

TELEMETRY RE-RADIATION SYSTEM

Paul Cook, Director, Missile Systems
Teletronics Technology Corporation, Newtown, PA USA
Louis Natale, F-22 Instrumentation Sr. Staff Engineer
Lockheed Martin Aeronautics Co., Marietta, GA USA

ABSTRACT

Enclosed weapon bays on modern aircraft interfere with prelaunch, Flight Termination System verification during training test launches. Range safety personnel need to verify the functionality of the flight termination system prior to missile launch. The missile telemetry RF is highly attenuated when the aircraft missile bay doors are closed, limiting the range for which the aircraft can fly during training flights.

Teletronics Technology Corporation and Lockheed Martin designed a system to provide telemetry data for these aircraft. The system re-radiates the telemetry from the missiles with the weapon bay doors closed. This paper describes the design considerations for this flexible system that accommodates multiple weapon systems in multiple weapon bay configurations.

KEY WORDS

Telemetry Re-Rad, Antennas, Multimode Receiver, Multimode Transmitter

INTRODUCTION

This paper discusses the system trade studies and implementation of a system that radiates the Flight Termination System (FTS) ground signal to the missile system in an enclosed weapons bay while re-radiating the telemetry Radio Frequency (RF) signals for a closed loop FTS system verification prior to launch.

CHALLENGES

Designing a Re-Radiation (Re-Rad) system with the multiple weapon system presented the following challenges to the design and implementation team:

- Multiple weapon systems at varying data rates and modulation schemes
- Avoid increasing the data error rates not to affect the overall link margin

- Antenna location for best reception with the varying missile arrangements
- Combining up to four RF/Data streams for transmission
- Providing enough radiated power to provide a viable transmission link
- Re-Radiating of the Ultra High Frequency (UHF) FTS signal with enough gain without oscillation when the bay doors are open
- Efficient programming of the center frequencies of the RF boxes used in the Re-Rad System
- Controlling the environments with the Re-Rad system

The block diagram shown in Figure 1 illustrates a Re-Rad system applicable to this paper. The system approach is to receive up to four individual telemetry RF links, demodulate and recover the data, then present this recovered data to a digital transmitter, recombined, and then radiate at a different frequency band.

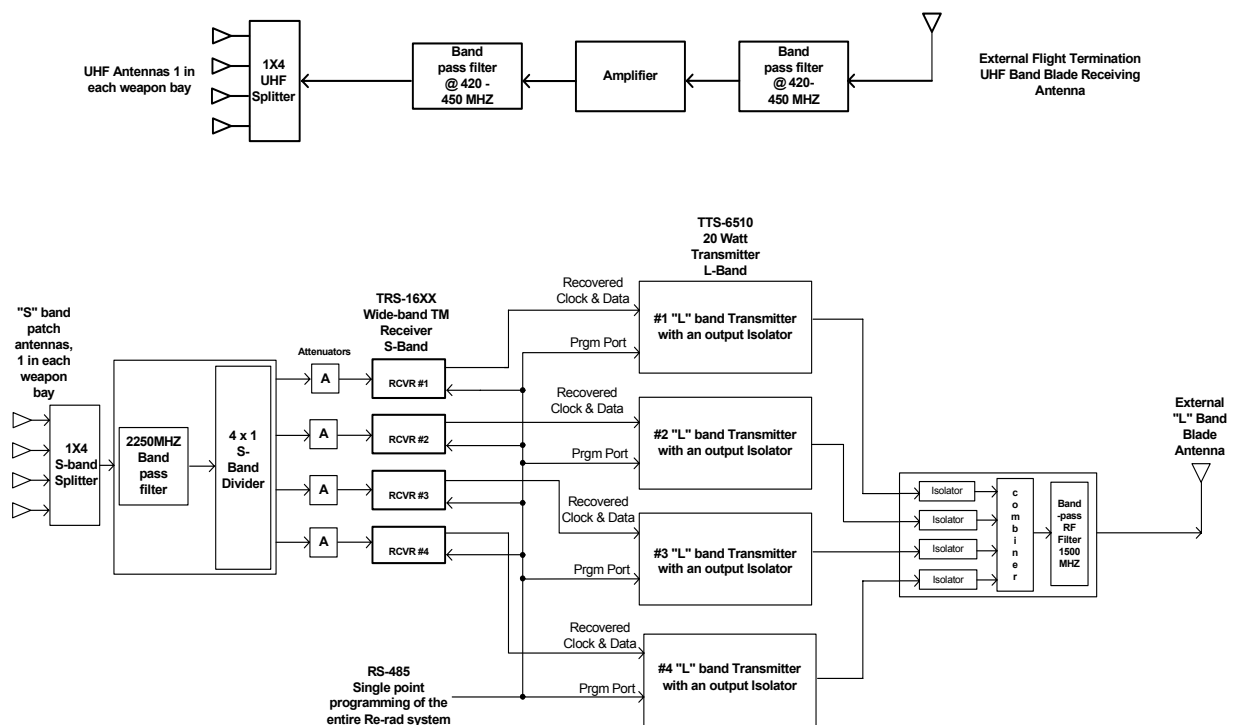


Figure 1 RTAS-2000 Block Diagram

The following paragraphs will describe the trade studies and solutions created to deal with the challenges of implementing a re-radiation system.

MULTIPLE WEAPON SYSTEMS

Supporting the multiple weapon systems for the RTAS-2000 provided a challenge and an opportunity. The challenge was to provide RF center frequency programmability with bit rate agility of the multiple telemetry streams. The opportunity was to utilize the modern modulation schemes to facilitate the retransmission of the telemetry streams as efficient as possible in using Shaped Offset Quadrature Phase Shift Keying (SOQPSK) in a frequency agile transmitter. As shown in Figure 1 the RTAS-2000 incorporates a modern airborne receiver, TRS-1600 series that provides center frequency and bit rate agility that provides compatibility with current and planned modulation scheme upgrades in the missile telemetry systems in a single box. The original approach included a separate assembly for clock and data recovery that is no longer required when using the TRS-1600 multimode receiver. For retransmission, the TTS-6500 multimode transmitter provides the same center frequency and bit rate agility with direct interface compatibility with the TRS-1600. The original approach utilized a standard Frequency Modulation (FM) receiver and a separate clock and data recovery device. Changing over to the new technology provides enhanced compatibility with the current and future weapon systems upgrades with no hardware changes, making the RTAS-2000 a viable platform for many years.

DATA ERROR RATES

Whenever data is relayed from system to system, the increase in error rates is a concern. Meaning the system should not add to the error rate performance of the original telemetry system. In a Re-Rad system, it is reasonable to assume that the RF link from the Missile telemetry to the RTAS system should be error free and add insignificant bit errors to the overall link performance. The antenna location becomes the significant factor here as multi-path induced by the reflections of the inner bay walls will affect the initial link performance.

ANTENNA LOCATIONS

Antenna locations with an enclosed area provide a good environment for reflections and multi-path. A thorough study of the system missile bays was performed to isolate the signal performance across the assigned frequency band.

After much discussion on how to implement a test to validate the RF performance, the final decision was to use a network analyzer to scan the desired band looking nulls, phase reversals, and provide some bit error rate information. A mock up the missile bay provided good training and alarming results with many nulls and regions with poor error rate performance. Amazingly, the real missile bay response, similarly shown in Figure 2 had rather good performance from two

of the three antenna positions. Specific areas of nulls produced by multi-path reflecting from the various shapes within the structure provided significant error rates in the test data. Lining up the telemetry transmitter frequencies against the measured bay performance, provided good confidence that the RF performance would be adequate for re-transmission.

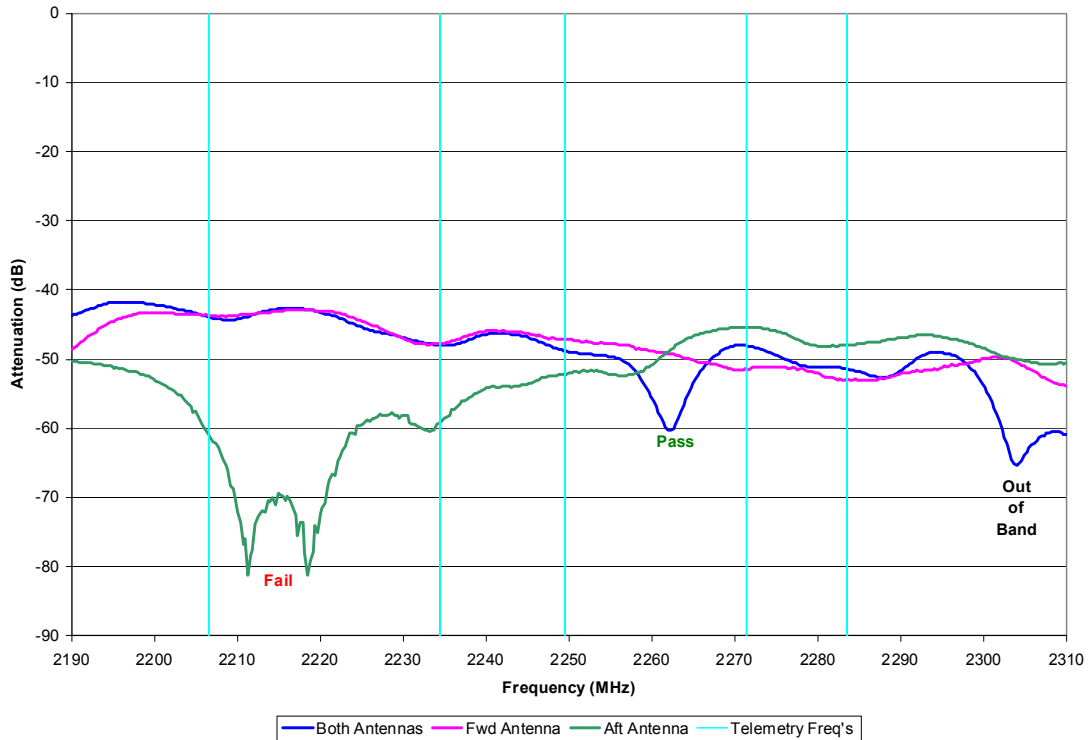


Figure 2 Typical Missile Bay RF performance

The only risk in this antenna testing was repeatability. Additional evaluation was planned to make sure that slight changes in the position of the antennas and the missile systems will not provide in significant changes to the RF performance.

COMBINING MULTIPLE RF/DATA STREAMS

The RTAS-2000 is required to receive multiple telemetry streams, re-modulate them and recombine them to be radiated through a single antenna. Fear of spurious outputs from inter-modulation distortion created when combining required a trade study to evaluate the compliance to a -25 dBm requirement. Two solutions were studied. The first was to combine at low power and then feed a single, high power, linear amplifier. The second was to combine the outputs of 4 medium power transmitters. The second of the two solutions was chosen for the RTAS-2000.

This first solution was to combine at low power (+5 to +10 dBm) and then amplify the composite signal with a high power amplifier. This implementation required a low distortion amplifier. Pre-distortion amplifiers readily exist in today's cell phone commercial market. Two local

companies were solicited and their products evaluated against the -25dBm spurious requirement. Even though both vendors products were found to be acceptable for spurious, the class-A Amplifier current draw and the resulting thermal dissipation was too much for the system to absorb.

The second solution was evaluated and later chosen, to be the more efficient of the two solutions was to develop a high power combiner, driven by standard, medium powered telemetry transmitters. The only potential issue was the required minimum port-to-port isolation required to keep the inter-modulation out down to an acceptable level. The high power combiner was implemented with high power levels (100 watts min) and provides a minimum of 60 dB of port-to-port isolation while inducing a 9 dB maximum of insertion loss from input port to output port. Figure 3 illustrates the High Power Combiner.

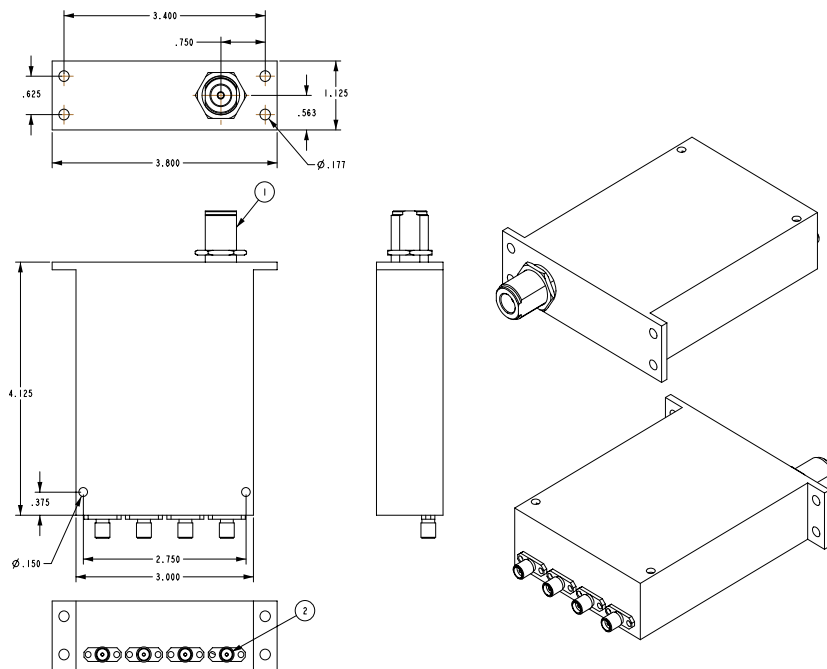


Figure 3 High Power Combiner Outline

PROVIDING ENOUGH RADIATED POWER

Providing enough radiated power to maintain a good telemetry link from the external antenna was a challenge with system losses from the high power combiner's 9 dB of insertion loss and the cable attenuate of more than 13 dB. With that, a link margin analysis was performed using the guidelines from IRIG-119-06¹. The system noise considering the highest bit rate and the resulting IF bandwidth/receiver noise figure provided a total noise calculated result of -99 dBm . The total gains and losses considering the path loss in lower L band and the typical ground

antenna gains calculate to be -128 dB. The transmitter power that is required to maintain a healthy, line of site Telemetry link with the calculated total noise and gains is a minimum of 41 dBm per channel; the RTAS-2000 has implemented 20 watt minimum transmitters that will provide good link margin.

Feedback from the range who have implemented less sophisticated re-radiation systems have been experiencing good link margins with similar radiated power of 2-3 watts as expected here in this application.

RE-RADIATING OF THE UHF FTS SIGNAL

Most of this paper describes the downlink which is the major contributor to the challenges. The most important feature is the UHF uplink as this RF link provides stimulus to the Flight termination system that the missile telemetry systems monitor and the RTAS-2000 re-radiates. A simple implementation was created to amplify the received UHF uplink RF link and split to re-radiate in all of the weapons bays. This simple design illustrated below in Figure 4 and consists of a bass band filter, an amplifier block (50 dB max), a secondary filter and a four-way splitter.

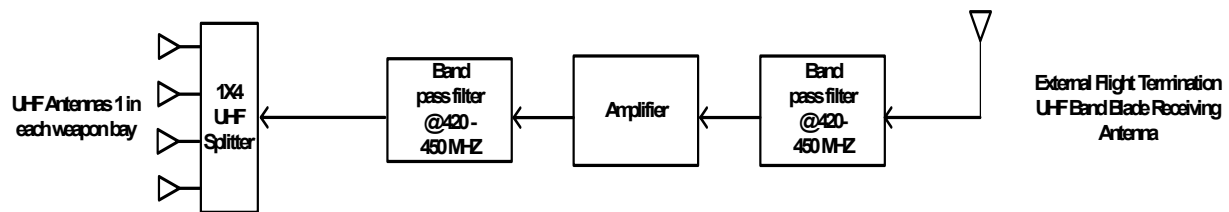


Figure 4 UHF Uplink

The purpose of the amplifier gain is to compensate for antenna, cable and splitter losses such that the power that arrives at the external aircraft antennas will be re-radiated in each weapons bay at the same level. The intent is to obtain pre-launch data from each of the missile telemetry while the missiles are still enclosed in the weapons bay and perform as they should if they are outside of the vehicle.

The obvious concern is coupling between the external antenna and the four radiating antennas. The solution was an attenuator stub that can be tailored in the RTAS-2000 to reduce the gain of the amplifier and therefore mitigating any cross coupling or feedback oscillation issues at the system level. This stub can be selected in the field to customize the system to a changing application.

EFFICIENT PROGRAMMING

The standard approach to program today's telemetry RF components is to adjust the center frequency using a jumper plug or on more modern equipments, via a serial communication port. In the case of the RTAS-2000, eight individual RF components, four receivers and four transmitters will require programming in an efficient manner. In addition to the efficiency factor, the inter-wiring of all these components created a large wire bundle. On the traditional RS-422 configuration, as shown in Figure 5, for each of the Transmit (Tx) and Receive (Rx) command lines, the controlling Personal Computer (PC) would be required to have a dedicated communication port to each of the RF components. This increases the complexity of the programming PC along with the increased wire bundle size of the interfacing cable. A novel solution was implemented in the RTAS-2000 to maintain the noise immunity of the differential pairs but also incorporate a bi-directional bus structure to allow multiple components to communicate on a single interface.

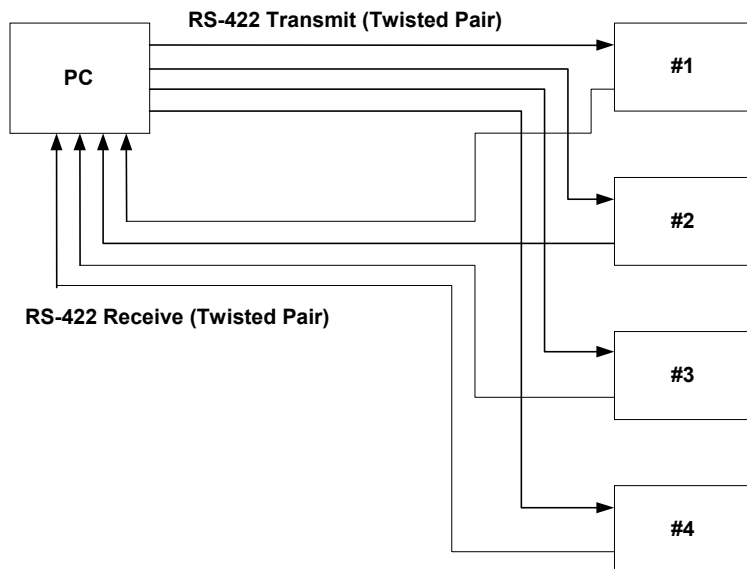


Figure 5 Traditional RS-422 Configuration with 4 units

This solution involved the conversion of the standard RS-422 differential interface, shown in Figure 6 to a RS-485 full duplex interface shown in Figure 7. This was achieved with minimum impact to the components by incorporating a MAX3160 interface device that can be selected either to a half-duplex RS-422 interface arrangement or to a full duplex RS-485 configuration. This conversion provides standard products portability to either configuration, depending on the system solution.

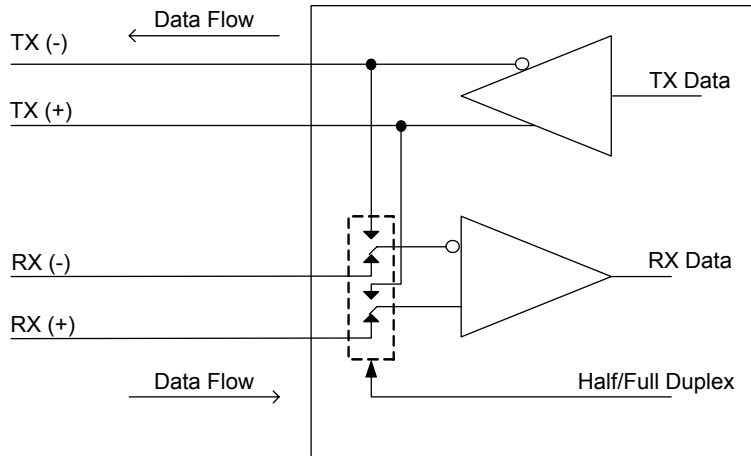


Figure 6 Standard RS-422

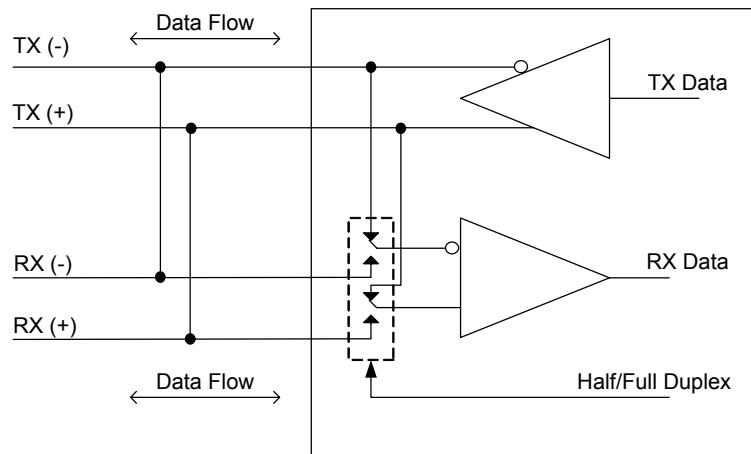


Figure 7 RS-422 to RS-485 Conversion

The unique feature in the RS-485 implementation is that the individual component can now utilize both sets (TX and the RX pairs) of differential lines from the RS-422 configuration to route the RS-485, full duplex communication through each component. This provides point-to-point wiring of the bus and minimizing the wiring complexity as illustrated in Figure 8.

RS-485 System with 4 units

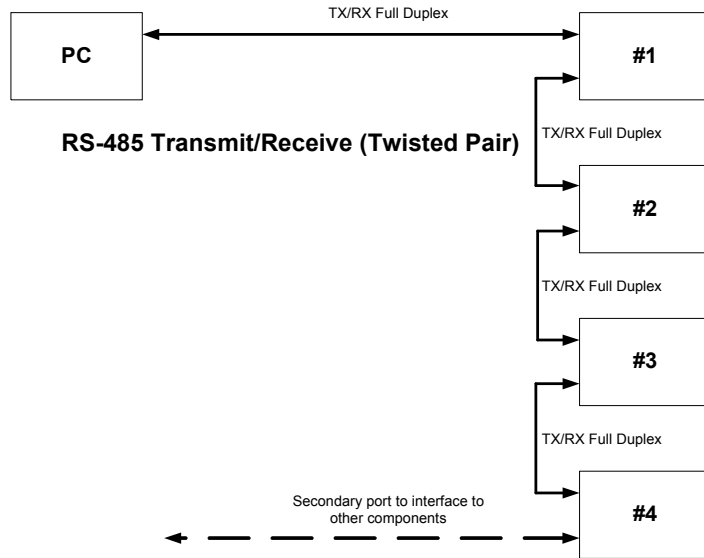


Figure 8 RS-485 Configuration

Test and troubleshooting of the RTAS-2000 system is enhanced as component fault or any breakage of the serial chain through each of the components can be easily detected by switching communication through the secondary port. Through this port, a breakage in the serial chain can be found via a series of structured command and replies. For added assurance, a secondary command port should be provided in the controlling PC to provide the ability to switch communication ports as a fault is detected.

ENVIRONMENTAL CONSIDERATIONS

The RTAS-2000 is illustrated in Figure 9 consisting of a main chassis of 11 x 15.4 x 3.5 inches. Two significant features of the RTAS-2000 make the system compatible with normal aircraft environments.

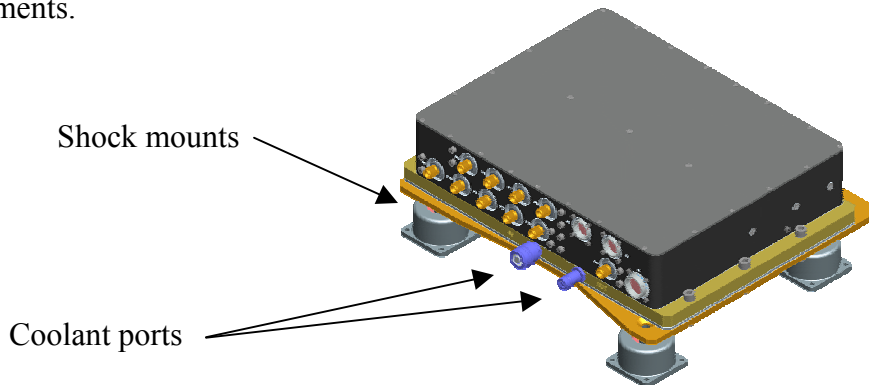


Figure 9 RTAS-2000

The first is a cold plate to allow the system that consumes about 400 watts to operate without overheating. This custom cold plate allows coolant to flow under the higher power components to include four transmitters and the high power combiner. This configuration allows the RTAS to maintain an operating temperature between 20 and 50 degree Celsius. The second feature is a shock isolated mounting plate that allows for the reduction of high frequency shock and vibration levels, while lowering the resonant frequency to an area where the input levels are significantly lower. This shock-mounted plate has been used successfully on other large boxes in aircraft applications.

SUMMARY

Re-radiation systems require a flexible and compatible solution for re-radiating pre-launch missile telemetry data. The major challenges identified in this paper were resolved with new technology, like the multimode receivers and transmitters. The RTAS-2000 implemented with this technology has increased the system simplicity and performance while reducing dissipation making the system solution compatible with the current and future applications.

ACKNOWLEDGEMENTS

The individuals listed below took part in this development and without their dedication; this effort would not have been successful.

Larry Michals, Lockheed Martin
Ron Raczy, Lockheed Martin
Stephen Bay, Teletronics Technology Corporation
Tim Wink, Teletronics Technology Corporation

REFERENCES

[1] RCC, Telemetry Application Handbook, Document 119-06, White Sands Missile Range, Chapter 2, paragraph 2.11-2.12