NAVAIR Public Release 2014-532
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Telemetry Receive/Record & Re-Radiation Pod

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ABSTRACT

This paper discusses the mission needs, design/development, and testing of the (L, S & C Band) Telemetry Receive/Record & Re-Radiation pod.

KEYWORDS

(AVMI) Air Vehicle Modification & Instrumentation, Naval Air Warfare Center Aircraft Division (NAWCAD), Naval Air Warfare Center Weapons Division (NAWCWD), Concept of Operations (CONOPS), "Shooter" aircraft (launches weapon), "Chase" aircraft (carries TM Receive/Record & Re-Radiation Pod), Pulse Coded Modulation (PCM).

INTRODUCTION

Weapon separation testing presents unique challenges when attempting to obtain decision quality data from the weapon under test. The telemetry system on the weapon is typically low power (less than 2 watts) and flight testing is conducted off shore for safety reasons. Many of the flight tests are at low altitudes and outside the range of the ground station. Flight test scenarios are becoming increasingly complex, with multiple PCM data streams from the weapon (inside & outside) the weapons bay, and additional PCM streams from the "Shooter" aircraft. A combined effort with the Naval Air Warfare Center's Aircraft Division (Patuxent River, MD) and Weapons Division (Pt. Mugu CA) developed a Telemetry Receive/Record & Re-Radiation pod to be carried on a chase aircraft. Due to the ever changing telemetry spectrum allocations, the pod must have the flexibility to work in the L, S, & C bands.

HIGH LEVEL REQUIREMENTS

- Receive (4) PCM data streams (configurable in L, S, & C band)
- Record (4) PCM data streams in the IRIG-106 CH-10 format
- Re-Transmit (4) PCM data streams (configurable in L,S, & C band)
- Pod carried on an F/A-18 A-F (port or starboard weapon stations)
- No modifications to the host aircraft permitted

- Support chase aircraft Concept of Operations (CONOPS) for weapons separation flight testing

TYPICAL WEAPONS SEPERATION CONCEPT OF OPERATIONS

A typical weapon separation flight test includes a minimum of two aircraft. Aircraft #1 is the "Shooter"; this aircraft launches the weapon under test (e.g. missile, bomb etc.) The weapon is modified to include a telemetry system that contains weapon specific data. The shooter aircraft also has several telemetry streams containing aircraft specific data. Aircraft #2 is the chase aircraft. The chase aircraft carries the Telemetry Receive/Record & Re-Radiation Pod, and serves as a safety observer, capturing video of the weapon separation event. Refer to figures 1, 2 & 3 for concept of operations diagrams.

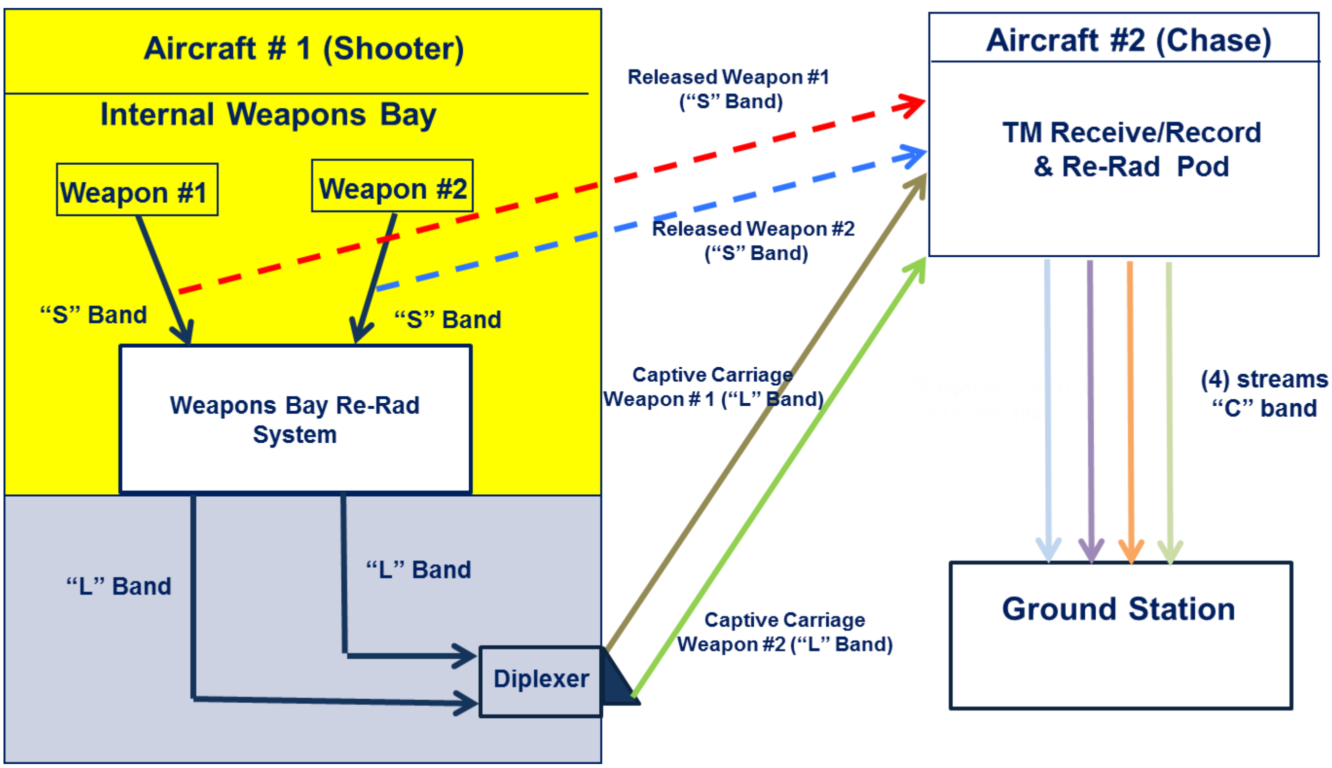

Figure 1.0 Internal Weapons Bay Concept

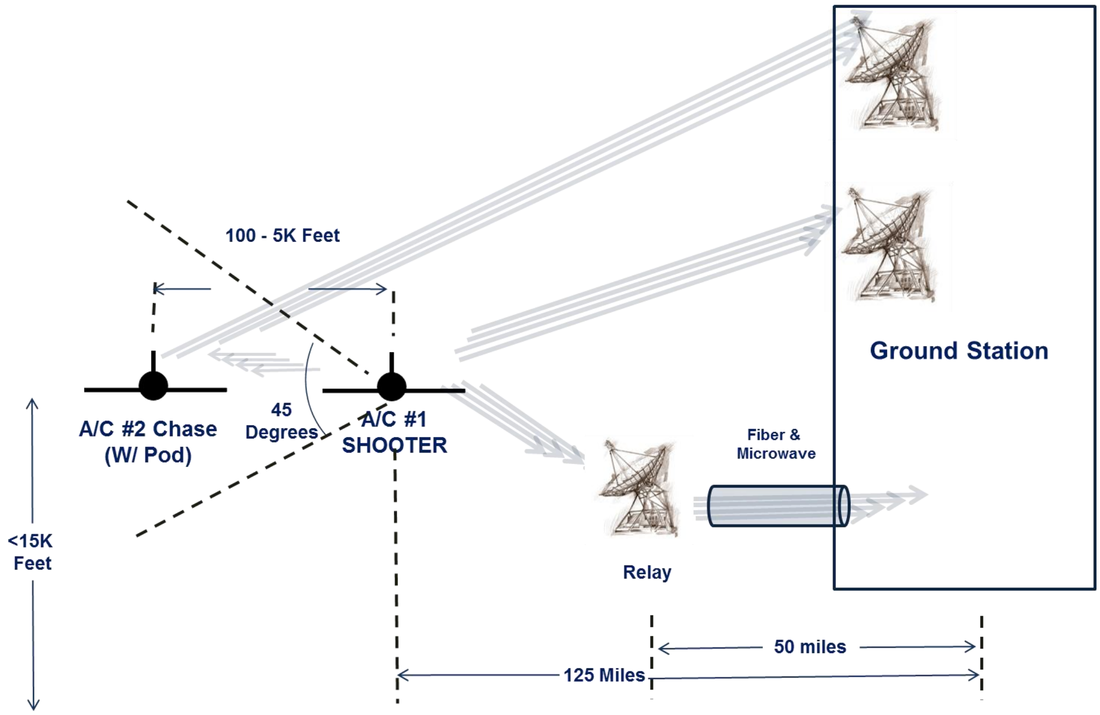

Figure 2.0 Nose on View

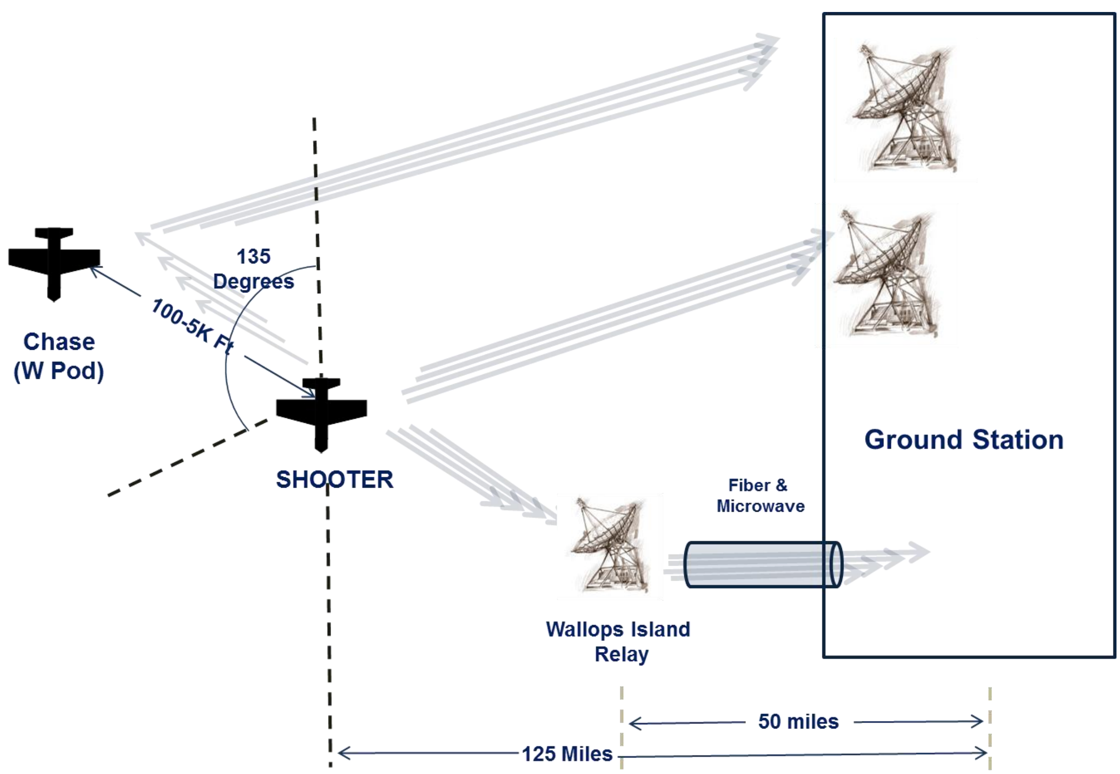

Figure 3.0 Top View

SYSTEM DESCRIPTION

The Telemetry Receive/Record & Re-Radiation pod consists of custom receive and transmit antennas, four receivers, four transmitters, IRIG-106 CH-10 recorder, and GPS time synchronization. The pod is capable of receiving/recording and re-transmitting four PCM streams in the L, S, & C bands. Refer to figure 4.0 for the system block diagram.

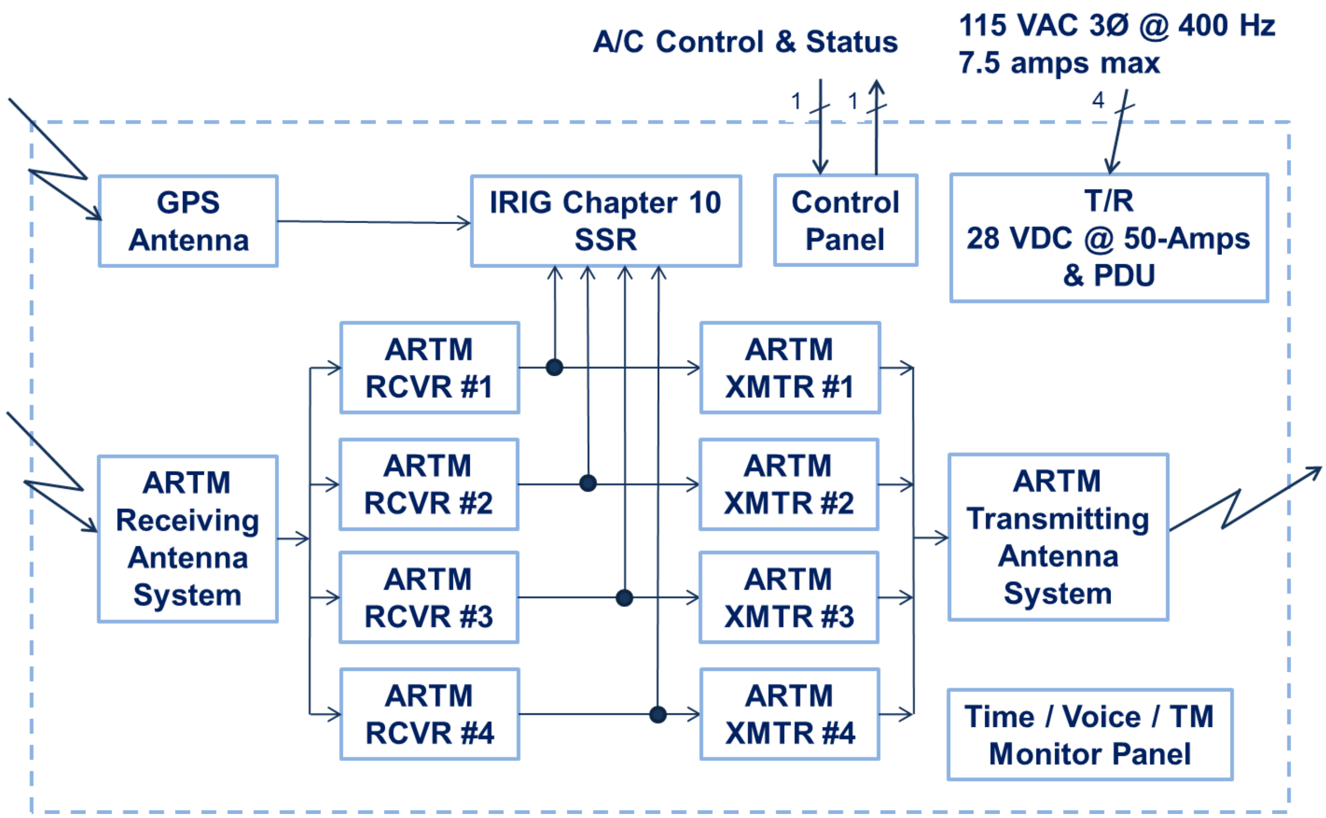

Figure 4.0 System Block Diagram

Receive Subsystem:

The receive system consists of configurable port & starboard receive antennas, multiplexers, amplifiers, splitters, and receivers (ARTM Tier 0, 1, &2) capable of operating in the following frequency ranges:

1435-1535 MHz (Lower L Band)

1750-1855 MHz (Upper L Band)

2200-2395 MHz (S Band)

4400-5250 MHz (C Band)

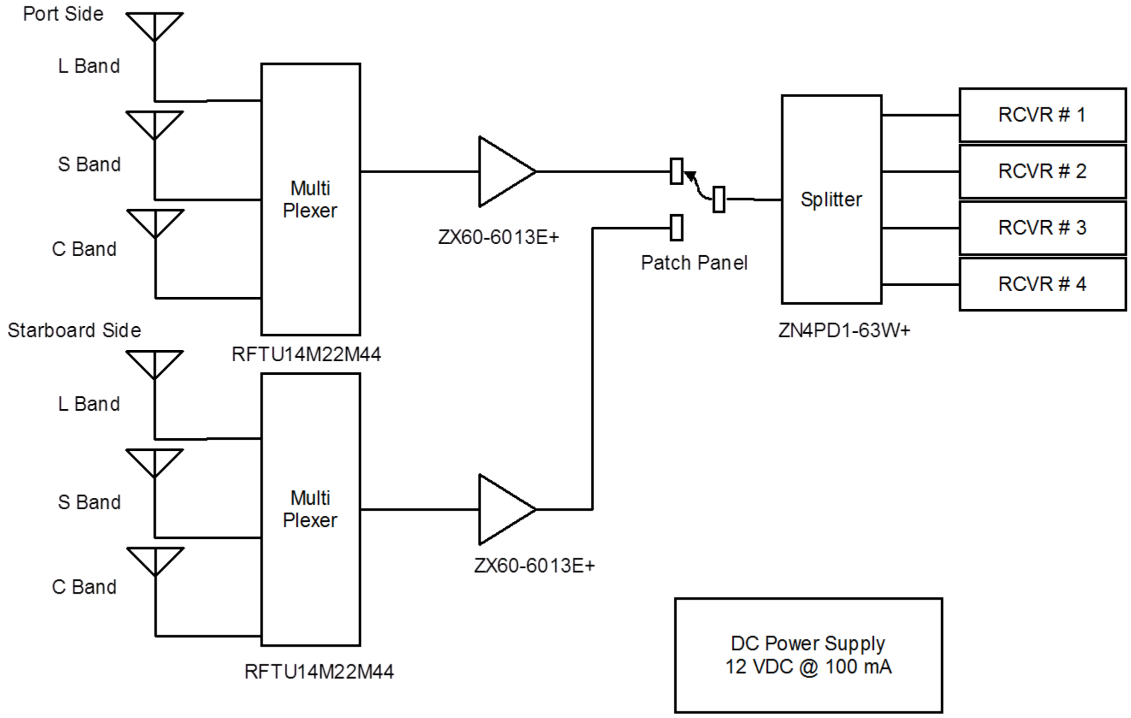

Figure 5.0 Receive Subsystem

The receive antennas are custom tri-element patch antennas configurable for each mission, refer to figure 6.0.

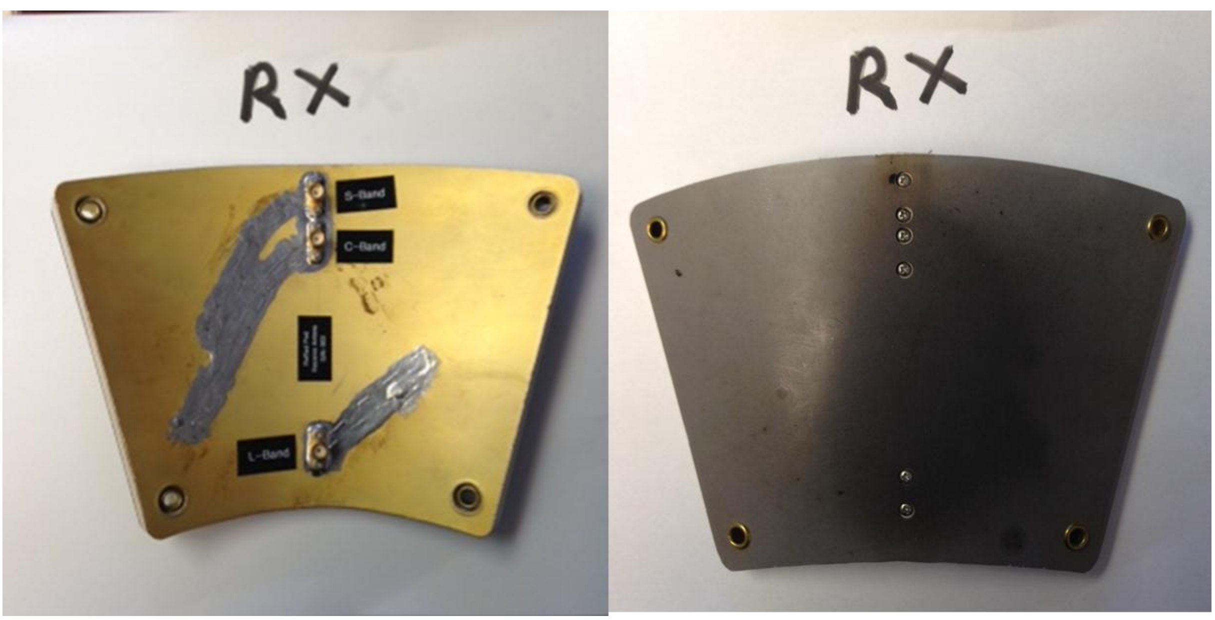

Figure 6.0 Receive Antennas

Transmitter Subsystem:

The transmitter system consists of four transmit antennas, isolators, multiplexers, and transmitters (ARTM Tier 0, 1, &2) capable of operating in the following frequency ranges:

1435-1535 MHz (Lower L Band)

1750-1855 MHz (Upper L Band)

2200-2395 MHz (S Band)

4400-4940 MHz (C Band)

5091-5150 MHz (C Band)

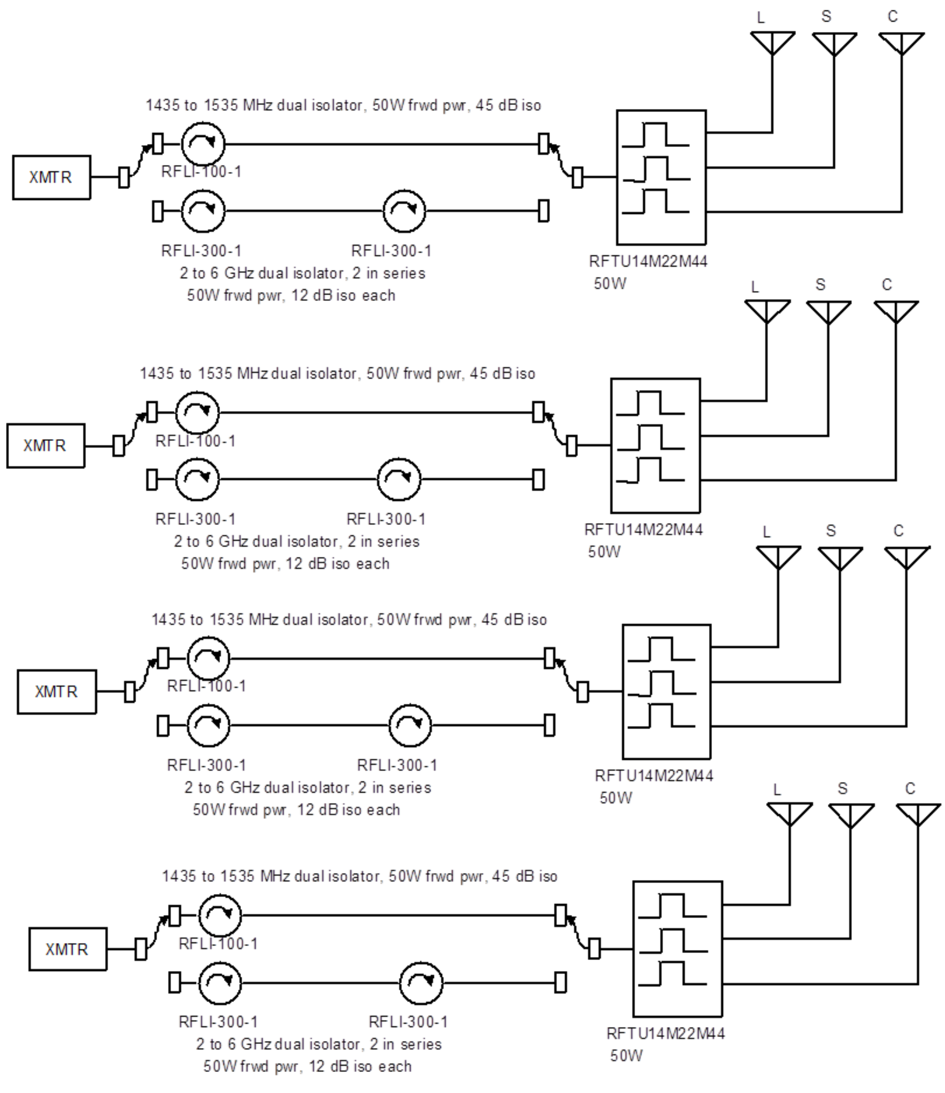

Figure 7.0 Transmit Subsystem

The transmit antennas are custom tri-element patch antennas configurable for each mission, refer to figure 6.0.

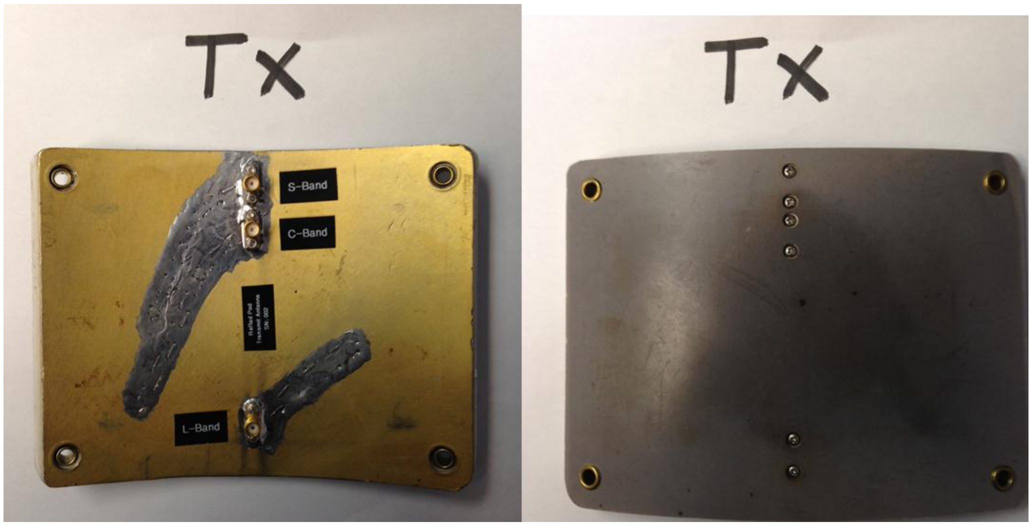

Figure 8.0 Transmit Antennas

Recording System:

The recording system consists of an IRIG-106 CH-10 recorder capable of recording four PCM streams at 20Mbps. The recording system also provides the native PCM stream playback for immediate data validation during preflight. 128Gbyte memory provides 3+ hours record time at 80Mbps.

System Performance:

To determine the system performance, two link analyses needed to be performed. The TM link from the "Shooter" to the "Chase" aircraft and the link from the "Chase" aircraft to the ground station. TK solver software was used to perform the link analysis. Based on a specific mission scenario these links are calculated to determine the expected performance and suggested separation range between the "Shooter" and "Chase" aircraft (Figure 9) and the Chase aircraft to the ground station (Figure 10). Using these tools to predict performance, several key inputs (e.g. Range, Frequency, Power Levels, Bit Rates etc.) can be varied for the aircraft, weapon and the pod to optimize the TM link performance.

Link Analysis Paramters		Shooter to Pod, L-Band		Shooter to Pod, S-Band		Shooter to Pod, C-Band	
	Units	Input	Output	Input	Output	Input	Output
>> Constants							
Speed of light	m/s	3.00E+08		3.00E+08		3.00E+08	
Boltzmann's constant	dBm	-198.6		-198.6		-198.6	
Reference noise temperature	K	290		290		290	
>> Path loss elements							
Range	ft	5,000		5,000		5,000	
Transmit frequency	MHz	1,525		2,300		5,150	
Space loss	dB		99.773		103.342		110.344
Atmospheric loss	dB	0.01		0.012		0.018	
transmitter antenna pointing and polarization loss	dB	0		0		0	
receiver antenna pointing and polarization loss	dB	3		3		3	
Total path loss, dB	dB		102.783		106.354		113.362
>> Transmitting terminal side							
Power amplifier output, watts	W	5		5		5	
Power amplifier output, dBm			36.990		36.990		36.990
Transmit antenna gain, dB	dB	-3		-3		-3	
TX coupling loss, cable loss + connectors, dB	dB	1		1		1	
Transmit VSWR loss, dB	dB	0		0		0	
Effective isotropic radiated power	dBm		32.990		32.990		32.990
>> Receiving terminal side							
Receiver signal power at antenna	dBm		-69.793		-73.364		-80.372
Receiver antenna gain, dB	dB	-3		-3		-3	
Received carrier power, dBm	dBm		-73.493		-77.164		-84.372
>> Noise temperature calculations							
antenna noise temperature	K	350		350		350	
multi-plexer (loss)	dB	0.7		0.8		1	
RF amp gain	dB	15.7		15.3		12.7	
RF amp NF	dB	3.3		3.3		3.3	
noise temp of amp	K		330.009		330.009		330.009
cable & connector (loss)	dB	1.1		1.5		2	
splitter 1:4 (loss)	dB	6.4		6.7		8	
ant+RF components noise temperature	K		333.397		333.537		322.427
rcvr noise figure	dB	4		4		4	
rcvr noise temperature	T		438.447		438.447		438.447
System noise temp	K		1121.844		1121.985		1110.874
>> Calculate SNR & Eb/No							
Noise spectral density, dBm/Hz	dBm		-168.101		-168.100		-168.143
carrier to noise ratio, dB/Hz	dB		94.607		90.936		83.771
Data rate	Mbps	12		12		12	
Eb/No	dB		23.816		20.144		12.980
>> Calculate link margin							
required EbNo for BER	dB	11.4		11.4		11.4	
Required link margin	dB	10		10		10	
Surplus	dB		2.416		-1.256		-8.420

Figure 9.0 "Shooter" to "Chase" Link Margin

		Pod to GND, L-Band		Pod to GND, S-Band		Pod to GND, C-Band	
Link Analysis Paramters	Units	Input	Output	Input	Output	Input	Output
>> Constants							
Speed of light	m/s	3.00E+08		3.00E+08		3.00E+08	
Boltzmann's constant	dBm	-198.601		-198.601		-198.601	
Reference noise temperature	K	290		290		290	
>> Path loss elements							
Range, nautical miles	nmi	125		125		125	
Transmit frequency	MHz	1,525		2,300		5,150	
Space loss	dB		143.404		146.973		153.975
Atmospheric loss	dB	1.461		1.83		2.708	
transmitter antenna pointing and polarization loss	dB	0		0		0	
receiver antenna pointing and polarization loss	dB	3		3		3	
Total path loss, dB	dB		147.865		151.803		159.683
>> Transmitting terminal side							
Power amplifier output, watts	W	10		10		10	
Power amplifier output, dBm			40.000		40.000		40.000
Transmit antenna gain, dBi	dB	0		0		0	
TX coupling loss, cable loss + connectors, dB	dB	1.7		3		3.7	
Transmit VSWR loss, dB	dB	0		0		0	
Effective isotropic radiated power	dBm		38.300		37.000		36.300
>> Receiving terminal side							
Receiver signal power at antenna	dBm		-109.565		-114.803		-123.383
G/T system: Gain/System noise temperature	dB/K	5.9		9.25		14.5	
>> Calculate CNR & Eb/No							
carrier to noise ratio, dB/Hz	dB/Hz		94.936		93.048		89.718
Transmitted data rate	Mbps	12		12		12	
Eb/No	dB		24.144		22.256		18.926
>> Calculate link margin							
required EbNo for BER	dB	11.4		11.4		11.4	
Required link margin	dB	10		10		10	
Surplus	dB		2.744		0.856		-2.474

Figure 10.0 "Chase" to Ground Link Margin

Test Equipment:

The test equipment to support the re-rad pod consists of a self-contained equipment rack built into the pod cradle. The test equipment rack allows full end to end data validation of the pod functionality on or off the aircraft. The equipment rack includes four transmitters, four stream PCM simulator, four receivers, bit synchronizer, decommutator, O'scope, spectrum analyzer, and time code reader.

Figure 11.0 Telemetry Receive/Record Pod with Pod Cradle & Equipment Rack

Conclusions

Designing a system that receives and transmits in the L, S, & C bands presents some unique challenges. Some of the challenges were addressed by instituting frequency utilization guidelines. Because of the size of the pod and proximity of the antennas, interference was a major concern. The design approach was to maintain a minimum of 20 dB of isolation between bands of the telemetry system. Through extensive lab testing it was determined these isolators could be bypassed in certain pod configurations, thus increasing the link margins. This was especially beneficial in the C band. Heat dissipation was also a major concern. The four receivers and transmitters generate a considerable amount of heat. The pod is a water tight sealed system with no external cooling available. The heat was managed using large heat sinks, thermal shutdown circuits in the transmitters, and pod operational procedures while to the aircraft is on the ground.

Acknowledgements:

Several people from NAWCAD Patuxent River, and NAWCWD Pt. Mugu contributed to the development of the Telemetry Receive/Record & Re-Radiation Pod.

Gary Waller, Mark Long, Danny Campbell, Cory Metcalfe, Andrew Chorney, Tony Cirineo, and Scott Kujiroaka

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