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PREDATOR UAV LINE-OF-SIGHT DATALINK TERMINAL RADIO FREQUENCY TEST REPORT

Prepared for

AIR COMBAT COMMAND
UAV Special Mission Office (ACC/DR-UAV)
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14. ABSTRACT The Predator Unmanned Aerial Vehicle (UAV) line-of-sight command link and return link frequency assignments permit the simultaneous operation of four General Atomics Aeronautical Systems Incorporated (GA-ASI) Predator air vehicles at the Indian Springs Air Force Auxiliary Field (ISAFAF). With increased operations of the RQ-1/MQ-1 Predator, and the introduction of MQ-9 Hunter-Killer (Predator B®) operations, a requirement was identified for the simultaneous operation of seven Predator UAVs at ISAFAF and an additional set of frequencies for ground test. The Air Combat Command UAV Special Mission Office requested that the Joint Spectrum Center investigate ways to satisfy the Predator frequency requirements. The Joint Spectrum Center, with support from the Aeronautical Systems Center and GA-ASI, performed transmitter spurious emissions, transmitter emission bandwidth, transmitter broadband noise, receiver sensitivity, receiver selectivity, receiver adjacent-signal rejection, and receiver gain compression measurements of the datalink terminals. This report describes the test efforts and presents the test results. The data in this report was current as of 30 July 2004.						
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PREFACE

The Joint Spectrum Center (JSC), a field activity of the Defense Information Systems Agency (DISA), was established to provide advice and assistance on all matters regarding the electromagnetic battlespace. Support is provided to the Secretary of Defense, the Joint Staff, the military departments, combatant commands, defense agencies, and other agencies of the US Government. The JSC works closely with the Joint Staff, Director for Command, Control, Communications, and Computer Systems, and the Assistant Secretary of Defense for Networks and Information Integration on spectrum matters. Direct support is provided to the Unified Commands and Joint Task Force Commanders on electromagnetic battlespace issues, including spectrum management and electronic warfare deconfliction. Support to DoD components and the US Government is provided through a sponsor-reimbursed electromagnetic compatibility (EMC) program that provides EMC analyses for specific projects.

Comments regarding this report should be submitted to the Commander, JSC, 2004 Turbot Landing, Annapolis, Maryland 21402-5064.

EXECUTIVE SUMMARY

The Predator Unmanned Aerial Vehicle (UAV) datalinks provide command and control information via an uplink to a UAV from a ground control station (GCS) and payload and status data from the UAV to the GCS using the downlink or return link. The Predator line-of-sight (LOS) command and return link frequency assignments permit the simultaneous operation of four General Atomics Aeronautical Systems Incorporated (GA-ASI) Predator UAVs at Indian Springs Air Force Auxiliary Field (ISAFAF). With increased operations of the RQ-1/MQ-1 Predator and the introduction of the MQ-9 Hunter-Killer (Predator B®), a requirement was identified for the simultaneous operation at ISAFAF of seven Predator UAVs and an additional set of frequencies for ground test purposes.

As part of the effort to satisfy the Predator frequency requirements, the Air Combat Command UAV Special Mission Office requested that the Joint Spectrum Center (JSC) to perform testing of the C-band LOS datalinks. The objective of the test was to determine the radio frequency characteristics of the Predator LOS datalink terminals to determine how to satisfy the UAV LOS frequency requirements. The JSC, with support from the Aeronautical Systems Center and GA-ASI, performed transmitter spurious emissions, transmitter emission bandwidth, transmitter broadband noise, receiver sensitivity, receiver selectivity, receiver adjacent-signal rejection, and receiver gain compression measurements of the datalink terminals to investigate and determine the various ways that the selected Predator frequency requirement could be met. The tests were conducted at the GA-ASI Predator Systems Integration Laboratory at Rancho Bernardo, CA.

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GLOSSARY

ACC	Air Combat Command
ASC	Aeronautical Systems Center
DLOS	Digital Line-of-Sight
FSK	Frequency Shift Keyed
GA-ASI	General Atomics Aeronautical Systems Incorporated
GCS	Ground Control Station
GDT	Ground Data Terminal
ISAFAF	Indian Springs Air Force Auxiliary Field
JSC	Joint Spectrum Center
LNA	Low Noise Amplifier
LOS	Line-of-Sight
MDS	Minimum Discernable Signal
NRZ	Non-Return-to-Zero
PCM	Primary Control Module
PSG	Precision Signal Generator
PSIL	Predator Systems Integration Laboratory
RF	Radio Frequency
SSI	Signal Strength Indicator
UAV	Unmanned Aerial Vehicle

SECTION 1 – INTRODUCTION

1.1 BACKGROUND

The Predator Unmanned Aerial Vehicle (UAV) line-of-sight (LOS) command link and return link frequency assignments currently permit the simultaneous operation of four General Atomics Aeronautical Systems, Inc., (GA-ASI) Predator UAVs at the Indian Springs Air Force Auxiliary Field (ISAFAF). With increased operations of RQ-1/MQ-1 Predator and the introduction of MQ-9 Hunter-Killer (Predator B®), a requirement was identified for the simultaneous operation of seven Predator UAVs and an additional set of frequencies for ground test purposes at the ISAFAF. The Air Combat Command (ACC) UAV Special Mission Office requested that the Joint Spectrum Center (JSC) investigate ways to satisfy the new Predator frequency requirements.

1.2 OBJECTIVE

The objective of this task was to conduct measurements to determine the radio frequency (RF) characteristics of the Predator UAV LOS command and return datalink terminals.

1.3 APPROACH

The JSC measurement team, with support from the Aeronautical Systems Center (ASC), traveled to Rancho Bernardo, California to collect RF characteristic data at the GA-ASI Predator Systems Integration Laboratory (PSIL) from July 26 – 30, 2004. These test measurements included transmitter spurious emissions, transmitter emission bandwidth, transmitter broadband noise, receiver sensitivity, receiver selectivity, receiver adjacent-signal rejection, and receiver gain compression. Test block diagrams, descriptions, and data sheets were prepared prior to testing via the test plan.[1-1]

The collected measurement data was adjusted to account for cable loss, low noise amplifier (LNA) gains, filter insertion losses and responses, and receiver bandwidth corrections. To remove any propagation uncertainties from the tests and test results, closed-system tests were used instead of radiating tests.

[1-1] S. Bonter, Y. Kim, J.Smith, *Predator UAV Line-of-Sight Datalink Terminal Radio Frequency Test Plan,* JSC-CR-03-062, Annapolis, MD: DoD Joint Spectrum Center, August 2003.

SECTION 2 – SYSTEM DESCRIPTIONS

The Predator datalink system provides command and control information from the ground control station (GCS) to the UAV using the command link. Payload data and UAV status information are transmitted from the UAV to the GCS using a return link. The command link, a ground data terminal (GDT) transmitter, operates at 5625 – 5850 MHz and the return link (UAV transmitter) transmits at 5250 – 5475 MHz. The transmitter and receiver units can be software configured to perform various command or return link functions.

2.1 PREDATOR UAV DATALINKS

Each Predator UAV utilizes two command datalinks and two return datalinks. This dual UAV datalink system contains transmitters, receivers, diplexers, and a shared computer. The diplexers permit full-duplex operation. Computer parity checks are performed to validate message data, select the optimum command link, and discard erroneous messages.

The GDT command link-configured terminals transfer 16-bit messages consisting of randomized 15-bit non-return-to-zero (NRZ) data (signal is at a constant level for the duration of a bit time) plus one parity bit at 19.2 kbps, or 200 kbps using frequency shift keyed (FSK) modulation.

The return link-configured terminals transfer either National Television System Committee video with data subcarriers at 6.8-MHz and 7.5-MHz offset, or 3.2-Mbps FSK data without subcarriers. The return link data is transferred using the command link 16-bit message structure consisting of 15-bit NRZ data and a parity bit.

The UAV and GDT datalink transmitter amplifier final stage can be software-controlled to switch between 1-mW and 10-W output power. The 1-mW low-power mode is used for ground testing. If the link cannot be maintained at 1 mW, the UAV transmitter will automatically revert to 10 W. Operators can monitor datalink quality with a signal strength meter, a message error counter, and observed video quality. The signal strength meter is an uncalibrated gauge that reads between 0 and 100% signal strength at approximately 0.5 dB per unit. The message error counter is incremented if a message parity check fails and the message is discarded. Received video quality is a subjective measure as perceived by the operators.

2.2 GCS

The Predator GCS includes pilot and payload operator workstations, data exploitation, mission planning, communication terminals, synthetic aperture radar workstations, an uninterruptable power supply and shelter air conditioning. Because the Predator has no onboard recording capability, all mission imagery recording is performed in the GCS. Power is supplied to the GCS by either commercially supplied power or generators. The Predator UAV is flown by an operator from inside the GCS via a C-band LOS datalink or a K_u-band satellite datalink for beyond line-of-sight flight. External communications consist of HF, UHF, VHF, landline/cellular telephones, and hardwire connectivity with the TROJAN SPIRIT II satellite communication terminal.[2-1]

The GCS is connected to a GDT that consists of an antenna system, a diplexer, and a custom-built LNA. The diplexer permits full-duplex operation. The LNA is utilized to reduce system noise. The GCS-GDT-UAV configuration is shown in Figure 2-1. The GDT-UAV RF configuration is shown in Figure 2-2. The command and return datalink component RF characteristics are listed in Table 2-1.[2-2] The link types in Table 2-1 are divided into command LOS and Digital LOS (DLOS) and return LOS and DLOS.

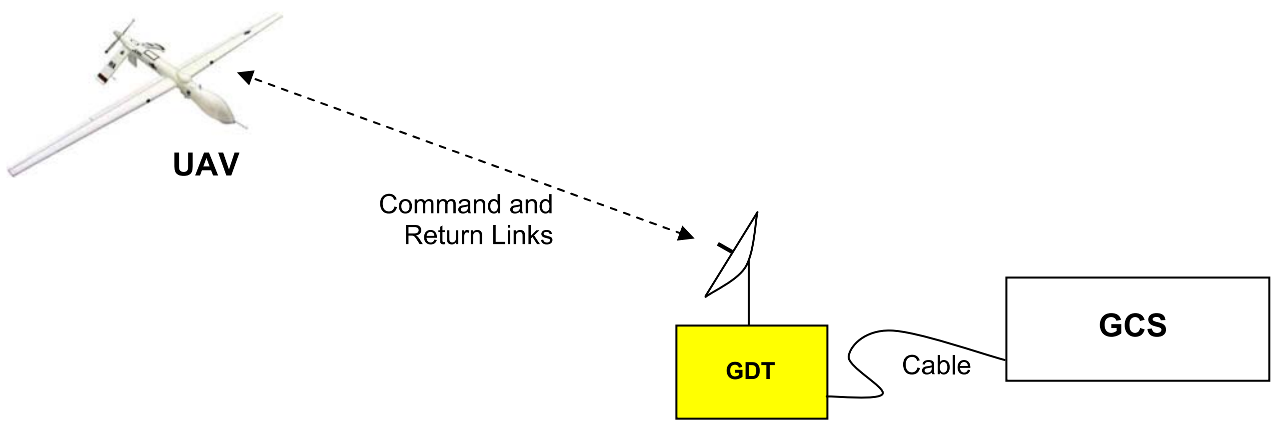

Figure 2-1. GCS-GDT-UAV Configuration

[2-1] "UAV Ground Control Station (GCS)," *Federation of American Scientists Intelligence Resource Program*, Washington, DC: FAS, Updated July 30, 1997. Available from Electronic Source; Internet http://www.fas.org/irp/program/collect/uav_gcs.htm.
[2-2] *Application for Equipment Frequency Allocation (DD Form 1494) for Predator C-Band MAE UAV Medium Altitude Endurance Unmanned Aerial Vehicle*, J/F 12/7253, Washington, DC: MCEB, 9 April 2003.

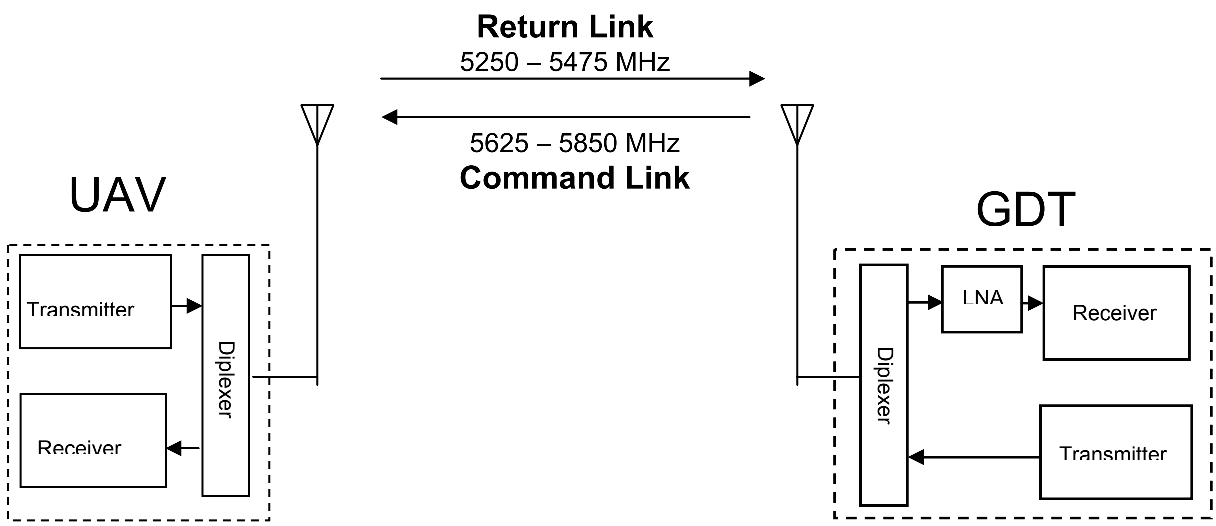

Figure 2-2. UAV and GDT RF Configuration

Table 2-1. Command and Return Datalink RF Technical Characteristics

Characteristics	Specifications			
Transmitter				
Tuning Range, MHz	5250 – 5850			
Tuning Increment, MHz	1			
Transmitter Power, dBm	40			
Spurious/Harmonic Attenuation, dB	65			
Link Type	**Command Link**		**Return Link**	
	LOS Command Link	DLOS Command Link	LOS Return Link	DLOS Return Link
Emission Designators	560KF1D	88K3F1D	17M0F9F	4M72F1D
Emission Bandwidth, MHz				
-3-dB	0.34	0.063	8.5	2.8
-20-dB	0.42	0.088	18.0	20.0
-40-dB	NA	0.219	NA	NA
-60-dB	1.2	0.671	46.2	66.0
Receiver				
Tuning Range, MHz	5250 – 5850			
RF Selectivity, MHz				
-3-dB	303			
-20-dB	375			
-60-dB	525			
1st IF Selectivity, MHz				
-3-dB	35			
-20-dB	55			
-60-dB	115			
Link Type	**Command Link**		**Return Link**	
2nd IF Selectivity, MHz				
-3-dB	1		20	
-20-dB	3.2		22.5	
-60-dB	4		28	
Emission Designators	560KF1D	88K3F1D	17M0F9F	4M72F1D
Sensitivity, dBm	-98	-98	-84	-86
Sensitivity Criterion	1×10^{-6} BER	1×10^{-6} BER	23-dB S/N	1×10^{-6} BER
Noise Figure, dB	2			
Spurious Rejection, dB	50			
Diplexer				
Low-Band Port Frequency Band, MHz	5250 – 5475			
Cross-Over Frequency Band, MHz	5475 – 5625			
High-Band Port Frequency Band, MHz	5625 – 5850			
GDT LNA				
Manufacturer	JCA Technologies			
Gain, dB	18			
Noise Figure, dB	1.8			
BER - Bit Error Rate S/N - Signal-to-Noise Power Ratio NA = Not Applicable				

2.3 TEST SETUP

The setup at the PSIL, shown in Figure 2-3, consists of a Predator UAV, operator station, GDT, Precision Signal Generator (PSG), LNA, laptop, signal generator, spectrum analyzer, and UAV Primary Control Module (PCM).

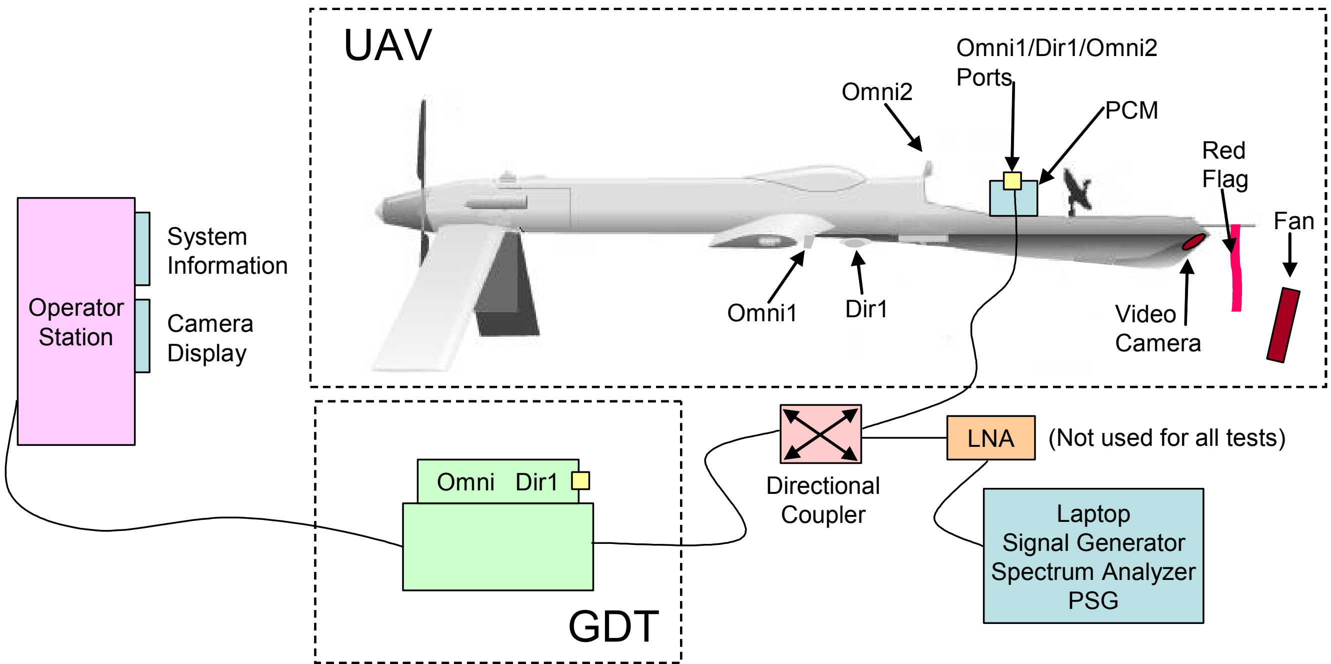

Figure 2-3. Test Setup

The Predator UAV used during testing was equipped with a C-band omnidirectional (Omni2) blade type antenna mounted on top and directly behind the communications electronics bay, a steerable directional antenna (Dir1), and a second omnidirectional C-band blade antenna (Omni1) located on the underside of the aircraft. The operator station was cabled directly to the GDT; two monitors in the operator station displayed the UAV system/status information and received imagery from the UAV video camera via the GDT. The Predator's top forward communications antenna dome was removed for access to the UAV electronics bay in order to make connections to the PCM (refer to Figures 2-3 and 2-4). The laptop, signal generator, and spectrum analyzer were connected to the Omni1, Dir1, or Omni2 port(s) located on the PCM. The choice of antenna/antenna port depended on the test performed (some tests required only one antenna to be disconnected, while others required two antennas to be disconnected). Antenna ports were used to remove any propagation uncertainties from the tests and test results. The PSG created the interfering source during several tests. The directional coupler allowed the observation of the desired link (UAV-GDT) or the injection of an interferer into the desired link without affecting signal integrity. The red flag and fan at the nose of the UAV was used to simulate movement to the video camera to determine when a link had been broken on the operator station camera display. Figure 2-4 shows a close-up of the UAV electronics bay, the PCM, and the Omni1, Dir1, and Omni2 antenna port connections.

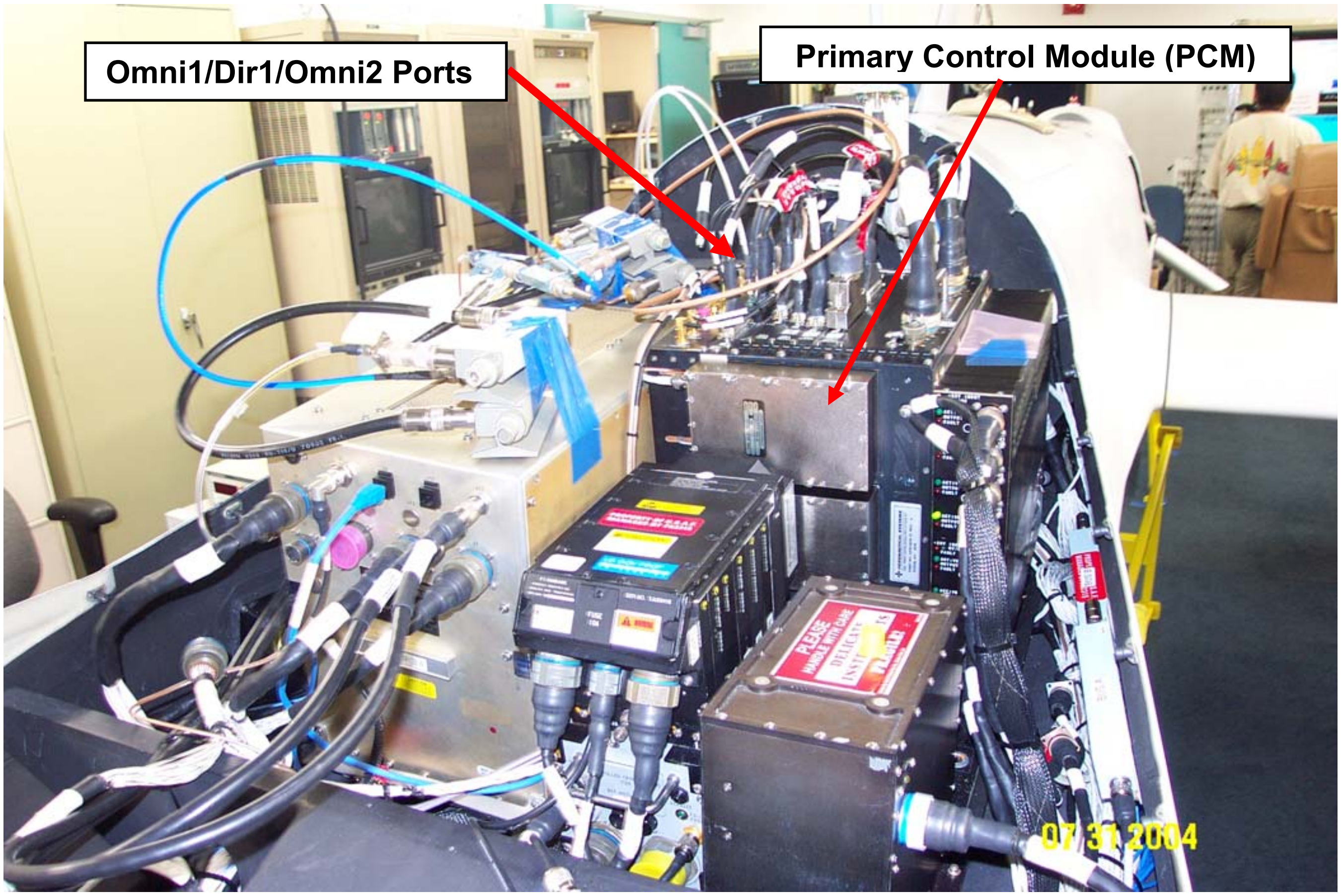

Figure 2-4. Predator UAV Electronics Bay Showing PCM and Antenna Ports

SECTION – 3 MEASUREMENTS METHODOLOGY

All tests were conducted by the JSC test team during 26-30 July 2004 at the GA-ASI PSIL, Rancho Bernardo, California. Data reduction and documentation were performed in August and September 2004.

Various tests were performed to measure GDT and UAV transmitter output power and emission bandwidth for receive-band broadband noise and spurious emissions. This involved collecting data for transmitter output power, emission bandwidth, and spurious emissions. The transmitter output was measured for each of the four emission designators (listed in Table 3-1) for in- and out-of-band emissions for both low- and high-power modes.

Table 3-1. Emission Designator Link Description

Emission Designator	Digital or Analog Link	Command or Return Link
560KF1D	LOS	Command
88K3F1D	DLOS	
17M0F9F	LOS	Return
4M72F1D	DLOS	

To remove any propagation uncertainties from the tests and test results, closed-system tests were used instead of radiating tests.

Test descriptions and setup block diagrams were prepared for transmitter spurious emissions, transmitter broadband noise, receiver sensitivity, receiver selectivity, receiver adjacent-signal rejection, and receiver gain compression measurements of the datalink terminals. All transmitter test data collected was saved electronically to a laptop computer for later data reduction. The transmitter tests are explained in more detail in Section 3.1.

During the July 26 – 30 timeframe, additional measurements were taken: receiver sensitivity, receiver selectivity, adjacent signal rejection, UAV receiver gain compression and GDT receive system gain compression including the LNA. As with transmitter tests, a closed-system test environment was utilized. Test descriptions and setup block diagrams were prepared before the tests and all receiver test data collected was saved electronically to a laptop computer for later data reduction. The receiver tests are explained in more detail in Section 3.2.

The total system losses from the output of the unit under test to the spectrum analyzer input was measured for each test configuration to provide calibration data.

3.1 TRANSMITTER CHARACTERIZATION

The GDT and UAV transmitter output power (Figures 3-1 and 3-2, respectively) and emission bandwidth were measured for spurious emissions (in the receive band).

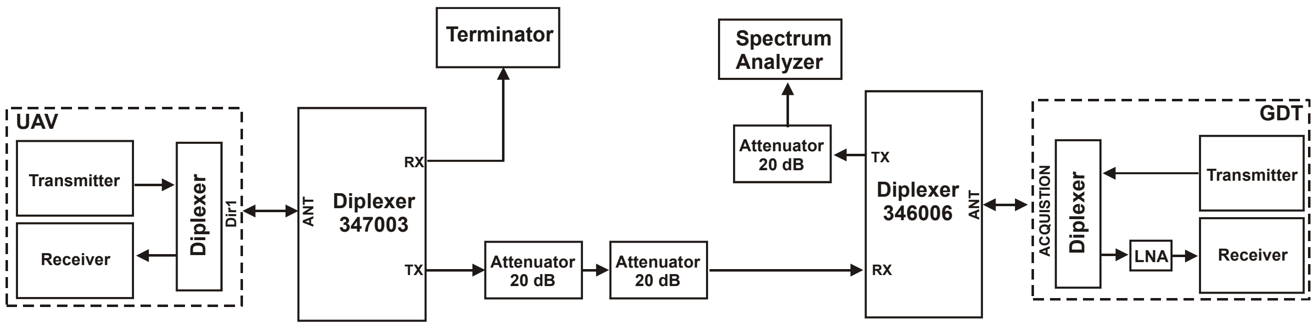

Figure 3-1. GDT Transmitter Output Power Test Setup

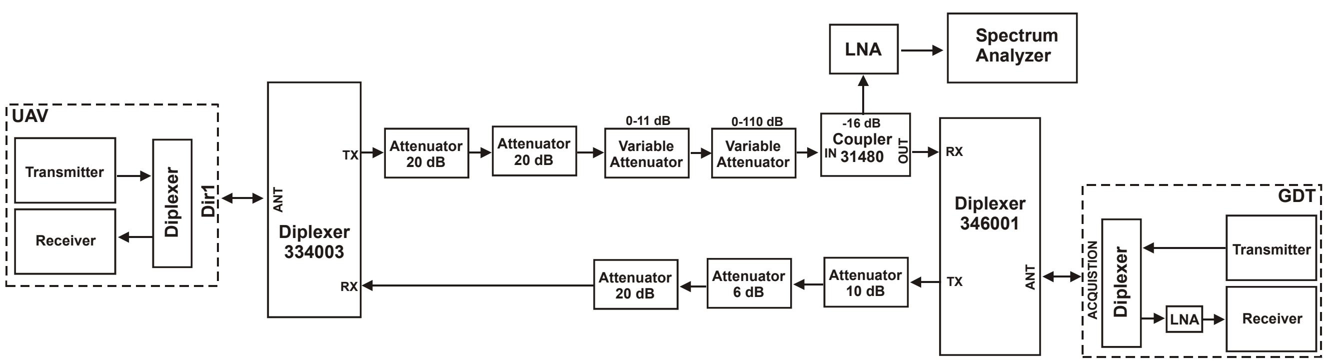

Figure 3-2. UAV Transmitter Output Power Test Setup

Transmitter output was measured for each emission designator for in-band and out-of-band emissions for low-power and high-power modes. During in-band measurements, a 20-dB attenuator (or other value, as appropriate) was inserted between the transmitter and the spectrum analyzer. Out-of-band measurements utilized a diplexer as a band pass filter to reject the fundamental energy and enable an LNA to be used to increase the test setup dynamic range for spurious emission measurements in the diplexer transmitter pass-band.

3.2 RECEIVER CHARACTERIZATION

Receiver sensitivity, selectivity, adjacent signal rejection, and gain compression measurements were performed. To remove any propagation uncertainties from the tests and test results, closed-system tests were used instead of radiating tests. The test equipment configurations utilized additional diplexers at each end of the path to enable independent control of the command link and return link isolations. These independent path losses were required to ensure that the results were dependent only on the link under test and not on the handshake message on the opposite link.

During receiver tests, the term “broken link” is the point at which the communication link between the UAV and the GDT was lost when the return link transmitter signal strength was reduced. A video camera mounted on the UAV sent video streaming data of a waving red flag (shown in Figure 2-3) to the GDT operator station camera display video screen. As the link quality between the GDT and UAV degraded, the video from the UAV video camera would show increasing amounts of snow. When the communications link was broken, the display would freeze on the last frame received. Link breakage was immediately evident by the video freezing and the red flag appearing stationary on the operator station camera display video screen.

Another indicator of a broken link was the Signal Strength Indicator (SSI) on the GDT that gave a percentage of how strong the link was between the UAV and GDT. The datalink was considered broken when the SSI reading dropped to 0%. During the following receiver tests, losing the video feed and the SSI dropping to zero occurred at roughly the same time.

3.2.1 Receiver Sensitivity and Gain Compression

The return link receiver sensitivity and gain compression were determined by using the test configuration shown in Figure 3-3. The following test addressed sensitivity, received power versus SSI, and receiver gain compression.

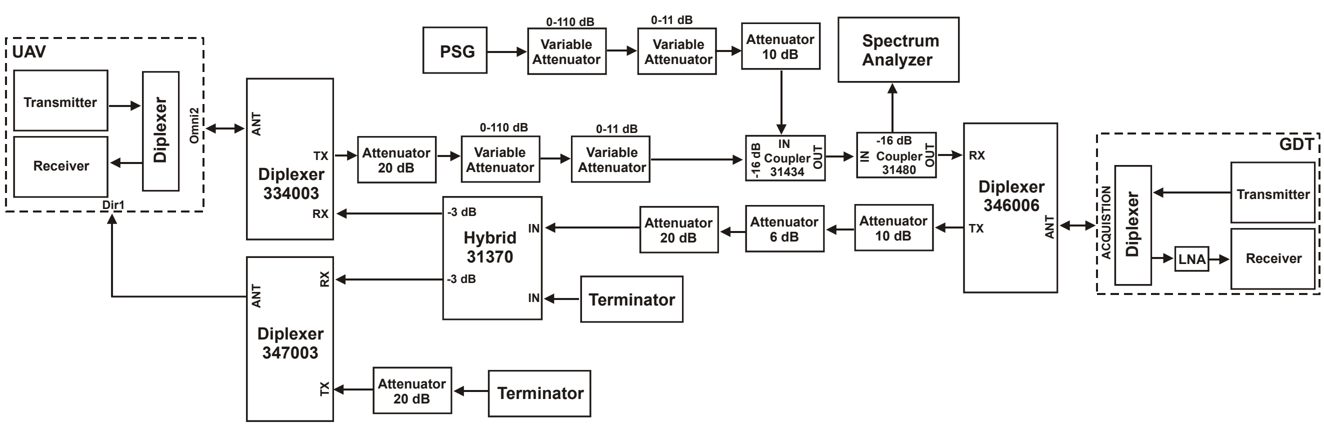

Figure 3-3. Return Link Sensitivity and Gain Compression Test Setup

Before completing the return link receiver sensitivity and gain compression tests, the total measurement system losses from the UAV to the GDT were measured (the return link variable attenuator was set to 0 dB and the command link variable attenuator was set to maximum) to provide calibration data. In addition, the total measurement system losses from the UAV to the spectrum analyzer were measured for calibration.

At the beginning of the return link receiver sensitivity test, a communications link was established between the receiver and the transmitter on a frequency of 5250 MHz, with the return link and command variable attenuators set to 0 dB. The GDT receiver sensitivity test was conducted for emissions 17M0F9F and 4M72F1D. The return link receiver sensitivity test was performed as follows:

1. The return link transmitter signal strength was stepped down by 1-dB increments until the link was broken.
2. The attenuation setting and the SSI at each setting were observed.
3. The attenuation setting and SSI for the largest attenuator setting where adequate link performance was observed, or the "last good link," were recorded.
4. The transmitter signal strength was stepped up by 1-dB increments until the link was re-established.
5. The attenuation setting and the SSI were then recorded.

The return receiver gain compression was then measured by stepping the attenuator setting down in 1-dB increments and recording the SSI indication at each step until decreases in the attenuation setting did not result in a change in the SSI indication.

These steps were repeated for each emission combination.

The command link receiver sensitivity was determined using the test configuration shown in Figure 3-4.

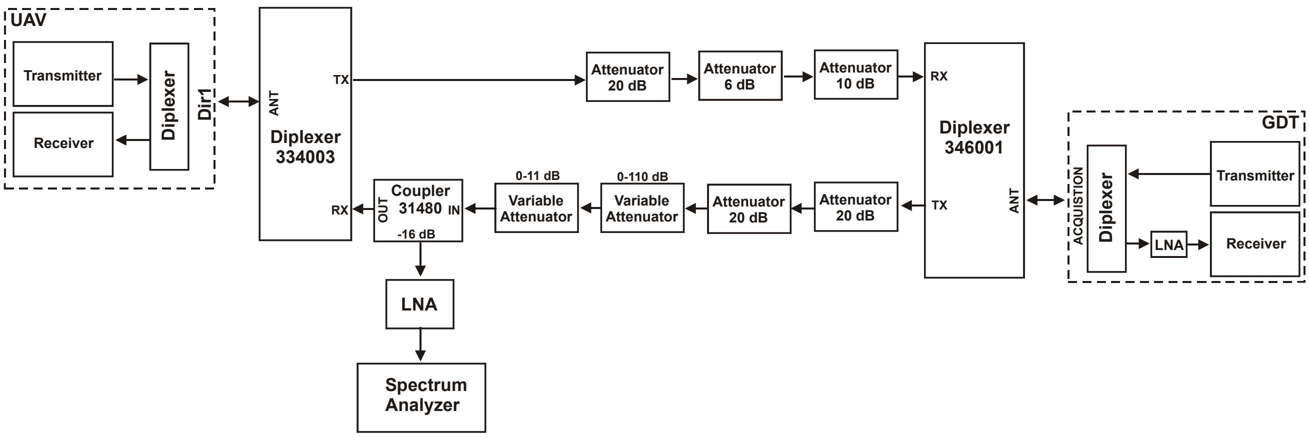

Figure 3-4. Command Link Receiver Sensitivity Setup

Before completing the command link receiver sensitivity tests, the total measurement system losses from the GDT to the UAV were measured (with the command link variable attenuator set to 0 dB and the return link variable attenuator set to maximum) to provide calibration data. In addition, the total measurement system losses from the UAV to the spectrum analyzer were measured for calibration.

After the losses were determined, a communications link was established between the receiver and the transmitter at 5625 MHz with the return link and command link variable attenuators set to 0 dB. The UAV receiver sensitivity tests were conducted for emissions 560KF1D and 88K3F1D. The following test steps are for the command link receiver sensitivity test:

1. The command link transmitter signal strength was stepped down by 1-dB increments until the link was broken.
2. The attenuation setting and the SSI at each setting were observed.
3. The attenuation setting and SSI for the last good link were recorded.
4. The transmitter signal strength was stepped up by 1-dB increments until the link was re-established.
5. The attenuation setting and the SSI were then recorded.

The return receiver gain compression was then measured by stepping the attenuator setting down in 1-dB increments and recording the SSI indicator at each step until decreases in the attenuator setting did not result in a change in the SSI indication.

These steps were repeated for each emission combination.

3.2.2 Receiver Selectivity

The return link receiver selectivity tests were conducted for emissions 17M0F9F and 4M72F1D. The return link receiver selectivity test setup is illustrated in Figure 3-5. The total measurement system losses from the PSG to the GDT and from the PSG to the spectrum analyzer were measured.

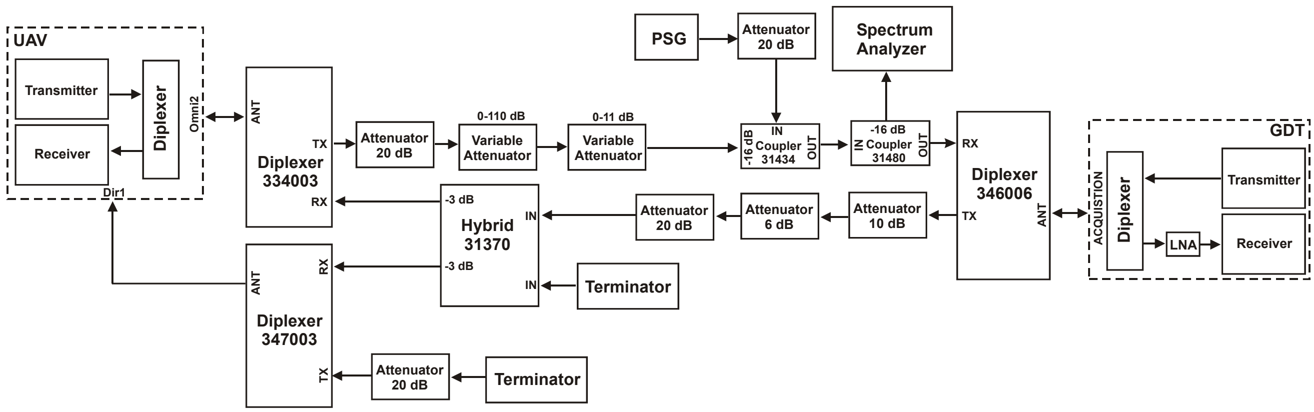

Figure 3-5. Return Link Receiver Selectivity Test Setup

Before the measurements were made, a communications link was established between the receiver and the transmitter with the return link and command link variable attenuators set to 0 dB using emission designator 17M0F9F. The GDT receiver selectivity tests were conducted for emissions 17M0F9F and 4M72F1D using the following steps:

1. The PSG was tuned to the return link center frequency.
2. The PSG variable attenuator was set to the maximum value.
3. The return link variable attenuator was increased in 1-dB increments until the link was broken.
4. The variable attenuator setting was noted.
5. The return link variable attenuator was decreased until the link was restored.
6. The return link variable attenuator was reduced 4 dB from when the link was broken. This raises the link power level to 3 dB above the minimal discernable signal (mds) [mds + 3dB].
7. The PSG variable attenuator was decreased by 1-dB steps until marginal performance was observed.
8. The PSG variable attenuator was increased until the link was restored.
9. The PSG variable attenuator setting was recorded.
10. The PSG frequency was increased 1 MHz.
11. Steps 7-10 were repeated until all data for the desired frequencies was obtained.

This established the selectivity curve for frequencies above the tuned frequency.

The command link receiver selectivity test was conducted for emissions 560KF1D and 88K3F1D. The test setup is illustrated in Figure 3-6.

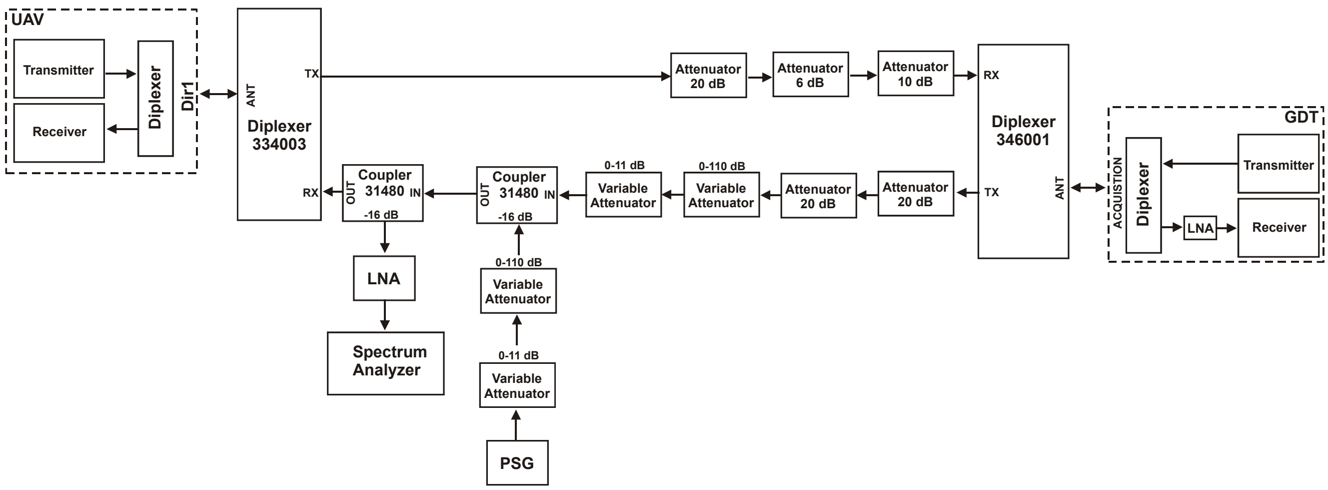

Figure 3-6. Command Link Receiver Selectivity Test Setup

The total measurement system losses from the PSG to the UAV and from the PSG to the spectrum analyzer were measured. The results of the receiver selectivity measurements were recorded. The procedures for the return link receiver selectivity test were repeated using 200-kHz step sizes for the command link.

3.2.3 Receiver Adjacent Signal Rejection

The return link and command link receiver adjacent signal rejection were determined using the test configuration shown in Figure 3-7.

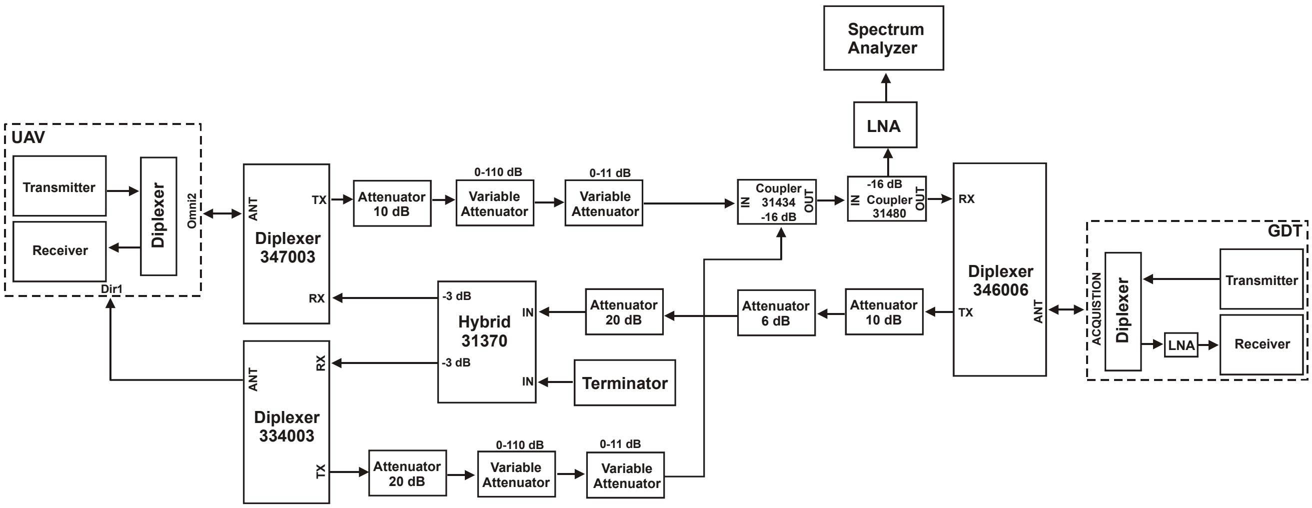

Figure 3-7. Test Setup for Receiver Adjacent Signal Rejection

For the return link, a communication link was established between the receiver and the desired transmitter. The desired signal transmitter was operated at 5300 MHz. The return link receiver adjacent signal rejection test included the following steps:

1. The input to the return link receiver was adjusted to MDS + 3 dB.
2. The interfering transmitter was started at 5265 MHz.
3. The interferer signal level was increased until the desired link was broken.
4. The interfering transmitter signal level at the spectrum analyzer was recorded.
5. The desired link was re-established by decreasing the power level of the interference source.
6. The interference source frequency was increased by 1 MHz.
7. Steps 3-6 were repeated until all data for desired frequencies was obtained.

For the frequency range of 5265 – 5335 MHz in 1-MHz steps, these steps were repeated using the four return link emission designator combinations listed in Table 3-2

Table 3-2. Return Link Adjacent Signal Rejection Test Parameters

Test	Desired Link Emission Designator	EMI Emission Designator
1	4M72F1D (DLOS Return Link)	4M72F1D (DLOS Return Link)
2	4M72F1D (DLOS Return Link)	17M0F9F (LOS Return Link)
3	17M0F9F (LOS Return Link)	17M0F9F (LOS Return Link)
4	17M0F9F (LOS Return Link)	4M72F1D (DLOS Return Link)

For the command link, a communication link was established between the receiver and the desired transmitter at 5700 MHz.

1. The input to the command link receiver was adjusted to MDS + 3 dB.
2. The interferer transmitter was started at 5697 MHz.
3. The interferer signal level was increased until the desired link was broken.
4. The interfering transmitter signal level at the spectrum analyzer was recorded.
5. The desired link was re-established by decreasing the power level of the interference.
6. The frequency of the interference was increased in by 200-kHz.
7. Steps 3-6 were repeated until all data for the desired frequencies was obtained.

For the frequency range of 5690 – 5710 MHz, these steps were repeated using the four command link emission designator combinations listed in Table 3-3

Table 3-3. Command Link Adjacent Signal Rejection Test Parameters

Test	Desired Link Emission Designator	EMI Emission Designator
1	560KF1D (LOS Command Link)	560KF1D (LOS Command Link)
2	560KF1D (LOS Command Link)	88K3F1D (DLOS Command Link)
3	88K3F1D (DLOS Command Link)	88K3F1D (DLOS Command Link)
4	88K3F1D (DLOS Command Link)	560KF1D (LOS Command Link)

SECTION – 4 TEST RESULTS

4.1 TRANSMITTER EMISSION SPECTRUM

Emission bandwidth measurements were performed for peak hold and average hold spectrum analyzer modes. The results of the transmitter emission spectrum measurements are shown in Tables 4-1 through 4-4. The return and command link spurious emission values are shown in Tables 4-5 and 4-6, respectively.

Table 4-1. Transmitter Emission Spectrum Results – High Power – Average Hold

Emission Type – Test Name	3 dB, kHz	20 dB, kHz	40 dB, kHz	60 dB, kHz
Command Link (GDT-to-UAV)				
560KF1D	275.0	358.3	483.3	1066.7
88K3F1D	233.3	441.7	841.7	1366.7
Return Link (UAV-to-GDT)				
17M0F9F	2000.0	5666.7	21000.0	33166.7
4M72F1D	166.7	14666.7	22500.0	35666.7

Table 4-2. Transmitter Emission Spectrum Results – High Power – Peak Hold

Emission Type – Test Name	3 dB, kHz	20 dB, kHz	40 dB, kHz	60 dB, kHz
Command Link (GDT-to-UAV)				
560KF1D	300.0	333.3	516.7	1050.0
88K3F1D	266.7	433.3	933.3	1450.0
Return Link (UAV-to-GDT)				
17M0F9F	2000.0	16000.0	21000.0	35000.0
4M72F1D	2000.0	8166.7	23000.0	46333.3

Table 4-3. Transmitter Emission Spectrum Results – Low Power – Average Hold

Emission Type – Test Name	3 dB, kHz	20 dB, kHz	40 dB, kHz	60 dB, kHz
Command Link (GDT-to-UAV)				
560KF1D	253.3	333.3	720.0	960.0
88K3F1D	226.7	440.0	973.3	1293.3
Return Link (UAV-to-GDT)				
17M0F9F	166.7	15000.0	15333.3	29833.3
4M72F1D	333.3	14666.7	28333.3	34666.7

Table 4-4. Transmitter Emission Spectrum Results – Low Power – Peak Hold

Emission Type – Test Name	3 dB, kHz	20 dB, kHz	40 dB, kHz	60 dB, kHz
Command Link (GDT-to-UAV)				
560KF1D	280.0	333.3	573.3	973.3
88K3F1D	260.0	466.7	873.3	1373.3
Return Link (UAV-to-GDT)				
17M0F9F	166.7	15000.0	15833.3	30666.7
4M72F1D	2000.0	14333.3	27500.0	34666.7

Table 4-5. Return Link Spurious Emission Values

Transmitter Tuned Frequency, MHz	Spurious Emission Frequency, MHz	Spurious Level 17M0 LOS, dBc	Spurious Level 4M72 DLOS, dBc
5250	5363	-73.7	-73.7
5475	5304	-89.7	
	5305	-85.2	
	5307	-86.0	
	5311	-89.9	
	5333	-91.0	

Table 4-6. Command Link Spurious Emission Values

Transmitter Tuned Frequency, MHz	Spurious Emission Frequency, MHz	Spurious Level 560K LOS, dBc	Spurious Level 88K3 DLOS, dBc
5625	5832	-98.3	-98.7
	5760	-98.2	-102.3
	5761	-98.2	
5850	5653		-110.5
	5669	-104.6	-108.1
	5672	-105.3	-105.7
	5685		-110.1
	5760	-100.0	
	5761	-101.5	
	5762		-105.7

4.2 RECEIVER SELECTIVITY TEST RESULTS

The results of the return link receiver selectivity tests are shown in Figure 4-1 and Table 4-7. The results of the command link receiver selectivity tests are shown in Figure 4-2, Tables 4-8 and 4-9.

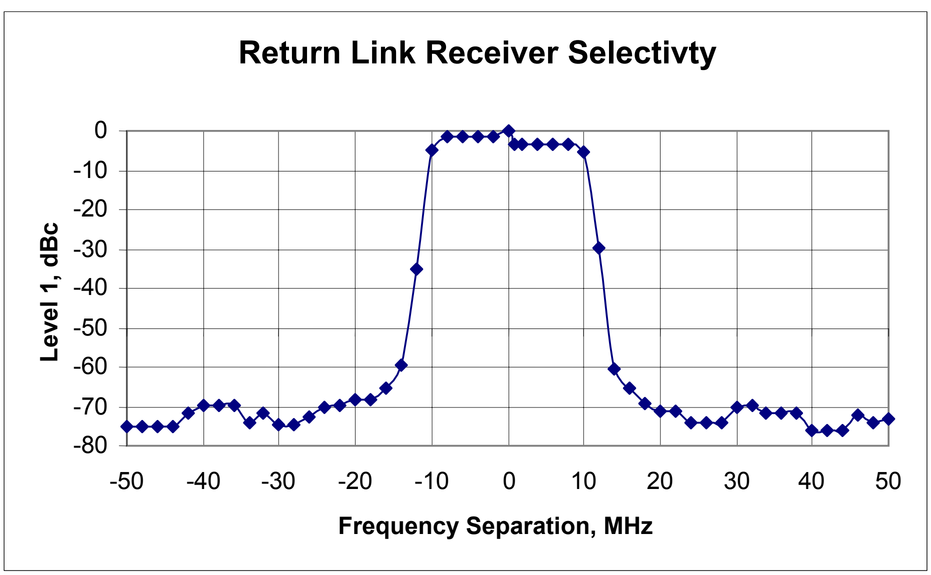

Figure 4-1. Return Link Receiver Selectivity Results

Table 4-7. Return Link Receiver Selectivity Test Results

Frequency Separation, MHz	Level 1, dBc
-50	-75
-48	-75
-46	-75
-44	-75
-42	-71.6
-40	-69.9
-38	-69.9
-36	-69.9
-34	-74
-32	-71.7
-30	-74.5
-28	-74.5
-26	-72.8
-24	-70.4
-22	-69.7
-20	-68.5
-18	-68.5
-16	-65.2
-14	-59.5
-12	-35.2
-10	-5.1
-8	-1.5
-6	-1.5
-4	-1.5
-2	-1.5
0	0
1	-3.4
2	-3.5
4	-3.5
6	-3.6
8	-3.6
10	-5.3
12	-29.7
14	-60.3
16	-65.3
18	-69.3
20	-71.4
22	-71.4
24	-74
26	-74
28	-74
30	-70
32	-69.8
34	-71.6
36	-71.6
38	-71.6
40	-76
42	-76
44	-76
46	-72
48	-74.1
50	-73

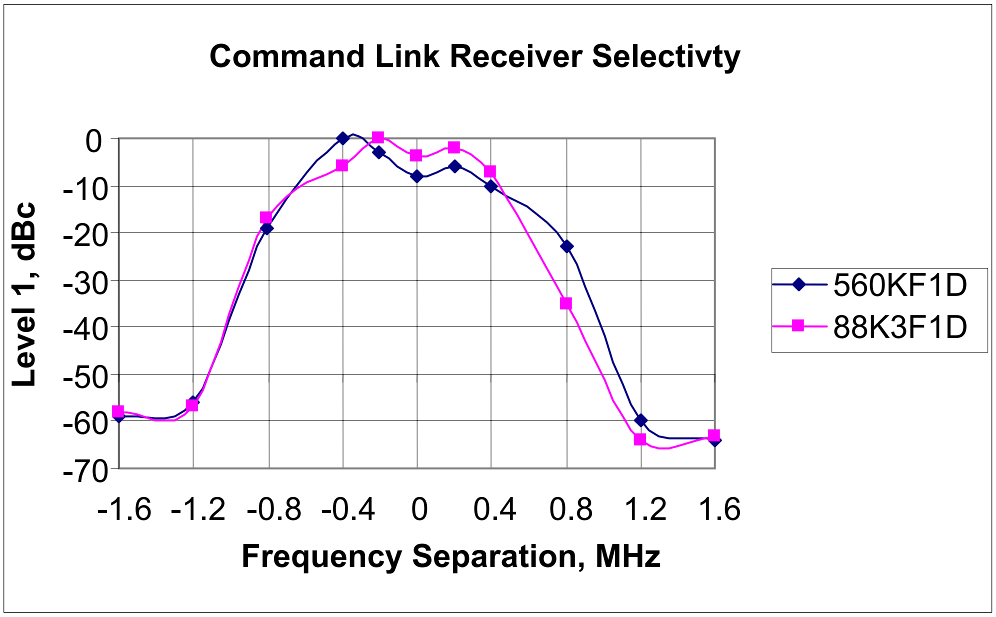

Figure 4-2. Command Link Receiver Selectivity Results

Table 4-8. Receiver Selectivity Test Results – 560KF1D LOS Command Link

Frequency Separation, MHz	Level 1, dBc
-1.6	-59
-1.2	-56
-0.8	-19
-0.4	0
-0.2	-3
0.0	-8
0.2	-6
0.4	-10
0.8	-23
1.2	-60
1.6	-64

Table 4-9. Receiver Selectivity Test Results – 88K3F1D DLOS Command Link

Frequency Separation, MHz	Level 1, dBc
-1.6	-58
-1.2	-57
-0.8	-17
-0.4	-6
-0.2	0
0.0	-4
0.2	-2
0.4	-7
0.8	-35
1.2	-64
1.6	-63

4.3 RECEIVER SENSITIVITY AND GAIN COMPRESSION

The results of the receiver sensitivity and gain compression return link tests are shown in Figure 4-3 and Table 4-10. The results of the return and command link receiver sensitivity and gain compression tests are shown in Tables 4-11 and 4-12, respectively. The results of the receiver sensitivity measurements are shown in Table 4-10.

Table 4-10. Receiver Sensitivity and Gain Compression Results

Emission Link Type	Receiver Sensitivity, dBm	Receiver Gain Compression, dBm
560KF1D LOS Command	-105.4	-34.4
88K3F1D DLOS Command	-101.4	
17M0F9F LOS Return	-88.3	-28.3
4M72F1D DLOS Return	-84.3	

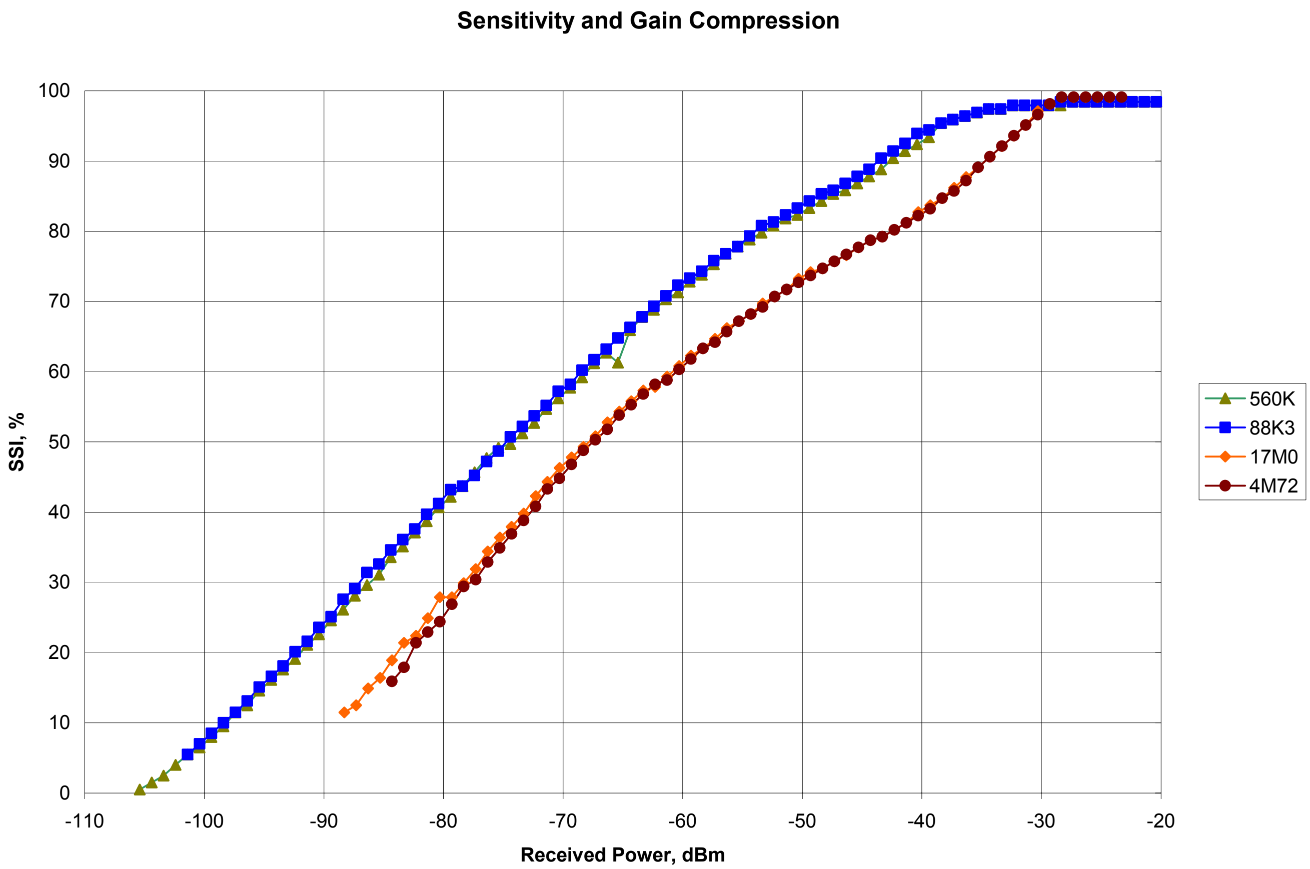

Figure 4-3. Sensitivity and Gain Compression

Table 4-11. Return Link Receiver Sensitivity and Gain Compression Test Results

Received Power, dBm	SSI % 4M72F1D DLOS	SSI % 17M0F9F LOS
-23.3	99.1	
-24.3	99.1	99.1
-25.3	99.1	99.1
-26.3	99.1	99.1
-27.3	99.1	99.1
-28.3	99.1	99.1
-29.3	98.1	98.1
-30.3	96.6	97.1
-31.3	95.1	95.1
-32.3	93.6	93.6
-33.3	92.1	92.1
-34.3	90.6	90.6
-35.3	89.1	89.1
-36.3	87.2	87.7
-37.3	85.7	86.2
-38.3	84.7	84.7
-39.3	83.2	83.7
-40.3	82.2	82.7
-41.3	81.2	81.2
-42.3	80.2	80.2
-43.3	79.2	79.2
-44.3	78.7	78.7
-45.3	77.7	77.7
-46.3	76.7	76.6
-47.3	75.7	75.7
-48.3	74.7	74.7
-49.3	73.7	74.2
-50.3	72.7	73.2
-51.3	71.7	71.7
-52.3	70.7	70.7
-53.3	69.2	69.7
-54.3	68.2	68.2
-55.3	67.2	67.2
-56.3	65.7	66.2
-57.3	64.2	64.7
-58.3	63.3	63.3
-59.3	61.8	62.3
-60.3	60.3	60.8
-61.3	58.8	59.3
-62.3	58.2	57.8
-63.3	56.8	57.3
-64.3	55.3	55.8
-65.3	53.8	54.3
-66.3	51.8	52.8

Table 4-11. Return Link Receiver Sensitivity and Gain Compression Test Results (continued)

Received Power, dBm	SSI % 4M72F1D DLOS	SSI % 17M0F9F LOS
-67.3	50.3	50.8
-68.3	48.8	49.3
-69.3	46.8	47.8
-70.3	44.8	46.3
-71.3	43.3	44.3
-72.3	40.8	42.3
-73.3	38.8	39.8
-74.3	36.9	37.9
-75.3	34.9	36.4
-76.3	32.9	34.4
-77.3	30.4	31.9
-78.3	29.4	29.9
-79.3	26.9	27.9
-80.3	24.4	27.9
-81.3	22.9	24.9
-82.3	21.4	22.4
-83.3	17.9	21.4
-84.3	15.9	18.9
-85.3	No Link	16.4
-86.3		14.9
-87.3		12.5
-88.3		11.5

Table 4-12. Command Link Receiver Sensitivity and Gain Compression Test Results

Received Power, dBm	SSI % 560KF1D LOS	SSI % 88K3F1D DLOS
-20.4	98.4	98.4
-21.4	98.4	98.4
-22.4	98.4	98.4
-23.4	98.4	98.4
-24.4	98.4	98.4
-25.4	98.4	98.4
-26.4	98.4	98.4
-27.4	98.4	98.4
-28.4	97.9	98.4
-29.4	97.9	97.9
-30.4	97.9	97.9
-31.4	97.9	97.9
-32.4	97.9	97.9
-33.4	97.4	97.4
-34.4	97.4	97.4
-35.4	96.9	96.9
-36.4	96.4	96.4
-37.4	95.9	95.9
-38.4	95.4	95.4
-39.4	93.4	94.4
-40.4	92.4	93.9
-41.4	91.4	92.5
-42.4	90.4	91.4
-43.4	88.8	90.4
-44.4	87.8	88.8
-45.4	86.8	87.8
-46.4	85.8	86.8
-47.4	85.3	85.8
-48.4	84.3	85.3
-49.4	83.3	84.3
-50.4	82.3	83.3
-51.4	81.8	82.3
-52.4	80.8	81.3
-53.4	79.8	80.8
-54.4	78.8	79.3
-55.4	77.8	77.8
-56.4	76.8	76.8
-57.4	75.3	75.8
-58.4	73.8	74.3
-59.4	72.8	73.3
-60.4	71.3	72.3
-61.4	70.3	70.8
-62.4	68.8	69.3
-63.4	67.8	67.8
-64.4	65.9	66.3

Table 4-12. Command Link Receiver Sensitivity and Gain Compression Test Results (continued)

Received Power, dBm	SSI % 560KF1D LOS	SSI % 88K3F1D DLOS
-65.4	61.3	64.8
-66.4	62.7	63.2
-67.4	61.2	61.7
-68.4	59.2	60.2
-69.4	57.7	58.2
-70.4	56.2	57.2
-71.4	54.7	55.2
-72.4	52.7	53.7
-73.4	51.2	52.2
-74.4	49.7	50.7
-75.4	49.2	48.7
-76.4	47.7	47.2
-77.4	45.7	45.2
-78.4	43.7	43.7
-79.4	42.2	43.2
-80.4	40.7	41.2
-81.4	38.7	39.7
-82.4	37.1	37.6
-83.4	35.1	36.1
-84.4	33.6	34.6
-85.4	31.1	32.6
-86.4	29.6	31.4
-87.4	28.1	29.1
-88.4	26.1	27.6
-89.4	24.6	25.1
-90.4	22.6	23.6
-91.4	21.1	21.6
-92.4	19.1	20.1
-93.4	17.6	18.1
-94.4	16.1	16.6
-95.4	14.6	15.1
-96.4	12.5	13.1
-97.4	11.5	11.5
-98.4	9.5	10
-99.4	8	8.5
-100.4	6.5	7
-101.4	5.5	5.5
-102.4	4	
-103.4	2.5	
-104.4	1.5	
-105.4	0.5	

4.4 RECEIVER ADJACENT SIGNAL REJECTION

The results of the receiver adjacent signal rejection tests are shown in Figures 4-4 and 4-5 and Tables 4-13 and 4-14.

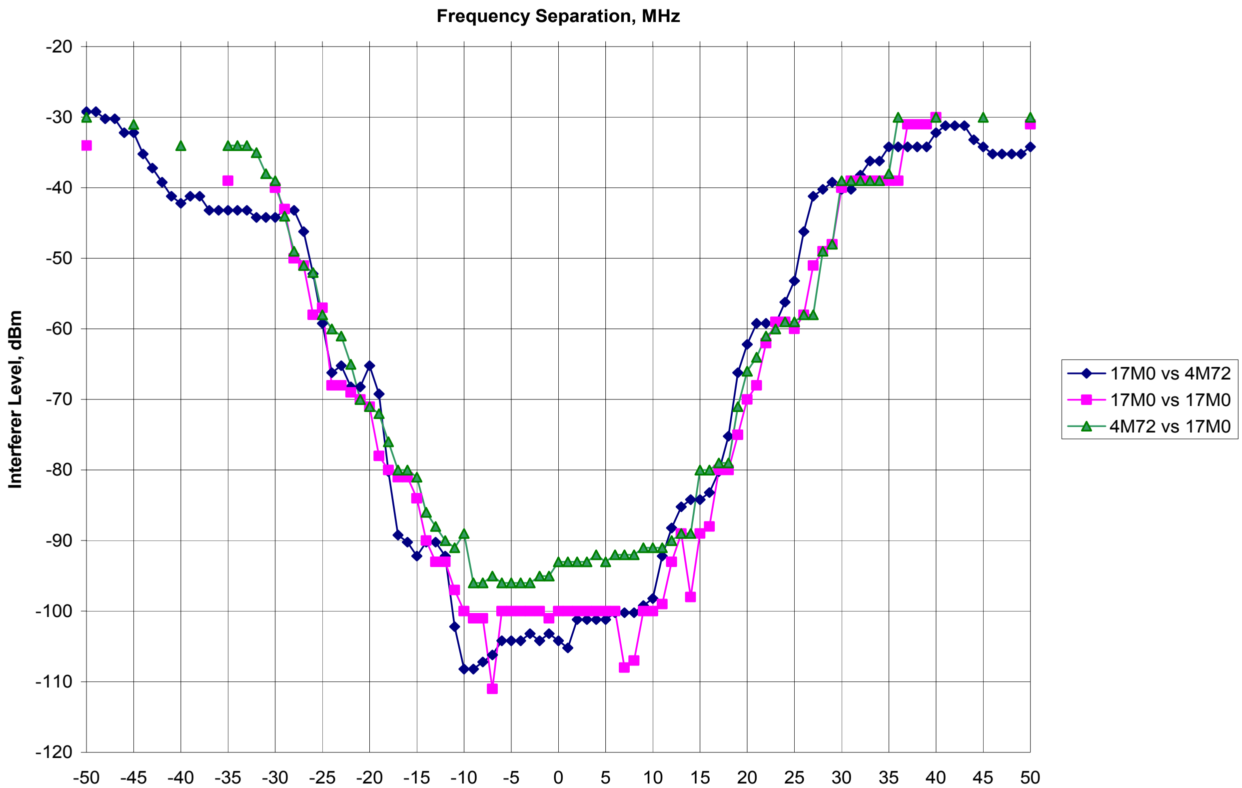

Figure 4-4. Return Link Adjacent Signal Rejection

Table 4-13. Return Link Adjacent Signal Rejection

Frequency Separation, MHz	Received Interference Power, dBm		
	4M72 to 17M0	17M0 to 4M72	17M0 to 17M0
-50	-30.0	-25.8	-34.0
-49		-25.8	
-48		-26.8	
-47		-26.8	
-46		-28.8	
-45	-31.0	-28.8	
-44		-31.8	
-43		-33.8	
-42		-35.8	
-41		-37.8	
-40	-34.0	-38.8	
-39		-37.8	
-38		-37.8	
-37		-39.8	
-36		-39.8	
-35	-34.0	-39.8	-39.0
-34	-34.0	-39.8	
-33	-34.0	-39.8	
-32	-35.0	-40.8	
-31	-38.0	-40.8	
-30	-39.0	-40.8	-40.0
-29	-44.0	-39.8	-43.0
-28	-49.0	-39.8	-50.0
-27	-51.0	-42.8	-51.0
-26	-52.0	-48.8	-58.0
-25	-58.0	-55.8	-57.0
-24	-60.0	-62.8	-68.0
-23	-61.0	-61.8	-68.0
-22	-65.0	-64.8	-69.0
-21	-70.0	-64.8	-70.0
-20	-71.0	-61.8	-71.0
-19	-72.0	-65.8	-78.0
-18	-76.0	-76.8	-80.0
-17	-80.0	-85.8	-81.0
-16	-80.0	-86.8	-81.0
-15	-81.0	-88.8	-84.0
-14	-86.0	-86.8	-90.0
-13	-88.0	-86.8	-93.0
-12	-90.0	-88.8	-93.0
-11	-91.0	-98.8	-97.0
-10	-89.0	-104.8	-100.0
-9	-96.0	-104.8	-101.0
-8	-96.0	-103.8	-101.0
-7	-95.0	-102.8	-111.0
-6	-96.0	-100.8	-100.0

Table 4-13. Return Link Adjacent Signal Rejection (continued)

Frequency Separation, MHz	Received Interference Power, dBm		
	4M72 to 17M0	17M0 to 4M72	17M0 to 17M0
-5	-96.0	-100.8	-100.0
-4	-96.0	-100.8	-100.0
-3	-96.0	-99.8	-100.0
-2	-95.0	-100.8	-100.0
-1	-95.0	-99.8	-101.0
0	-93.0	-100.8	-100.0
1	-93.0	-101.8	-100.0
2	-93.0	-97.8	-100.0
3	-93.0	-97.8	-100.0
4	-92.0	-97.8	-100.0
5	-93.0	-97.8	-100.0
6	-92.0	-96.8	-100.0
7	-92.0	-96.8	-108.0
8	-92.0	-96.8	-107.0
9	-91.0	-95.8	-100.0
10	-91.0	-94.8	-100.0
11	-91.0	-88.8	-99.0
12	-90.0	-84.8	-93.0
13	-89.0	-81.8	-89.0
14	-89.0	-80.8	-98.0
15	-80.0	-80.8	-89.0
16	-80.0	-79.8	-88.0
17	-79.0	-76.8	-80.0
18	-79.0	-71.8	-80.0
19	-71.0	-62.8	-75.0
20	-66.0	-58.8	-70.0
21	-64.0	-55.8	-68.0
22	-61.0	-55.8	-62.0
23	-60.0	-55.8	-59.0
24	-59.0	-52.8	-59.0
25	-59.0	-49.8	-60.0
26	-58.0	-42.8	-58.0
27	-58.0	-37.8	-51.0
28	-49.0	-36.8	-49.0
29	-48.0	-35.8	-48.0
30	-39.0	-36.8	-40.0
31	-39.0	-36.8	-39.0
32	-39.0	-34.8	-39.0
33	-39.0	-32.8	-39.0
34	-39.0	-32.8	-39.0
35	-38.0	-30.8	-39.0
36	-30.0	-30.8	-39.0
37		-30.8	-31.0

Table 4-13. Return Link Adjacent Signal Rejection (continued)

Frequency Separation, MHz	Received Interference Power, dBm		
	4M72 to 17M0	17M0 to 4M72	17M0 to 17M0
38		-30.8	-31.0
39		-30.8	-31.0
40	-30.0	-28.8	-30.0
41		-27.8	
42		-27.8	
43		-27.8	
44		-29.8	
45	-30.0	-30.8	
46		-31.8	
47		-31.8	
48		-31.8	
49		-31.8	
50	-30.0	-30.8	-31.0

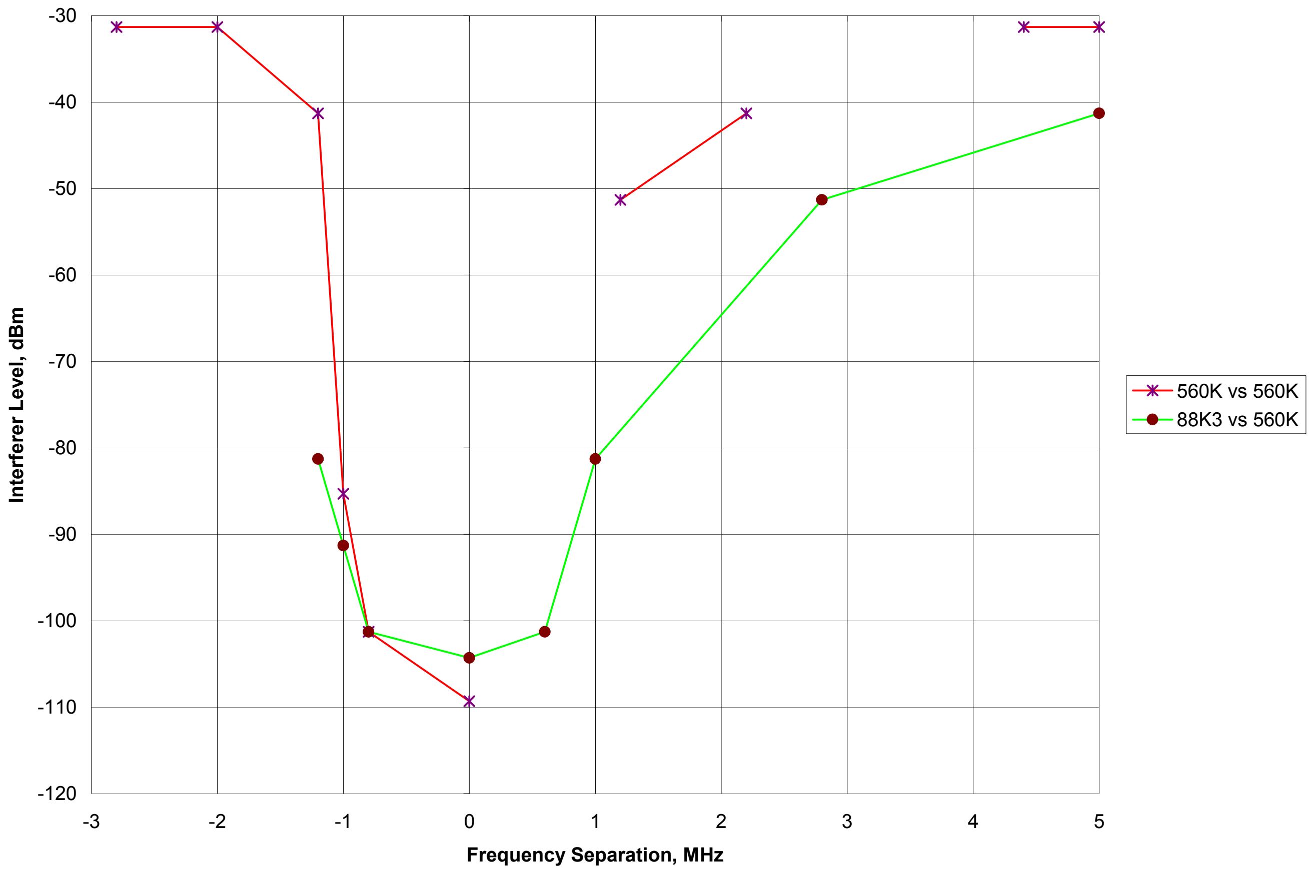

Figure 4-5. Command Link Adjacent Signal Rejection

Table 4-14. Command Link Adjacent Signal Rejection

Frequency Separation, MHz	SSI % 560K to 560K	SSI % 88K3 to 560K
-2.8	-31.3	
-2.0	-31.3	
-1.2	-41.3	-81.3
-1.0	-85.3	-91.3
-0.8	-101.3	-101.3
0.0	-109.3	-104.3
0.6		-101.3
1.0		-81.3
1.2	-51.3	
2.2	-41.3	
2.8		-51.3
4.4	-31.3	
5.0	-31.3	-41.3

Table 4-15. Diplexer Sweep Calibration Test Results

Serial Number – Diplexer Ports	-60 dB, MHz	-40 dB, MHz	-20 dB, MHz	-3 dB, MHz	-3 dB, MHz	-20 dB, MHz	-40 dB, MHz	-60 dB, MHz
GDT Diplexers								
SN 334003 – Tx to Antenna	5040.0	5101.3	5160.0	5202.7	5504.0	5549.3	5600.0	5640.0
SN 347003 – Tx to Antenna	4978.7	5101.3	5101.3	5213.3	5510.7	5545.3	5582.7	5690.7
SN 334003 – Antenna to Rx	5537.0	5571.0	5592.0	5609.0	5918.0	5937.0	5966.0	6025.0
SN 347003 – Antenna to Rx	5512.0	5554.0	5581.0	5601.0	5907.0	5923.0	5950.0	6009.0
UAV Diplexers								
SN 346006 – Tx to Antenna	5118.7	5174.7	5200.0	5214.7	5506.7	5526.7	5552.0	5585.3
SN 346001 – Tx to Antenna	5120.0	5173.3	5200.0	5221.3	5509.3	5526.7	5552.0	5592.0
SN 346006 – Antenna to Rx	5408.0	5526.7	5564.0	5596.0	5909.3	5949.3	6006.7	6117.3
SN 346001 – Antenna to Rx	5413.3	5536.0	5565.3	5596.0	5906.7	5948.0	6009.3	6136.0
Tx – Transmitter Rx – Receiver								

APPENDIX A – SPECTRUM ANALYZER SCREEN CAPTURES

The emission bandwidth measurement examples shown are a pictorial representation of the emission bandwidth numbers identified in Tables 4-1 through 4-4. Emission bandwidth measurement results for the four emission modes are shown in Figures A-1 through A-4.

Diplexer frequency response was measured for two GDT diplexers and two UAV diplexers. The results, shown in Figures A-5 through A-8, are a pictorial representation of the data listed in Table 4-15.

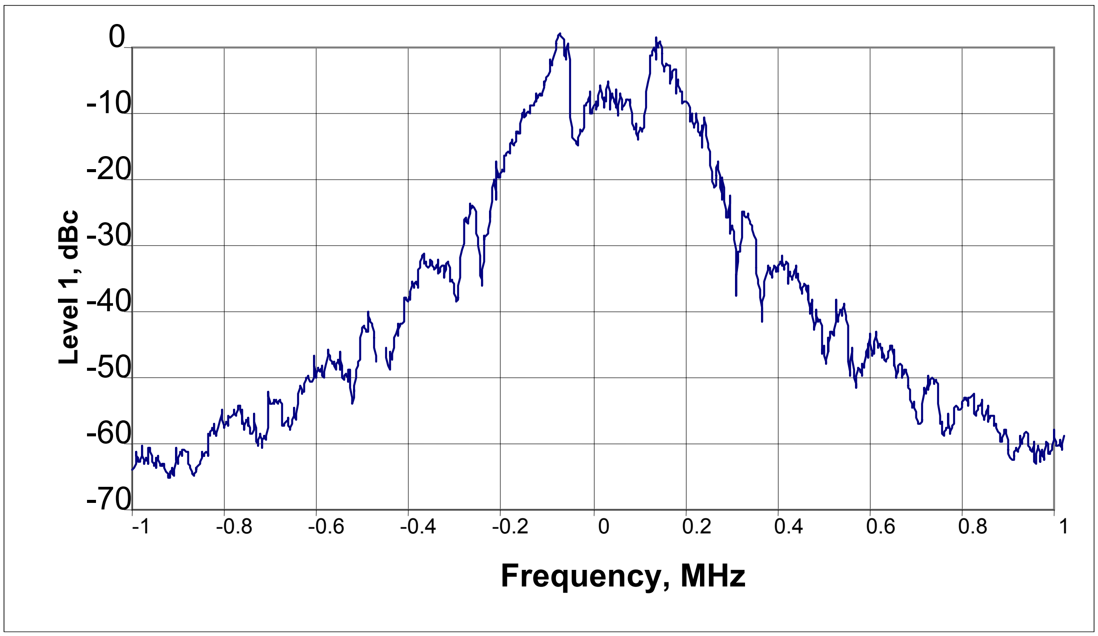

Figure A-1. 88K3F1D DLOS Command Link Emission Spectrum - High Power

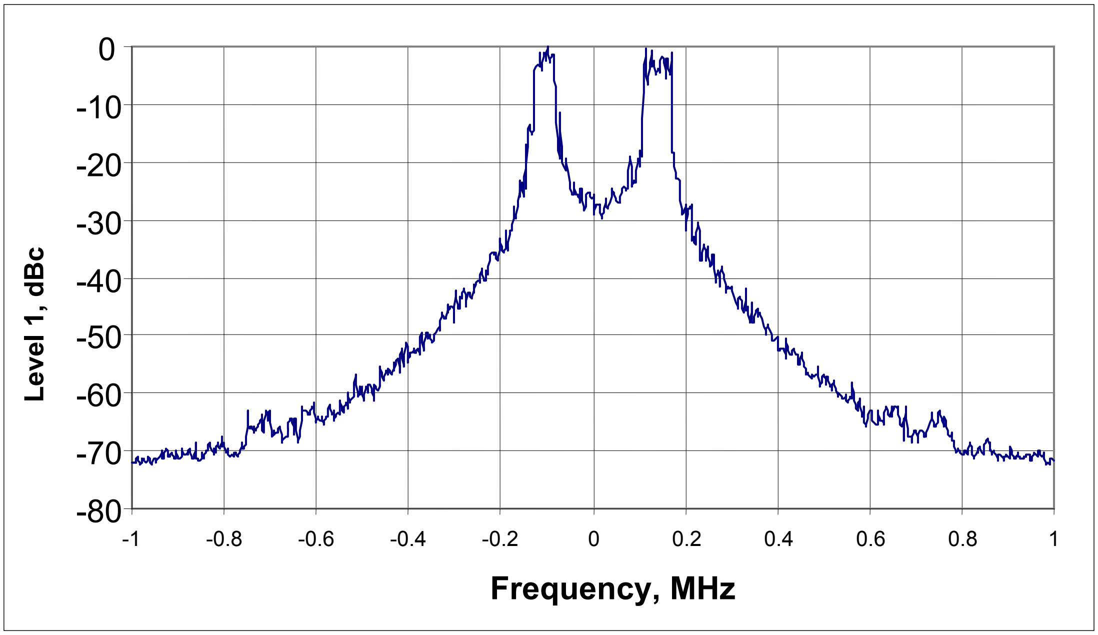

Figure A-2. 560KF1D LOS Command Link Emission Spectrum - Low Power

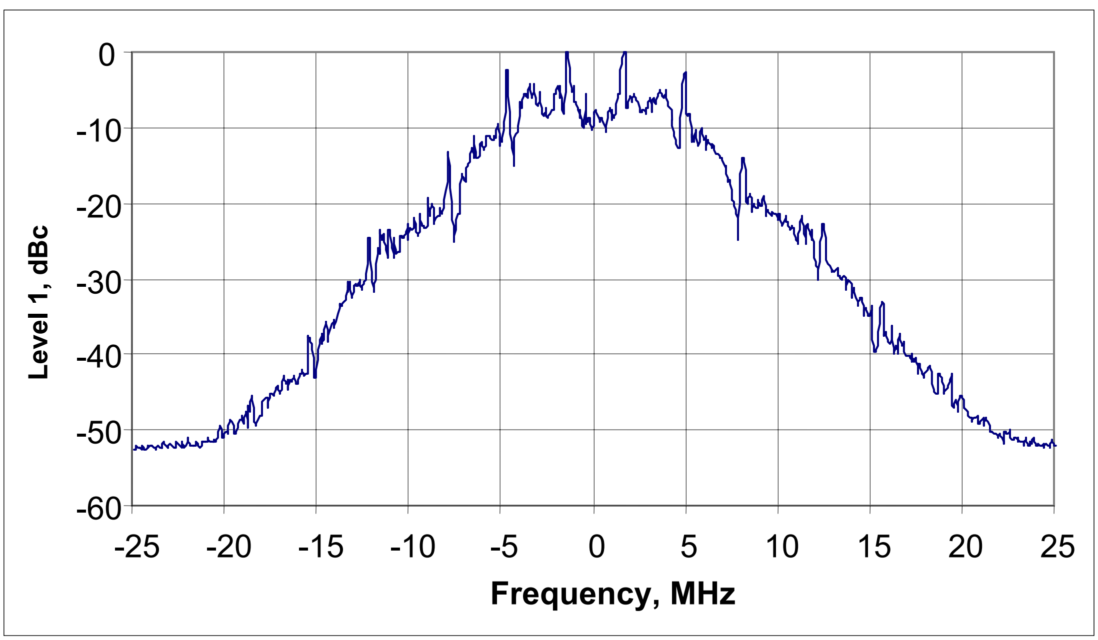

Figure A-3. 4M72F1D DLOS Return Link Emission Spectrum - High Power

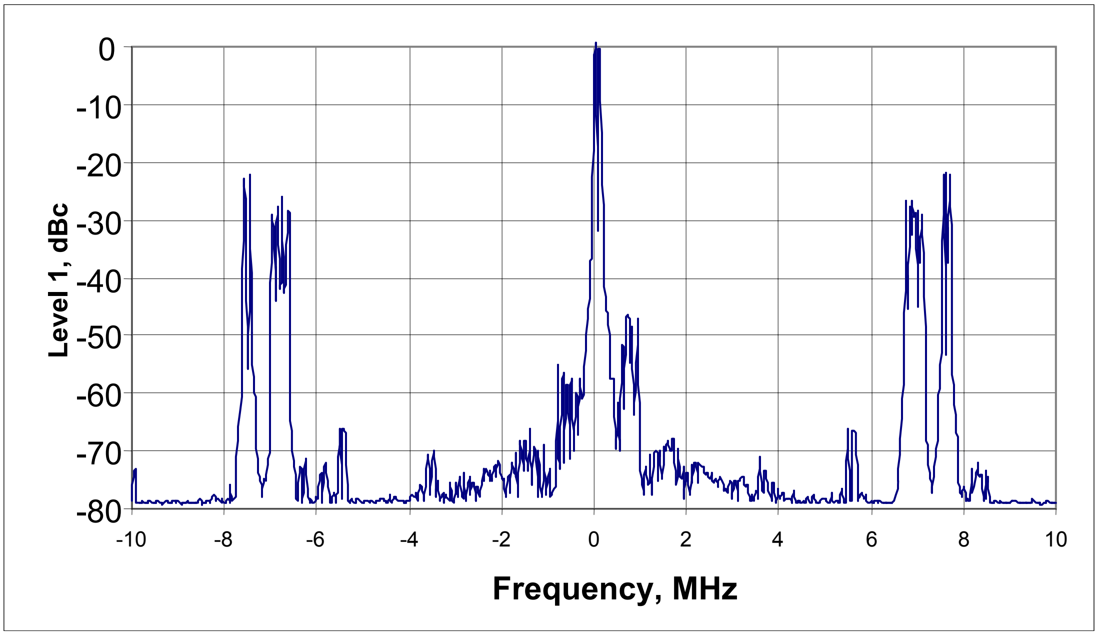

Figure A-4. 17M0F9F LOS Return Link Emission Spectrum - Low Power

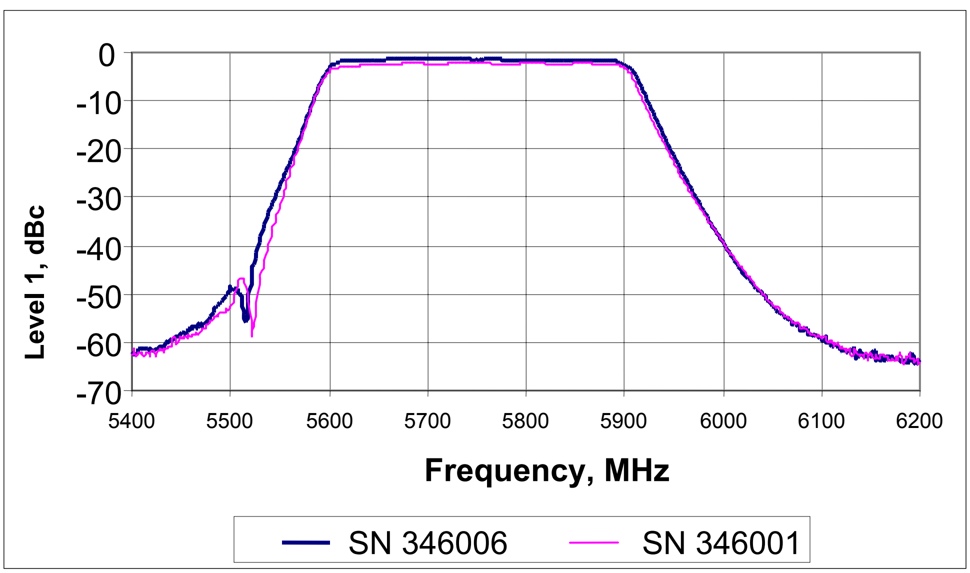

Figure A-5. UAV Diplexer Receiver-to-Antenna Ports

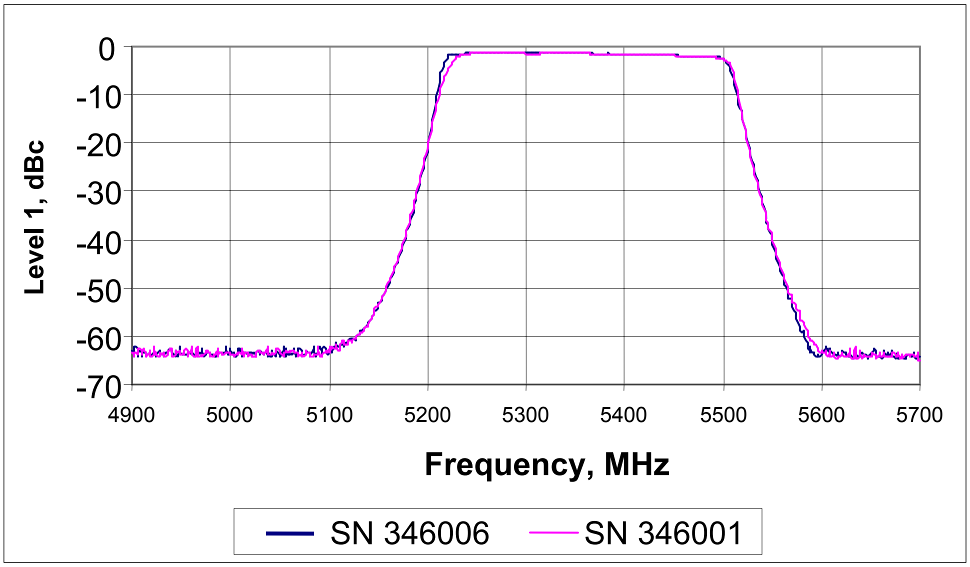

Figure A-6. UAV Diplexer Transmitter-to-Antenna Ports

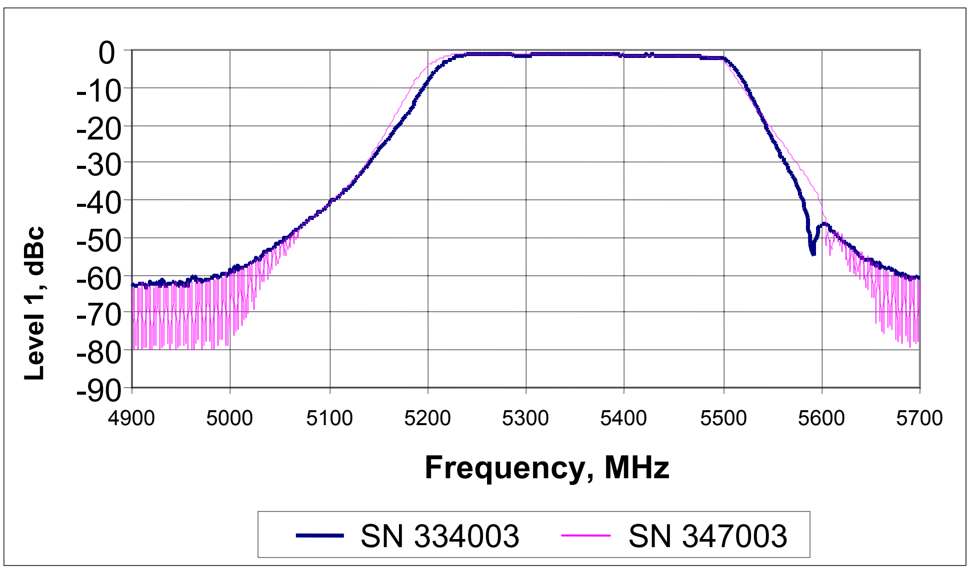

Figure A-7. GDT Diplexer Antenna-to-Receiver Ports

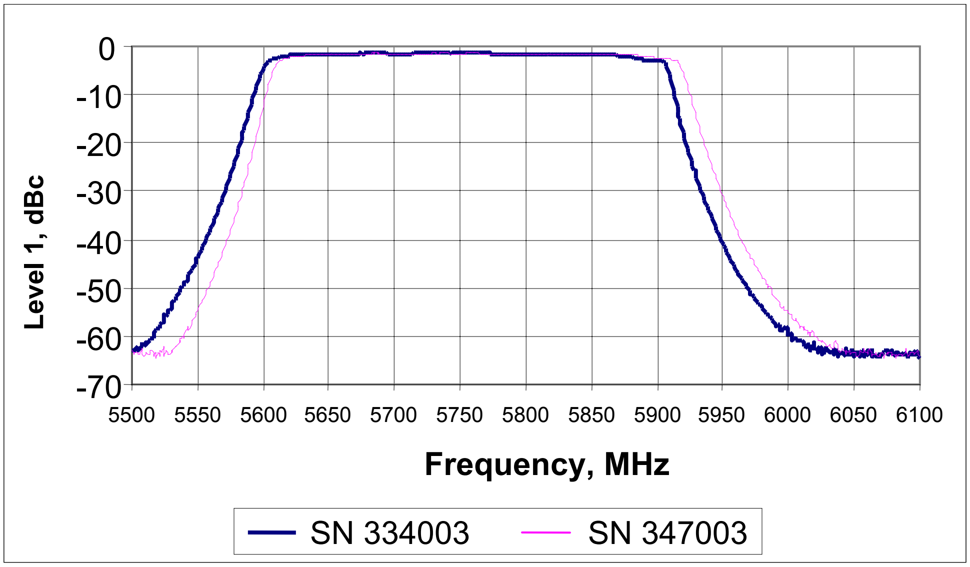

Figure A-8. GDT Diplexer Transmitter-to-Antenna Ports

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