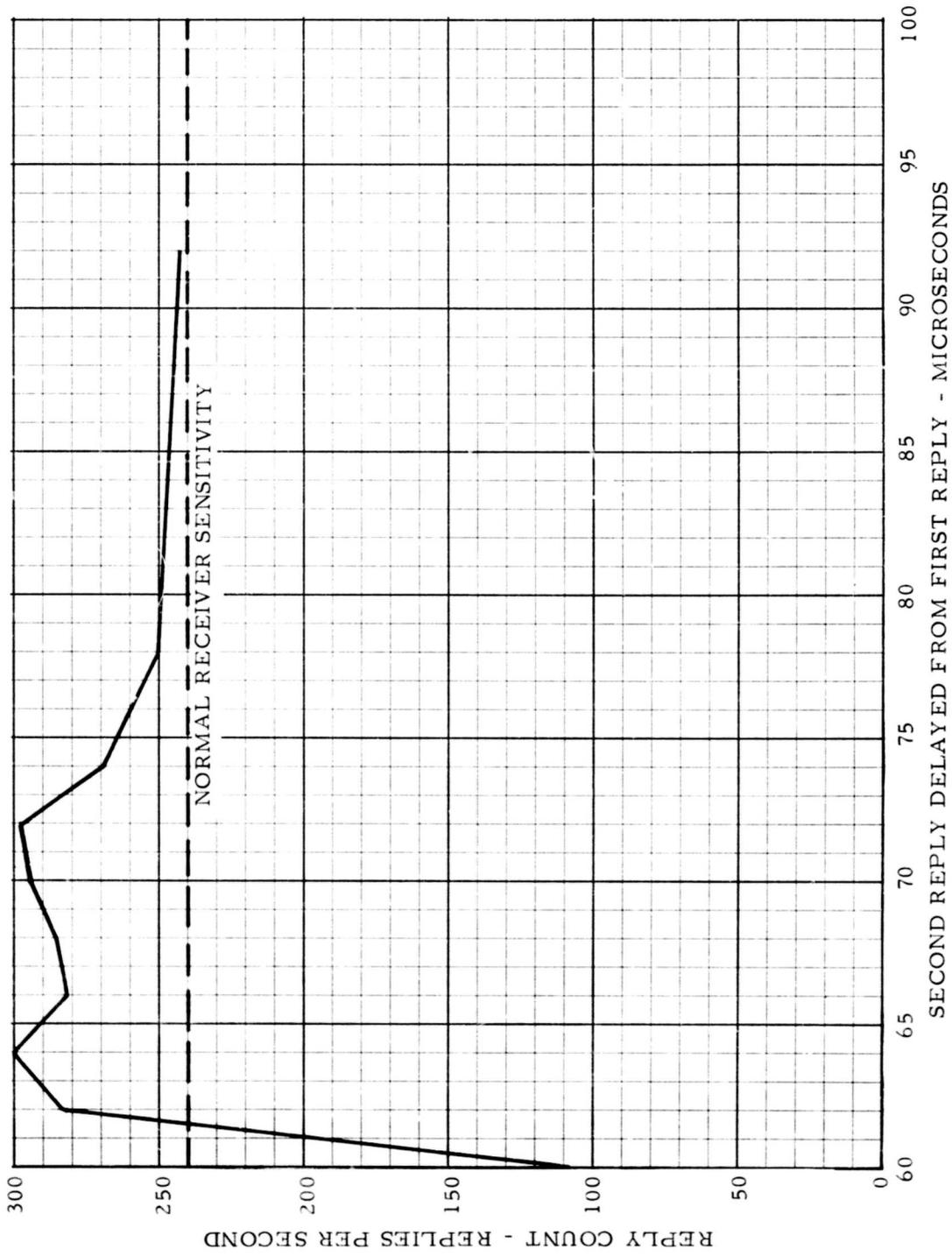GRN-9

TULSA
GRN-9

TYRONE
GRN-9

12

FIGURE 6 – RECEIVER SENSITIVITY AFTER DEAD TIME

Laboratory Test Analysis.

The bunching of squitter tests demonstrate conclusively that there are no normal occurring phenomenona in the standard TACAN system that cause an inherent false DME problem. That a false DME problem could exist in an abnormal TACAN system, caused by a defective or mistuned FMO or cable leakage, is recognized. This type of problem warrants correction and not modification.

The receiver sensitivity-after-dead-time test results do demonstrate a tendency for a 1 to 2 dB increase in receiver sensitivity to occur near the end of the dead time of a previous interrogation. The authors believe that this phenomenon is caused by the high probability of decoding following the protected area of the dead time gate. The possibility of falling in a random squitter dead time gate does not exist and thus a higher probability of decoding must exist. The Automatic Repetition Rate Control (ARRC) voltage or the squitter control voltage time constants appear to be too long to be affected by the 60 μs dead time gate and therefore cannot be the cause of an increase in receiver sensitivity.

The laboratory tests at NAFEC and the field sites with the various ground equipments (RTB-2, GRN-9B, GRN-9C, RTC-1, and RTC-2) showed that the monitored parameters are unaffected with the Crazy Woman modification installed. Utilizing a 2,500 interrogation rate at a high enough level to enable the Crazy Woman modification resulted in a less than 2 dB decrease in measured receiver sensitivity. The 2 dB decrease in receiver sensitivity did not cause an alarm at the sites tested. A portion of the decrease in receiver sensitivity is probably attributed to the normal desensitization caused by the action of the squitter control voltage (GRN-9) or the automatic repetition value control voltage (RTB-2) at the high interrogation rates.

The laboratory tests at the high interrogation rate provides an insight into the effect the long gates of the Crazy Woman modification will have on the DME traffic-handling capability of the ground station. The tests show that an interrogator at a level slightly above the normal receiver sensitivity will receive normal DME service from a ground station that is randomly interrogated at a rate near the theoretical maximum of 2,700 and at a level high enough to enable the long gates of the Crazy Woman modification. Thus, the affect of the Crazy Woman modification on the traffic-handling capability of the TACAN ground station is minimal.

Flight Tests.

Two series of flight tests were conducted. The flight profile for both series was 5-mile orbits, 1,000 feet above the station.

For the first series, all data were collected at the ground station. An air-ground synchronizing system was set up such that the ground test equipment was synchronized with the airborne interrogation. Figure 7 is a block diagram of the air-ground synchronizing system and the ground station test equipment configuration. The airborne slave transmitter/receiver is a
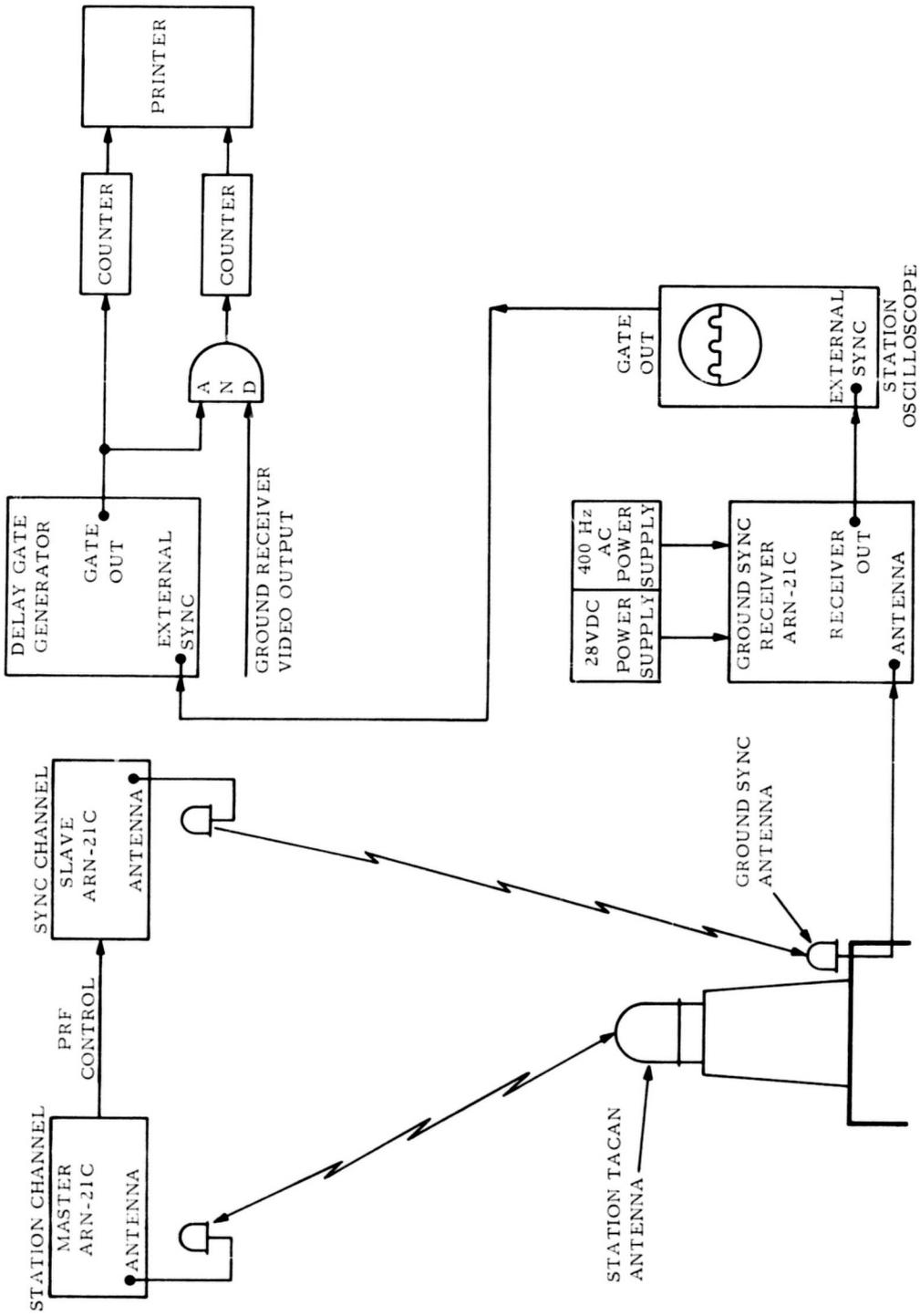
FIGURE 7 - TEST CONFIGURATION FOR FLIGHT TESTS

15

standard 21C with the pulse repetition frequency (PRF) control disconnected. The PRF control and thus the interrogation rate and timing are paralleled with the PRF control of the master 21C. Therefore, the airborne package contains two synchronous transmitter/receivers that can be set to any of the TACAN channels. The master is set to the TACAN station under test and the slave is set to any clear channel. The master interrogates the station normally and the slave is utilized to synchronize the ground test equipment with the master interrogation.

On the ground, the slave transmission is received by a standard TACAN airborne antenna (AS133) and fed to a modified ARN-21C. The 21C is modified to allow it to receive on the transmitted frequency of the airborne slave unit. Normally the 21C receiver frequency is 63 MHz below its transmitted frequency for the low band channels and 63 MHz above for the high band channels. By interchanging leads of the ground sync receiver's preselector, the receiver frequency is 63 MHz below its transmitter frequency for high band and 63 MHz above for the low band. An example will illustrate the modified sync receiver. Assume the clear slave channel selected is Channel 25. The transmitted frequency of the slave is 1049 MHz. The ground sync receiver channel selected is Channel 88. The transmitted frequency for Channel 88 is 1112 MHz. Channel 88 is a high band channel and the modified sync receiver frequency is, therefore, 1112-63 MHz, which is 1049 MHz (the selected slave channel frequency). The details of the modification are covered in Appendix A.

The sync receiver output is fed to the external sync of the oscilloscope. The gate out of the oscilloscope is utilized as sync for the delay generator. The gate out of the oscilloscope is triggered at the same time as the external sync signal from the sync receiver. Utilizing the gate out of the oscilloscope as sync for the delay gate generator allows for protection from multiple triggering caused by multipath signals of the slave signal. Only one gate out pulse is produced for each sweep of the oscilloscope. For the test, the gate width is set to 40 µs and the gate delay is adjusted to start the gate with the trailing edge of the master's receiver dead time gate. The delay generator output count is a measure of the master interrogation rate and the count of the gated ground receiver video is a measure of the false reply rate. Both counters simultaneously are printed out. Figure 8 is a data sample of the ground data for the first flight series. The first flight series included identification of the false DME problem, tests of the ARINC modification and other similar tests. The FAA fourth stage IF amplifier modification was removed from the ARINC receiver during all of the FAA tests.

For the second flight series, data were collected on the ground and in the aircraft. The synchronizing system and ground configuration were the same as for the first flight series. Figure 9 is a block diagram of the airborne test configuration. The master slave configuration is the same as explained previously. The suppression trigger of the master, which is in time-synchronism with the interrogations, is used as external sync for an
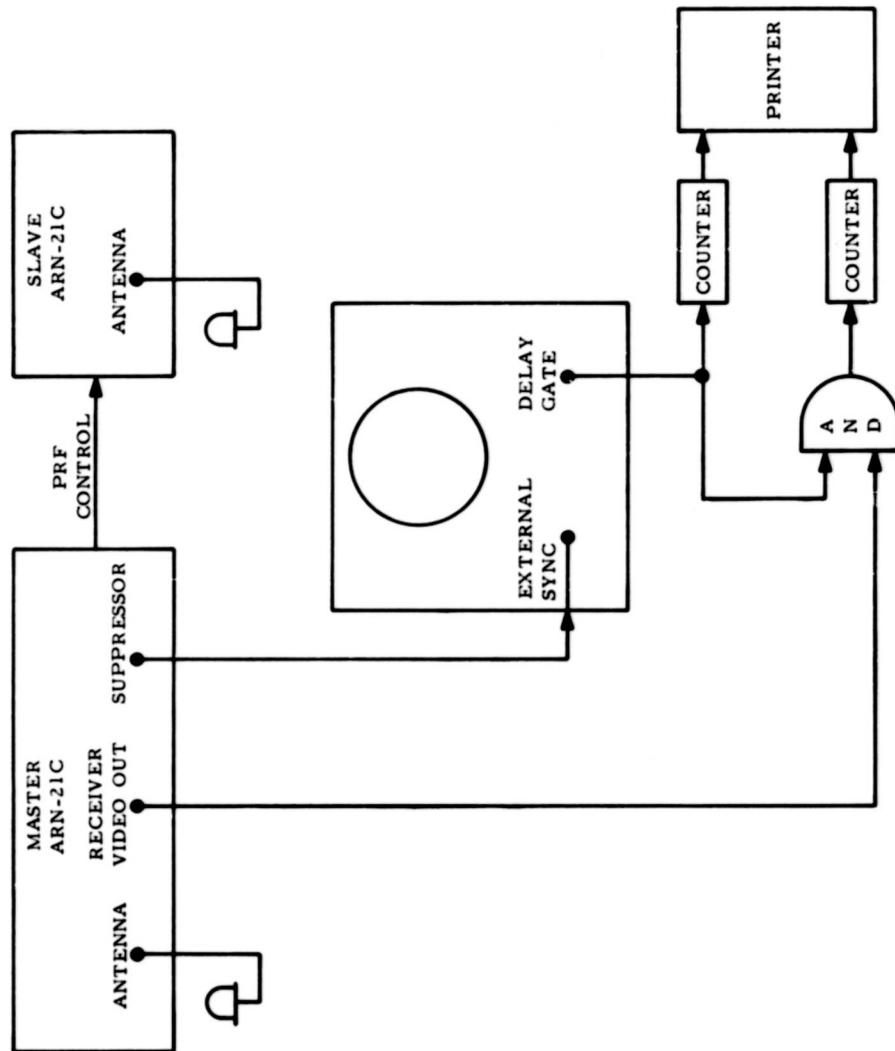
FIGURE 8 - GROUND DATA SAMPLE

17

FIGURE 9 - TEST CONFIGURATION FOR AIRBORNE DATA COLLECTION

18

oscilloscope. The delayed gate out of the oscilloscope gates the desired video output pulses from the master 21C. The delay gate width and position are adjusted by the time base controls of the oscilloscope. The gate width was adjusted for 40 μs for the test, and the position was adjusted to gate the desired video output pulses. The delayed gate and the receiver video output were both viewed on the oscilloscope. The delayed gate out, which is the interrogation rate, and the gated receiver video output, which is the false reply rate, are each counted on separate counters and simultaneously printed on a printer. The master 21C was also modified to allow controlled unlocking and positioning of the 21C gate so that lock-on can be attempted on any receiver video output signal desired. Details of the modification and the airborne data package are contained in Appendix B. Figure 10 is a data sample of the airborne and ground data taken at the same time.

Flight Test Results.

Reduced Receiver Sensitivity and Tulsa Modification - Figure 11 contains a set of data taken at the Tyrone, Pennsylvania VORTAC during the first flight series. The data are the average false DME rate for the full 360° orbit. The receiver sensitivity of the unmodified GRN-9 receiver was reduced by attenuating the local oscillator signal and thus reducing the mixer crystal current. The data show the percentage false replies falling in the count gate 60 to 100 μs following the master's interrogation. The condition of the receiver is annotated on the figure. The data show, as the receiver sensitivity is reduced from -94 dBm to -90 dBm and then to -87 dBm, the false reply rate is reduced by 18 and 14 percent, respectively. The data also indicate that the Tulsa modification (tighter decoder tolerances) provides a 12 percent reduction in the false reply rate.

As indicated earlier in the report, there has been considerable difficulty with implementing the full Chapter 182 modification to the GRN-9 Series ground systems. The problem is mainly concerned with reducing the value of the coupling capacitor between the first and second video amplifiers to 47 pF. The problem manifests itself in indicated zero squitter voltage and low pulse count at the receiver output. The data from Figure 11 show the 47 pF capacitor in the GRN-9 receiver at Tyrone reduces the percent false reply rate by only 2 percent.

ARINC Modification - Figure 12 shows the percentage of false replies of the unmodified receiver and the ARINC modified receiver for the five sites tested in the first flight series. The data are a full orbit average of the false reply rate. In all cases the ARINC reduces the average false reply rate below 30 percent. At the Tyrone, Salt Lake City and Delta VORTACs, the false reply rate was fairly consistent throughout the orbit and the false reply fell in the 60 to 100 μs count gate. At the Sheridan VORTAC the false reply fell in the 80 to 120 μs count gate and the percent false reply rate was 55 percent for an 80° segment and 33 percent for another segment of 60°. At the Crazy Woman VORTAC, the false reply rate was about 10 percent in the 60 to 100 μs count gate and averaged 35 percent (as shown in Figure 12) when the count gate was 190 to 230 μs. The false reply rate was over 50 percent

AIRBORNE DATA

INTERROGATION | FALSE REPLY

130

140

150

GROUND DATA

| INTERROGATION | FALSE REPLY | |
|---|---|---|
| 00050 | 24 | |
| 00049 | 23 | 130 |
| 00050 | 25 | |
| 00049 | 19 | |
| 00050 | 22 | |
| 00050 | 23 | |
| 00050 | 21 | |
| 00049 | 24 | |
| 00050 | 25 | |
| 00050 | 36 | |
| 00050 | 29 | 140 |
| 00050 | 26 | |
| 00050 | 32 | |
| 00050 | 31 | |
| 00050 | 23 | |
| 00050 | 28 | |
| 00049 | 26 | |
| 00050 | 27 | |
| 00050 | 28 | |
| 00049 | 24 | 150 |
| 00050 | 28 | |
| 00050 | 22 | |
| 00050 | 30 | |
| 00049 | 18 | |
| 00050 | 25 | |
| 00049 | 26 | |
| 00050 | 29 | |
| 00050 | 25 | |
| 00049 | 23 | |

FIGURE 10 - AIRBORNE AND GROUND DATA SAMPLE

20

UNMODIFIED GRN-9 RECEIVER
-94 dBm RECEIVER SENSITIVITY

UNMODIFIED GRN-9 RECEIVER
-90 dBm RECEIVER SENSITIVITY

UNMODIFIED GRN-9 RECEIVER
-87 dBm RECEIVER SENSITIVITY

MODIFIED GRN-9 RECEIVER
TO PROVIDE TIGHTER DECODER
TOLERANCE

MODIFIED GRN-9 RECEIVER WITH
47 pF CAPACITOR ONLY OF
AF P6780.1 CHAPTER 182

GRN-9 RECEIVER -90 dBm RECEIVER
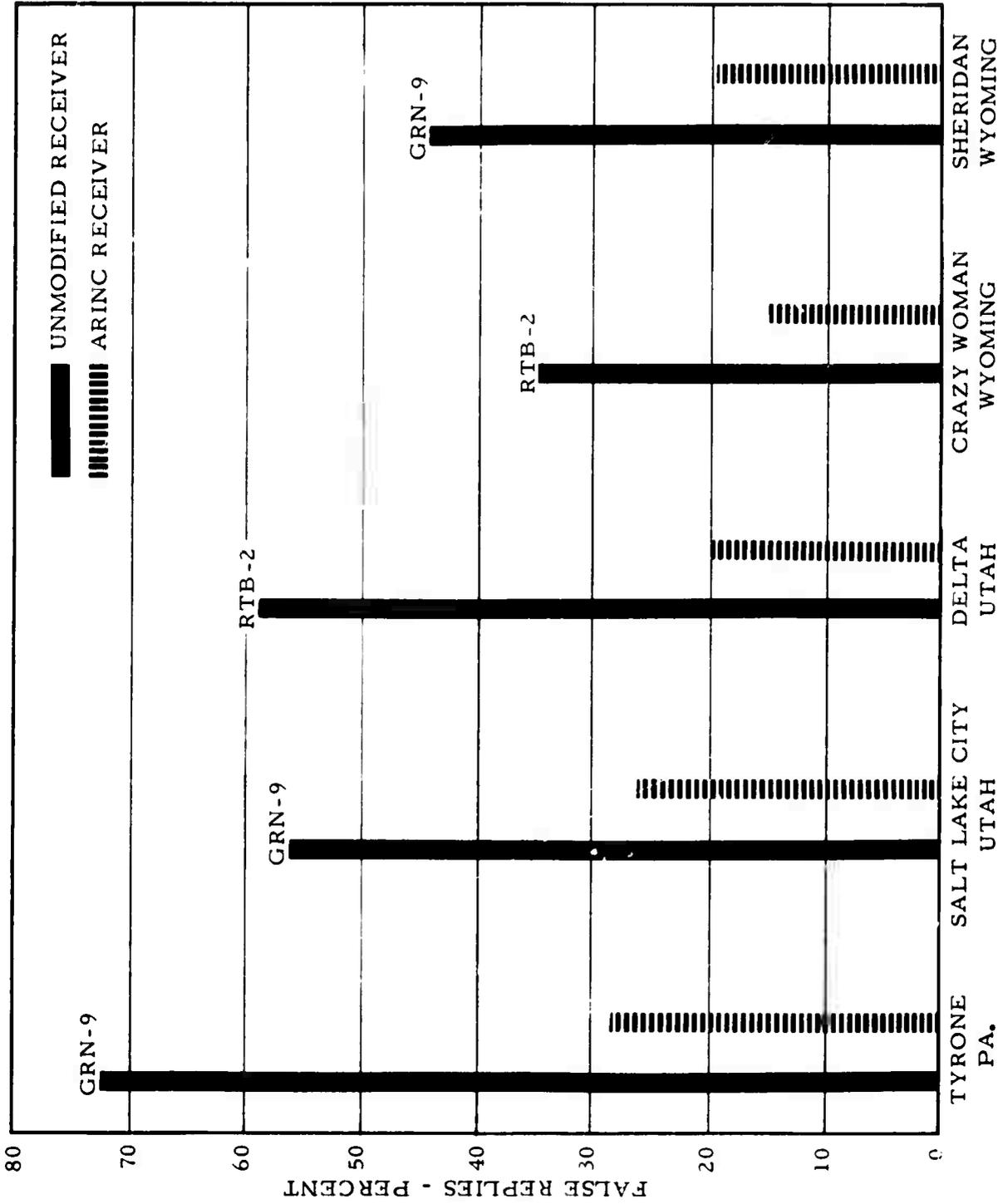SENSITIVITY AND TIGHTER DECODER
TOLERANCE

FALSE REPLIES - PERCENT

FIGURE 11 - FLIGHT TESTS AT TYRONE VORTAC

21

FIGURE 12 - FLIGHT TEST RESULTS OF UNMODIFIED RECEIVER AND ARINC RECEIVER

22

for a fair portion of the Crazy Woman VORTAC orbit. Figure 13 is a plot of the percent false replies using 10° segment averages vs azimuth to show azimuthal relationship with the false reply rate at the Crazy Woman VORTAC. Note the low azimuth consistency of the 60 to 100 μs count gate false reply rate and the high false reply rate during a significant portion of the orbit with the count gate at 190 to 230 μs.

Some preliminary tests were conducted at the Crazy Woman and Sheridan VORTACs to identify the features of the ARINC modification that were reducing the false reply rate. These tests indicated that the count down was occurring between the decoder output and the card that contained a short pulse inhibitor feature. Flight tests were conducted at the Tyrone VORTAC to attempt to isolate certain features of the ARINC receiver. These tests were conducted with the assistance of the ARINC design engineer. Figure 14 contains the results of these tests. Note, from the figure that a separate squitter source or transmitter blanking contributes very little to the reduction of the false reply rate. The data also show that the narrow pulse inhibitor is a major contributor to the reduced false reply rate of the ARINC receiver. The difference in the percent false replies of the graph annotated ARINC receiver narrow pulse inhibitor bypassed and the one annotated "unmodified GRN-9" is mainly a difference in measured receiver sensitiviy. The unmodified GRN-9 measured -94 dBm receiver sensitivity and the ARINC receiver measured -91 dBm receiver sensitivity.

Montek Modification - Figure 15 shows the percent false replies of the unmodified receiver with and without the Montek modification installed. The data were collected in the air and on the ground. The airborne data collection package was not completed until after the Tyrone tests. Note, in all cases the Montek modification significantly reduced the percent false DME count. A full orbit lock-on was attained on the false DME at the Salt Lake City VORTAC using the unmodified receiver. With the Montek modification installed at the Salt Lake City VORTAC, no false DME lock-on's were obtained. Using the unmodified receiver at the Albuquerque VORTAC resulted in no false DME lock-ons and utilizing the unmodified receiver at the Tulsa VORTAC resulted in false DME lock-ons during portions of the orbit. The Montek modification allowed no false DME lock-ons at the Albuquerque or Tulsa VORTACs.

Crazy Woman Modification - Figure 16 shows the percent false replies for the unmodified receiver, the unmodified receiver with receiver sensitivity reduced to -80 dBm and the unmodified receiver with the Crazy Woman modification installed. Note the significant reduction in percent false replies with either the receiver sensitivity reduced or the Crazy Woman modification installed. The airborne data collection package was not completed until after the Tyrone flight tests. The ground data collection package was inoperative during the Delta flight tests. Utilizing the unmodified receiver, full orbit false DME lock-on was obtained at the Salt Lake City VORTAC; partial orbit false DME lock-on was obtained at the Delta, Sheridan, and Tulsa VORTACs and no lock-on was obtained at the Albuquerque VORTAC. No lock-ons were obtained at any of the sites tested when the receiver sensitivity was reduced to -80 dBm or the Crazy Woman modification was installed.
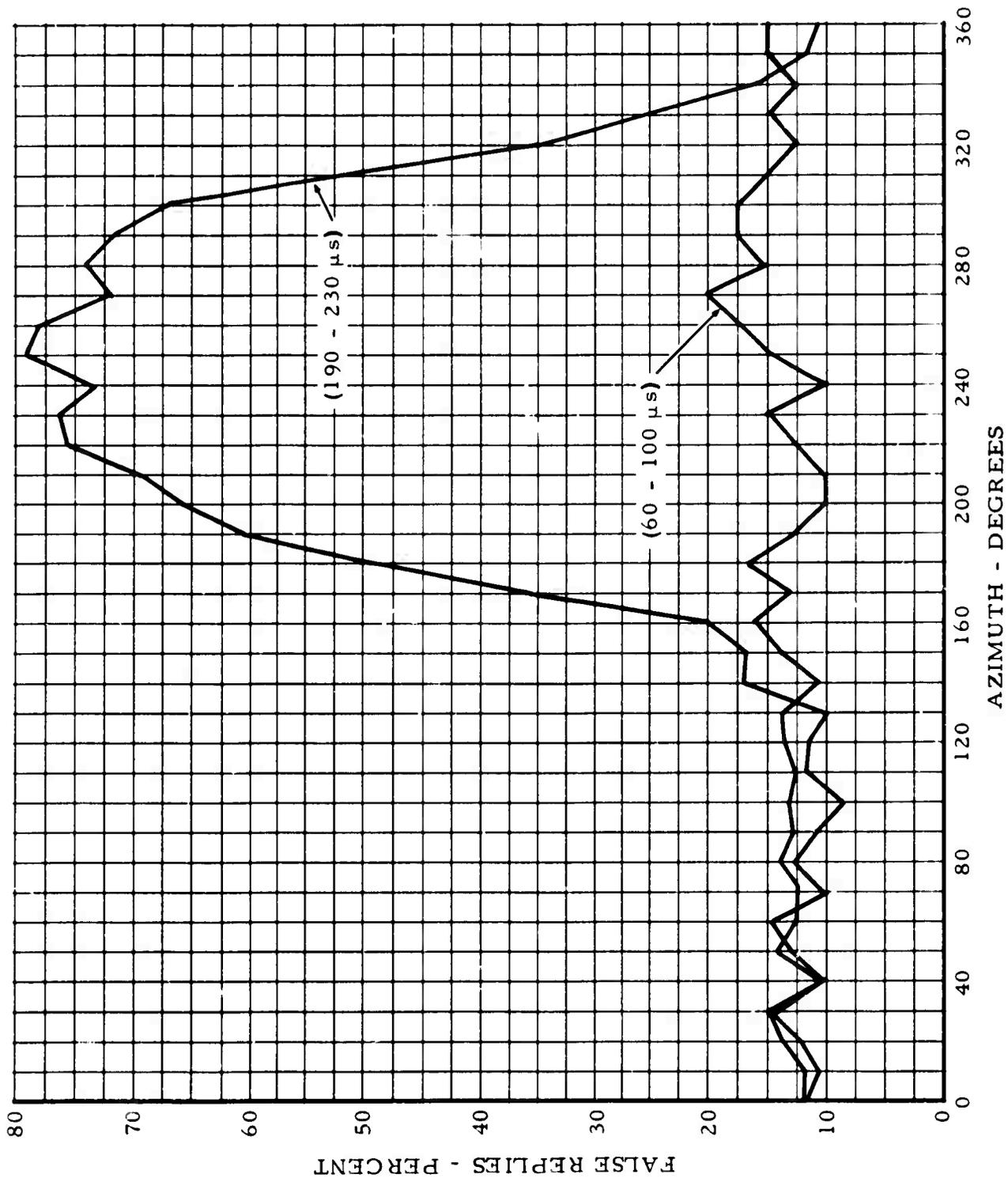
FIGURE 13 - FLIGHT TEST RESULTS AT CRAZY WOMAN VORTAC

24
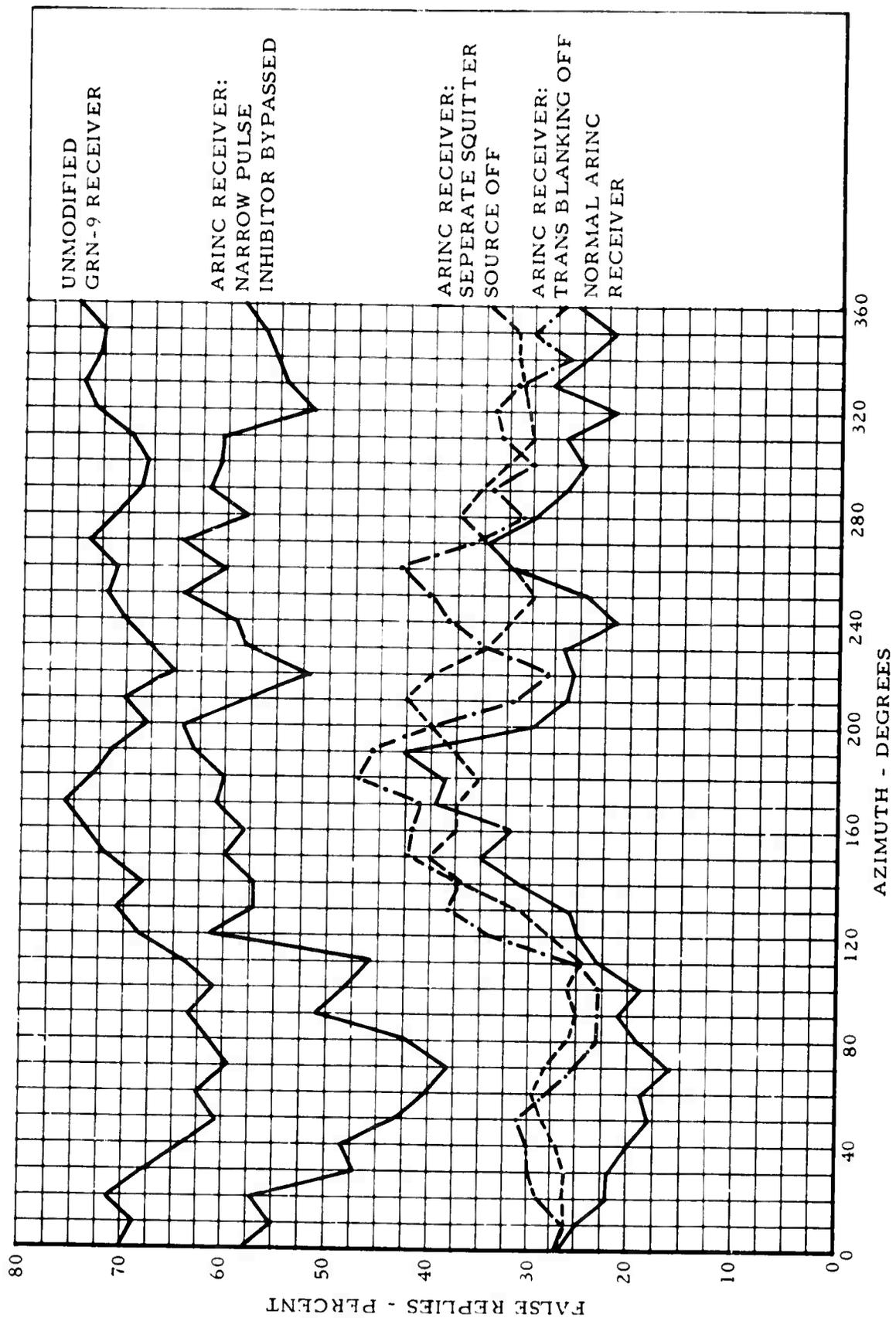
FIGURE 14 - TYRONE VORTAC TEST RESULTS OF ARINC RECEIVER

Legend:

UNMODIFIED
GRN-9 RECEIVER

ARINC RECEIVER:
NARROW PULSE
INHIBITOR BYPASSED

ARINC RECEIVER:
SEPERATE SQUITTER
SOURCE OFF

ARINC RECEIVER:
TRANS BLANKING OFF

NORMAL ARINC
RECEIVER

Axis labels: FALSE REPLIES - PERCENT (vertical), AZIMUTH - DEGREES (horizontal)
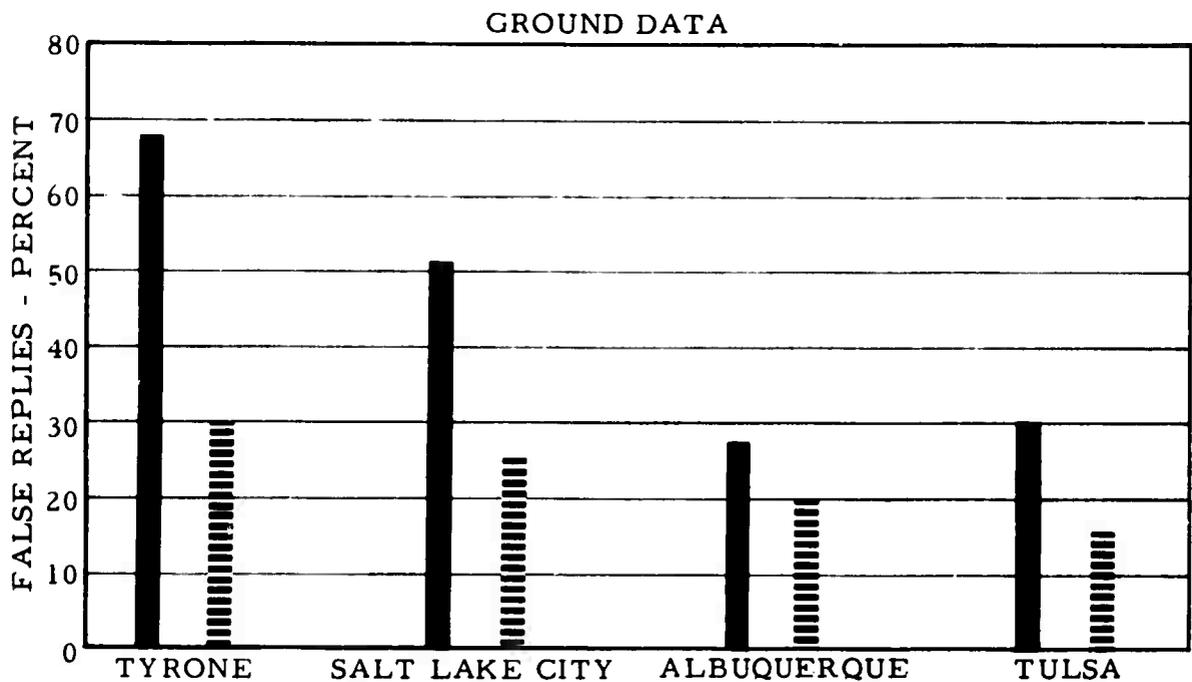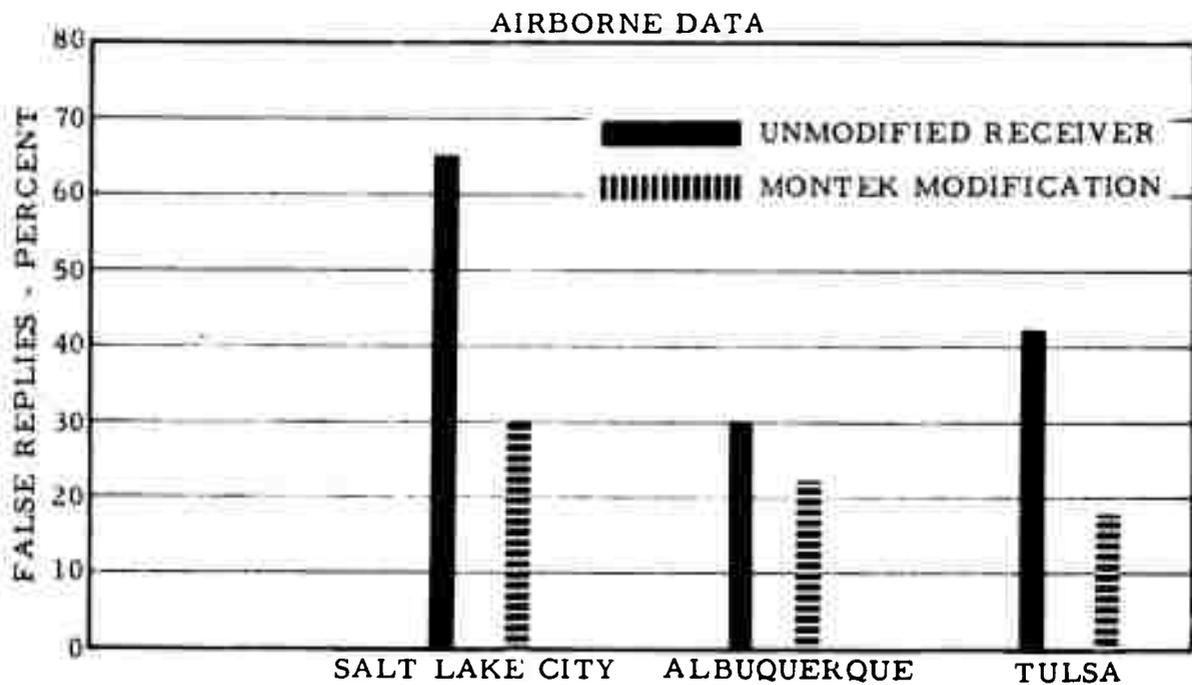
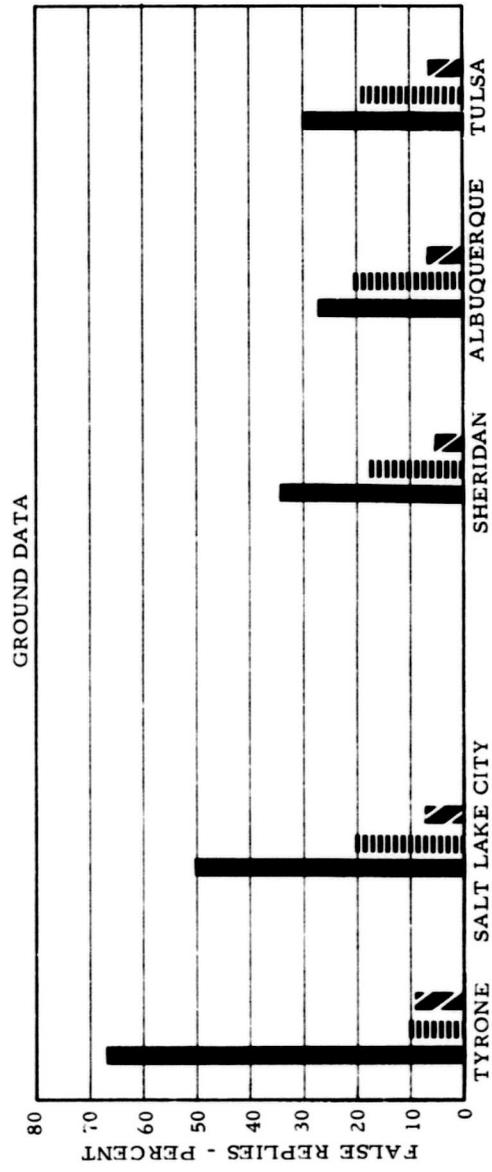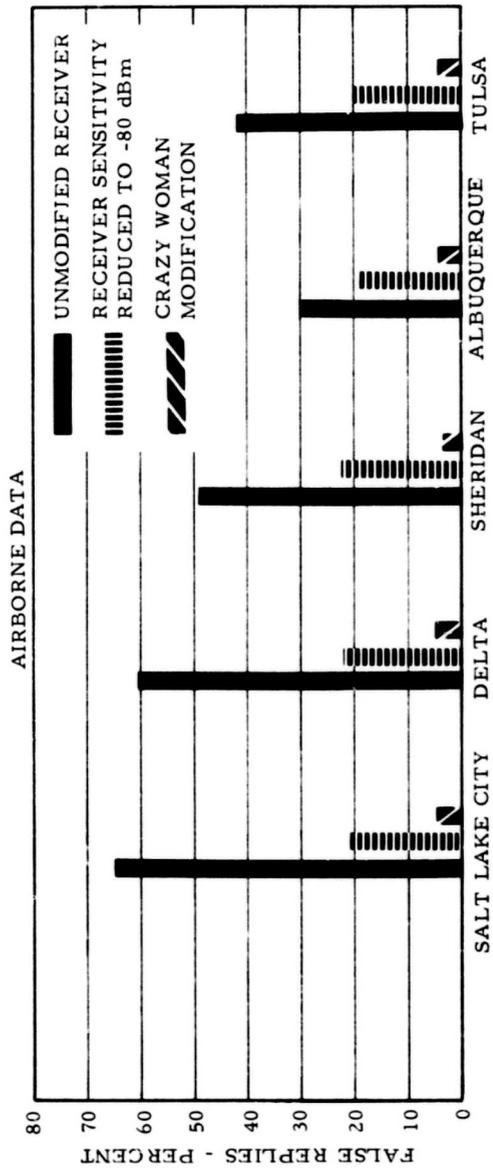FIGURE 15 - TEST RESULTS OF UNMODIFIED RECEIVER AND MONTEK MODIFICATION

FIGURE 16 – TEST RESULTS OF UNMODIFIED RECEIVER, REDUCED RECEIVER SENSITIVITY AND CRAZY WOMAN MODIFICATION

27

## Flight Test Analysis

The laboratory test data have indicated that the false DME problem is not a ground system problem at the sites tested. The flight test data have indicated that the false DME problem is not necessarily a 6-mile false DME problem as reported by previous investigators. The flight test data show the problem to be simply an air-to-ground multipath problem. The data show that when a ground fix is installed to reduce the air-to-ground multipath signals, the false DME problem as seen by the aircraft is significantly reduced.

The data from the Crazy Woman VORTAC were the best example of the cause of the false DME problem. Note from Figure 13 that the 6-mile false DME problem is nonexistent while a longer distance DME error is most evident. Figure 17 is a sectional aeronautical chart of the area around the Crazy Woman VORTAC. The inner dashed circle is the NAFEC aircraft 5-nautical mile orbit and the geography encompassed between the two outer dashed circles cause the multipath signals falling in the 190 to 230 μs delay gate. The azimuth indications of Figure 17 correspond to the azimuth degrees of Figure 13. The correlation of the mountains and the high percent false replies and the flat lands and the low percent false replies is evident when comparing Figures 13 and 17.

Previous investigators have identified the false DME problem to manifest itself in the receiver by a phenomonon called bunching of squitter after dead time. The idea was that the IF amplifier gain control voltage which controls the squitter, overreacted at the end of dead time and caused an overabundance of squitter pulses. In the early TACAN ground systems, the IF amplifier was disabled during dead time and at the end of dead time the phenomenon of squitter bunching probably existed as the gain control of the IF went from an "OFF" condition to an "ON" condition. The present TACAN ground systems do not operate in this manner. When the dead time gate is initiated, the gate simply inhibits the decoder. The IF squitter control voltage is normally impervious to the dead time gate. Thus, the phenomenon of squitter bunching that may have existed in earlier TACAN systems is not present in the existing TACAN systems.

A previous report entitled, "Evaluate TACAN Separate Squitter Source," concluded that the modification eliminates the false DME reply problem. As mentioned in the description of equipment, the modification contained various receiver desensitizing schemes and the separate squitter source was only used to replace the squitter pulses lost when the receiver was desensitized. The title of the report confused many and added credibility to the misconception of bunching of squitter after dead time.

The Tulsa modification operated on the premise of squitter bunching and theorized that by reducing the wide decoder tolerances one could expect the number of decodes at the the end of dead time to be reduced. Tulsa indicated a subsequent flight inspection with the modification installed and reported no false DME lock-on where there had previously been lock-ons. The flight data at the Tulsa VORTAC show a relatively low percentage of false replies
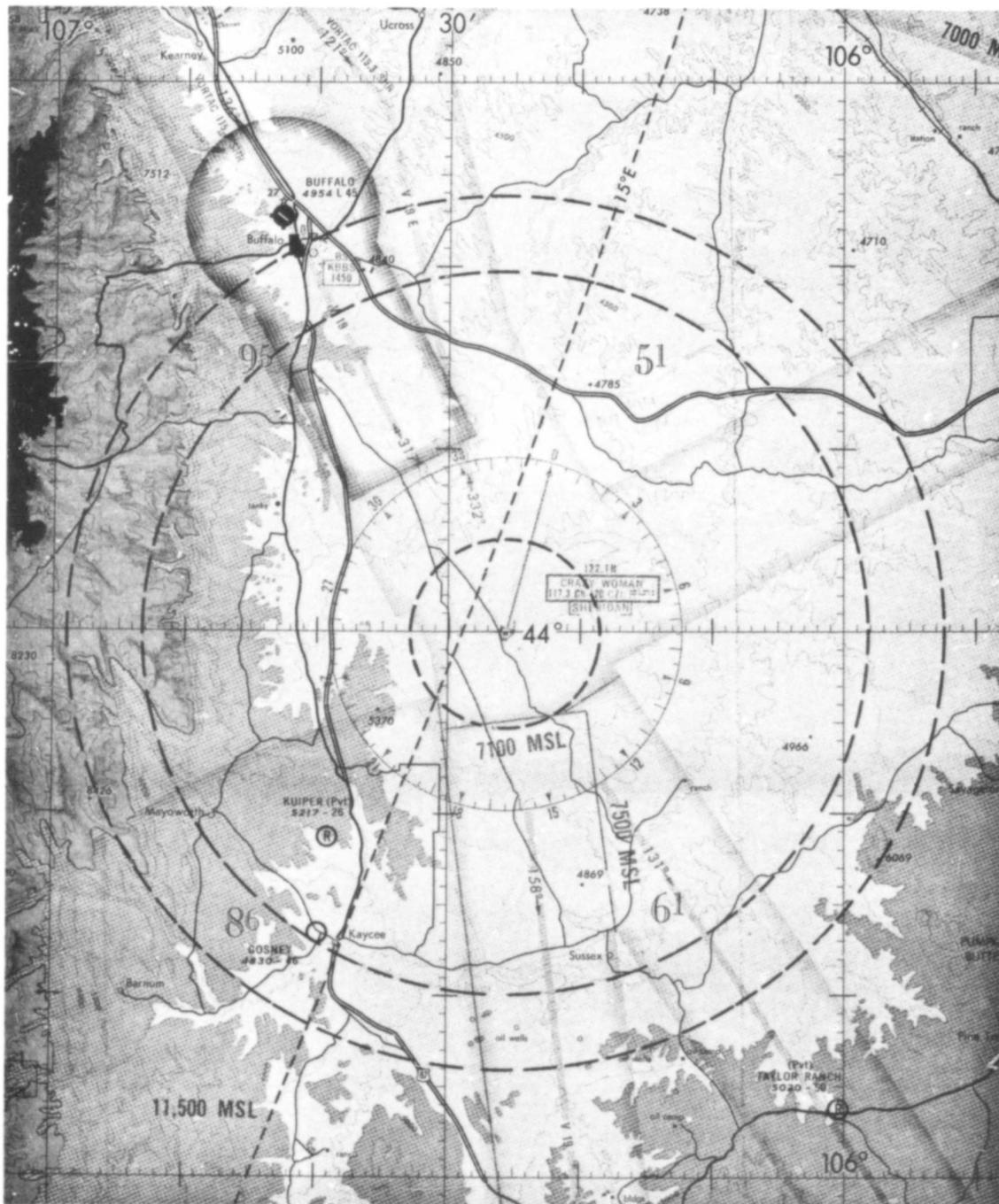
28

FIGURE 17 - SECTIONAL AERONAUTICAL CHART OF CRAZY WOMAN VORTAC

using an unmodified receiver and some false lock-ons were obtained. Note from Figure 11 that the Tulsa modification reduces the percent false replies by about 12 percent. This 12 percent reduction at a site having a magnitude of false replies, such as Tulsa, reduces the false DME rate below that necessary to attain a lock-on. At sites such as Tyrone, Salt Lake City or Delta, the reduction would not be sufficient to eliminate false distance lock-on.

Figure 14 shows that transmitter blanking or a separate squitter source has very little effect in reducing the percent false DME replies. This same figure does show that the ARINC narrow pulse inhibitor is the major contributor of the ARINC modified receiver to reduce false DME rate. Similar tests were performed at the Crazy Woman and Sheridan VORTACs with the same results. The success of the narrow pulse inhibitor in reducing false DME's can be attributed to either the nature of the multipath is such as to manifest itself as narrow pulses or the circuitry before the narrow pulse inhibitor operates on a multipath signal such as to create narrow pulses. The RTB-2 ground TACAN equipment has a narrow pulse eliminator on the output of the Ferris discriminator and this equipment has experienced false DME's (Delta and Crazy Woman from NAFEC tests). Thus, the multipath does not manifest itself as narrow pulses and any circuitry that creates narrow pulses from multipath signals must occur after the Ferris discriminator.

Subsequent investigations indicated that gated CW synchronous and following a signal generator interrogation was a reasonable false DME simulator. Injecting a 40 μs burst of CW into the unmodified GRN-9 system resulted in a 70 to 80 percent false reply rate. Using the false DME simulator showed that a video coupling capacitor between the two video stages following the Ferris discriminator actually differentiates the simulated false DME signal and creates a series of narrow pulses. These narrow pulses were eliminated by the ARINC narrow pulse inhibitor and the false reply count was reduced from 70 percent to approximately 30 percent. Figure 18 is a sketch of the results of the simulated false DME tests. Note, the coupling capacitor creates one pulse of from 3 to 4 μs in width and then a series of narrower noise pulses for the duration of the gated CW. The ARINC quantizer creates narrow pulses from the noise pulses. The short pulse inhibitor eliminates the narrow pulses and the decoder eliminates the one remaining normal width pulse.

A simple version of the short pulse inhibitor was installed in the unmodified GRN-9 receiver. A small capacitor was connected from the output of the GRN-9 IF chassis to ground. The IF chassis contains two video stages and the differentiating coupling capacitor of interest. A .004 pF capacitor reduced the false reply count from 70 percent to approximately 50 percent. A .005 pF capacitor reduced the false reply count from 70 percent to approximately 35 percent. Unfortunately as the value of the capacitor is increased to cause an appreciable false reply count down, the squitter control voltage becomes less negative. This is probably caused because the short-pulse inhibitor also eliminates narrow squitter pulses and the squitter control voltage goes less negative to generate more receiver noise and thus more squitter. To legitimately incorporate a narrow-pulse inhibitor in the receiver would require a separate source for squitter that is fed into the system after the narrow-pulse inhibitor.
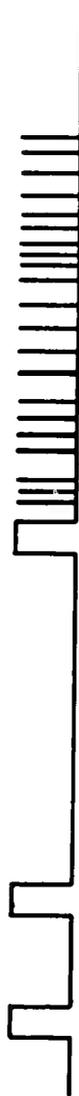
LEGITIMATE INTERROGATION

SIMULATED MULTIPATH

OUTPUT OF FERRIS
DISCRIMINATOR GRN-9

40 μs

INPUT TO VIDEO STAGE AFTER
DIFFERENTIATION BY C343
(1000 pF)

AFTER QUANTIZING BY
ARINC RECEIVER

AFTER THE ARINC SHORT
PULSE INHIBITOR

AFTER THE ARINC
DECODER

FIGURE 18 - SIMULATED FALSE DME TEST RESULTS

31

The Montek modification caused a significant false reply count down at the sites tested. Montek notes in their papers that the cause or causes of the false DME problem are not completely explained. They do state that it is known that the false reply signals occur just after the end of a dead time gate generated by a previous interrogation. The sites tested with the Montek modification have the false reply occurring close to the end of dead time when flying a 5-mile orbit and thus the modification is quite successful. At a site such as Crazy Woman, the average dead time gate from the Montek modification would have to be over 200 us. With the Montek modification, this long average dead time would be genera ed for both squitter and DME interrogations. Utilizing calculations from Montek's presentation to the RTCA committees, a 200 us dead time gate produced 2,700 times per second would cause the reply efficiency of the ground system to be so low as to cause all user airborne TACAN/DME's to unlock from the station. The point is that if the geometry of the aircraft and the multipath causing objects are such as to produce a false reply near the end of dead time then the Montek modification is successful. However, if the geometry is such as to produce a false reply at a longer distance, the Montek modification cannot be designed to reduce the false replies without causing system problems.

The effectiveness of the Crazy Woman modification is seen from the data contained in Figure 16. In all cases, the false reply rate is below 10 percent as seen by both the airborne and ground equipment. Since the modification is basically a long dead time gate, the impressive results could have been predicted. Previous investigators had recognized the effectiveness of a long dead time gate, but had also been aware of the effect this long dead time gate would have on system reply efficiency. The uniqueness of the Crazy Woman modification allows for the advantage of the long dead time gate without the disadvantage of reduced system reply efficiency. By adjusting the threshold of the modification at some level above the multipath signal, only legitimate DME interrogations will enable the long dead time gate. Note that the normal shorter dead time gate enabled by squitter still exists in the system. The uniqueness of the modification allows that any interrogation that exceeds the modification threshold will terminate the previous gate, be decoded itself and generate its own long dead time gate. Thus, by the nature of the modification it is impossible to ever generate 2,700 long dead time gates that would effect system reply efficiency to DME interrogations. Figure 16 also shows that the majority of the multipath false replies are below -80 dBm. Therefore, at the sites tested with an ARN-21C interrogator (1,000 watts) interrogating the station from a 5-mile distance and an altitude 1,000 feet above the station, the resulting multipath signals received by the ground station are below -80 dBm.

The present TACAN ground equipments contain echo-suppression circuits that are designed to come into play when the input signal level reaches -70 dBm. This -70 Bm level seems like an acceptable threshold setting for the Crazy Woman modification. Appendix C contains the specific preinstallation and installation procedures for installing the Crazy Woman modification in the RTB-2 and GRN-9 TACAN ground equipments. There are a few preliminary checks

that are required before the Crazy Woman modification is installed. At a
normal operating TACAN, the noise level at the input to the modification is
less than 1 volt and any stray pickup is also less than 1 volt. High
noise levels and high stray pickup signals from poor cable connections on
mistuned FMO's are considered non-standard and must be corrected before
installing the modification.

As suggested by personnel from AAF-410, some consideration must be
given to monitoring the operation of the modification. There appears to be
no simple solution to the monitoring problem since a signal source is needed
at a high enough level to initiate the action of the long dead time gate.
An approach similar to that employed in the Butler DME equipment for
monitoring reply delay and receiver sensitivity could be used to monitor the
operation of the Crazy Woman modification. Basically, the signal generator
generates a low level signal for monitoring receiver sensitivity and a high
level signal for monitoring reply delay. A free running multivibrator
alternates between each parameter. A similar approach could be used in the
present system where the low level is used for receiver sensitivity, and the
high level for reply delay and operation of the Crazy Woman modification.
This modification could possibly be incorporated into the present contract
that SRDS has initiated to upgrade the present TACAN ground systems.

# SUMMARY OF RESULTS

The results of the project effort were:

1. The cause of the false DME problem has been determined to be air-to-ground multipath interrogations.

2. The feature of the ARINC receiver modification that was successful in reducing the false DME problem was the narrow pulse inhibitor.

3. The Montek modification was successful in reducing false DME's that occurred near the end of dead time.

4. The Crazy Woman modification was successful in reducing false DME's occurring up to 300 μs after the end of dead time.

5. The Crazy Woman modification in operation did not cause an alarm to any of the monitored parameters at the sites tested.

6. Laboratory tests with the Crazy Woman modification randomly interrogated at a rate near the theoretical saturation limit indicated the retriggerable long dead time gates have a minimal affect on the DMF traffic-handling capacity of the TACAN ground stations.

## CONCLUSIONS

Based on the test results it is concluded that:

1. The false DME problem is caused by only one factor, that is, air-to-ground multipath signals.

2. Of all the modifications tested, the Crazy Woman modification is the most successful for reducing false DME.

3. The Crazy Woman modification has a minimal effect on the DME traffic-handling capacity of the TACAN ground stations.

# APPENDIX A

## GROUND DATA COLLECTION SYSTEM

In order to properly monitor the airborne AN/ARN-21C interrogation pulse at the ground station, the following system was designed. (See block diagram.) This system was used to synchronize the HP-150A oscilloscope which is part of Monitors RTC-1, and RTC-2 located in all VORTAC facilities. By use of this method, any false DME replies being received by the aircraft could be monitored simultaneously on the ground, affording the user the opportunity to determine if the applied fix to eliminate these false replies was effective.

Two airborne AN/ARN-21C receiver/transmitters were rack-mounted in the aircraft; one acted as a master, the other as a slave. The slave was furnished its PRF and 4046 CPS signal from the master as per attached diagram. The master was tuned to the normal ground station channel, the slave to another channel, different from any local station. The ground receiver had its preselector portion reversed; so that, as the slave, it was on the same frequency.

As stated, the 4046 CPS signal and PRF control from the master was tapped into the slave multivibrator. The slave unit then became a telemetry transmitter in synchronization with the master. This signal was then received by the ground-located AN/ARN-21C with the preselector leads reversed. The EXT sync located on the ground for the oscilloscope was taken from E-201 on the VIDEO DECODER.

In order for this signal to be properly received, the following was accomplished. Normally, there is a 63 MHz difference between transmit-receive frequencies of any particular TACAN channel. When tuned to a low band channel, the receiver frequency will be 63 MHz below the transmitter, and 63 MHz above when tuned to a high band station. In order to have both receiver and transmitter on the same frequency, the preselector was reversed. By selecting a low band channel for the slave transmitter and a high band channel for the airborne receiver on the ground, the same transmit and receive frequencies were obtained.

For example:

Transmitter Channel #1      fr = 1025 MHz
Receiver Channel #64      fr = 1151 MHz

The 1151 MHz rate is the result obtained when adding 63 MHz to the transmitter frequency of Channel 64 (1088 MHz). With the modifications to the preselect 63 MHz is subtracted from the transmitter frequency of Channel 64. This frequency is equal to 1088 MHz; therefore, 1088-63 = 1025 MHz which is the same as the transmitting frequency of Channel 1. Prior to implementing this procedure, Frequency Management should be consulted for use of non-interfering channels.

ATTACHMENT #1

Prior to modification and installation, it is recommended that the AN/ARN-21C's be checked in accordance with TI-4176.2-2 FAA ARN/21C TACAN Manual (USAF 12R5-2ARN21-42). (Wiring of equipment in attached block diagram I/A/W above manuals.)

Detailed Description of Ground Modification

(Refer to Print)
(Figure 1-1)

1. Remove dust cover from AN/ARN-21C. Reverse wires on preselector as per print.

2. Using a suitable length of PG-58/U solder one end to TP-(E-201) on Video Decoder, connect the other end to "Ext Sync" Jack of HP-150A part of monitor test equipment.

3. Short interlock switch S-103 located on bottom rear of AN/ARN-21C, to permit fan operation for cooling while dust cover is removed.

4. Connect AS-133 antenna to key stone on counterpoise.

5. Connect all equipment as shown, place C-1763/ARN-21 control in receive position.

Detailed Description of Airborne Modification

(Refer to Print)
(Figure 1-2)

1. Remove dust covers from AN/ARN-21C's.

2. a. On master, using #22 shielded wire, approximately 18" in length, connect one to Pin 1 of J107, and one Pin 11 of J07 (solder), located on bottom of AN/ARN-21C as per diagram.

    b. On slave disconnect existing wires on plug J107. Replace with wire as in 2a above.

3. Drill two 3/8" holes in front dust cover of both master and slave units. Make sure connectors clear channel selection servo assembly. Use UG-625/B-5935-835-0510 type connectors. Label each Pin 1 and Pin 11. Solder wires installed in 2a and 2b above.
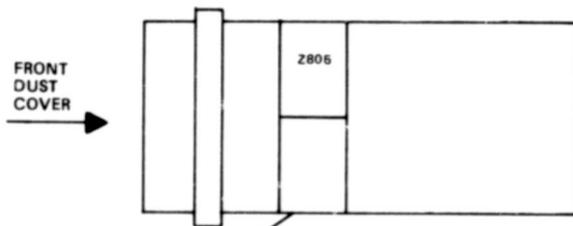
4. Replace front dust covers only at this time. Connect equipment for airborne installation as per attached block diagram; and connect to a suitable signal source (AN/ARN-22).

5. Connect frequency counter to J112 Suppression Jack, located in front of AN/ARN-21C. Both master and slave units should read approx 30 pps in track if not, adjust R-732. Place units in search. Both units should read approx 130 pps if not, adjust R-718.
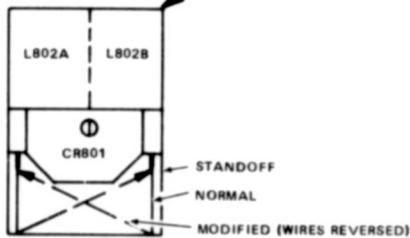
### Equipment Required for Air/Ground Installation

| Quantity | | Ground | Air | Description |
|---|---|---|---|---|
| 3 | A* | 1 | 2 | AN/ARN-21C Receiver/Transmitter |
| 3 | B* | 1 | 2 | ID-310 Distance Indicator |
| 3 | C* | 1 | 2 | ID-307 Azimuth Indicator |
| 3 | D* | 1 | 2 | ID-387 Course Indicator |
| 3 | E* | 1 | 2 | C-1763/ARN-21 Control Box |
| 3 | F* | 1 | 2 | AGC Meter 0-50 mA Full Scale |
| 3 | G* | 1 | 2 | Speaker 3" |
| 3 | H* | 1 | 2 | Antenna AS-133, Freq Range 960-1215 MC |
| 3 | I* | 1 | 2 | CV-279/ARN Phase Detecting Network |
| 1 | | 1 | 0 | 115VAC-400 cps, 5 AMP Power Supply |
| 1 | | 1 | 0 | 28V DC 5 AMP Power Supply |

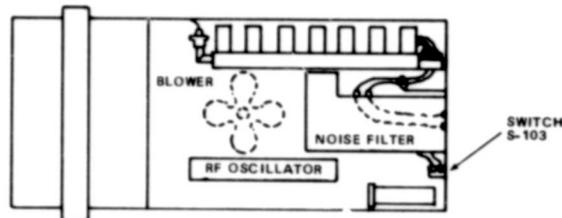NOTE: Starred (*) letters refer to block diagram (Figure 1-3).

FRONT
DUST
COVER ➤

Z806

SIDE VIEW
AN 1ARN-21C

L802A | L802B

CR801

STANDOFF
NORMAL
MODIFIED (WIRES REVERSED)

EXPLODED VIEW 2805

RANGE CONTROL
RANGE GATE
TRANSMITTER PRESELECTOR
MODULATOR ASSEMBLY
AZIMUTH GATE
AZIMUTH GATE
VIDEO DECORDER
POWER SUPPLY
E201

DANGER
HIGH
VOLTAGE

HP150A
OSCILLOSCOPE

EXTERNAL
SYNC

ADDED
RG-58/L1

TOP VIEW    AN/ARN-21C

BLOWER

NOISE FILTER

SWITCH
S-103

RF OSCILLATOR
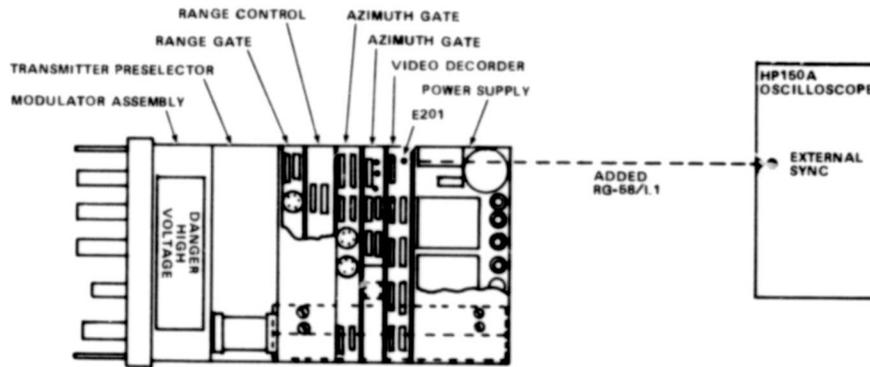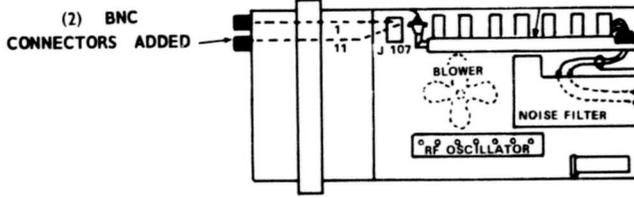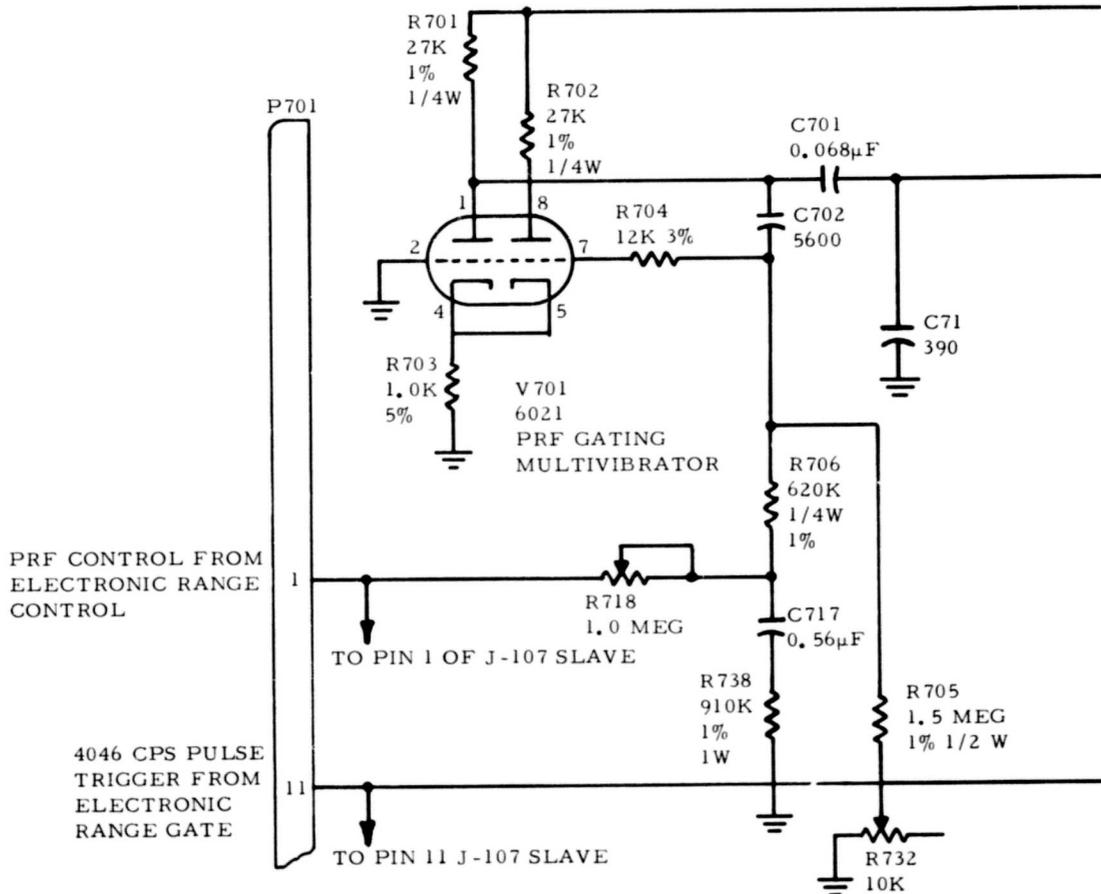
BOTTOM VIEW    AN/ARN-21C

FIGURE 1-1 - MODIFICATION TO GROUND ARN-21C

39

BOTTOM VIEW AN/ARN 21-C



PARTIAL DIAGRAM OF MODULATOR ASSEMBLY 2107

NOTE:
WIRES ADDED TO PINS 1 AND 11 ON MASTER WIRES
REMOVED FROM PINS 1 AND 11 J-107 ON SLAVE AND
STOWED. TWO WIRES ADDED TO J-107 AND CONNECTED
TO CONNECTORS ON FRONT DUST PANEL.

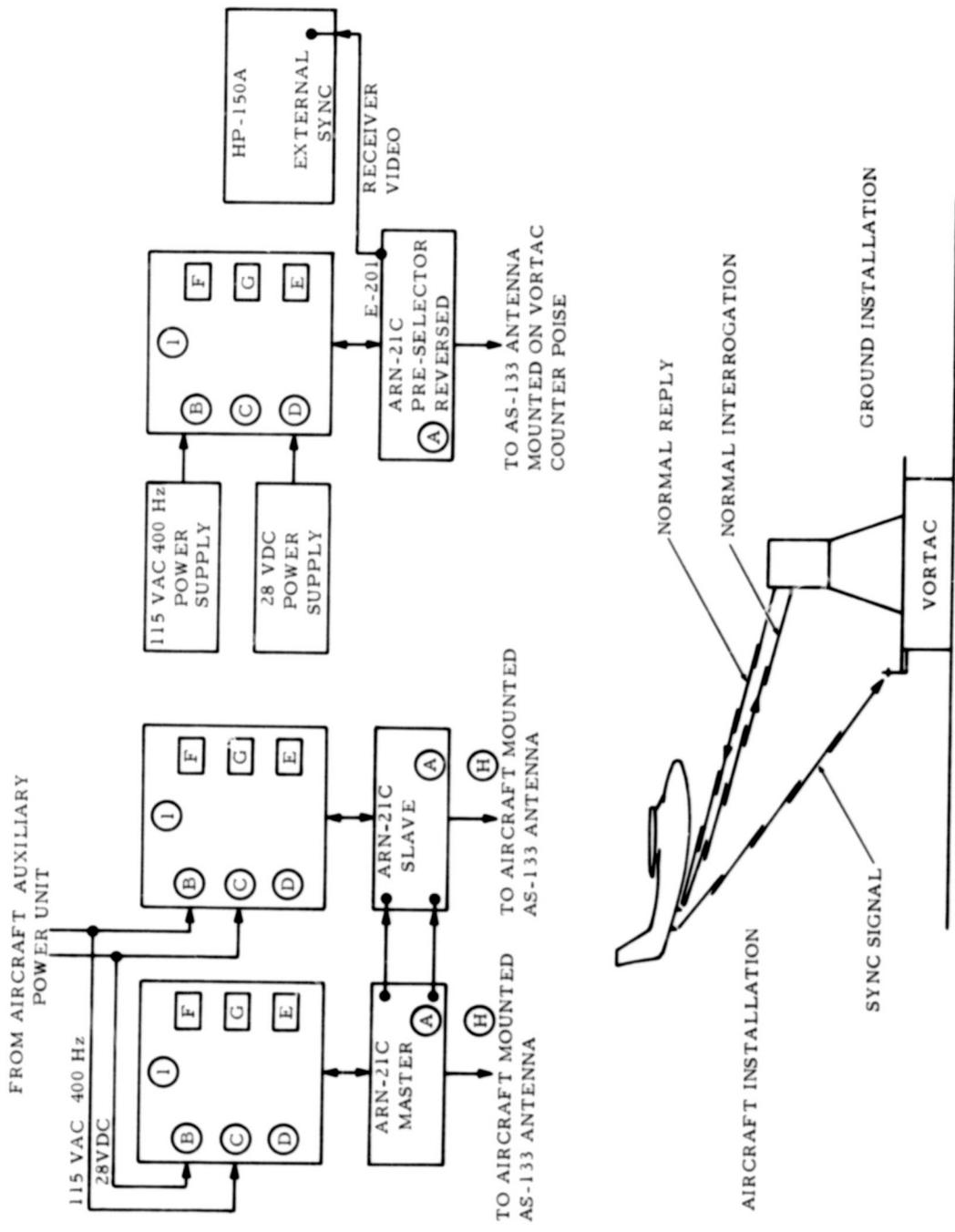FIGURE 1-2 - MODIFICATION TO AIRBORNE ARN-21C

FIGURE 1-3 - BLOCK DIAGRAM OF DATA COLLECTION SYSTEM

A-6

# APPENDIX B

## AIRBORNE DATA COLLECTION SYSTEM

In order to measure the occurrence and range of ground-to-air false distance replies, an airborne technique was developed to provide for acquisition of synchronous replies, and to display and count the efficiency of such replies.

Due to propagation anomalies in the DME system, additional synchronous replies with varying signal strength can be received along with the true replies. The erroneous replies can cause a false distance indication if the level and occurrence is high enough to sustain the airborne unit in track. It is imperative to measure the quality of any false replies that are associated with a particular facility, not only for the purpose of investigation of the phenomenon, but also for determination of ambiguous distance readout for the users.

Previously, the detection and confirmation of false distance replies required abnormal operation of the airborne equipment to acquire lock-on, and did not yield consistent results. The method generally used was to confirm the false replies on a scope and cause an unlock by channelling off frequency, and then channel on frequency to attempt a lock-on at the false distance. The 10-second long memory of the airborne set was not conducive to ensure lock-on of the false replies as the aircraft moved in position.

To determine the validity of a false reply to cause erroneous distance information, it is necessary to control the range circuits of the airborne set to coincide in time with the suspected reply and let the range logic determine the efficiency for lock-on. Reply efficiency is taken as the number of replies returned per number of interrogations from the airborne set, and is a measure of range acquisition. To implement the counting of reply efficiency for any specific reply, a window or gate adjustable in distance and in sync with system timing is needed.

The improved technique to measure qualitative false reply information was instrumented as simply as possible to ensure reliability of operation in the aircraft. The less complex implementation and operation of the technique is due to the utilization of the controllable time delay of an HP-180A scope. The HP-180A with an 1821A plug-in has the capability of a delayed gate output whose width and start time can be adjusted by the front panel controls. This method causes the main sweep to be intensified during the time the delayed sweep is produced and is triggered by the main sweep, eliminating the need for a separate delay generator. An external gate circuit was designed to perform in conjunction with the delayed gate output of the HP-180A scope providing a controllable "count gate." In addition to manually selecting a reply to be counted, an ARN-21C was modified to provide a range slew and also to bypass the range freeze in memory to control the distance information of the airborne set for coincidence with a false reply to determine lock-on.

42

The complete instrumentation is shown in Figure 2-1 and consist of (1) a modified ARN/21C, (2) gate circuit, (3) an HP-180A scope, (4) two counters, and (5) a BCD recorder.

The function of technique is best described by following the block diagram of Figure 2-1. The decoded reply pulses from the ARN/21 are fed as one input to the AND gate, the delayed gate from the HP-180A scope being the other input to the gate circuit. When both inputs are present at the same time, a gated reply output is produced and fed to the reply counter and to the B trace of the scope for monitoring. The main sweep of the scope is triggered by the suppressor pulse output of the ARN/21 which is the reference for system timing. The delayed gate is triggered by the main sweep at a controllable time lag, which allows a selectable "window" to count replies at any distance. The PRF of the delayed gate is the same as the suppressor pulse and after inverting and shaping by the gate circuit, is fed to the counter to record the number of interrogations.

In the range-tracking mode, the early gate from the ARN/21, which is controlled in distance by the range circuits, is fed to the delayed trigger input of the 180A scope, which results in the selectable count gate being controlled by the range circuits of the airborne set.

The reply and interrogation counts are commanded to print simultaneously for a unit time of 1 second on the digital recorder.

In operation, after triggering has been adjusted and gate width set, it is only necessary to position the intensified gate on the reply of interest and the number of replies per interrogations in unit time will be recorded. There are two modes of operation which are:

      1. Manual tracking mode in which the count gate delay time is controlled by the front panel controls of the HP-180A scope.

      2. Range-tracking mode in which the count gate delay time is controlled by the range gate from the ARN-21C which can be slewed in distance.

Detailed Description.

ARN/21C Modification - The ARN/21C airborne set was modified for the measurement of false distance replies by providing a BNC output jack for the decoded reply, adding a remote distance slew switch range freeze bypass and by providing an output for the range controlled early gate.

A BNC jack was located on the front skirt of the ARN/21C and was connected to Pin 5 of J-102 which mates with P-201 of the VIDEO DECODER module. This is test point E-203 which is the decoded reply pulses. In the system hook-up, these replies are fed as one input to the gate circuit.
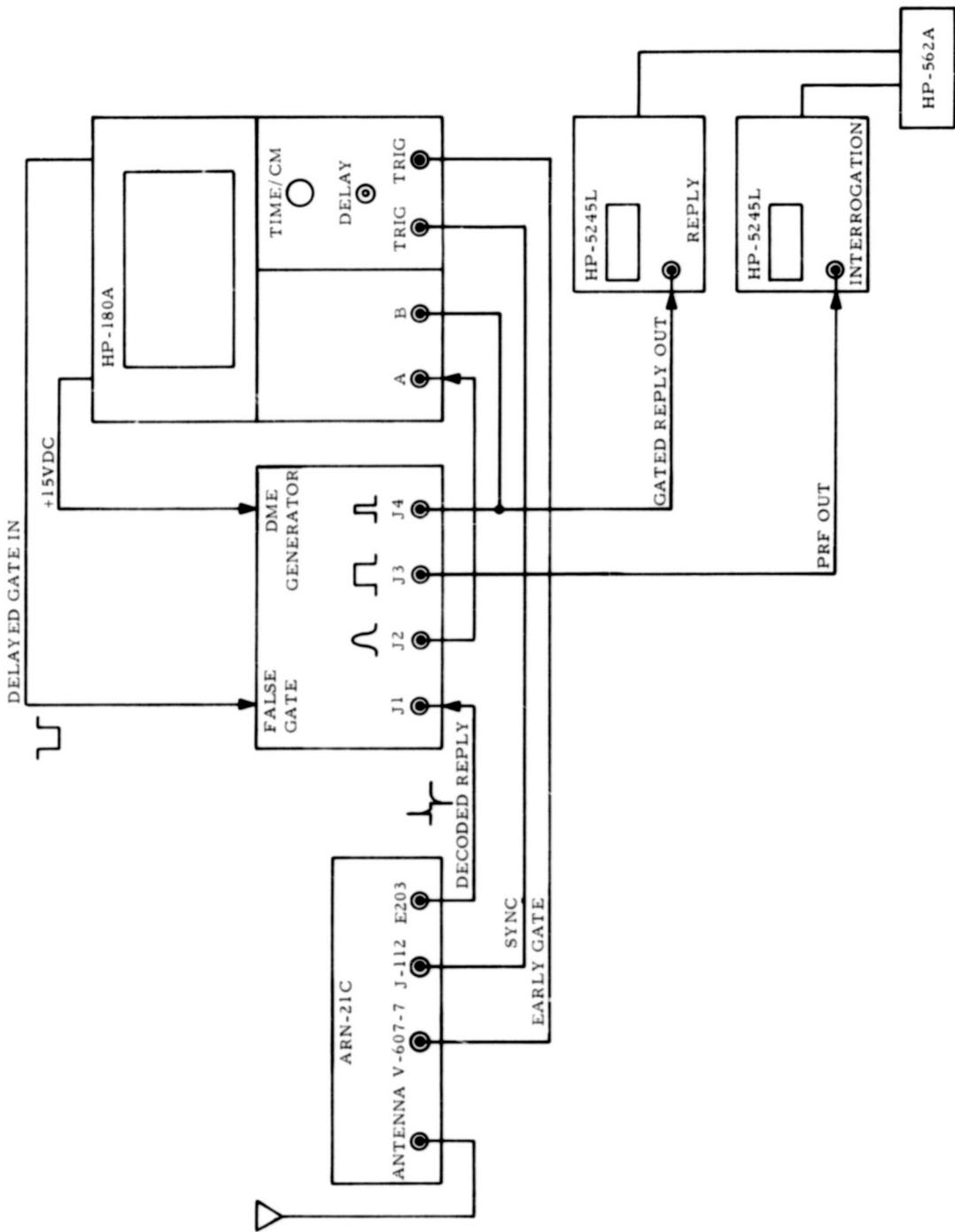
**43**

FIGURE 2-1 - AIRBORNE BLOCK DIAGRAM

The range indicator, ID-310, and hence the range gate, were made to slew in or out in distance by inserting a center off, double pole, double throw switch in the grid circuit of the motor control amplifier, V-505. In addition, a normally closed pushbutton switch was attached to the lever knob of the DPDT slew switch to remove the ground from the range indicator which freezes the distance read-out, and range ate, during memory. The partial range control schematic with the added mudification is shown in Figure 2-2. The slew switch was connected to the electronic range control module in the ARN/21C by a seven-conductor cable to allow for physical location near the scope for convenient operation. The cable was attached to the top of the module and routed to the front of the set and out a slot cut in the top front of the dust cover, because there were no spare pins available. Refer to Figure 7-45 in the ARN/21C manual for the complete electronic range control schematic.

The early gate out of the airborne set was used to control the delay time of the count gate in the range-tracking mode of operation. The early gate, available at test point J-9 in the electronic range gate module was fed to the scope delayed-trigger input by a shielded wire routed through the dust cover along with the slew cable. A voltage divider, consisting of a 100K and a 4-7K resistor, was added in the module to reduce the amplitude to about 10 volts. Refer to Figure 7-48 in the ARN/21C manual for the complete electronic range gate schematic gate circuit.

Gate Circuit. The function of the gate circuit is to produce a pulse output to the reply counter when the decoded reply pulse and the controllable gate are coincident.

One input to the gate is the decoded reply from E-203 in the ARN/21, which is approximately a 50-volt pulse, and is fed by J-1 to a network consisting of C-1, R-1, and a diode to limit and clip the negative portion, and is applied to the base of emitter follower, Q-1. The output of Q-1 is a 4-volt positive pulse, which is one input to NAND Gate 2, and is also available at J-2 for display on trace A of the scope. The other input to the gate is the negative going delayed gate from the HP-180A scope, which is fed to and inverted by NAND Gate 1 and is applied as a positive gate, as the second input to NAND Gate 2, and as this gate is in sync with the scope mainsweep triggered by the ARN/21 suppressor pulse, it is available at J-3 as an output for the interrogation counter. The output of NAND Gate 2 is inverted by NAND Gate 3, and is the gated reply output at J-4. J-4 is fed to scope for display on trace B and is also fed to the reply counter.

A Quad 2 input NAND gate, signetic N-8880, and a NPN transistor, 2N697 were used for the gate circuit. Three of the four NAND gates were utilized in the IC, two for inverting the signal, and the transistor was used as an emitter follower for signal isolation. The schematic is shown in Figure 2-3. The positive 5 volts necessary for the circuit were obtained from the positive 15-volt supply of the HP-180A scope. The positive 15 volts were
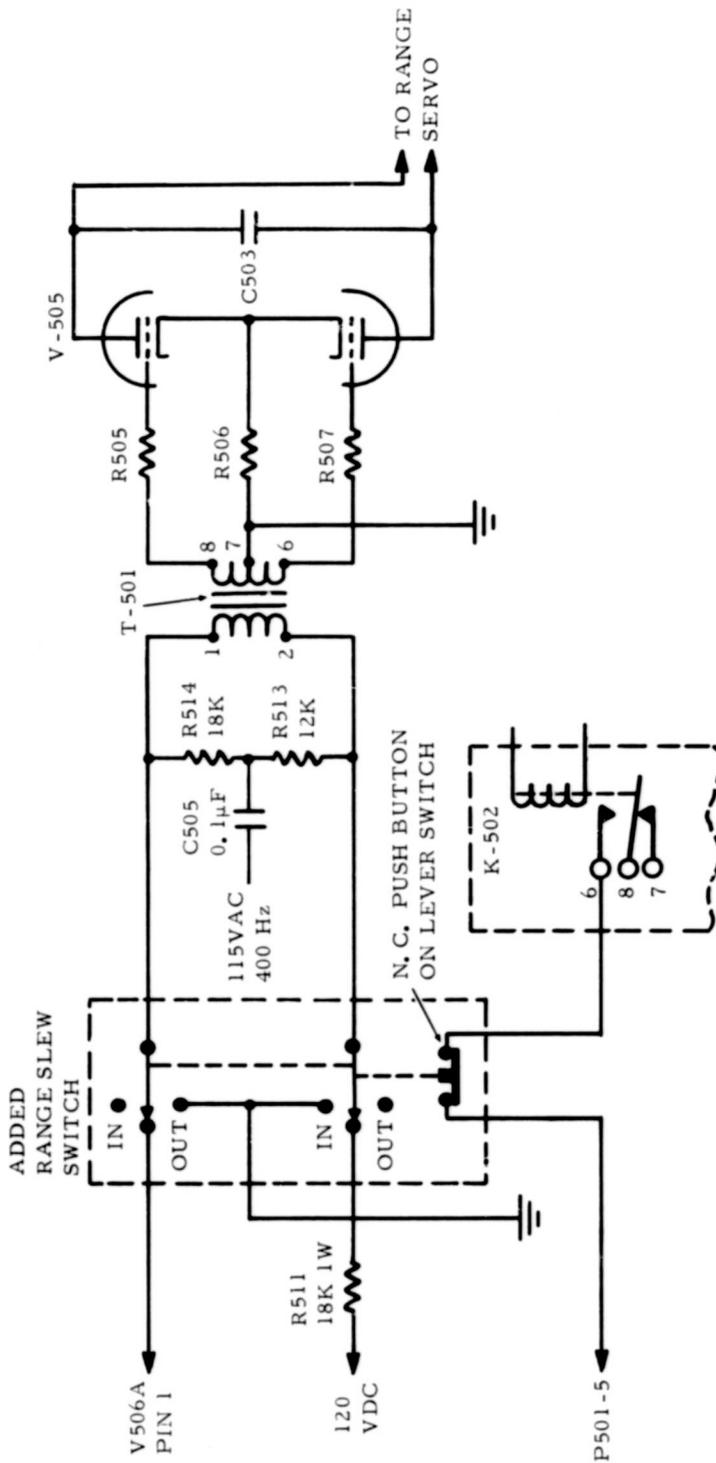
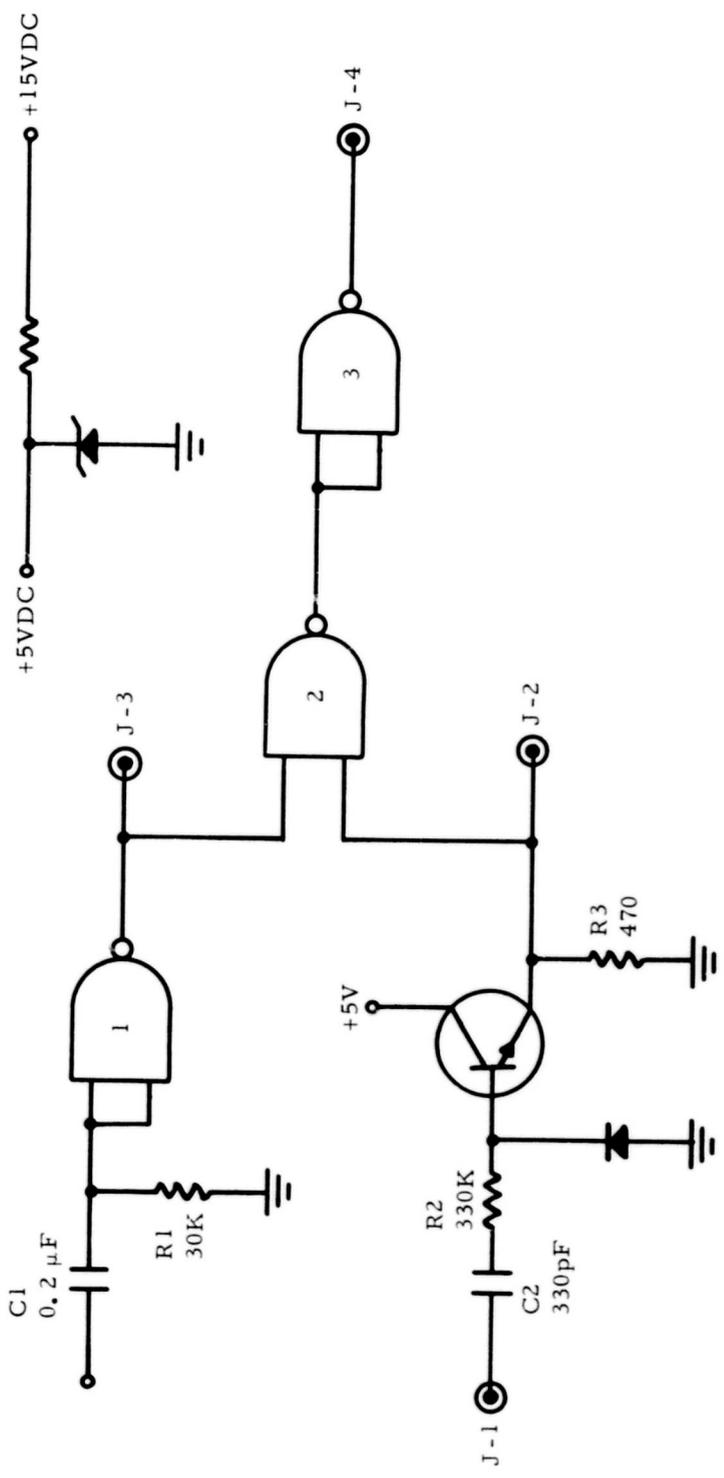FIGURE 2-2 - PARTIAL SCHEMATIC OF ELECTRONIC RANGE CONTROL

FIGURE 2-3 - LOGIC DIAGRAM OF GATING CIRCUIT

47

B-6

reduced and regulated by a 5-volt zener diode. The circuit was mounted on a printed circuit board and enclosed in a chassis with four BNC jacks for system hook-up. The wiring diagram is shown in Figure 2-4.

HP-180A Scope - The HP-180A scope with a 1801A dual channel vertical amplifier plug-in and a 1821A time-base and delay generator plug-in were used not only for display of the replies, but also as an integral control of the count gate.

The simplicity of the technique is due to the feature of the 1821A plug-in that has the delayed gate output available at a rear jack on the scope, that is identified by an intensified portion of the main sweep. The delayed gate output is adjustable in time delay by the CM DELAY control, and in width by the delayed TIME/CM switch and VERNIER control. The HP-180A scope and annotated controls are shown in Figure 2-5a and 2-5b.

Operation.

Connect equipment as shown in the block diagram, Figure 2-1. Energize equipment, tune to desired channel and switch airborne set to transmit. Assuming the airborne set is locked on a normal reply and it is desired to count synchronous replies, proceed as follows:

Obtain a baseline with SWEEP MODE in AUTO, display to INT, Magnifier to X1. Adjust intensity, FOCUS, VER, and HOR position controls for suitable trace on screen. Refer to Figure 2-5a. Set the controls on the 1801A plug-in as follows:

1. DISPLAY - ALT

2. A and B VOLTS/CM

3. A and B POLARITY - + UP (positive)

4. A and B Coupling - DC

Refer to Figure 2-5b. Set 1821A time base controls as follows:

1. Sweep Display - MAIN

2. TIME/CM (MAIN) - 50 μs/CM (distance less than 35 miles).

3. VERNIER (MAIN) CAL(CW)
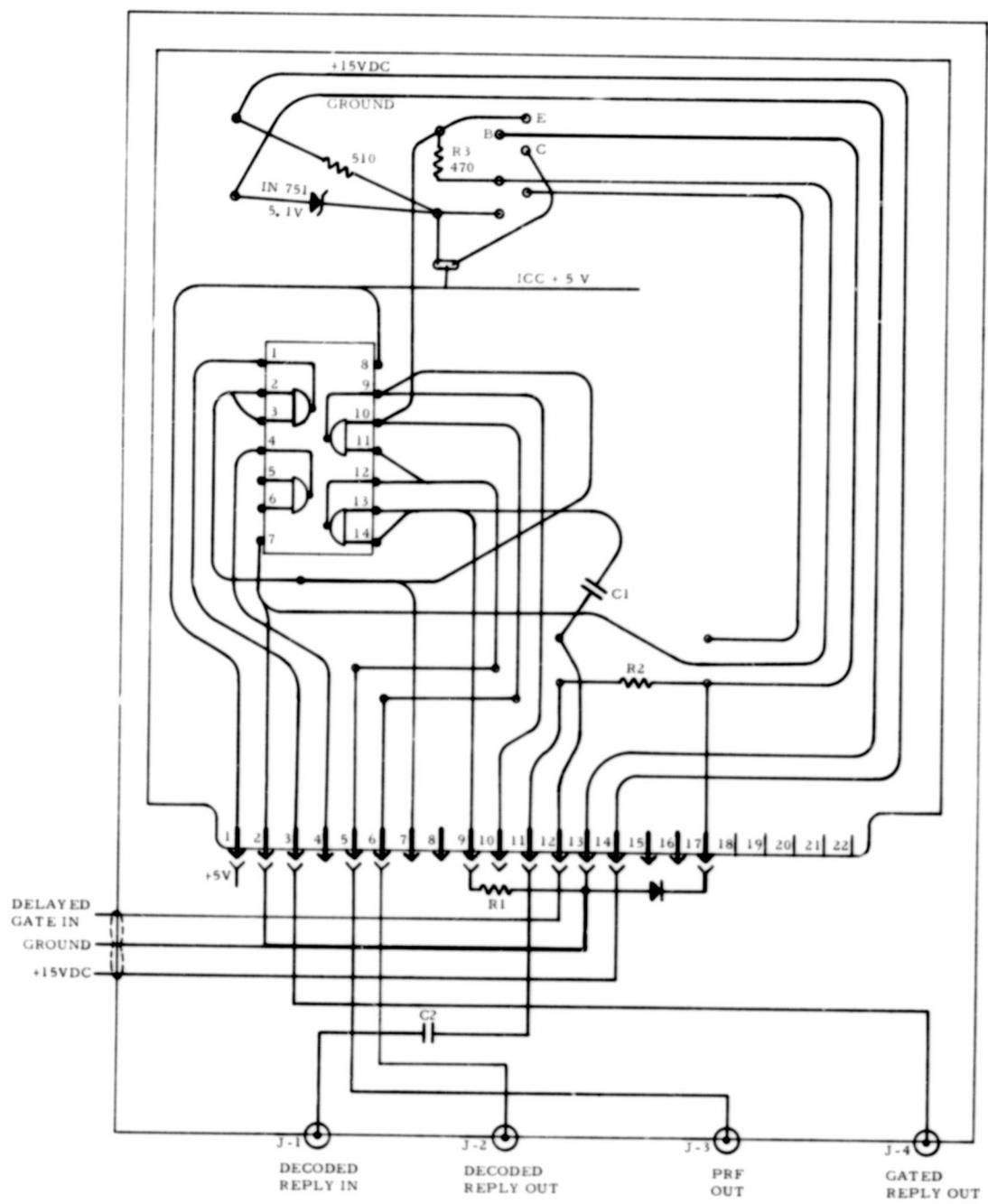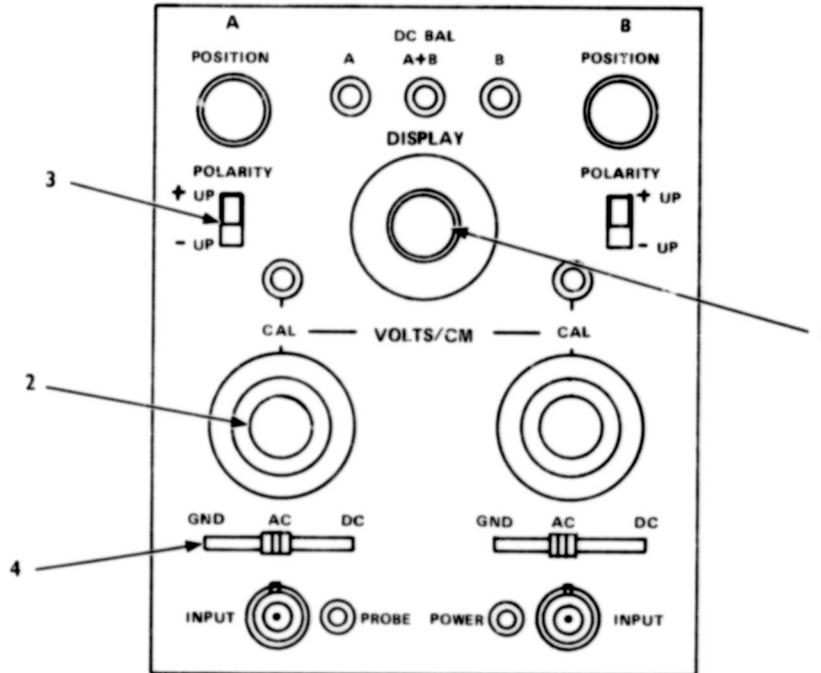
4. SWEEP MODE - NORM

5. TRIGGER Source (MAIN) - Ext + 10

B-7

FIGURE 2-4 - WIRING DIAGRM OF GATING CIRCUIT

FIGURE 2-5a - OSCILLOSCOPE CONTROLS  HP180A

1821 BASE AND
DELAY GENERATOR

HEWLETT PACKARD
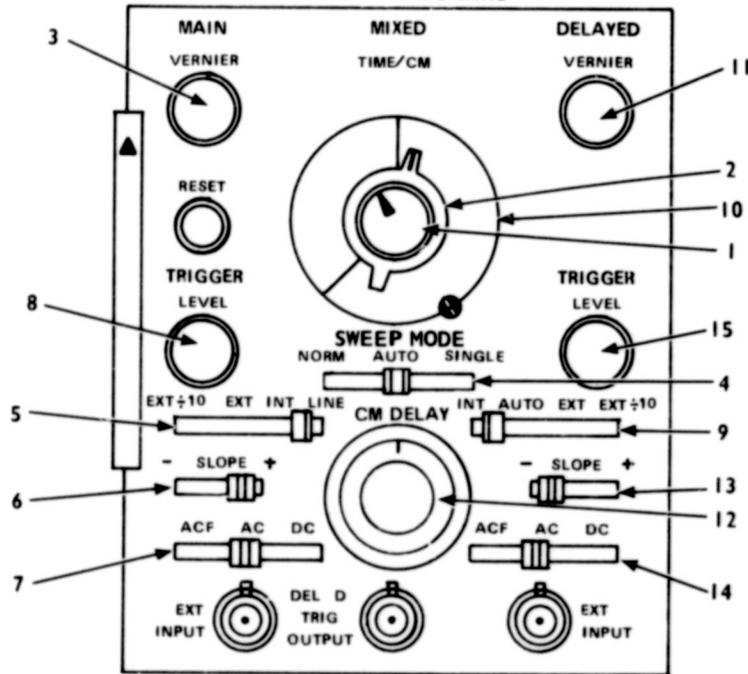
1. SWEEP DISPLAY
2. TIME/CM (MAIN)
3. VERNIER
4. SWEEP MODE
5. TRIGGER SOURCE (MAIN)
6. SLOPE (MAIN)
7. TRIGGER COUPLING (MAIN)
8. TRIGGER LEVEL
9. TRIGGER SOURCE (DELAYED)
10. TIME/CM (DELAYED)
11. VERNIER (DELAYED)
12. CM/DELAY
13. SLOPE (DELAYED)
14. TRIGGER COUPLING (DELAYED)
15. TRIGGER LEVEL (DELAYED)

FIGURE 2-5b - OSCILLOSCOPE CONTROLS   HP180A

6.   SLOPE (MAIN) - + UP (positive)

7.   Trigger Coupling (MAIN) - ACF

8.   TRIGGER LEVEL - Adjust for stable sweep.

9.   TRIGGER Source (DELAYED) - AUTO

10.   TIME/CM (DELAYED) - 5 μs/CM (results in intensified sweep
                                  portion of MAIN).

11.   VERNIER (DELAYED) - Adjust for 40 μs wide intensified sweep.

12.   CM/DELAY - Adjust to intensify particular replies to be counted.
      For range-tracking mode with range trig from ARN-21 connected
      to EXT INPUT (DELAYED), set as for manual mode and set as
      follows:

   9.   TRIGGER Source - Switch to EXT ÷ 10

   10.   CM/DELAY - Setting should be less in range than the
         indicated by the ID-310.

13.   SLOPE (DELAYED) - + (positive)

14.   Trigger Coupling (DELAYED) - ACF

15.   TRIGGER LEVEL (DELAYED) - Adjust for stable intensified
      sweep.

The upper or A trace will display the decoded replies, and the lower or B
trace will display the gated output to the reply counter to enable monitoring.
The counters should both be set for an input sensitivity of 1 volt and a
time-base of 1 second.

The efficiency is found by dividing the reply count by the interrogation
count.

# APPENDIX C

## CRAZY WOMAN MODIFICATION

The modification is designed to prevent false DME replies caused by air-to-ground multipath interrogations. The modification was conceived and designed by Mr. George Oltion, Sector Chief from Casper, Wyoming. The modification has been in successful operation at the Crazy Woman VORTAC for the last few years. The effectiveness of the modification has been tested at various problem sites and has been found to be quite successful in reducing false replies generated by air-to-ground multipath interrogations.

Prior to installing this modification, all false DME modifications must be removed (Chapter 117, 182, etc.).

After removal of all false DME modifications, TP-2 of the GRN-9s and Pin 3 V11520 of the RTB-2 must be checked to:

1. Determine that the noise level is at or below 1 volt.

2. Determine that at least a 4 to 1 signal-to-noise ratio exists at the signal saturation point.

3. Determine that any stray pick-up is at or below 1 volt.

If any of the above criteria are not met, the equipment operation is considered non-standard, and the Crazy Woman false DME modificaiton should not be installed until the equipment is returned to standard operation.

Install modification as per appropriate attached installation schematic (Figure 3-1).

Connect oscilloscope to following points:

### Channel A

Pin 1 of tube socket on modification 1V/CM, 50  s/CM

### Channel B

Pin 5 of tube socket on modification 10V/CM, 50  s/CM
Sync ext, rear, sweep alternate
Channel A is the input to the DME modification
Channel B is gate output

To determine the proper modification input setting for each facility, a chart similar to the one attached should be obtained (Figure 3-2). This chart will show signal generator signal level versus amplitude of video pulses

FIGURE 3-1 — CRAZY WOMAN MODIFICATION SCHEMATIC

BLANKING GATE GENERATOR
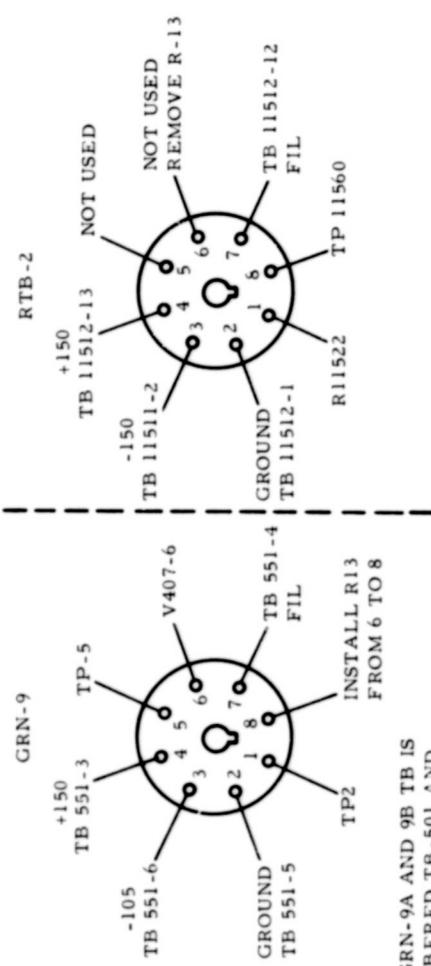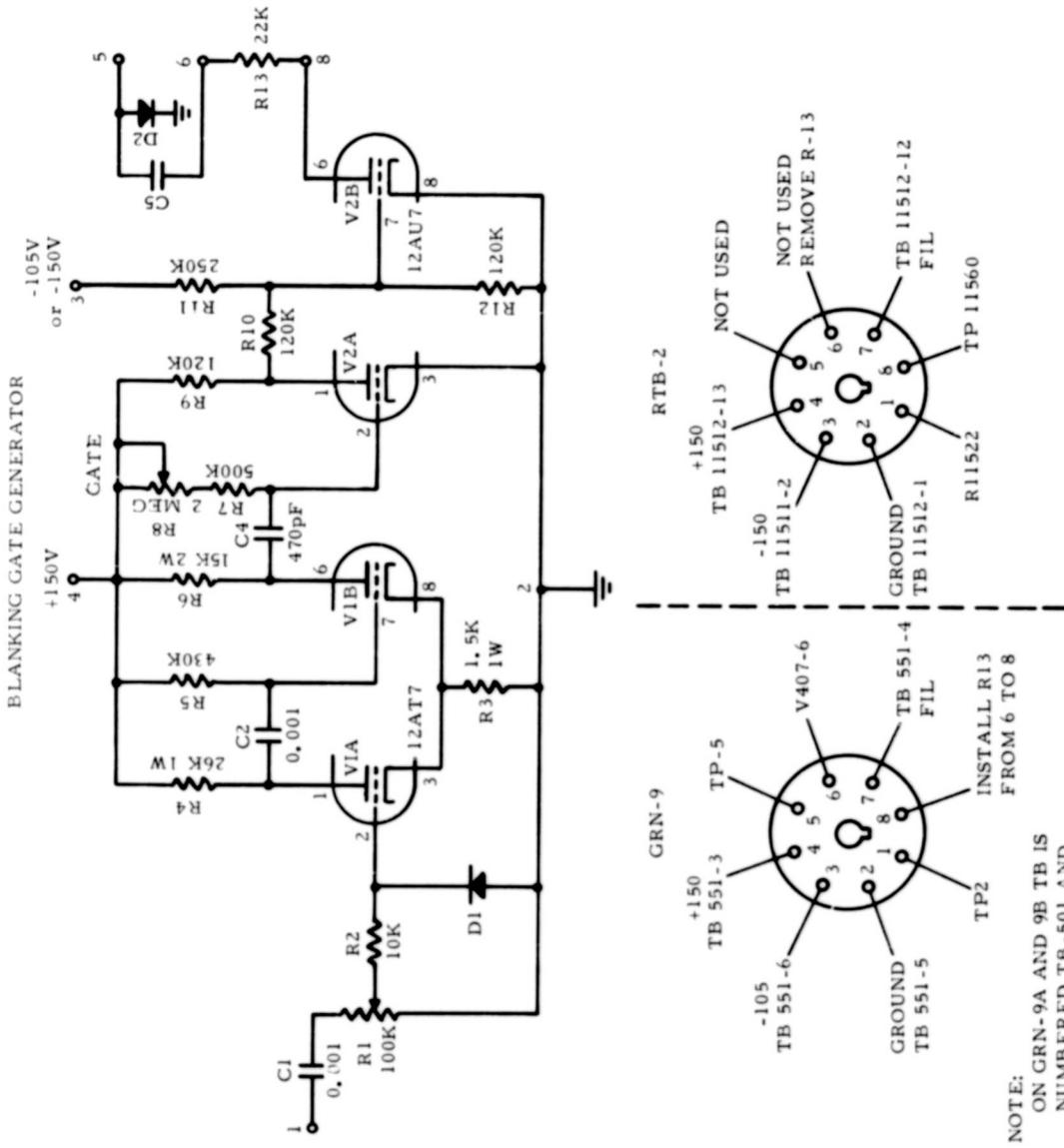
NOTE:
ON GRN-9A AND 9B TB IS
NUMBERED TB-501 AND
-105 VDC IS ON TB 501-5.

54

C-2

SENSITIVITY SET APPROXIMATELY
0.5 VOLTS BELOW THE KNEE SIGNAL
GENERATOR (-73 dBm)
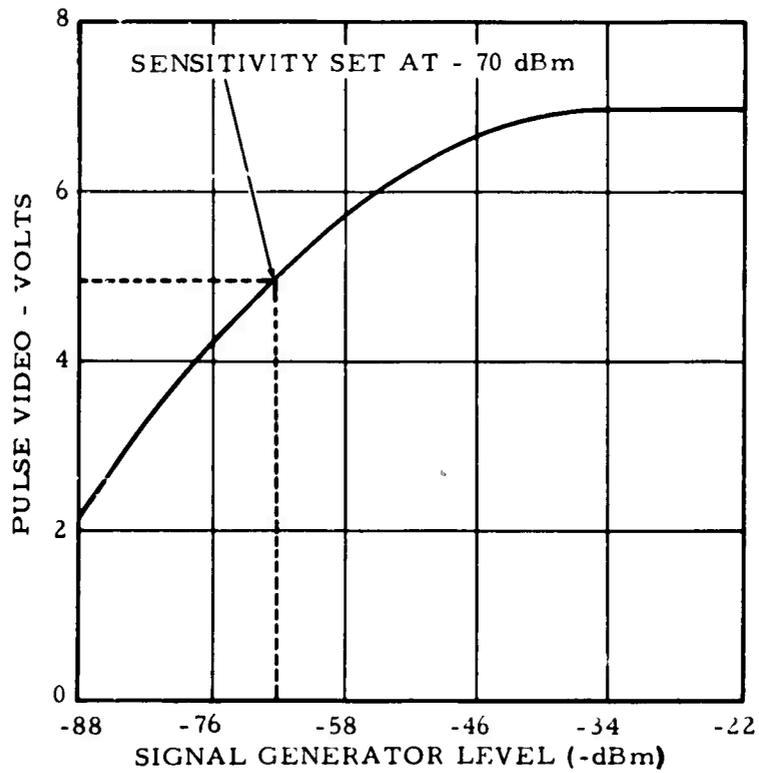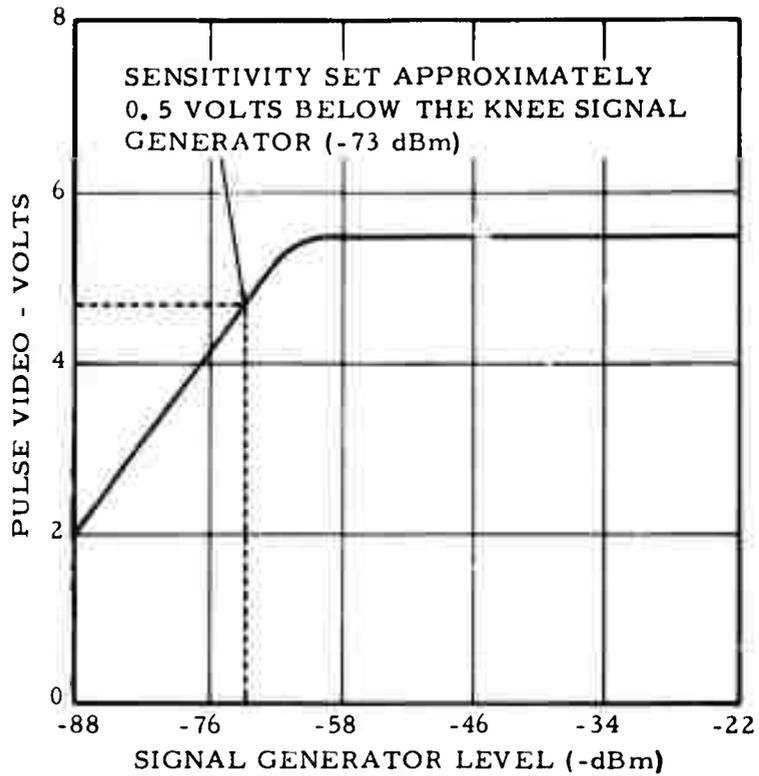
SENSITIVITY SET AT - 70 dBm

FIGURE 3-2 - CALIBRATION CURVE

C-3

at Pin 1 of tube socket (input to modification). As long as the knee of the chart obtained occurs 0.5 volt after a signal generator level -70 dBm, the sensitivity of the modification should be set to -70 dBm. Should the knee of the chart occur at a signal generator level of -70 dBm or above, then the sensitivity of the modification should be set to whatever signal generator level results in a pulse amplitude 0.5 volt below the knee. Attachment 1 shows the desirable sensitivity setting for each condition.

Once the modification is enabled, adjust the length of the gate to 300 µs as viewed on Channel B of the oscilloscope.

The following test configuration may be utilized to check operation of the modification.

a. Place Function Selector Switch on Monitor No. 1 to test pulse modulation.

b. Connect a cable from Test Pulse Output of test pulse generator to Test Pulse Input of Monitor No. 1.

c. Place Function Selector Switch of Monitor No. 2 to External Trigger.

d. Externally synchronize the oscilloscope from the signal generator of Monitor No. 2.

e. Connect a cable from the Test Pulse Output of the GRN-9 or Receiver Output of the RTB-2 to the vertical amplifier of the oscilloscope.

f. Adjust the test pulse delay of the test pulse generator to maximum delay.

With both signal generators set below the threshold of the modification, two pulses should appear on the oscilloscope. The first pulse from signal generator No. 2 and the second pulse from signal generator No. 1. The second pulse should be delayed from the first pulse by 80 to 100 µs. The first pulse represents a reply to a legitimate interrogation and the second pulse represents a false reply caused by a multipath reflection of the legitimate interrogation.

Increase signal generator No. 2 to a level that will threshold the Crazy Woman modification. Note that the simulated low level multipath pulse is eliminated by viewing the oscilloscope.

Now increase signal generator No. 1 output to a level that will threshold the Crazy Woman modification. Note that the second pulse reappears on the oscilloscope.

This demonstrates that when a legitimate interrogation is followed by a multipath interrogation, the multipath interrogation is eliminated. Should a second legitimate interrogation follow the first, the second interrogation will terminate the gate of the first, be decoded and generate its own long dead time gate.

The following is a description of the circuit operation as supplied by the designer of the Crazy Woman modification.

Circuit Operation (Refer to Schematic).

1. The sensitivity control, R-1, presents a high impedance to the source video. R-2 is an isolating resistor to prevent pulses generated in V-1 from feeding back to the source.

2. D-1 is a clamping diode and eliminates negative overshoots on the grid of V-1.

3. Components C2, R3, R4, R5, and R6 were selecte to provide a 40 µs output pulse with a 2-volt interrogation signal applied to the input.

4. The pulse at the plate of V1-B serves a dual purpose. The differentiated output through C-4 will terminate any existing dead time gate by its leading edge positive going spike and, 40 µs later, the negative spike will start a new dead time gate. This 40 µs period is sufficient time to generate a reply to the interrogation.

5. The bias voltage divider resistor R-11 was changed to a compromise value so that either a -105 volt or -150 volt supply could be used.

6. R-13 was installed to reduce the amplitude of the dead time gate to the level of the normal 40 µs gate in the GRN-9. This is approximately 20 volts. R-13 is mounted externally on the octal socket. This allows the box to work on either the RTB-2 or GRN-9 without any internal changes.

7. C-5 and D-2 were added in order to clean up the output pulse at TP-5. Coupling capacitor C-415 is too small to pass a 350 µs gate. The addition of C-5, a .1 uf, is adequate to do the job. D-2 is a clamping diode and prevents a positive overshoot at TP-5.