Final Report on the Testing of the Antenna Diplexer for Aircraft Antenna Sharing between the SSR Transponder and ADS-B Universal Access Transceiver (UAT)

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NOTICE

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16. Abstract

An option to use a passive frequency Diplexer is provided herein to allow sharing of a single antenna between the ATCRBS/Mode S Transponder and the UAT unit. Sharing a common antenna between the two systems may be desirable in aircraft to minimize antenna installation cost and complexity. The Diplexer is a passive three port component which provides connectivity from the UAT port to the antenna port (UAT Channel) and connectivity from the ATCRBS/Mode S port (Transponder Channel) to the antenna port. The UAT Channel frequency response requirements insure adequate passband bandwidth around the 978 MHz UAT frequency to insure that UAT signal integrity is maintained through the UAT unit, Diplexer and antenna path. Likewise, the Transponder Channel frequency response requirements insure adequate passband bandwidth around the 1030 MHz and 1090 MHz frequencies to insure that interrogation and reply signal integrity is maintained through the transponder, Diplexer and antenna path. The Diplexer characteristics insure that performance of both the UAT and Transponder systems is equivalent to their performance without the Diplexer with the exception of the in-band attenuation and delay of signal through the Diplexer. The insertion loss and delay characteristics of the Diplexer must be taken into consideration when determining cable loss and cable delay budgets between the UAT unit and antenna and the Transponder and the antenna.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

ADS-B	Automatic Dependent Surveillance – Broadcast
AP	Address Parity
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
CPFSK	Continuous Phase Shift Key
DATAS	Data and Transponder Analysis System
DPSK	Differential Phase Shift Key
ES	Extended Squitter
FEC	Forward Error Correction
GA	General Aviation
GPS	Global Positioning System
ICAO	International Civil Aeronautical Organization
Mode S	Mode Select
MOPS	Minimum Operational Performance Standards
MHz	Megahertz
MSR	Message Success Rate
MTL	Minimum Triggering Level
PAM	Pulse Amplitude Modulation
PRF	Pulse Repetition Frequency
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
SLS	Side Lobe Suppression
SSR	Secondary Surveillance Radar
TIS-B	Traffic Information Services – Broadcast
UAT	Universal Access Transceiver
VSWR	Voltage Standing Wave Ratio

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Executive Summary

This report details a testing activity that was conducted to evaluate the potential use of a passive Diplexer to allow sharing of the aircraft Secondary Surveillance Radar (SSR) transponder antenna with the Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast (ADS-B) system. This is potentially a significant installation savings for aircraft owners who desire to equip with ADS-B by eliminating the need to add additional antenna to accommodate ADS-B. The testing that has been completed that verifies compatibility with the SSR transponder eliminates the need for additional extensive testing to verify the SSR transponder operation with a Diplexer. If a Diplexer meeting the technical specifications contained in the Radio Technical Commission for Aeronautics (RTCA) UAT Minimum Operational Performance Standards (MOPS) is used, the testing conducted and described in this report serves as verification that acceptable SSR transponder performance is maintained with the use of a Diplexer.

Diplexer specifications evolved from preliminary specifications for a prototype Diplexer included in Appendix E, Aircraft Antenna Characteristics, of the UAT MOPS, RTCA document DO-282. Prototype Diplexers developed to these specifications were used in the testing conducted for this report. The test results presented in this report were used in developing final Diplexer requirements and test procedures that are included in the first revision of the UAT MOPS, RTCA-DO-282A and are planned to be included in the revision of Technical Standard Order TSO-C154, UAT ADS-B Equipment Operating on the Frequency of 978 MHz. Also, Diplexer requirements are being incorporated in the UAT International Civil Aeronautical Organization (ICAO) requirements to allow the use of a Diplexer internationally.

Three categories of tests were performed. The first set of tests verified the basic characteristics of the Diplexer itself. These measured characteristics were utilized to establish the baseline for assessing performance. The second set of tests verified that the UAT equipment performance through the Diplexer with the SSR ATCRBS/Mode S transponder operating and connected to the Diplexer was acceptable. The last set of tests verified that the SSR ATCRBS/Mode S transponder performance through the Diplexer with the UAT equipment operating and connected to the Diplexer was acceptable.

The tests to verify the characteristics of the Diplexer included determining the loss through each channel as a function of frequency. It was determined that the maximum loss was well within the 0.5 dB maximum target for each of the Diplexers tested. Also the channel to channel frequency isolation was measured to verify that the Diplexers provided adequate frequency separation between channels to minimize SSR transponder and UAT equipment signal impact on the alternate system. Testing verified that the Diplexers were designed with adequate bandwidth on each channel to pass UAT signals (978 MHz) on the UAT channel and the 1030 and 1090 MHz SSR transponder signals on the transponder channel without distortion.

To assess the impact of the Diplexer on UAT equipment, transmit-receive pairs were utilized to transmit and receive UAT signals across the Diplexer to verify that the Diplexer did not distort the UAT signals and cause performance degradation when comparing the performance of transmit-receive pairs without the Diplexer. In addition, the receiver was subjected to overlapping ATCRBS and Mode S reply signals from the on-board transponder operating connected to the Diplexer port. The test results showed that there was no measurable distortion of the UAT signal through the Diplexer. The only impact of the Diplexer on the UAT equipment was about a 0.3 dB measured signal loss through the Diplexer, less than the 0.5 dB maximum required in the UAT MOPS.

To test the impact of the Diplexer on the SSR transponder, a comprehensive set of tests was run on both Mode S and ATCRBS transponders to measure transmitter and receiver characteristics, reply pulse characteristics, side lobe suppression, undesired replies, and pulse decoder characteristics. For each test parameter, the performance of the SSR transponder with a Diplexer is consistent with the performance of an SSR transponder without a Diplexer. The Diplexers tested introduced less than the maximum of 0.5 dB losses across either the SSR transponder equipment to antenna path. The Diplexers also introduced up to a 10 nanosecond delay across either path, which has minimal impact to either system. The loss across the Diplexer would have to be factored into an installation where the loss allocation between the box and antenna is normally 3 dB.

The results of the extensive testing of SSR transponder and UAT performance verify that the use of a Diplexer to share the SSR antenna with UAT equipment on an aircraft is an acceptable configuration. The characteristics of the prototype Diplexer used in this testing were recommended and adopted in the relevant UAT requirements document (RTCA/DO-282A). The testing results documented herein provides verification that a Diplexer meeting the specifications of the prototype Diplexer tested insures compatibility with SSR transponder operation. It is important to note that the tests were conducted using available production ATCRBS and Mode S transponders. Use of a Diplexer with SSR transponders requires verifying that the off frequency power that the equipment will be subjected to at the input of the equipment can be tolerated. UAT equipment designs must also factor the off frequency power that the equipment would be subjected to through the use of a Diplexer. These same issues would need to be addressed without a Diplexer as the co-site of UAT, SSR and TCAS equipment require these same power considerations to be factored into their design. The use of a Diplexer designed to the specifications defined in the UAT MOPS should obviate the need for additional tests to be conducted and submitted to FAA certification authorities to verify operation of the SSR transponder and UAT with the use of a Diplexer. Aircraft installations that are candidates for Diplexer use must determine the existing cable loss on the aircraft between the SSR transponder and antenna. Most installations allow 3 dB between antenna and equipment and adequate margin exists in most installations since the Diplexer itself introduces a 0.5 dB, or less, additional loss.

1 INTRODUCTION

1.1 Background

Automatic Dependent Surveillance – Broadcast (ADS-B) is a system in which equipped aircraft and ground vehicles will broadcast their position, altitude, velocity and other data periodically. Concurrently, equipped aircraft and ground vehicles will receive the same information from other proximate ADS-B participants. The Satellite Global Positioning System (GPS) provides the basis for the ADS-B technology. With such information provided by other ADS-B participants, the position and movement of other nearby aircraft (and ground vehicles) can be displayed in the cockpit enhancing situational awareness. Ground-based facilities can also monitor ADS-B transmissions to provide or enhance surveillance capabilities.

Traffic Information Services – Broadcast (TIS-B) is a ground based system that uses ADS-B signal formats to uplink surveillance data on non-ADS-B equipped aircraft as well as aircraft using different ADS-B data links. ADS-B and TIS-B are enabling technologies for advance surveillance capabilities associated with free flight.

The FAA and industry have designated two separate Radio Frequency (RF) "links" to convey ADS-B Messages: 1090 MHz Extended Squitter (ES) and Universal Access Transceiver (UAT). The 1090 MHz ES link is an extension of Mode Select (Mode S) transponders and is primarily for Air Transport class aircraft. The UAT link is intended for installation on General Aviation (GA) aircraft that currently do not have Mode S capability.

For GA aircraft to equip with UAT ADS-B, the necessary avionics components must be installed on the aircraft. One such component is the antenna that provides the RF link to the UAT ADS-B world. Since there is limited surface area on most general aviation aircraft for locating antennas for various on-board avionics, it has been proposed to install a passive Diplexer to allow sharing of the current Secondary Surveillance Radar (SSR) transponder antenna with the installed UAT ADS-B system. Because of the frequency separation (UAT center frequency is 978 MHz), and low duty cycle of the UAT system, the use of a Diplexer is considered a viable option. Also, the isolation provided by a Diplexer may be greater than that of separate antennas for an SSR transponder and UAT equipment within close proximity. An antenna Diplexer may also be used by air transport category aircraft equipped with broadcast ADS-B 1090 MHz Extended Squitter equipment. These aircraft may desire to see and be seen by other UAT equipped aircraft without relying on FAA ground infrastructure investment to provide a crosslink function to allow ADS-B applications across both UAT and 1090 MHz Extended Squitter links. Air transport aircraft could benefit from the use of the existing SSR transponder antenna by eliminating the need of an additional antenna to equip with UAT. Therefore, the use of a Diplexer has benefit for all classes of aircraft. Along with existing aircraft, the use of a Diplexer is also an advantage in new installations that could benefit from the ability to reduce the number of antennas to incorporate ADS-B. Figure 1-1 shows the connectivity associated with an aircraft Diplexer installation with antenna diversity.

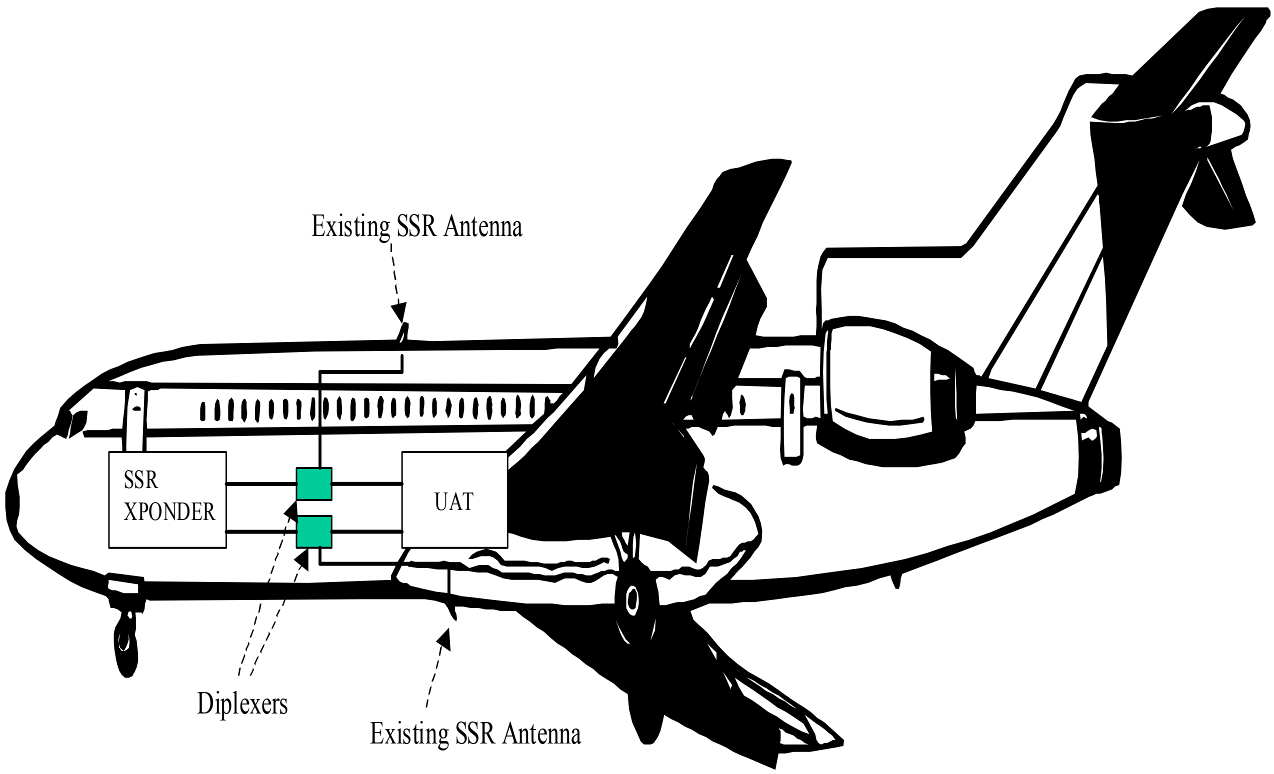

Figure 1-1 – Antenna Diplexer Connectivity Example

1.2 Purpose and Rationale

To pursue the antenna Diplexer installation option, it is necessary to first conduct tests to determine if such an installation will have an adverse effect on the proper operation of either the ATC SSR transponder or the UAT ADS-B system. This document presents test results from validating the performance of ATC transponders and UAT ADS-B systems when sharing an antenna by incorporating a Diplexer into the installation. The purpose of the tests is to insure that both the UAT equipment and ATC transponders perform according to the applicable standards and that the Diplexer does not introduce any signal distortions on the 978 MHz frequency of the UAT and the 1030/1090 MHz frequencies of the transponders. This comprehensive set of tests was performed to measure any potential degradation of equipment performance due to the Diplexer installation.

In addition to the objective of evaluating the potential use of a Diplexer, determining and refining specifications for a Diplexer that would be adequate to insure proper operation of both systems on an aircraft was also an objective. Prior to conducting the tests outlined in this document, a set of specifications was produced for a prototype Diplexer and included as part of Appendix E, Aircraft Antenna Characteristics, of the UAT MOPS, RTCA Document DO-282. The testing outlined in this document was run concurrently with the development of final specifications. Final Diplexer requirements were produced to be included in the first revision of the UAT MOPS, RTCA Document DO-282A. Also, Diplexer requirements were incorporated in the UAT International Civil Aeronautical Organization (ICAO) requirements to obtain approval for the use of a Diplexer internationally. At the time of this report, UAT international standards were under review for approval by ICAO and expected to be published in the 2007 timeframe. As a result, the testing process was valuable in refining the specifications for Diplexer performance and developing test procedures that are necessary to certify a Diplexer unit and its installation.

2 TEST APPARATUS

2.1 Diplexers

The requirements for a Diplexer were developed prior to the testing effort described herein. The concept was introduced during the development of the UAT MOPS where the RTCA Working Group producing the requirements for the MOPS considered taking advantage of the fact that most aircraft had existing SSR transponder antenna suitable for the UAT frequency.

There were general guidelines established that were necessary restrictions on Diplexer design.

First, the Diplexer is required to be a passive device with no active components. It was determined that adding active components to the SSR transponder antenna path which could potentially impact reliability and/or availability of the on-board SSR transponder was not a viable option.

Second, the passband characteristics of the Diplexer needed to conform to the signal characteristics of UAT and the SSR transponder. The UAT signal on the UAT channel is a Continuous Phase Shift Key (CPFSK) modulated signal centered at 978 MHz. The frequency offset is +/- 312.5 KHz and the modulation rate is 1.041667 megabits per second. The occupied bandwidth of the signal has been determined to be 1.3 MHz, so the Diplexer bandwidth was specified to accommodate the UAT signal. The transponder channel of the Diplexer required passing signals of varying types and at two center frequencies. The transponder receives 1030 MHz centered interrogation signals. These signals include ATCRBS interrogations that use Pulse Amplitude Modulation (PAM) and Mode S interrogations that are either PAM or Differential Phase Shift Key (DPSK) modulation. SSR transponders transmit PAM signals at 1090 MHz where signals are approximately 21, 64 or 112 microseconds in duration.

Prototype Diplexers were specified and obtained to conduct the testing activities. Three different Diplexers were obtained with similar specifications and each was utilized in the bench test measurements. One Diplexer was purchased from FSY Microwave and the other two were obtained from Lorch Microwave. The full part number identification for the three Diplexers is as follows:

- FSY Microwave 80491-DC DC0219
- Lorch Microwave WD-00046
- Lorch Microwave WD-00046-R1

The second Lorch Microwave Diplexer (WD-00046-R1) was obtained after performing most of the tests with the other two Diplexers. During testing on the impact of the Diplexer and UAT System on ATCRBS/Mode S Transponders with the original two Diplexers, a varying number of spontaneous ATCRBS replies were recorded during the undesired reply tests (see section 4.12). It was determined that these replies were occurring during the UAT transmission caused by leakage of the UAT signal over the transponder channel of the Diplexer. The signal at the transponder channel was at a high enough level to cause the transponder receiver to falsely decode ATCRBS and/or Mode S interrogation pulses and trigger replies. Lorch Microwave developed the WD-00046-R1 to provide increased channel to channel isolation to reduce or eliminate this effect. Tests were conducted, and results verified that there were no unsolicited replies with the revised Lorch Diplexer. However, there were other performance characteristics associated with it that were unacceptable for proper Diplexer performance. The revised Diplexer was unable to meet the required 0.5 dBm maximum signal loss through the specified frequency band from 1015 MHz to 1105 MHz. Also, using a high frequency oscilloscope it was observed that there was distortion on the leading edge of pulses passed through the Diplexer and that signal delay across the Diplexer increased to approximately 20 nanoseconds. This additional delay across the Diplexer results in a 40 nanosecond round-trip increase in delay for each interrogation/reply transaction. Because of its shortcomings, the Lorch WD-00046-R1 was not further considered a candidate design for the intended use outlined in this report. For this reason, a complete set of tests was not completed on the Lorch WD-00046-R1 Diplexer. Since tests were included in the assessment on the performance on ATCRBS/Mode S transponders, the test data with all three Diplexers is presented there.

2.2 Transponders

The tests were conducted with nine different transponders that included 5 Mode S, and 4 ATCRBS only transponders. Of the 5 Mode S transponders, there were 3 different transponder types from 3 different manufacturers (two units were tested for two of the types). Of the four ATCRBS only transponders, there were two different manufacturers, with two *different* models from each manufacturer. The following is the designation used to identify the transponders in the test data sections:

<u>Mode S Transponders</u>

MS-1A
MS-1B (same model as MS-1A)
MS-2
MS-3A
MS-3B (same model as MS-3A)

<u>ATCRBS Transponders</u>

A-1
A-2 (same manufacturer as A-1, different model)
A-3
A-4 (same manufacturer as A-3, different model)

2.3 UAT System

Diplexer testing made use of several UAT units to simulate co-site interference, as well as to act as the UAT receiver. The UAT equipment used was three 966 MHz Capstone units modified to be functionally compliant with the UAT MOPS, including operating at the approved 978 MHz frequency. One unit was configured to act as a transmitter. The other two units were configured to act as receivers. One receiver was modified to operate with a 1.2. MHz bandwidth, and the other receiver was modified to operate with a 0.8 MHz bandwidth. Power output of the transmitting UAT was measured to be approximately +46 dBm at the antenna terminal, although the power level varied slightly over time.

The UAT transmitter was supplied with a test PROM to enable the generation of 32 UAT test messages per second, and the UAT transmitter also output a digital logic pulse for each transmitted UAT test message. The UAT receiver output a pulse for each successfully received and decoded UAT test message. By using these pulses, it was possible to compute Message Success Rate (MSR) from the ratio of "good" to "total" pulse counts when utilized for the Diplexer impact on UAT testing. By sending UAT messages from the transmitter through attenuation, and through the Diplexer to the receiver, and by varying the signal level of the received UAT messages, MSR was computed from a sufficient number of samples in order to determine a statistically accurate baseline sensitivity.

During interference scenarios, using transmissions from various off frequency equipment, interference transmissions were pseudo-randomly positioned directly over the top of the UAT message payload 100% of the time. In this manner, a worst case environment was simulated, and all positions throughout the UAT payload were tested. The same procedure was used to compute MSR.

3 TEST PROCEDURE AND CONFIGURATIONS

Testing is divided into three major portions. The first set of tests verifies the basic characteristics of the Diplexer itself. These measured characteristics establish the baseline for assessing performance. The second set of tests measures the performance impact of the Diplexer with the ATCRBS/Mode S transponder configuration on the UAT equipment. Performance is examined and assessed for the on-board UAT receiver and its ability to receive UAT messages at the limits established by the UAT MOPS. The last set of tests measures the performance impact of the Diplexer with the UAT equipment configuration on the ATCRBS/Mode S transponder. Performance of the transponder's 1030 MHz receiver is assessed and reply characteristics of the 1090 MHz transmissions are assessed.

3.1 Test Procedure for Assessing Diplexer Characteristics

A set of measurements was made to baseline the Diplexer characteristics of the prototype Diplexers specified and fabricated to be utilized in the testing effort. Initially, draft requirements were developed as a starting point in the Diplexer concept investigation. The loss across the Diplexer for both the SRR transponder and UAT channels had to be minimized. Normally, a 3 dB installation loss is allowed between the transmit/receiving equipment and the antenna.

Receiver sensitivity and transmit power specifications are usually referenced at the antenna end of the cable connecting the antenna and equipment. Higher losses between the antenna and equipment can be compensated for by higher transmit power and improved receiver sensitivity of the equipment. Taking into consideration that the use of a Diplexer is directed toward both new and existing installations, minimizing the loss across a Diplexer was necessary so that the Diplexer did not severely cut into the 3 dB budget. In order to accomplish the goal of loss containment due to the Diplexer, the loss across each channel was specified to be 0.5 dB or less. This evolved as the design goal so that the loss allocation required by the insertion of a Diplexer could be minimized and achievable with current technology. It was concluded that this was a reasonable design goal based on practical filter designs for the Diplexer required to meet the frequency characteristics of UAT and SSR transponder signals.

Additionally, the filter characteristics and bandwidth of the UAT channel and the SSR transponder channels had to pass signals without impact to the performance of each of the systems. UAT signals are centered at 978 MHz and use a form of frequency modulation and are narrowband signals. The SSR transponder channel had to encompass signals at both 1030 MHz and 1090 MHz as the SSR system uses 1030 MHz interrogation signals and 1090 MHz ATCRBS and Mode S signals to operate. The transponder transmits at 1090 MHz and receives 1030 MHz interrogations. The Diplexer was envisioned to allow operation with either ATCRBS or Mode S transponders.

Testing was conducted to verify the operation with both transponder types. Measurements were performed to determine the channel characteristics of the Diplexer. This was done to verify that the characteristics matched the requirements that were determined from the bandwidth analysis of both UAT and SSR transponder signals. The loss across the Diplexer as a function of frequency was measured using CW signals to verify the frequency and loss characteristics. Also, the channel to channel frequency characteristics were measured. Isolation between the channels was desired to protect against distortions caused by signal leakage from the alternate channel. There was benefit derived by the channel isolation provided which is the same affect as providing distance between the antenna of each system on-board an aircraft. Also, this helped to minimize the off frequency power at the antenna port of the UAT equipment and the SSR transponder.

3.2 Test Procedure for Assessing Impact of Diplexer and ATCRBS/Mode S Transponder on UAT System

Testing was conducted to assess the performance of the UAT system when using a Diplexer. The test configuration incorporated a Diplexer into the path of two UAT units, one connected to the UAT channel of the Diplexer representing the on-board UAT device and the second connected to the antenna port representing a remote UAT. Transmit-receive pairs were utilized to transmit and receive UAT signals across the Diplexer to verify that the Diplexer did not distort the UAT signals and cause performance degradation when comparing the performance of transmit-receive pairs without the Diplexer.

The data collected and analyzed initially measured the Minimum Trigger Level (MTL) of the UAT receiver without a Diplexer. Messages were transmitted with power levels in 1 dB steps to measure the MTL of the receiver.

UAT receivers have two basic designs according to the equipment class of the unit. High end equipment intended to operate at high altitude and designed to support long range ADS-B applications are designed with a narrower filter (0.8 MHz) to enable better DME rejection. Some DMEs operate at frequencies of 979 and 980 MHz, so the UAT receiver design considered the DME impact to UAT reception capability so the narrower filter acts to improve DME rejection. The typical UAT receiver has a 1.2 MHz filter. Both filter types were included in the testing to verify proper operation with the Diplexer.

Along with measuring the performance of UAT receivers with signals through the Diplexer, the receiver was subjected to overlapping ATCRBS and Mode S reply signals from the on-board transponder operating connected to the Diplexer port.

The performance of the UAT system was simulated using future high-density scenarios to verify that acceptable UAT performance is achieved even under the extreme aircraft densities that were projected for the aircraft population centered around the busiest airports in the future. The basic assumption made in the performance models for UAT assumed that any co-site transmission from the SSR transponder would result in a failed decode of a UAT Message at the on-board UAT receiver.

The performance of the UAT receiver was assessed when the SSR transponder is connected on-board with a Diplexer to determine the reception characteristics of UAT when UAT Messages are overlapped by a transponder 1090 MHz signal through the Diplexer. Benefit from the isolation provided by the Diplexer was expected to enhance performance. It was not expected that SSR signals received by the UAT through the antenna port of the Diplexer would have any effect on UAT receiver performance. Tests were conducted where the power levels of SSR signals at the antenna port were raised to unrealistic amplitudes to determine the effect on UAT Message reception that the Diplexer may cause that can only be measured at such extremes.

3.3 Test Procedure for Assessing Impact of Diplexer and UAT System on ATCRBS/Mode S Transponder

A comprehensive set of tests was run on each transponder to measure:

1. Transmitter and Receiver characteristics,
2. Reply pulse characteristics,
3. Side lobe suppression,
4. Undesired replies, and
5. Pulse decoder characteristics.

The Data and Transponder Analysis System (DATAS) was used to perform the tests. DATAS is a system specifically designed to measure performance of the ATCRBS/Mode S transponders and to provide detailed test results.

Most tests were conducted in two test configurations:

(1) With the DATAS connected directly to the transponder, and

(2) With the DATAS connected to the antenna port of the Diplexer, which was connected to the transponder under test and the UAT system on the appropriate input channels (see Figure 3-1).

The data from each configuration is compared to determine what effect if any, the Diplexer/UAT installation has on each test parameter.

To minimize the impact of cable losses and connections on test data, short lengths of low-loss cable were used, and the number of cable connections was consistent and kept to a minimum. Because the insertion of a Diplexer into the circuit requires a second cable to connect the Diplexer to the transponder, this cable was also used when a Diplexer was not in the circuit. In this case, the Diplexer was replaced with a short barrel (configuration 1 in Figure 3-1).

During testing it was discovered that some of the parameters were affected by changes in VSWR caused by inserting or removing the Diplexer. For this reason, when appropriate, a slotted line and stub tuner were inserted at the antenna port of the transponder to monitor and control VSWR. A proper installation of an antenna Diplexer will require using appropriate cable lengths between the Diplexer and all attached devices and antennas to control VSWR.

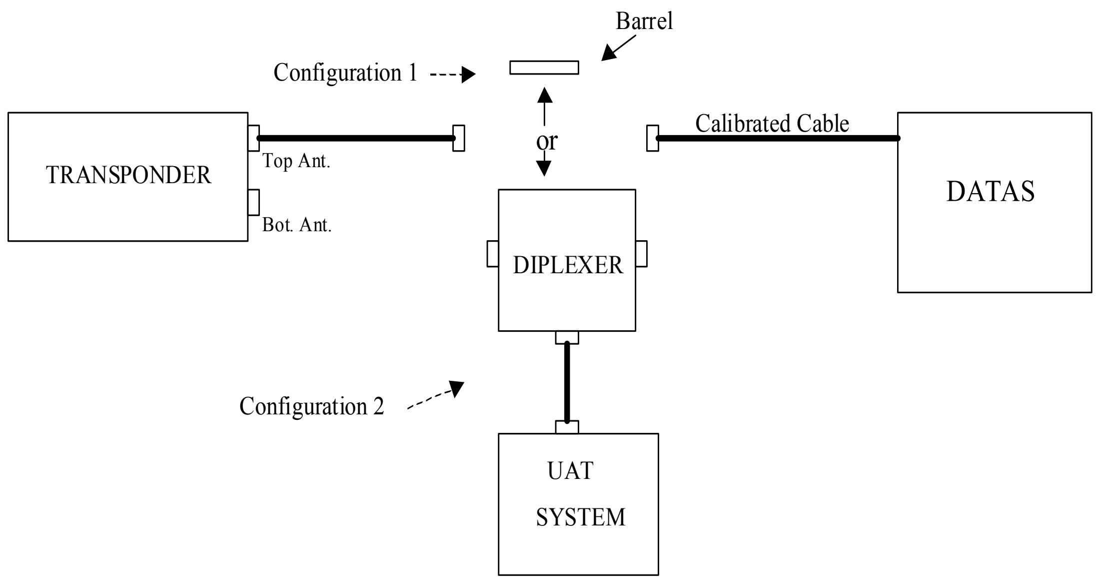

Figure 3-1 – Diplexer Test Configurations for Assessing the Impact on the ATC Transponder

Unless otherwise indicated, the UAT system was operating in a test mode where it was transmitting at an accelerated rate of 32 PRF (Pulse Repetition Frequency). This was done to enhance any potential effect the UAT might have on the transponder performance. In cases where this affected transponder performance, the tests were repeated with the UAT transmitting at the normal 1 PRF and/or not transmitting at all to better ascertain true Diplexer/UAT installation effects.

4 TEST DATA

4.1 Diplexer Characteristics

Measurements were performed to determine the channel characteristics of the Diplexer. The frequency response of each channel was measured and compared against expected performance. The UAT and Transponder channels were both measured as well as the channel to channel characteristics to determine the amount of isolation that could be expected across the Diplexer channels.

Figure 4-1 through Figure 4-3 depicts the channel characteristics of the Lorch Diplexer. Figure 4-4 through Figure 4-6 depicts the channel characteristics of the FSY Diplexer. After review of the requirements, it was anticipated that both Diplexers were designed with a wide enough bandwidth to pass UAT signals on the UAT channel and the 1030 and 1090 MHz SSR transponder signals on the transponder channel without distortion. As shown by Figure 4-2 and Figure 4-5, the transponder channel bandwidth encompasses both 1030 and 1090 MHz with approximately a span from 1015 to 1105 MHz to contain adequate bandwidth for each center frequency. The signals on 1030 and 1090 MHz are PAM with rise and fall times minimums of 50 nanoseconds. Also, 1030 MHz Mode S interrogation signals use DPSK modulation at a 4 MHz bit rate.

Testing that is described in Section 4.3 verifies that the Diplexer passes these signal types adequately to prevent performance degradation of the SSR transponder. The UAT channel bandwidth meets the CPFSK modulated UAT signal with frequency offsets of +/- 312.5 KHz and a data rate of 1.041667 Megabits per second. The UAT channel bandwidth of the Diplexer easily meets the bandwidth requirements of the UAT signal.

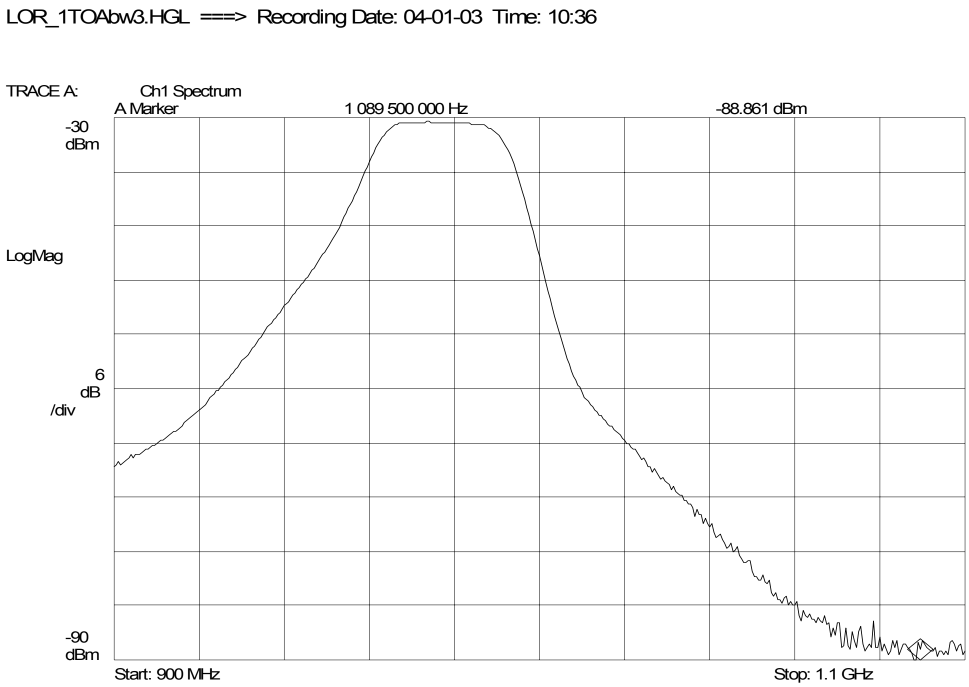

Figure 4-1 – Lorch Diplexer UAT Channel Frequency Characteristics

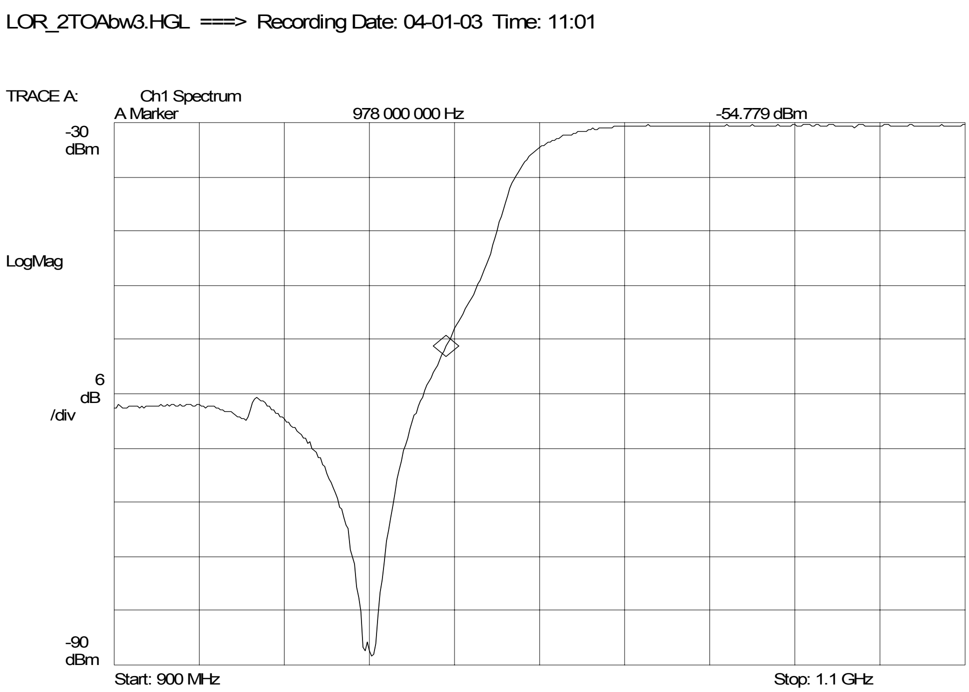

Figure 4-2 – Lorch Diplexer Transponder Channel Frequency Characteristics

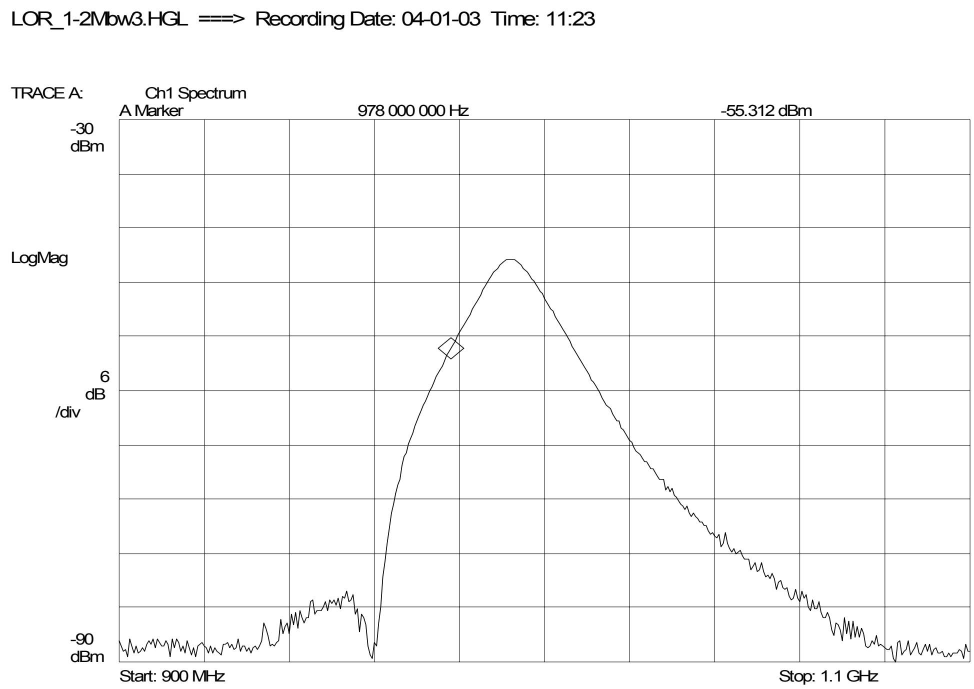

Figure 4-3 – Lorch Diplexer UAT to Transponder Channel Frequency Characteristics

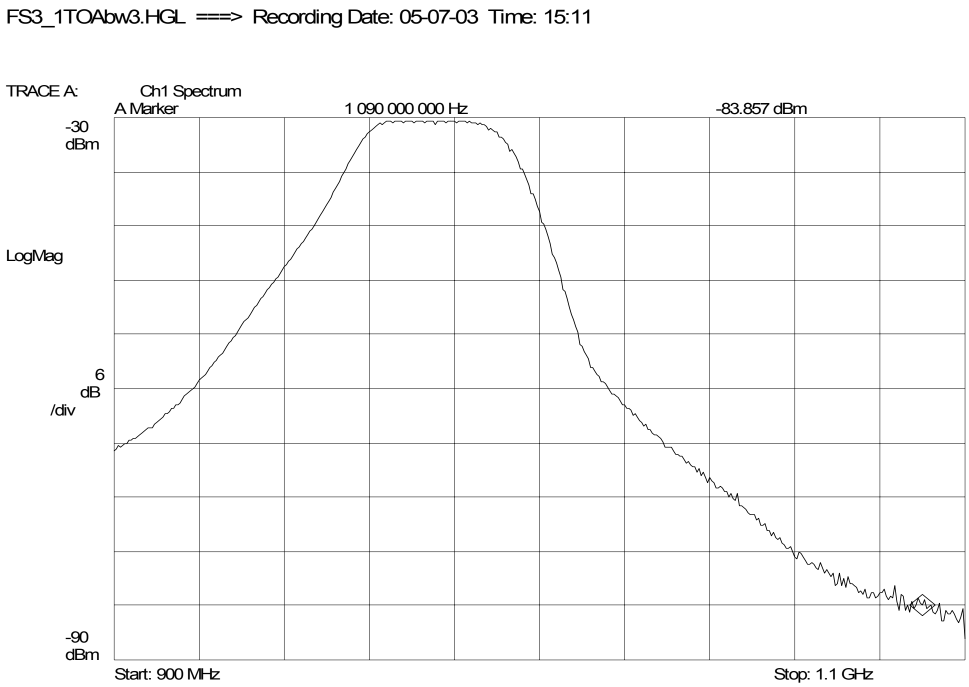

Figure 4-4 – FSY Diplexer UAT Channel Frequency Characteristics

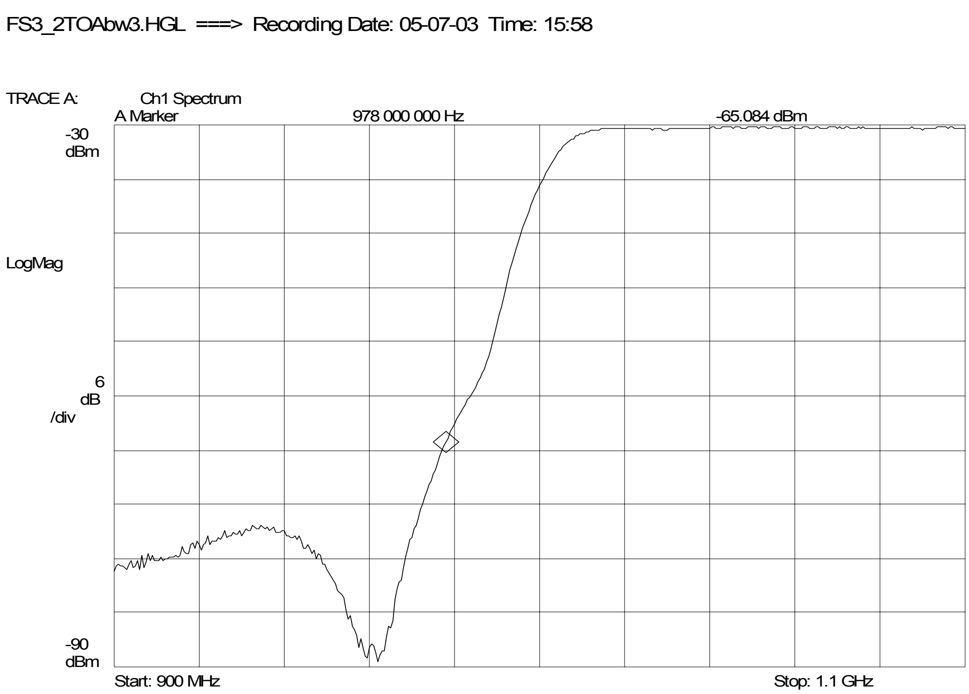

Figure 4-5 – FSY Diplexer Transponder Channel Frequency Characteristics

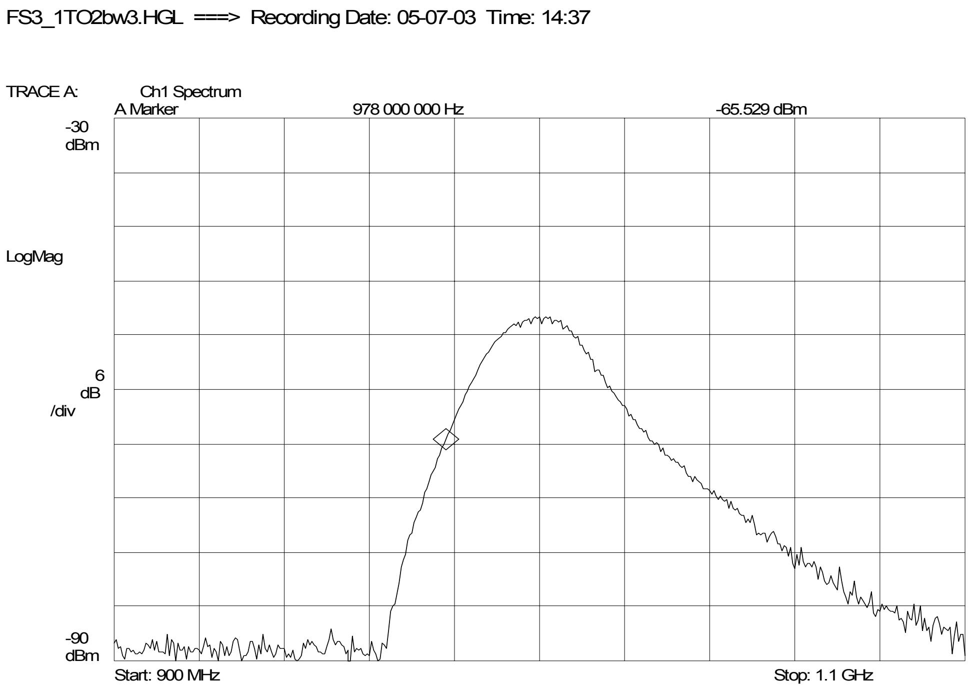

Figure 4-6 – FSY Diplexer UAT to Transponder Channel Frequency Characteristics

4.2 Impact of ATCRBS/Mode S Transponder on UAT System

Tests were conducted to determine the performance of UAT receivers when receiving UAT signals through the Diplexer. The assessment was performed using the message success rate of UAT reception of the UAT Long Message since the UAT sensitivity specification for Long Message reception is the more difficult to meet. The standard for performance used to assess the effect of the Diplexer was to compare results with the performance measured without the Diplexer. As shown in Figure 4-7 and Figure 4-8, the sensitivity of the UAT receiver is less than 0.5 dB less sensitive through both the Lorch and FSY Diplexers. This is consistent with the expected loss across the Diplexer. Figure 4-7 shows the results with the 1.2 MHz receiver filter and Figure 4-8 contains the 0.8 MHz filter results.

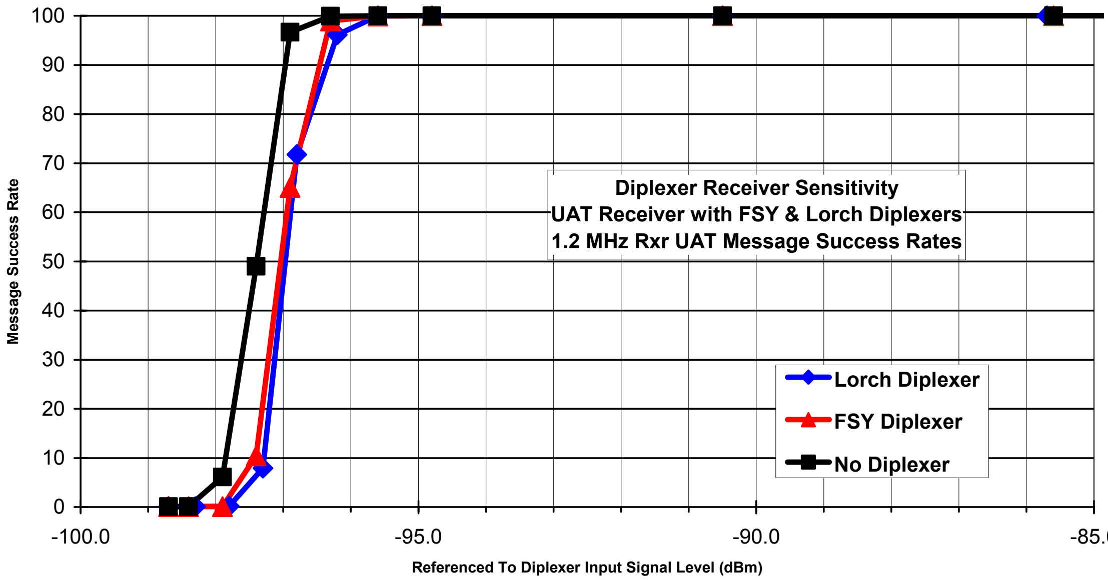

Figure 4-7 – UAT 1.2 MHz Receiver Sensitivity with Diplexer

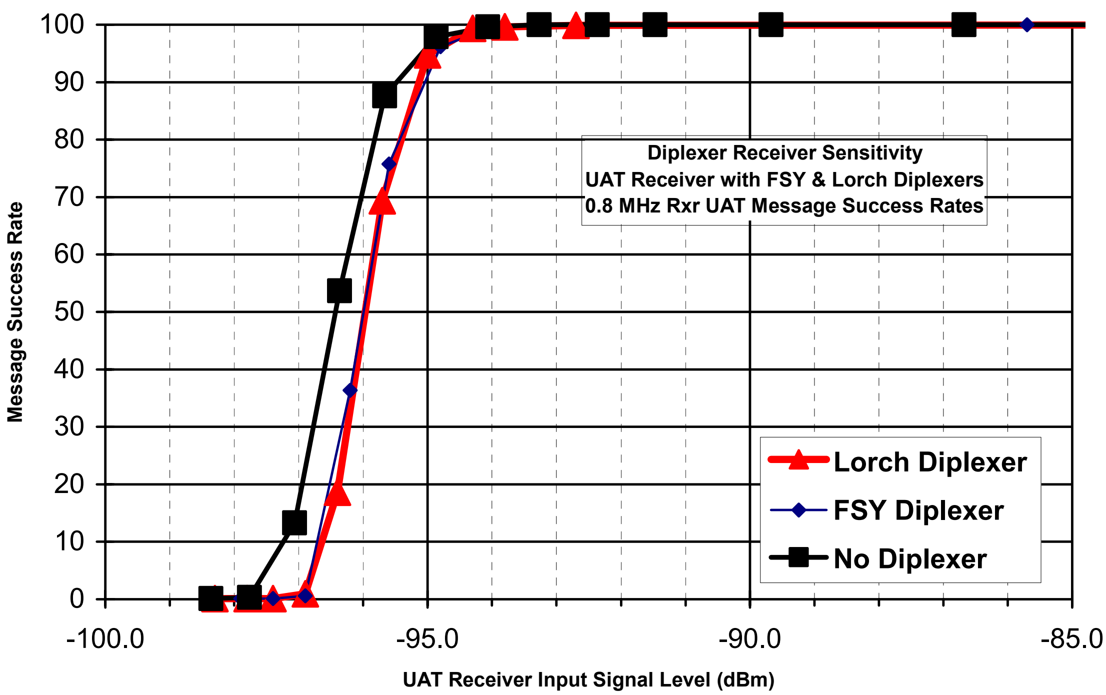

Figure 4-8 – UAT 0.8 MHz Receiver Sensitivity with Diplexer

To insure that the Diplexer was not introducing any distortion to the UAT signal, further tests were conducted with the Forward Error Correction (FEC) disabled. The prototype UAT units that were used for the testing incorporated additional test related features to assist in testing efforts conducted during the UAT MOPS development. One of the test features was the ability to disable FEC at the receiver. With FEC off, it could be determined if there were any low level effects to the UAT signal caused by the Diplexer that might have been masked by FEC. FEC allows bit errors to be corrected, up to 7 bit errors in up to 7 bytes can be corrected with the Reed-Solomon coding of the UAT Long Message. With FEC disabled, any single bit error that would be caused by the Diplexer would lead to an unsuccessful message decode enabling measurement to even the slightest degradation that the Diplexer may cause. Tests were conducted with both the Lorch and FSY Diplexer to verify that message success rate versus amplitude was not impacted by the Diplexer. Figure 4-9 contains the results from these tests. As shown, the performance with and without the Diplexer are comparable, within the 0.5 dB loss attributable to the Diplexer, verifying that the Diplexer does not introduce bit errors that would have been corrected and undetected at the message level of analysis. The results indicate that a Diplexer will pass the UAT signals without distortion and that UAT receiver performance is not degraded by the Diplexer.

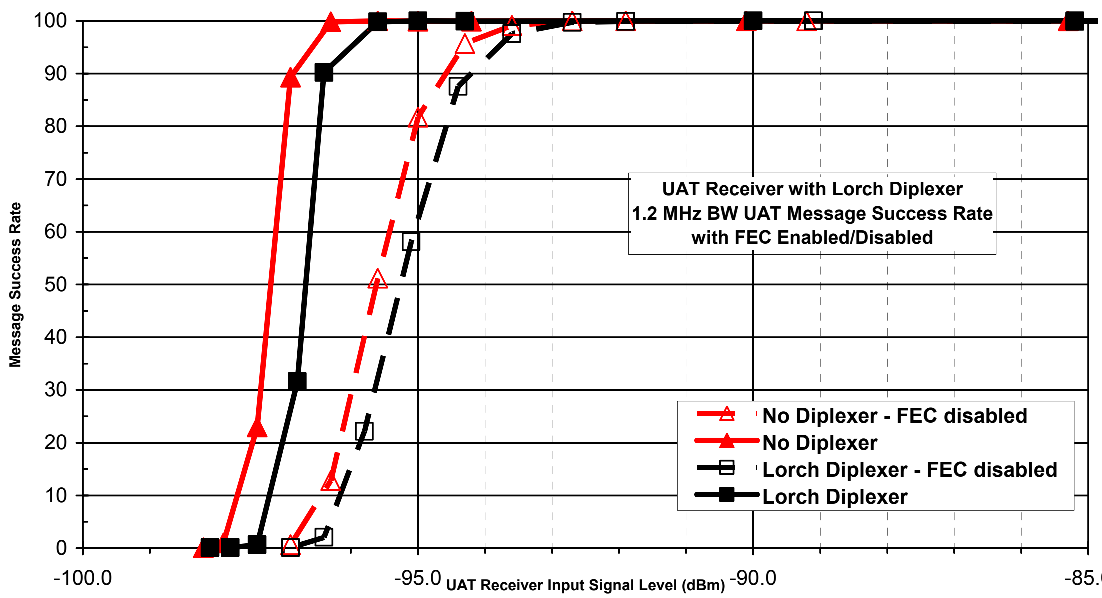

Figure 4-9 – UAT 1.2 MHz Receiver with Lorch Diplexer – FEC Disabled Comparisons

Additional tests were conducted to insure proper operation of UAT receivers with the use of a Diplexer. Because of the frequency separation between UAT and SSR signals, there was no anticipated performance issue with overlapping UAT transmissions and transponder reply signals through a Diplexer. To insure that this was the case, tests were conducted to verify that Mode S reply and UAT Long Message signals, that are transmitted simultaneously from the on-board transponder and UAT equipment, resulted in successful message reception by a remote UAT receiver. The test was conducted by varying amplitude to simulate distance between the transmitting aircraft and the receiving aircraft. Measurements were made to compare the reception of the UAT signal as a function of amplitude or distance. Measurements were made with and without FEC enabled to verify that the Diplexer was not impacting performance at the bit detection level that would otherwise be masked by FEC. The tests were performed with a Mode S reply signal since it is a higher duty cycle signal and would be more destructive than an ATCRBS reply if a problem with overlapping signals happened to occur. The results are shown in Figure 4-10 and Figure 4-11.

The performance with UAT signals overlapped with Mode S replies is identical to the non-overlapping baseline results, with the exception of the loss across the Diplexer. There were no performance differences without FEC enabled, verifying that the Diplexer was not causing low level distortions masked by FEC.

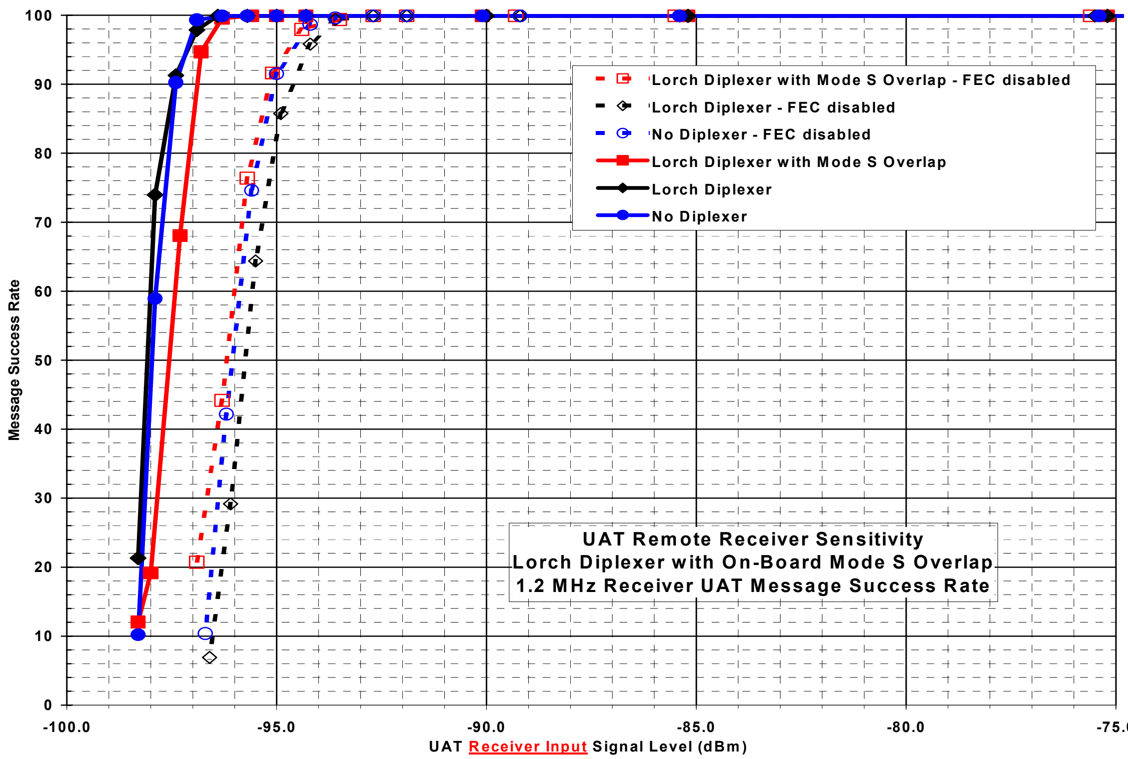

Figure 4-10 – Mode S with Lorch Diplexer and Remote UAT 1.2 MHz Receiver

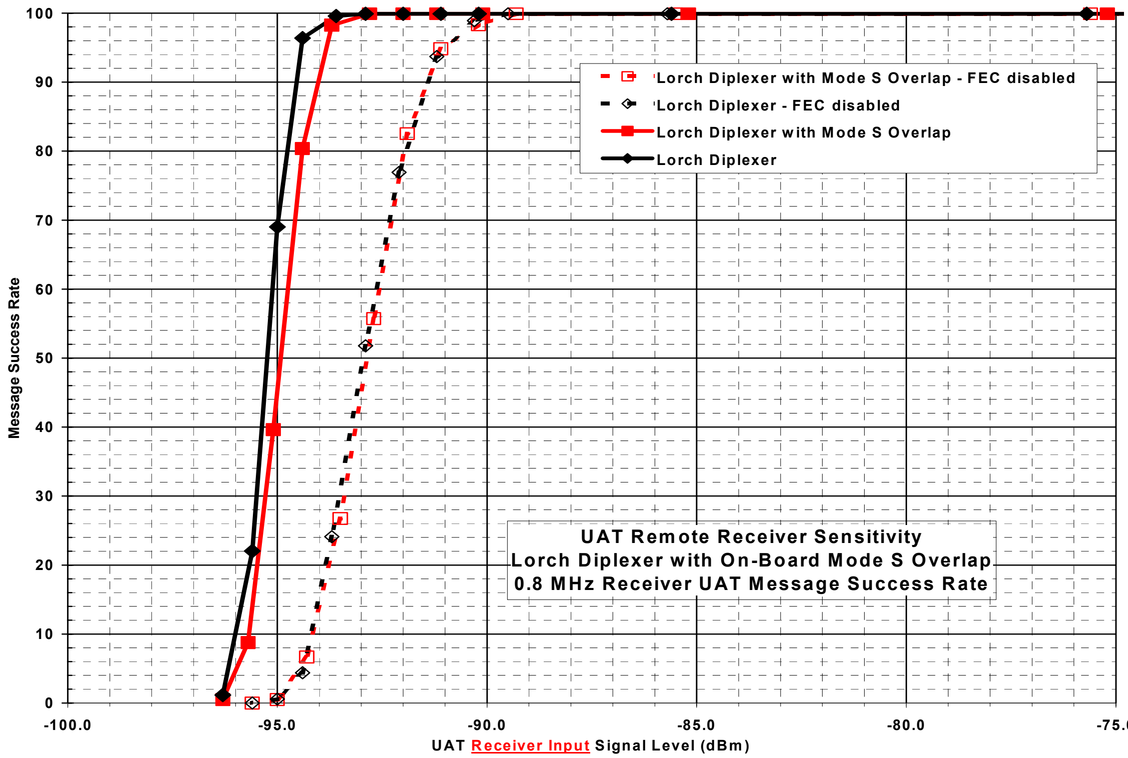

Figure 4-11 – Mode S with Lorch Diplexer and Remote UAT 0.8 MHz Receiver

Tests were conducted to determine the effects of SSR transponder signals on UAT reception on the aircraft. During the development of the UAT MOPS, the performance of UAT receivers on the aircraft factored co-site transmissions into the performance evaluation. A conservative approach was adopted that assumed that any 1090 MHz SSR transmission that overlaps a UAT signal results in a lost message.

Tests were conducted during the development of the UAT MOPS that showed that UAT Messages, when overlapped by a co-site ATCRBS or Mode S reply or squitter transmission, could be decoded by the on-board UAT receiver. Obviously, the performance of the UAT receiver depended on the power level of the 1090 MHz ATCRBS or Mode S replies relative to the UAT received power level.

Tests were performed with the Diplexer to compare the ability of the on-board UAT receiver when overlapped by SSR 1090 MHz transmissions through a Diplexer. The Diplexer does provide isolation between the SSR transponder port and the UAT port, so the UAT reception could benefit from the use of a Diplexer. Results are shown in Figure 4-12, Figure 4-13 and Figure 4-14.

Figure 4-12 shows results using a +47 dBm ATCRBS reply presented at the input port to the Transponder Channel of the Diplexer. As shown, the results indicate no discernible difference in performance between the UAT receiver with and without the ATCRBS reply overlap through the Diplexer. The loss across the Diplexer is the only difference in performance between the Diplexer without an ATCRBS overlap, the Diplexer with an ATCRBS overlap and the test cases with no Diplexer.

Figure 4-13 shows the impact on performance because of on-board Mode S replies transmitted through the Diplexer Transponder Channel with power levels of +30 dBm and +48 dBm. The UAT receiver is severely desensitized by the 1090 MHz Mode S signal. The UAT receiver is desensitized by more than 9 dB with the Mode S reply level of +30 dBm at the Transponder Channel input to the Diplexer. The UAT receiver is desensitized over 17 dB by the +48 dBm Mode S signal as shown. The isolation provided between the channels of the Diplexer improves the performance of the on-board UAT receiver in the face of an overlapping Mode S reply, but the performance is not significant enough to derive benefit with the Diplexer.

Figure 4-14 shows the performance of the 0.8 MHz receiver when overlapped by an ATCRBS reply with a power level of +30 dBm at the Transponder Channel input to the Diplexer. Performance is essentially the same as the performance without the ATCRBS reply overlap.

Tests were conducted to verify that the overlap of ATCRBS and Mode S replies did not impact UAT Message reception through the Diplexer. This test case was not deemed as particularly meaningful since it was already demonstrated that the on-board UAT receiver was fairly tolerant of high power overlapping ATCRBS and Mode S signals from the on-board SSR transponder. Power levels expected at the antenna port of the Diplexer would be lower than the power levels caused by the on-board transponder and experienced by the on-board UAT receiver. UAT reception had previously been shown to be tolerant of overlapping ATCRBS and Mode S 1090 MHz signals due to the frequency separation. Therefore, ATCRBS and Mode S 1090 MHz signals from remote aircraft are not an issue for UAT reception at expected power levels. An extreme condition was tested to determine the resilience of the on-board UAT receiver when subjected to an unrealistic power level at the antenna port. An overlapping ATCRBS reply was used with a power level of +30 dBm to measure receiver performance. The results are shown in Figure 4-15. The results indicate that even with the +30 dBm ATCRBS overlap, the UAT receiver performance degradation was negligible. A set of measurements was done with FEC disabled to determine if bit errors were occurring that were masked by the FEC. As shown, bit errors were caused by ATCRBS at +30 dBm.

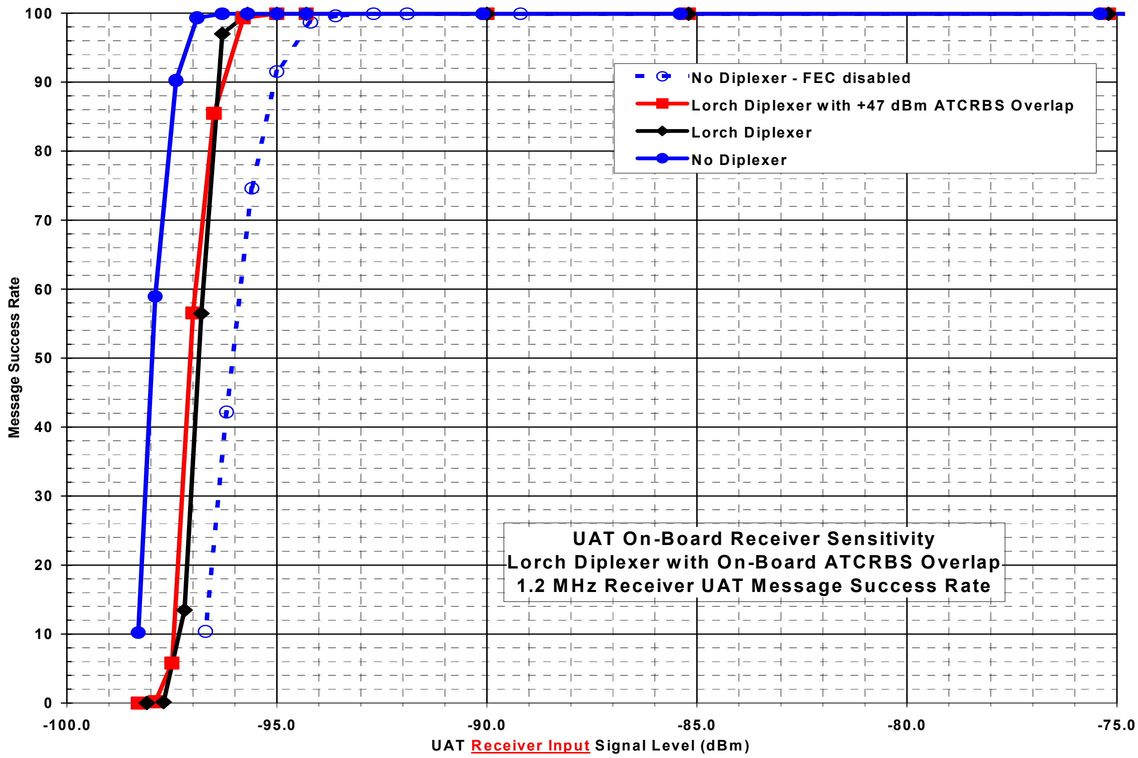

Figure 4-12 – Co-Site UAT 1.2 MHz Receiver with Lorch Diplexer and ATCRBS

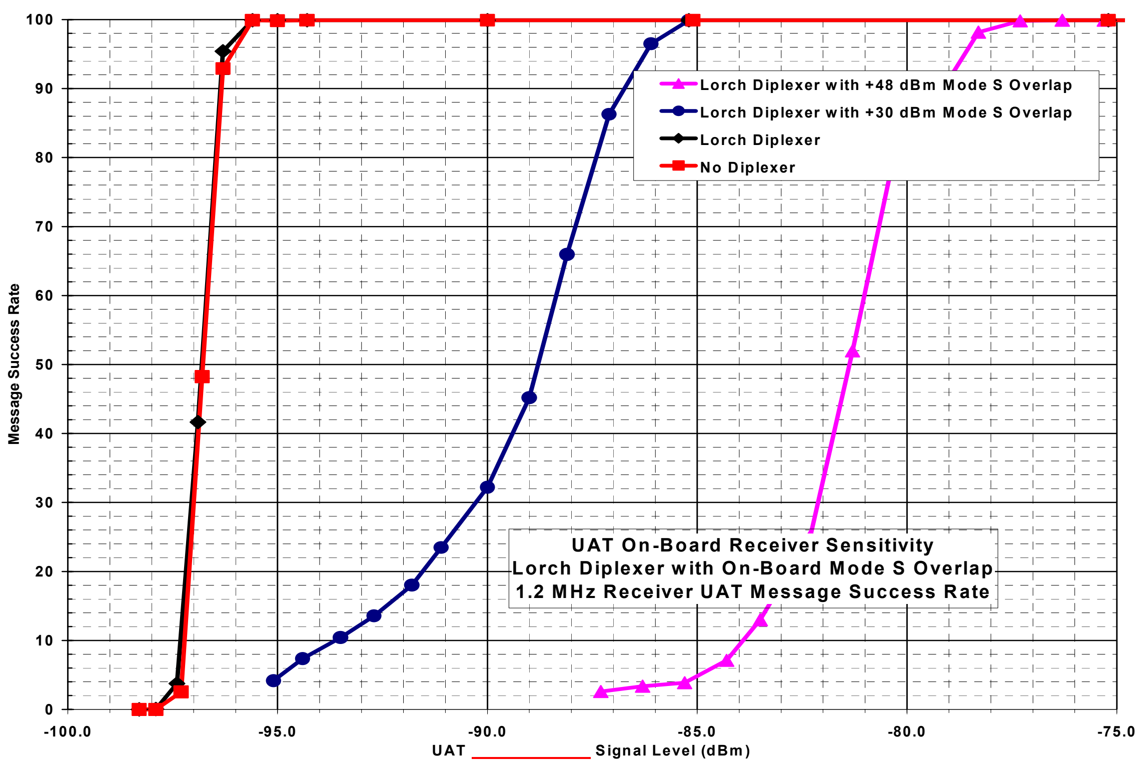

Figure 4-13 – Co-Site UAT 1.2 MHz Receiver with Lorch Diplexer and Mode S

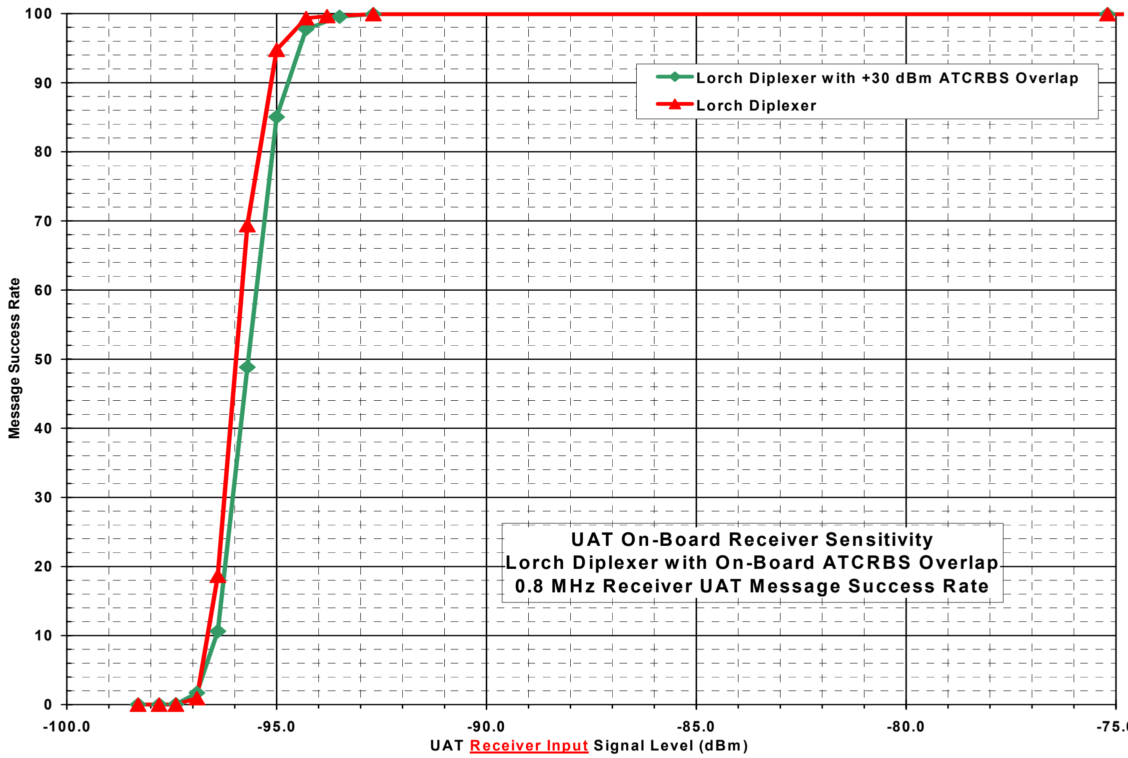

Figure 4-14 – Co-Site UAT 0.8 MHz Receiver with Lorch Diplexer and ATCRBS

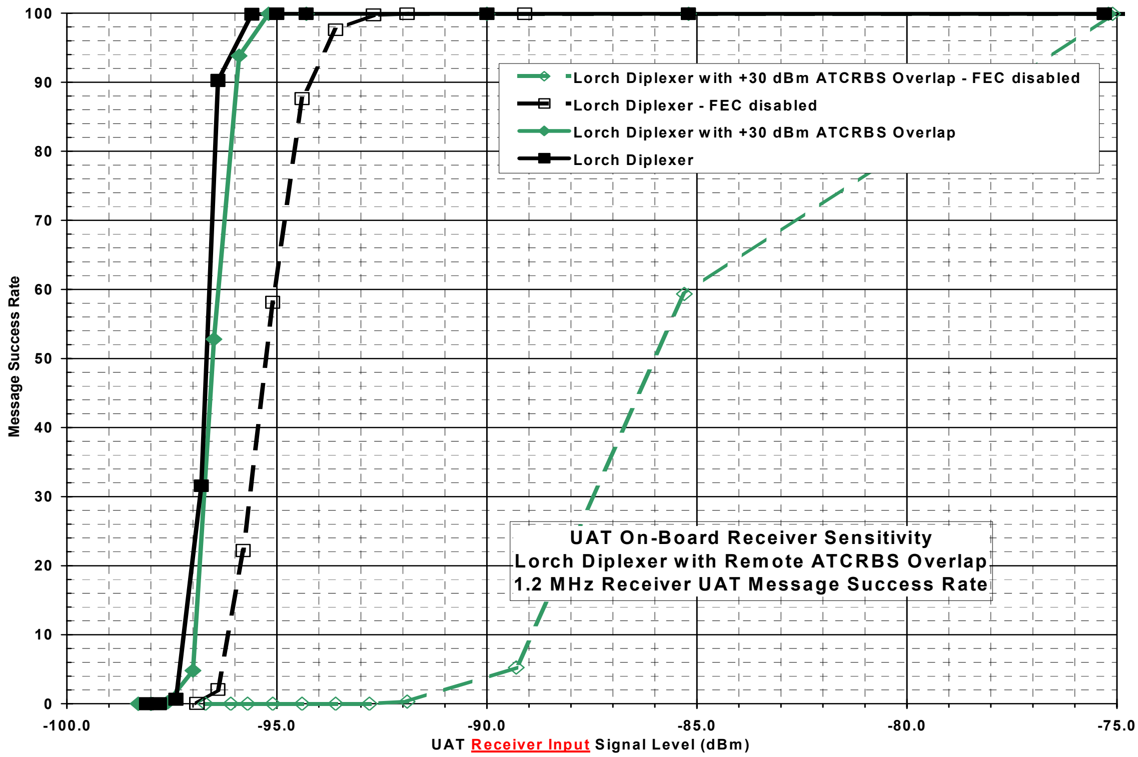

Figure 4-15 – UAT 1.2 MHz Receiver with Lorch Diplexer and Remote ATCRBS

4.3 Impact of UAT System on ATCRBS/Mode S Transponder

In anticipation of running parametric tests on the transponders through the Diplexers, the 1030 and 1090 MHz signals were observed using an oscilloscope to visually assess the effect a Diplexer might have during testing. Figure 4-16 shows the leading edge of an interrogation pulse at 1030 MHz before and after the Lorch WD-00046 Diplexer. The Diplexer does not appear to distort the pulse, but adds approximately 10 nanoseconds of delay. As this same delay will occur on the return path for the 1090 MHz reply, the overall affect will be an increase in 'reply delay' of 20 nanoseconds when using the Diplexer.

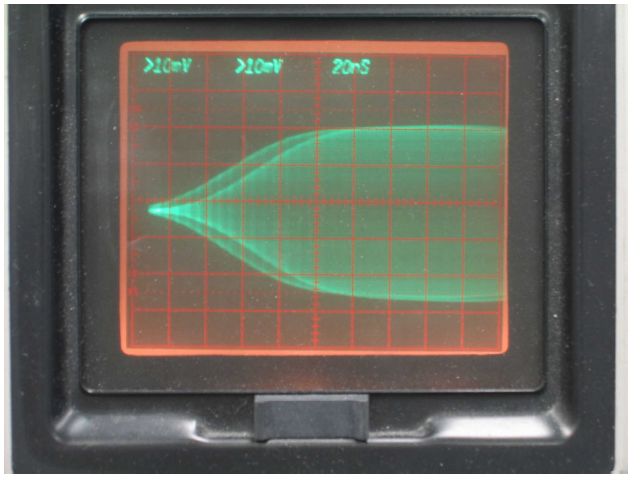

Figure 4-16 – 1030 MHz Interrogation Pulse Leading Edge Before and After the Lorch WD-00046 Diplexer.

The picture in Figure 4-17 below shows the first reply pulse of an ATCRBS reply with and without a Diplexer. The data was taken using a Mode S transponder. Although not shown on this picture because the oscilloscope was synchronized via 'internal' trigger, the pulse is also 'delayed' by approximately 20 nanoseconds when using the Diplexer. This is because of the 'two way' delay described above.

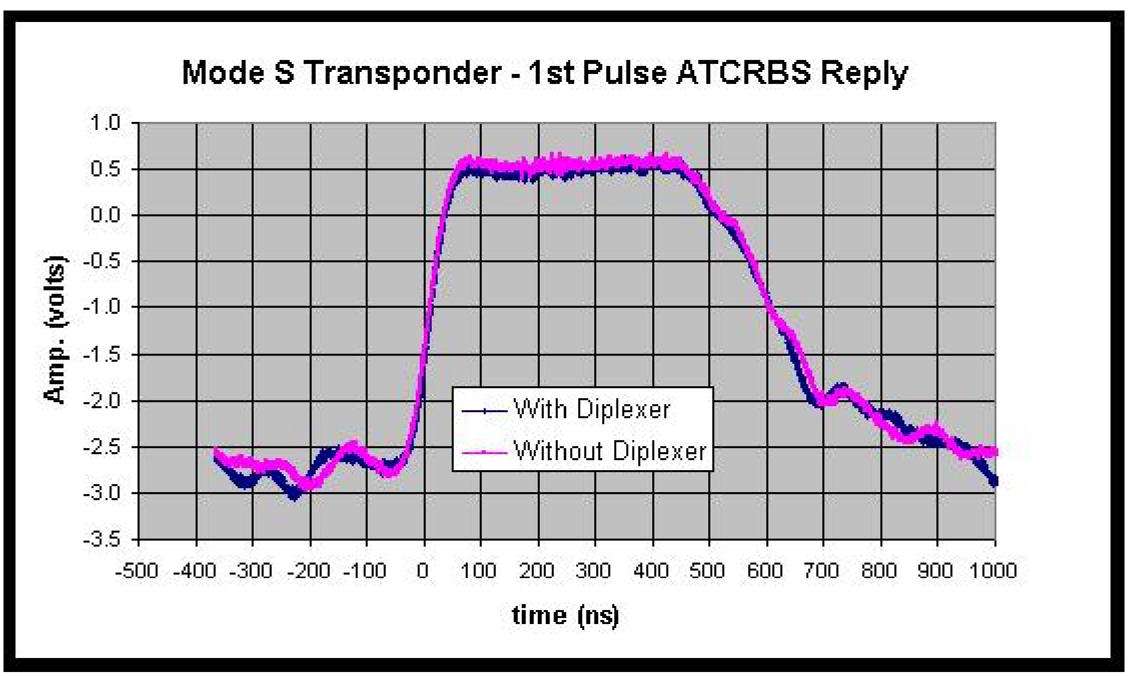

Figure 4-17 – 1090 MHz ATCRBS Reply Pulse (Video Signal) Before and After the Lorch WD-00046 Diplexer

The remainder of the data presented in this section to assess the impact of UAT System on ATCRBS/Mode S Transponder is the test results of the individual parameter testing.

4.3.1 Sensitivity

To determine the receiver sensitivity of each transponder, the Minimum Triggering Level (MTL) was measured. The MTL, as defined, is the minimum input power level required that produces at least a 90% reply rate. The interrogation signals used to determine MTL had all nominal pulse spacing and widths. ATCRBS MTL was measured for all 9 transponders, and ATCRBS/Mode S and Mode S only MTL was measured for the Mode S transponders. Receiver sensitivity is a parameter that is affected by VSWR therefore there is some variation in the measured MTL data. To lessen these effects, a subset of the transponders was re-tested with a slotted line and stub tuner installed to control VSWR. Each transponder was tested with and without each Diplexer to compare the effect on receiver sensitivity. There is expected to be a slight reduction in sensitivity with the Diplexer because of the transponder channel insertion loss. According to the Diplexer specifications required by the ADS-B MASPS, RTCA/DO-242A this insertion loss should be a maximum of 0.5 dB. To present the data, the following graphs show the change in transponder sensitivity after the addition of each Diplexer/UAT combination.

4.3.1.1 ATCRBS Sensitivity

Figure 4-18 and Figure 4-19 shows the average measured change in Mode 3/A and Mode C transponder receiver sensitivity after the installation of each antenna Diplexer. The data is very similar between the two interrogation modes, but there is some variation with the different transponders. The data in these plots was acquired with no means to control VSWR, and the variation can be mostly attributed to different VSWR values with each transponder. The overall effect is about a 0.33 dB loss of sensitivity with the FSY Diplexer, a 0.26 dB loss of sensitivity with the Lorch WD-00046, and about a 0.19 dB loss of sensitivity with the Lorch WD-00046-R1 Diplexer.

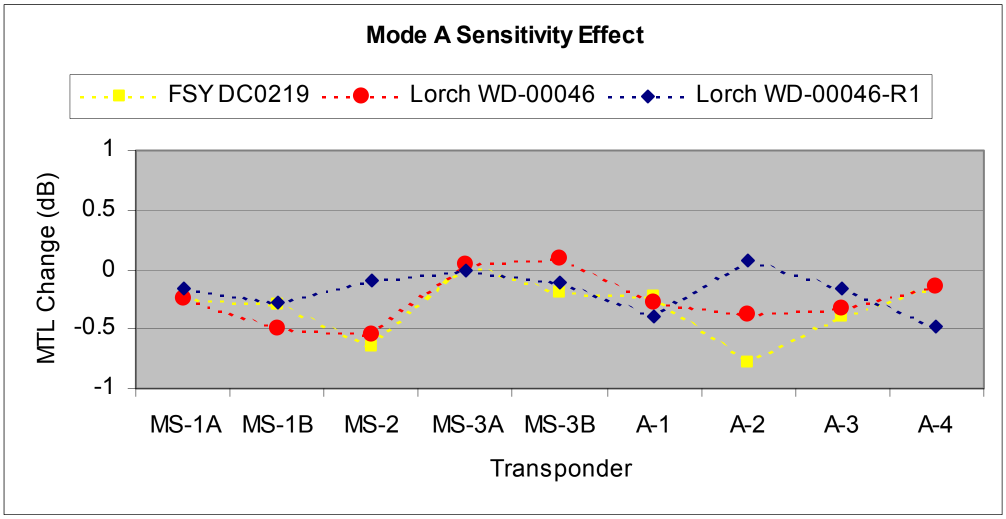

Figure 4-18 – Mode A Sensitivity

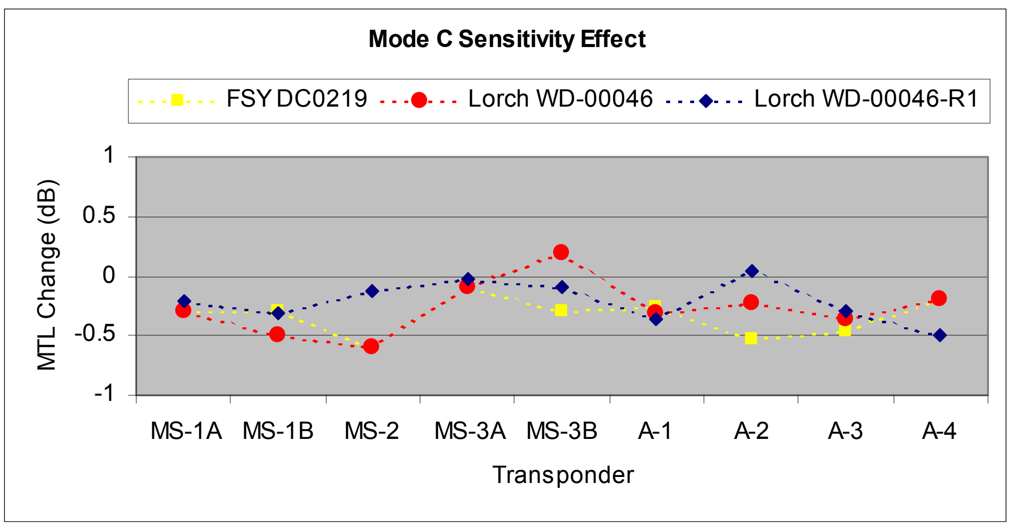

Figure 4-19 – Mode C Sensitivity

Mode 3/A and Mode C sensitivity tests were repeated with a slotted line and stub tuner installed to monitor and control VSWR. Because of test complexity, these tests were repeated on a subset of the transponders using only the Lorch WD-00046 Diplexer. The Lorch WD-00046 Diplexer was used because it is the prototype unit that meets all of the requirements set forth in RTCA/DO-242A. The data is presented in Figure 4-20.

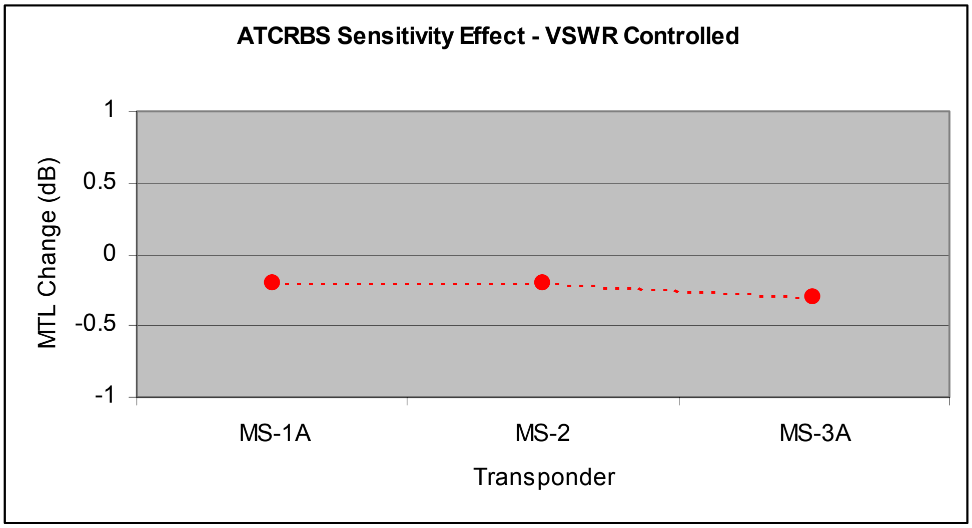

Figure 4-20 – ATCRBS Sensitivity with VSWR Controlled, Lorch WD-00046

The line in Figure 4-20 shows the data for Mode 3/A and Mode C (the results were the same for both modes). The overall reduction in MTL is an average of 0.23 dB in this case. The measured ATCRBS sensitivity loss with the Diplexers is less than the allowed maximum insertion loss (0.5 dB Max.).

4.3.1.2 Mode S Sensitivity

A similar method as was used to measure the Diplexers effect on ATCRBS sensitivity, the Mode A/Mode S, Mode C/Mode S, and Mode S only MTL's were measured for the five Mode S type transponders. With each Mode S signal format tested, the interrogation pulse characteristics were set to nominal. As was the case with the ATCRBS tests, there were variations in the measured effect because of changes in VSWR.

Again, the same subset of the transponders was re-tested while controlling VSWR. The results of the tests before controlling VSWR are presented in Figure 4-21 through Figure 4-23. The average overall effect with all three modes combined is about a 0.35 dB loss of sensitivity with the FSY Diplexer, a 0.26 dB loss with the Lorch WD-00046, and about a 0.14 dB loss of sensitivity with the Lorch WD-00046-R1 Diplexer.

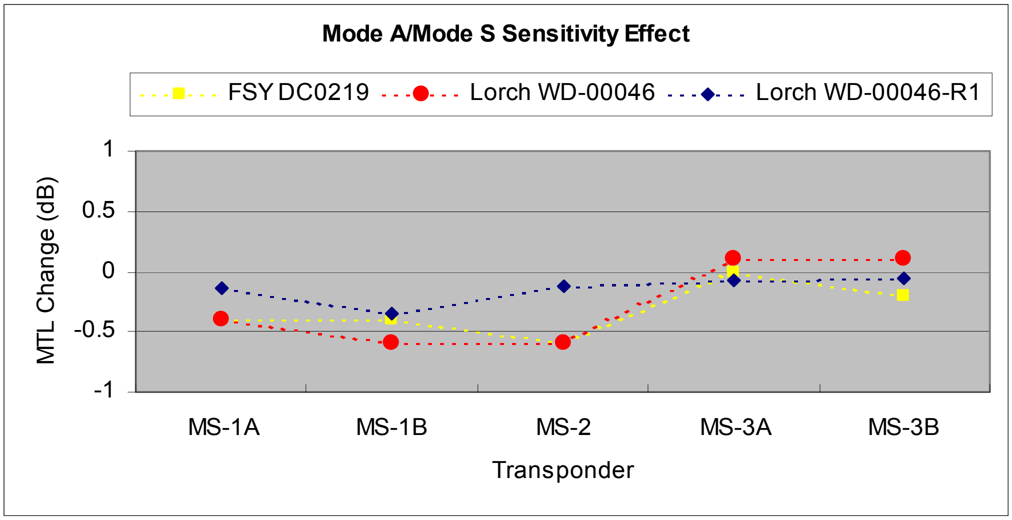

Figure 4-21 – Mode A/Mode S Sensitivity

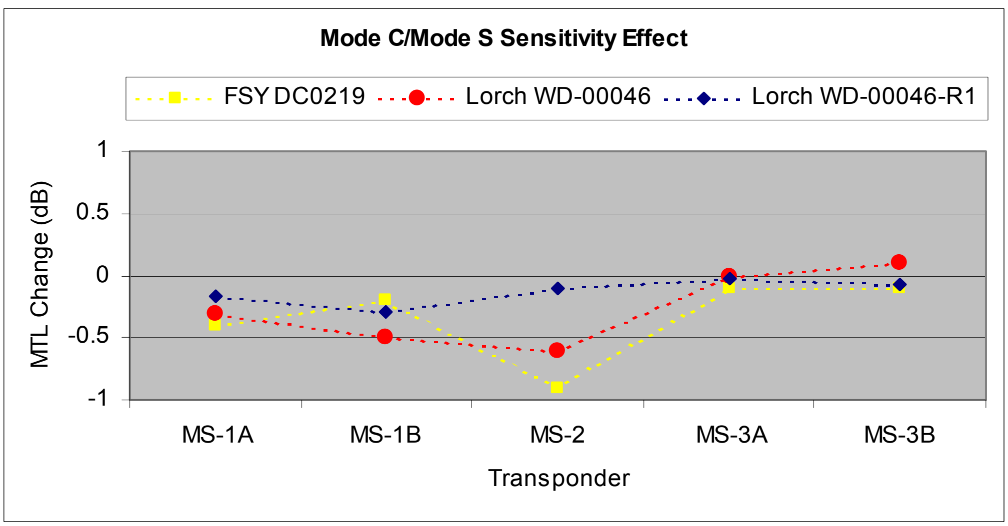

Figure 4-22 – Mode C/Mode S Sensitivity

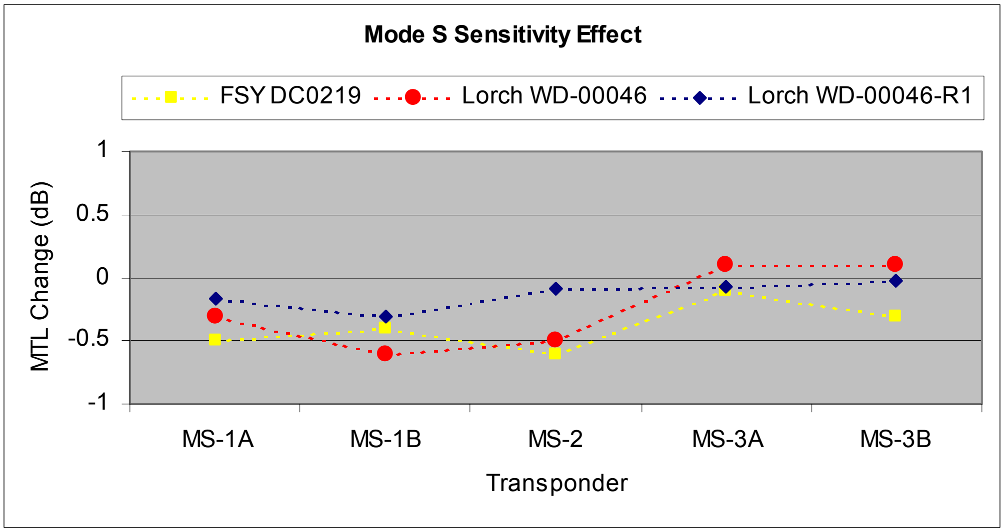

Figure 4-23 – Mode S Sensitivity

The MTL tests for the three Mode S signal formats were repeated with three of the transponders using the Lorch WD-00046 Diplexer while controlling VSWR. The results for the three formats were very similar and were averaged together to produce Figure 4-24.

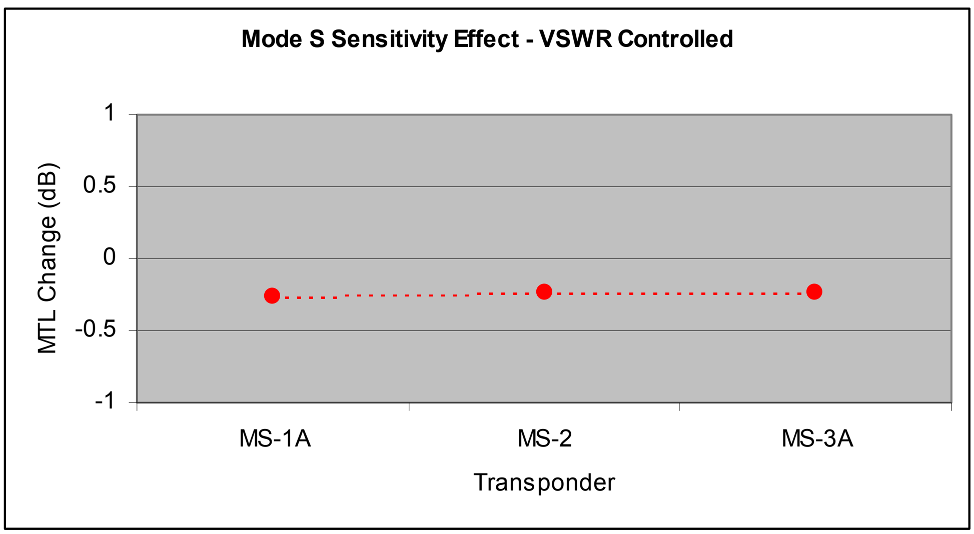

Figure 4-24 – Mode S Sensitivity with VSWR Controlled, Lorch WD-00046

The overall average effect the Lorch WD-00046 Diplexer had on Mode S receiver sensitivity that was measured while controlling VSWR was about -0.24 dB. This is consistent with the results using ATCBRS format interrogations, and is less than the required maximum signal loss through the Diplexer (0.5 dB max).

4.4 Dynamic Range

The term "Dynamic Range" refers to the reply probability exhibited by a transponder through the full range of interrogation amplitudes to which it is required to reply. The reply probability is required to be at least 90 percent for ATCRBS and ATCRBS/Mode S All-Call interrogations between MTL and –21 dBm. For Mode S interrogations, the reply ratio is required to be at least 99 percent between MTL+3 and –21 dBm.

The Dynamic Range tests were performed by measuring the average reply rate while varying the interrogation power through the defined range. The purpose of these tests is to determine if the Diplexer/UAT installation is a detriment to the reply probability of the transponder. The data is presented by comparing the reply probability measured with and without the Diplexer/UAT installed. The '0' point on the Y-axis represents the average reply rate with no Diplexer. The three curves show the relative reply rates measured with the three Diplexers. Each data point is the deviation in cumulative average reply rate from the entire interrogation power range. Since the baseline average reply rate (the '0' point on the Y-axis) may be less than 100%, data points with the Diplexer/UAT may show a positive effect. For all dynamic range tests, the UAT was configured to transmit at the standard rate (1/Sec.) because the accelerated test rate (32/sec.) is not representative of operational conditions and may affect the average reply rate for some transponder/Diplexer combinations.

4.5 ATCRBS and ATCRBS/Mode S Dynamic Range

For ATCRBS Dynamic Range, the interrogation amplitudes used ranged from –21 dBm to –69 dBm in 1 dB increments. Figure 4-25 and Figure 4-26 shows the ATCRBS Mode A and Mode C Dynamic Range data respectively.

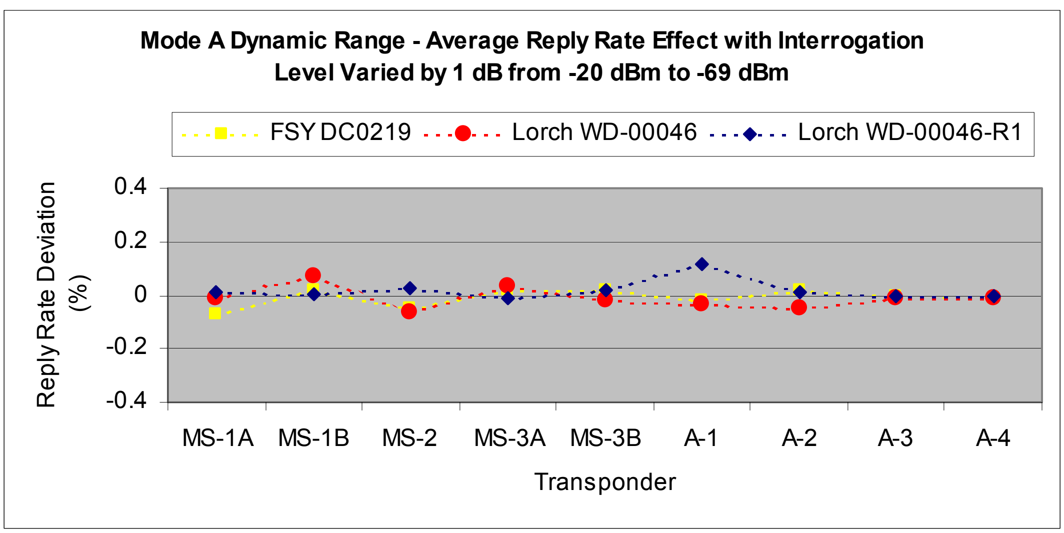

Figure 4-25 – Mode A Dynamic Range

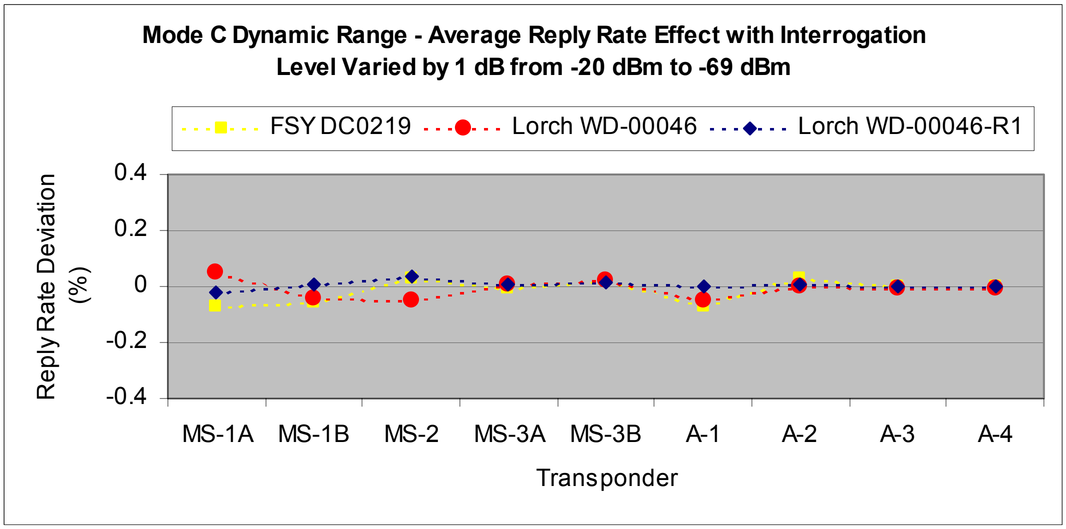

Figure 4-26 – Mode C Dynamic Range

The ATCRBS/Mode S Dynamic Range tests were measured in 5 dB steps from –20 dBm to –65 dBm. The 5 dB steps were used to reduce test time because of the lower PRF required for Mode S transmissions yet still provide a sufficient data sample to determine reply rate consistency. The results are presented in Figure 4-27 and Figure 4-28 for Mode A/Mode S and Mode C/Mode S Dynamic Range respectively.

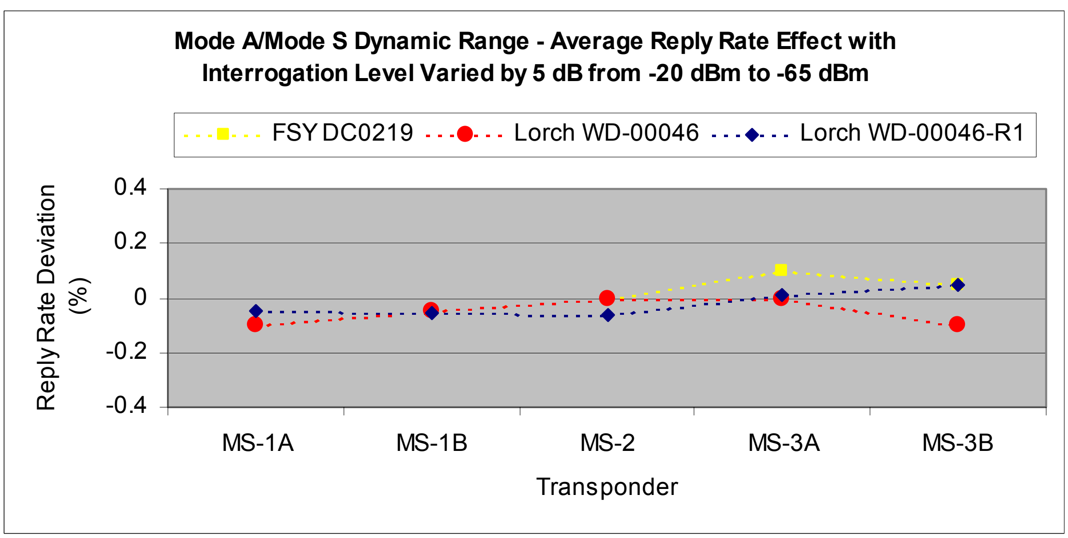

Figure 4-27 – Mode A/Mode S Dynamic Range

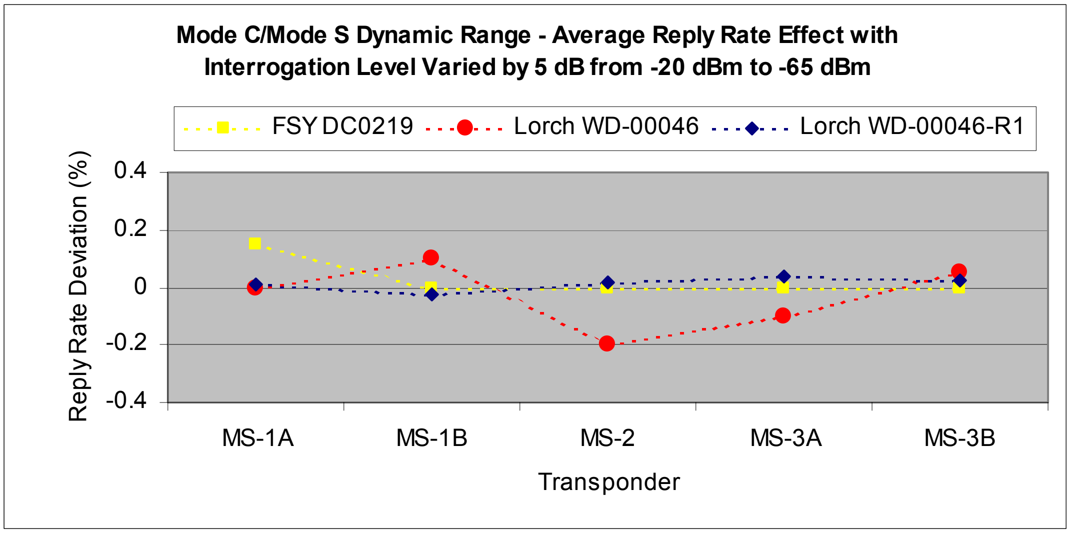

Figure 4-28 – Mode C/Mode S Dynamic Range

4.6 Mode S Dynamic Range

The reply ratio is required to be at least 99 percent for Mode S interrogations between MTL+3 and –21 dBm. The Mode S dynamic range tests were measured in 5 dB steps from –20 dBm to –65 dBm. Figure 4-29 shows the Mode S dynamic range test results.

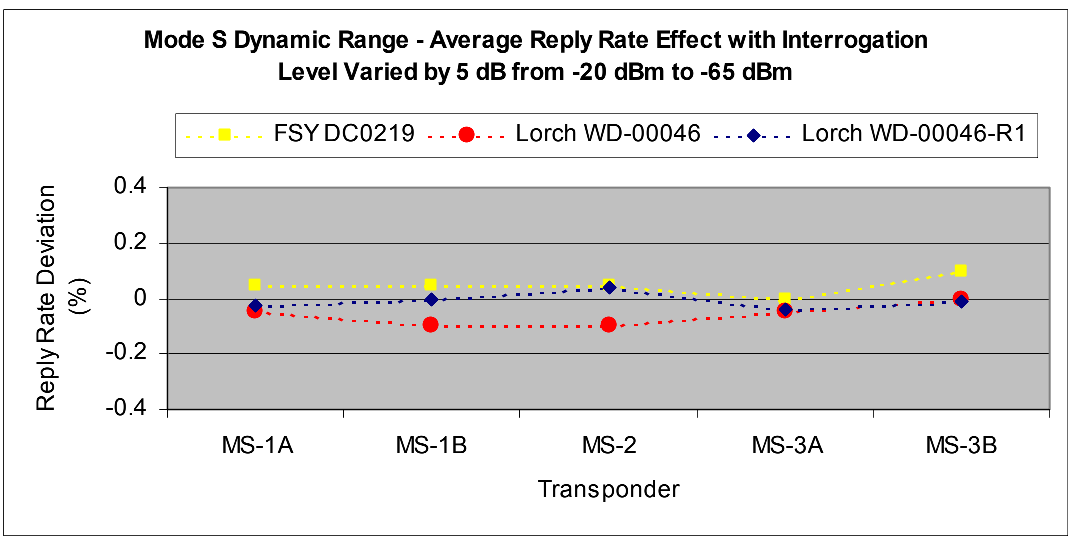

Figure 4-29 – Mode S Dynamic Range

All Dynamic Range data points show 0.2 percent or less reply probability deviation, and with most Diplexers the deviations are both positive and negative. The data shows that with an antenna Diplexer installation with a UAT transmitting at the once per second standard rate, there is no significant effect on the transponder reply probability through the dynamic range.

4.7 Reply Delay and Jitter

Reply delay is the time between a reference position of an interrogation and the start of the subsequent reply. The reference position used depends on the interrogation type, for ATCRBS it is the leading edge of the P3 pulse. For ATCRBS/Mode S it is the leading edge of the P4 pulse. And, for Mode S only interrogations, it is the sync phase position. Reply delay is customarily measured at the transponder port. The internal reply delay of the transponder is irrelevant to Diplexer testing, but the reply delay test is used here to measure the signal delay through the Diplexers.

"Reply delay jitter" is the extreme variation in the reply delay through the defined interrogation power range. Since Diplexers are passive devices it is not expected that they would affect reply delay jitter.

The DATAS procedure measures the delay while varying the signal level between the minimum triggering level and –20 dBm in 5 dB increments, and computing the average and extreme variations in reply delay. In the following graphs, for reply delay, each data point shows the deviation in the round-trip reply delay. It is referred to as round-trip delay because the measurement is made at the input to the Diplexer, therefore signal delay may be added both to the interrogation through the Diplexer as well as the subsequent reply back through the Diplexer. The reply delay jitter plots show the deviation in reply delay jitter measured with each transponder/Diplexer combination.

4.7.1 ATCRBS Reply Delay and Jitter

The ATCRBS reply delay and jitter tests use a Mode 3/A interrogation. Figure 4-30 shows the average increase in round-trip signal delay through the Diplexers with each transponder. The overall average with each Diplexer is as follows:

a. About 18 nanoseconds with the FSY Diplexer,
b. About 10 nanoseconds with the Lorch WD-00046 Diplexer, and
c. About 41 nanoseconds with the Lorch WD-00046-R1 Diplexer.

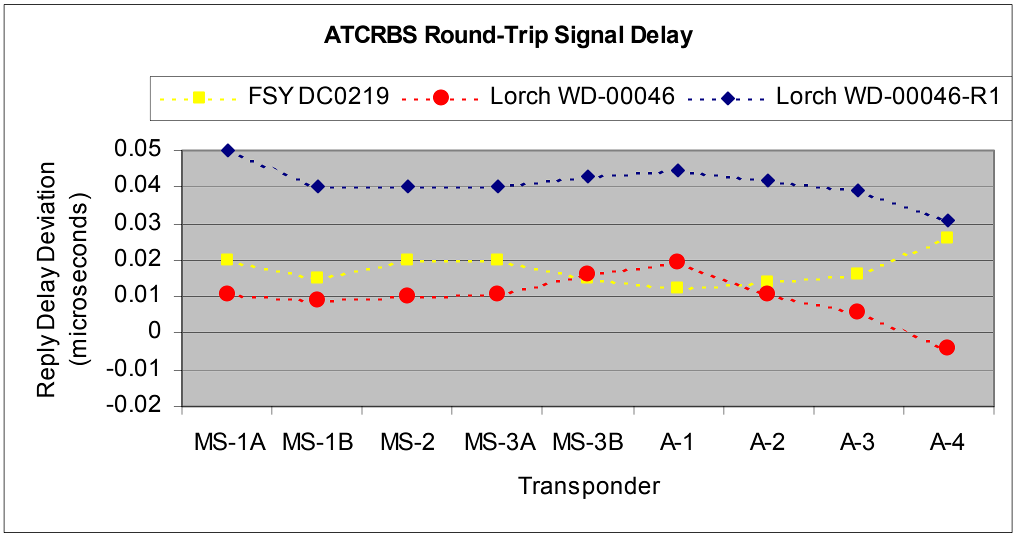

Figure 4-30 – ATCRBS Round Trip Signal Delay

Figure 4-31 shows the ATCRBS reply delay jitter deviation with the three Diplexers compared to the baseline jitter. There are slight variations in the measured reply jitter both positive and negative that normally occur as the test is repeated. The Diplexers had no measurable effect on ATCRBS reply delay jitter.

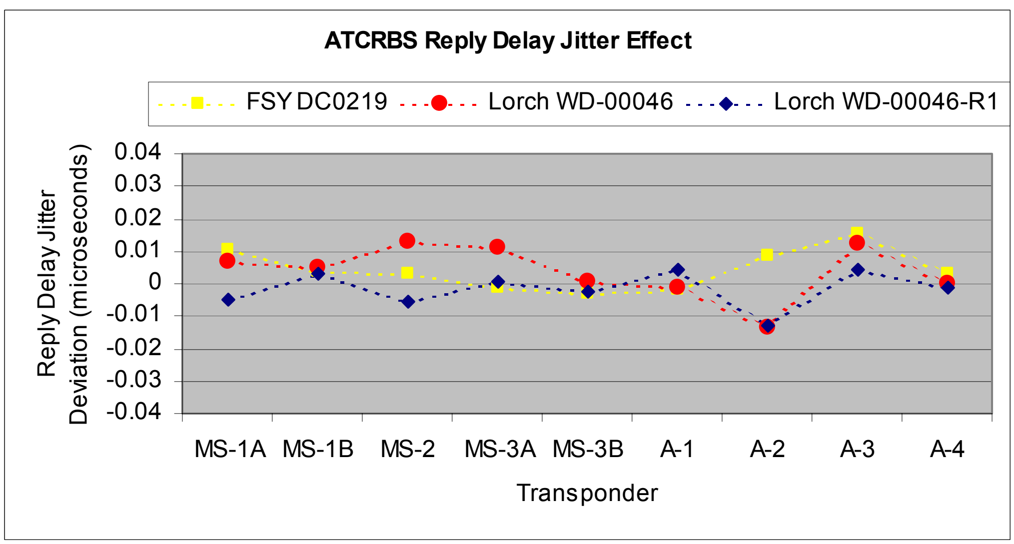

Figure 4-31 – ATCRBS Reply Delay Jitter

4.7.2 ATCRBS/Mode S Reply Delay and Jitter

The ATCRBS/Mode S reply delay and jitter tests use an ATCRBS/Mode S (P4 pulse) interrogation. Figure 4-32 shows the average increase in round-trip signal delay through the Diplexers with each transponder. The overall average with each Diplexer is as follows:

a. About 17 nanoseconds with the FSY Diplexer,
b. About 12 nanoseconds with the Lorch WD-00046 Diplexer, and
c. About 44 nanoseconds with the Lorch WD-00046-R1 Diplexer.

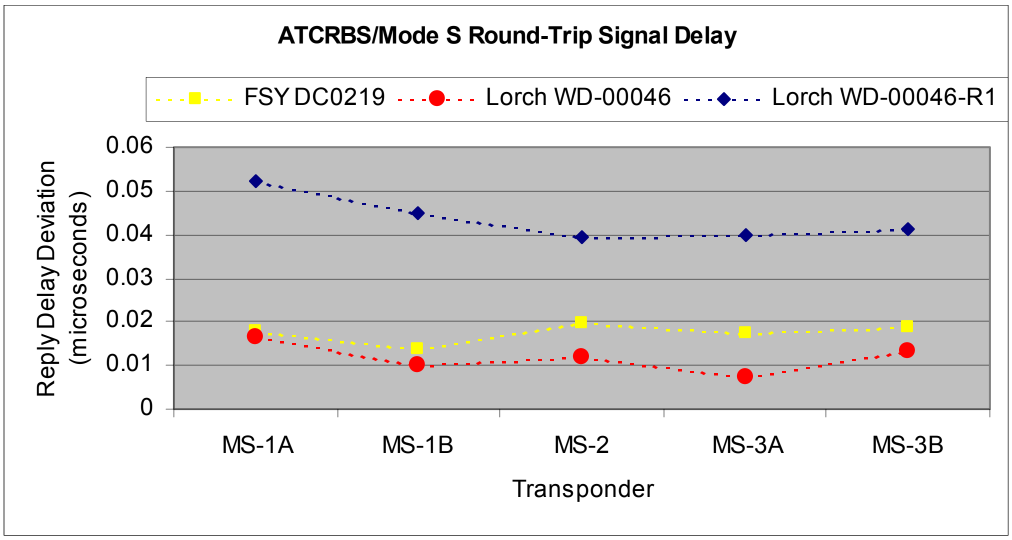

Figure 4-32 – ATCRBS/Mode S Round Trip Signal Delay

Figure 4-33 shows the ATCRBS/Mode S reply delay jitter deviation with the three Diplexers compared to the baseline jitter. There are slight variations in the measured reply jitter both positive and negative that normally occur as the test is repeated. The Diplexers had no measurable effect on ATCRBS/Mode S reply delay jitter.

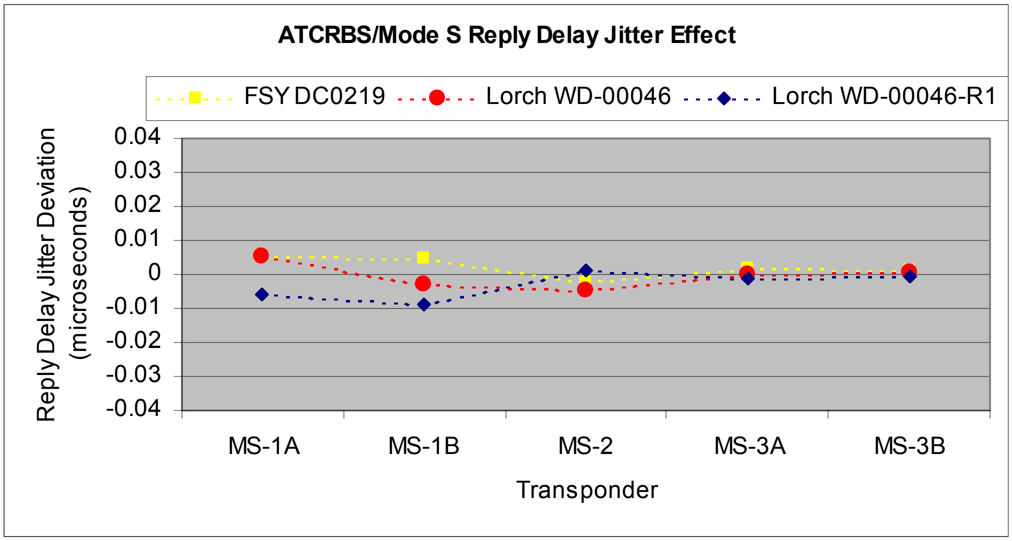

Figure 4-33 – ATCRBS/Mode S Reply Delay Jitter

4.7.3 Mode S Reply Delay and Jitter

The Mode S reply delay and jitter tests use a Mode S (P6 pulse) interrogation. Figure 4-34 shows the average increase in round-trip signal delay through the Diplexers with each transponder. The overall average with each Diplexer is as follows:

a. About 18 nanoseconds with the FSY Diplexer,
b. About 12 nanoseconds with the Lorch WD-00046 Diplexer, and
c. About 38 nanoseconds with the Lorch WD-00046-R1 Diplexer.

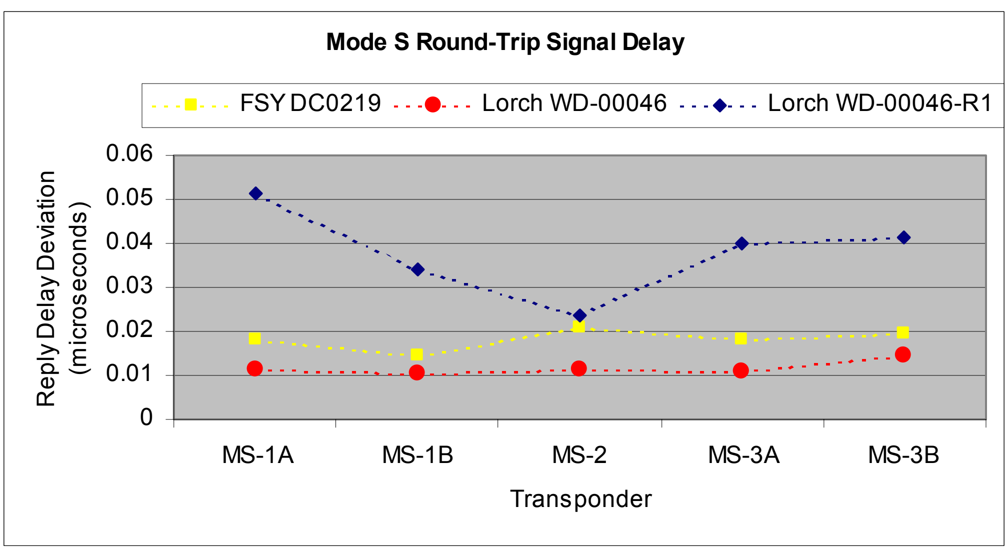

Figure 4-34 – Mode S Round Trip Signal Delay

Figure 4-35 shows the Mode S reply delay jitter deviation with the three Diplexers compared to the baseline jitter. There are slight variations in the measured reply jitter both positive and negative that normally occur as the test is repeated. The Diplexers had no measurable effect on Mode S reply delay jitter.

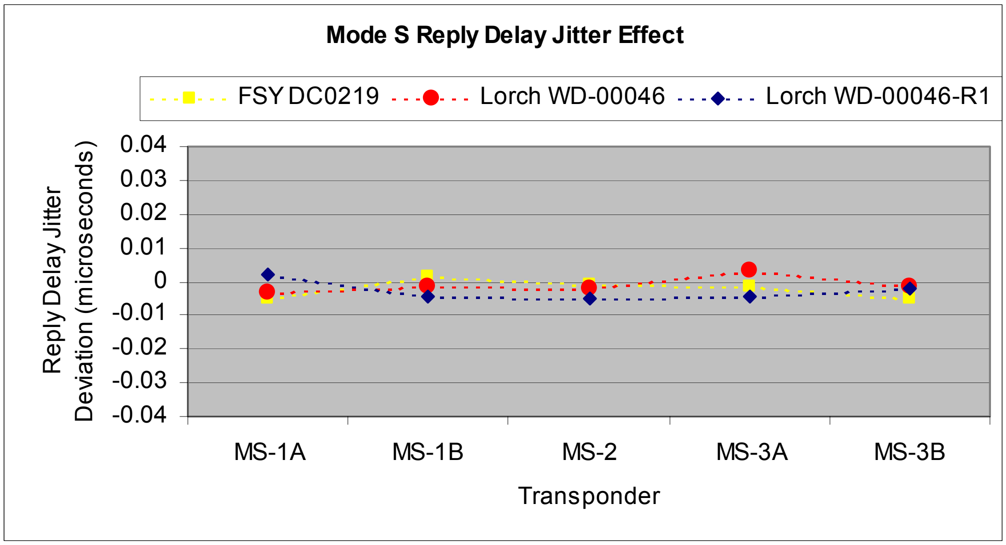

Figure 4-35 – Mode S Reply Delay Jitter

4.8 Reply Transmission Frequency

Tests were performed to measure the reply transmission frequency of the transponders. The reply transmission frequency of ATCRBS and Mode S transponders is nominally 1090 MHz. The DATAS test procedure automatically samples the frequency of each reply pulse and a minimum of 100 reply pulse groups were used to measure the average reply transmission frequency of each transponder. The test data compares the frequency at the antenna port of the transponder (with no Diplexer installed) to that of the antenna port of the Diplexer.

Figure 4-36 shows the average deviation in reply frequency measured with each Diplexer. There were no significant variations in reply frequency with the Mode S transponders. The ATCRBS transponders showed a frequency variation of up to about 4 MHz. Further testing determined that this variation is not directly due to the Diplexer, but due to the Diplexer installation changing the VSWR. Similar results were obtained just by installing various cable lengths with no Diplexer. A slotted line was installed to measure VSWR and it was verified that there is a change in VSWR when the Diplexer is installed. Frequency shift can be abated when installing a Diplexer by properly adjusted cable lengths to minimize VSWR and adjusting the transmitter frequency of the transponder, if necessary.

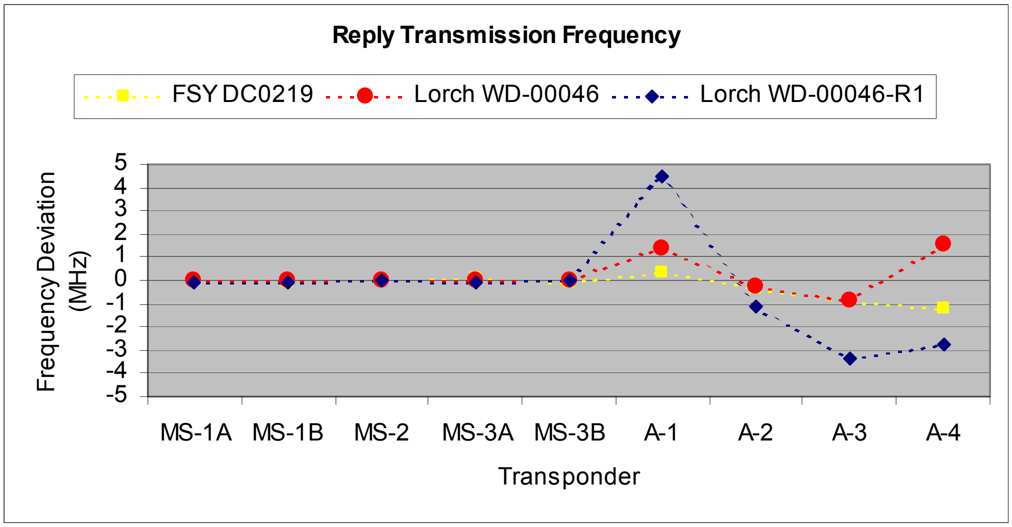

Figure 4-36 – Reply Transmission Frequency

4.9 RF Peak Output Power

The transponder RF peak output power was measured by determining the peak power of each pulse of each reply and computing the average power. The purpose of this test is to determine the transmit power loss through the Diplexer. To that end, the output power at the transponder antenna (with no Diplexer installed) is compared to that at the Diplexer antenna port after installation. The transponder RF peak output power is a parameter that is affected by VSWR. Therefore, there is some variation in the measured power data. In some cases the data even shows an increase in reply power after the Diplexer installation. Such variations can be achieved simply by adjusting cable lengths. Certainly, the Diplexers do not provide power output gain. To lessen these effects, and to better assess power loss through the Diplexer, a subset of the transponders was re-tested with a slotted line and stub tuner installed to control VSWR. These tests were performed only on the Lorch WD-00046 Diplexer and are presented in Figure 4-39 and Figure 4-40.

There is expected to be a slight reduction in power output with the Diplexer due to the transponder channel insertion loss. According to the Diplexer specifications required by RTCA/DO-282A this insertion loss should be 0.5 dB maximum. To present the data, the following graphs show the change in transponder output power after the addition of each Diplexer/UAT combination.

Figure 4-37 and Figure 4-38 show the initial measurement of ATCRBS and Mode S peak output power loss through the Diplexers without controlling the VSWR. The FSY Diplexer reduced the ATCRBS reply power an average of about 0.22 dB, the Lorch WD-00046 Diplexer reduced an average of about 0.17 dB, and the Lorch WD-00046-R1 reduced the ATCRBS reply power about 0.32 dB. These averages include both ATCRBS and Mode S type transponders.

The FSY Diplexer reduced the Mode S reply power an average of about 0.4 dB, the Lorch WD-00046 reduced an average of about 0.31 dB, and the Lorch WD-00046-R1 reduced the Mode S reply power about 0.31 dB.

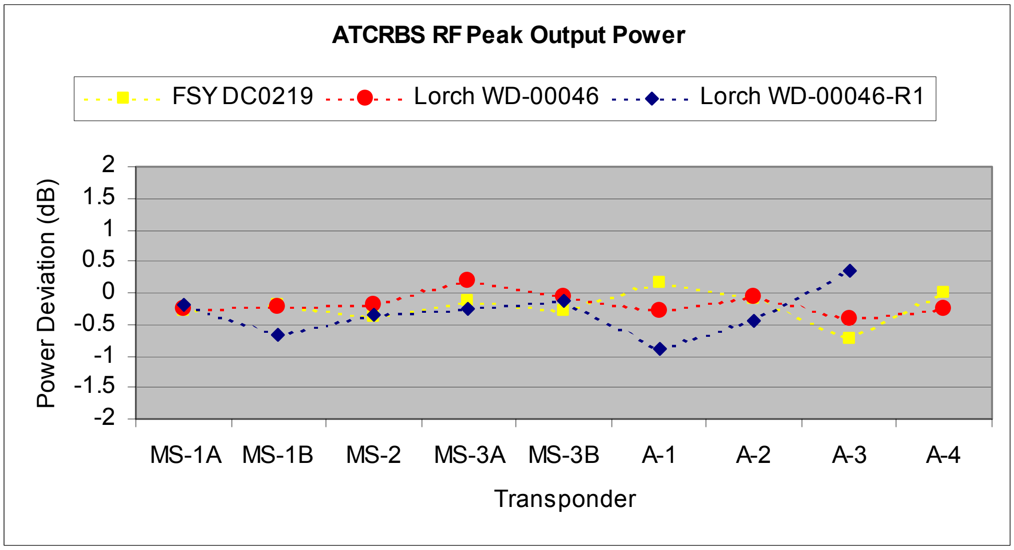

Figure 4-37 – ATCRBS RF Peak Output Power

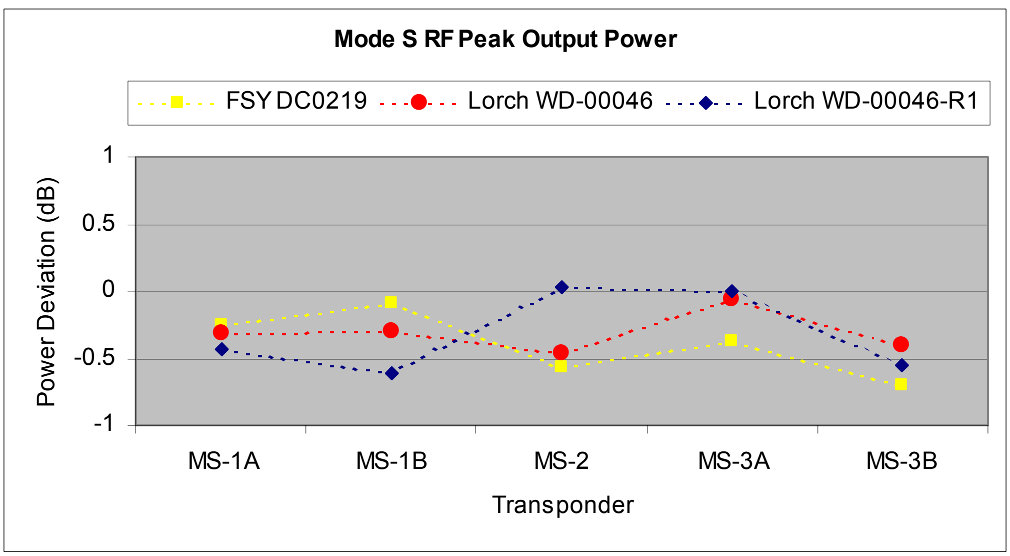

Figure 4-38 – Mode S RF Peak Output Power

Figure 4-39 and Figure 4-40 shows the RF peak power loss measured with the Lorch WD-00046 Diplexer with three of the transponders with VSWR controlled. A slotted line and stub tuner were used to monitor and tune the VSWR same value with both test configurations.

The average RF peak power loss measured using an ATCRBS reply was about 0.22 dB and with a Mode S reply was 0.34 dB.

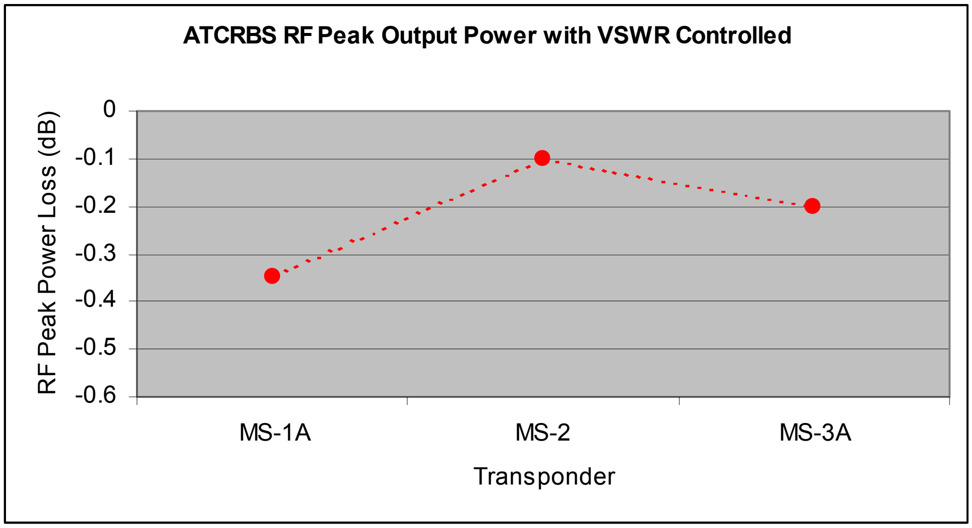

Figure 4-39 – ATCRBS RF Peak Power Loss Measured with VSWR Controlled, Lorch WD-00046 Diplexer

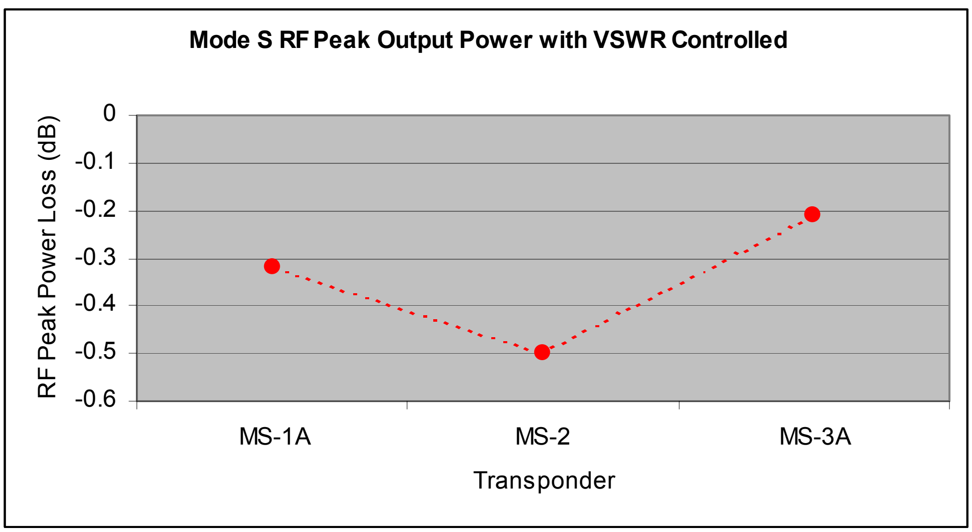

Figure 4-40 – Mode S RF Peak Power Loss Measured with VSWR Controlled, Lorch WD-00046 Diplexer

The overall average RF peak output power loss measured through each Diplexer was less than the specified maximum of 0.5 dB.

4.10 Reply Pulse Spacing

The reply pulse spacing of a sample of at least 100 reply pulse groups was measured and compared with, and without, each Diplexer installed. The reply pulse spacing test will help to determine if there is any distortion introduced that would affect the leading edge positions of the reply pulse group. The ATCRBS reply pulse spacing for all reply pulses is required to be within +/- 0.10 microsecond with respect to the first framing pulse. With each test run, the average position error of each reply pulse is recorded. To measure the Diplexers' effect, if any, the cumulative average reply pulse position error of all reply pulses is compared with, and without, the Diplexers. The results are shown in Figure 4-41.

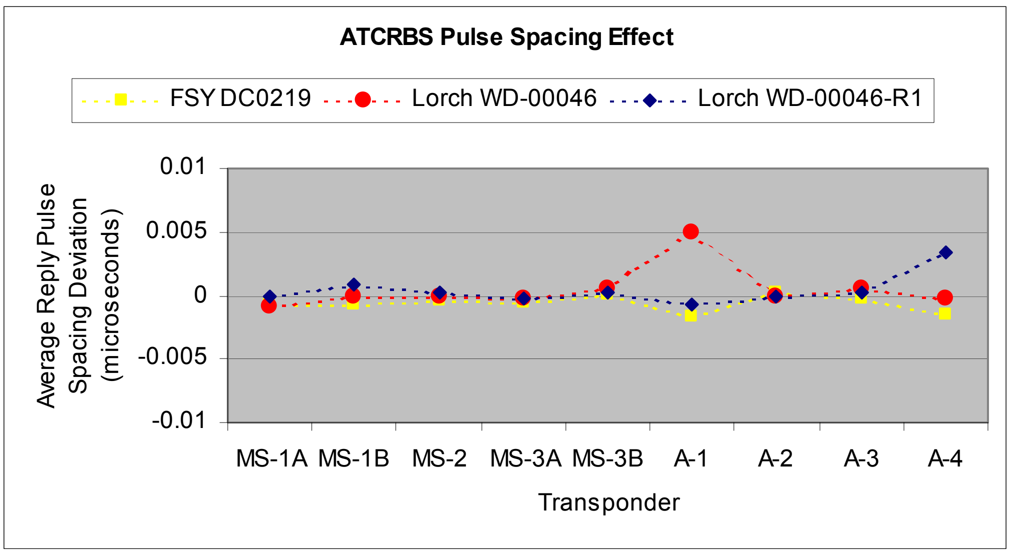

Figure 4-41 – ATCRBS Reply Pulse Spacing

There is no significant effect on pulse spacing from the Diplexers. The maximum effect measured was only about 5 nanoseconds (transponder A-1 with the Lorch WD-00046 Diplexer) and that may be attributed to the margin of measurement error for this transponder. Subsequent measurement samples with transponder A-1 and the Lorch WD-00046 showed variations in pulse spacing from as high as 9 nanoseconds and as little as 1 nanosecond. The data in Figure 4-41 is the average of all samples. Also, the reply pulse spacing deviation measured with the Lorch WD-00046 was much less with all other transponders.

The Mode S reply pulse spacing tolerance is 50 nanoseconds of the nominal position. The DATAS test procedure acquires 100 replies and measures the average position error of each reply pulse. The maximum pulse position error of all pulse samples is compared with and without the Diplexers in Figure 4-42.

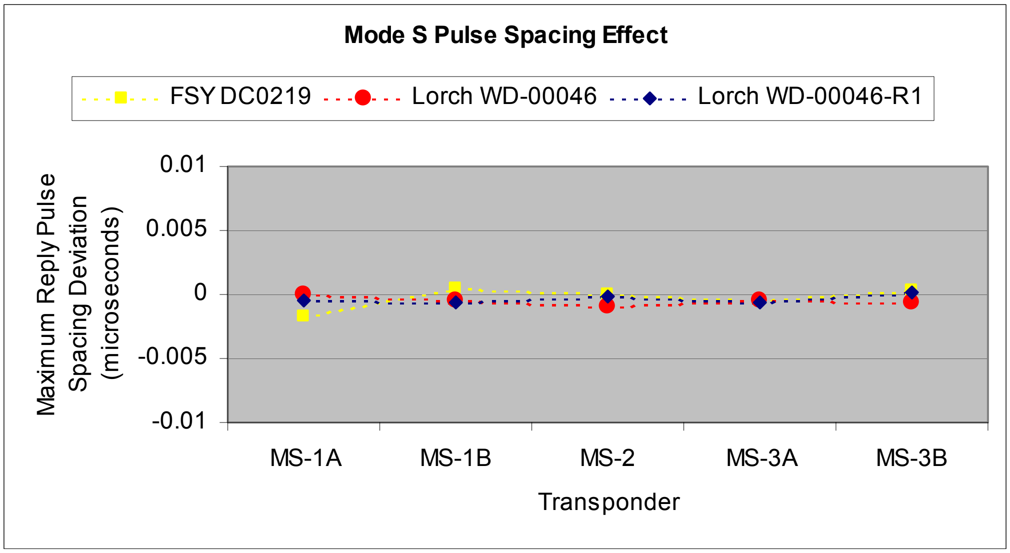

Figure 4-42 – Mode S Reply Pulse Spacing Error

The Diplexers had no significant effect on Mode S reply pulse spacing.

4.11 Reply Pulse Width

The reply pulse width test is an indicator to determine if there is any distortion introduced by the Diplexers affecting the pulse shape of the transponder's 1090 MHz transmissions. ATCRBS and Mode S pulse widths were measured at the antenna port of each Diplexer and compared to the pulse widths measured at the antenna port of the transponder. The reply pulse widths of a sample of at least 100 reply pulse groups was measured with each transponder and compared with, and without, each Diplexer.

ATCRBS reply pulse width tolerance is plus or minus 0.1 microseconds from nominal. The test determines the average width of all reply pulses from all sample reply groups. The results are presented in Figure 4-43. The pulse width variation is minimal with most transponders, and is both plus and minus. There is no indication that the Diplexers significantly affect reply pulse width.

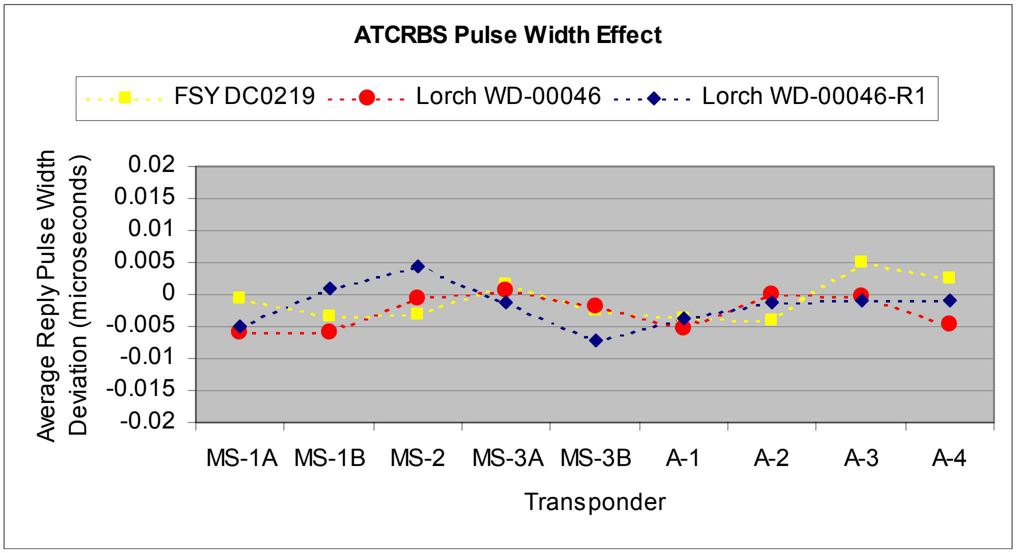

Figure 4-43 – ATCRBS Pulse Width

Mode S reply pulse width tolerance is plus or minus 0.05 microseconds of nominal. The test procedure acquired a sample of 100 replies and determined the average pulse width. Because the Mode S reply format uses pulse position modulation, the data pulse widths can be either 0.5 or 1.0 microsecond in width depending on the alignment of consecutive bit values. For this reason, pulse width comparisons were made with like bit values. The pulse width measurements were compared with and without the Diplexers. The results are presented in Figure 4-44. The data shows no significant effect with any of the transponders from either Diplexer.

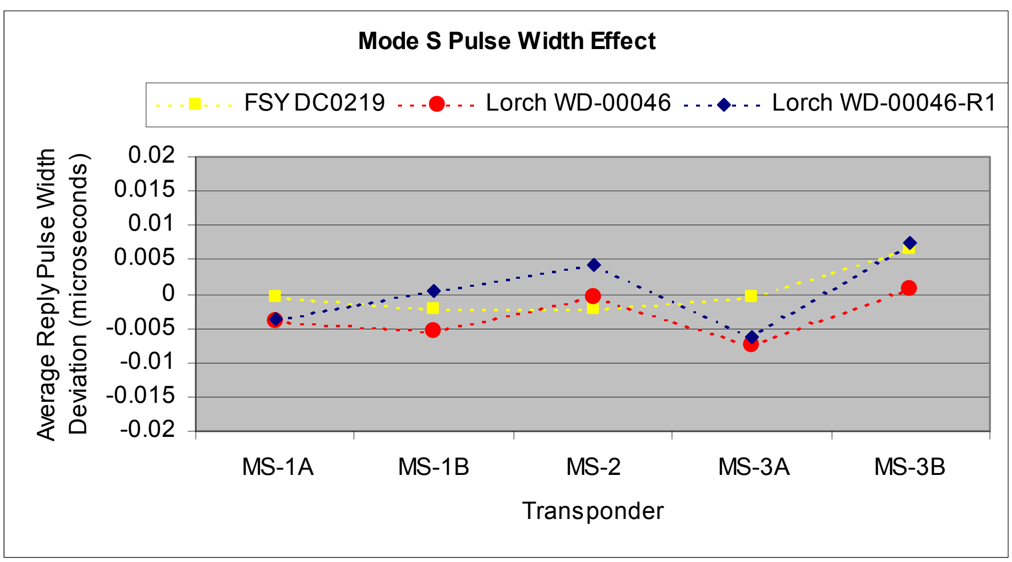

Figure 4-44 – Mode S Pulse Width

4.12 Undesired Replies

The Undesired reply rate was measured by monitoring ATCRBS and Mode S reply transmissions without interrogating the transponder, with the UAT system on, and transmitting with each Diplexer configuration. The undesired reply rate for ATCRBS modes is required to be 5 replies per second or less, averaged over a 30-second interval. (This is the requirement for Mode S transponders – RTCA/DO-181B.) The required undesired reply rate for Mode S replies is no more than once per 10 seconds. The transponders were monitored for undesired replies for at least five 60-second intervals to obtain an average reply rate. Some transponders that exhibited undesired replies were tested up to ten 60-second intervals to get a better average rate. Table 4-1 shows the measured results.

Table 4-1 – Average Undesired ATCRBS Replies per UAT Transmission

TRANSPONDER	FSY DC0219	LORCH WD-00046	LORCH WD-00046-R1
MS-1A	0.09	0	0
MS-1B	0.006	0	0
MS-2	0.7	0	0
MS-3A	0.0005	0	0
MS-3B	0.0005	0	0
A-1	0	0	0
A-2	0.0025	0.05	0
A-3	0.01	0	0
A-4	0.18	0	0

The data in Table 4-1 shows the probability of an undesired reply being triggered by a single UAT transmission for each Diplexer/transponder combination. This data is derived by computing the average number of replies divided by the number of UAT transmissions in each measurement interval. With the FSY Diplexer, all but one transponder showed at least some unsolicited ATCRBS reply activity. The highest undesired reply rates occurred with the MS-2 and A-4 transponders. With the Lorch WD-00046 Diplexer, only the A-2 ATCRBS transponder showed undesired ATCRBS reply activity, and it was at a low rate. The Lorch WD-00046-R1 Diplexer was designed to provide more inter-channel isolation. There were no undesired replies measured with the Lorch WD-00046-R1 Diplexer. None of the transponders transmitted any undesired Mode S replies in any configuration.

The undesired replies appear to be triggered by a low-level UAT signal present on the transponder channel of the Diplexer. This is apparent with the increase only occurring when an operational UAT is in the configuration and it was verified during testing with an oscilloscope.

This analysis shows that even with the most active configuration (MS-3 transponder with FSY Diplexer and UAT) there is far below the 5 replies per second tolerance. Although the undesired reply rates are quite low, any increase in the undesired reply rate is not desirable and the suppression bus is a requirement when installing UAT equipment with on-board SSR transponders to prevent such transmissions. UAT will only drive the suppression bus to suppress other on-board L-Band systems but will not receive suppression signals since UAT transmissions rely on exact timing for transmissions.

4.13 Sensitivity Variation With Frequency

While varying the RF signal frequency over the range 1029.8 to 1030.2 MHz, the variation in RF signal level required to produce a 90 percent reply rate must not exceed 1 dB. An assessment of Mode S sensitivity variation with frequency was performed. Mode S interrogation formats were used in this case since the Digital Phase Shift Keying (DPSK) modulation requires a wider bandwidth than that of pulse leading edge detection.

Of interest is whether the Diplexer will accommodate the wider bandwidth required by Mode S DPSK interrogation types, and whether the pass-band of the Diplexer has any limiting effects as the frequency is varied. The test was performed while using a slotted line and stub tuner to monitor and control VSWR. This was done to reduce sensitivity variations that might occur due to changes in VSWR as the Diplexer is added to the circuit. The tests were limited to three of the Mode S transponders that included one from each manufacturer.

Figure 4-45 shows a plot of the Sensitivity Variation with Frequency measurements for transponder MS-1A. The interrogation used consisted of a UF code of '4' and all other data bits equal to binary '1' except the Address Parity (AP) field which was properly coded to elicit a response from the transponder. The all binary 1's format was used to maximize the number of phase shifts in the uplink interrogation. This was the primary interrogation format used to test all three transponders. It was intended to use a long format interrogation. However, since there was no available means of connecting the ARINC 429 interface of the three transponders, the transponders would not reply to long interrogation formats. The data shows a consistent average reduction in sensitivity of about 0.2 dBm that does not vary significantly with frequency.

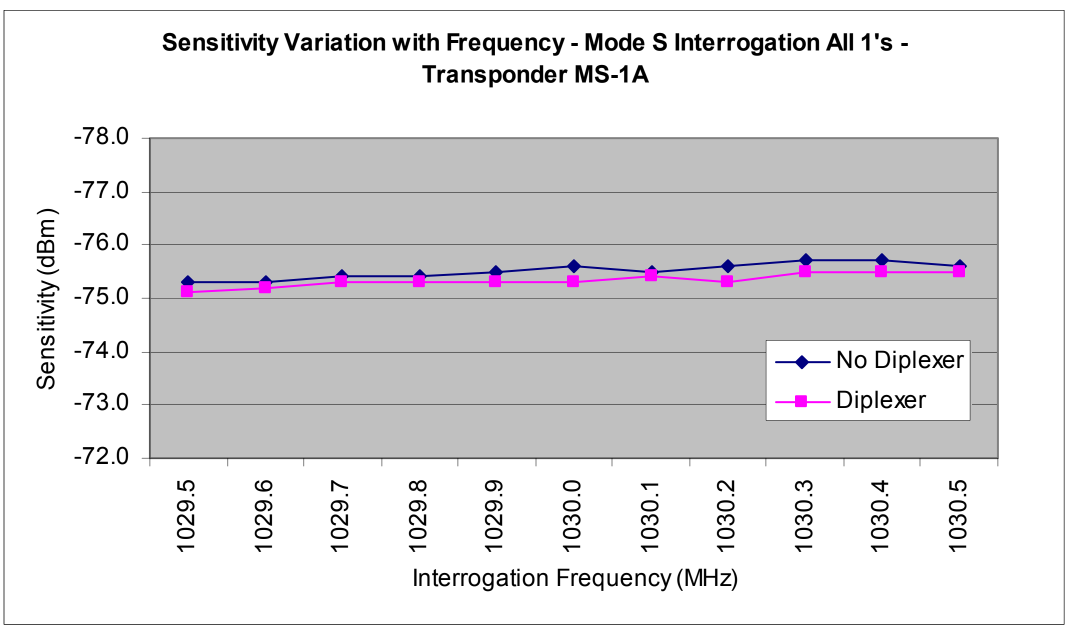

Figure 4-45 – Sensitivity Variation with Frequency, All 1's Interrogation, Transponder MS-1A

Figure 4-46 shows the Sensitivity Variation with Frequency of transponder MS-1A with a Mode S interrogation using all variable data bits set to binary ‘0’ (again, except for UF and AP fields). This interrogation format will minimize DPSK phase shifts in the interrogation. There are only 3 data points per configuration on this plot because only a subset of the data points was run in this case since the data showed no significant difference between this and the all 1’s interrogation format. Subsequent spot checking using the all 0’s interrogation with the other two transponders also showed no significant effect from the interrogation data content of the interrogation.

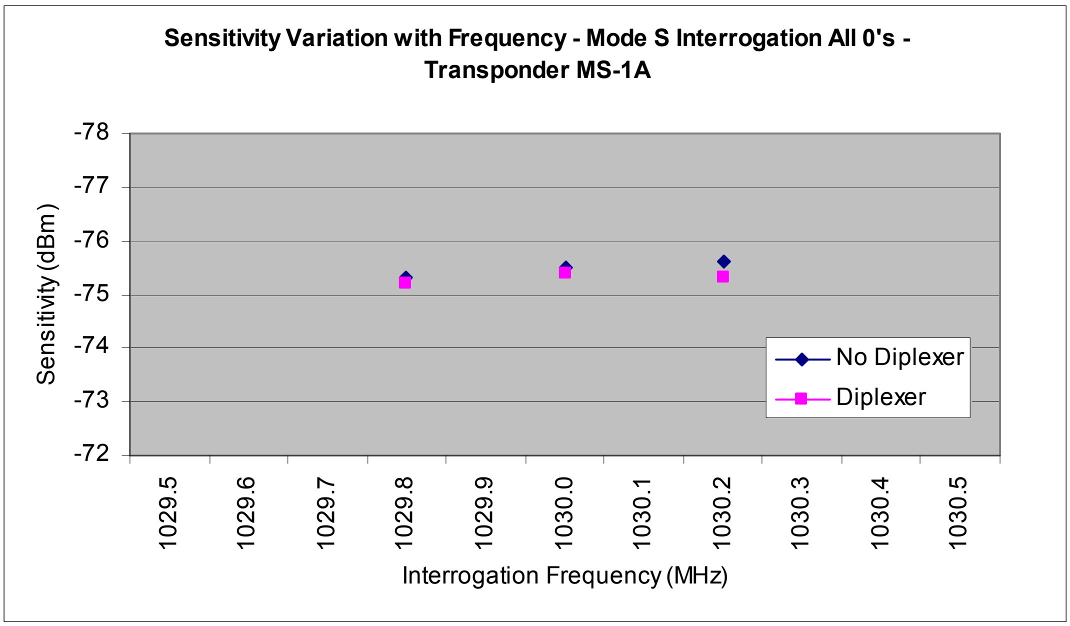

Figure 4-46 – Sensitivity Variation with Frequency, All 0’s Interrogation, Transponder MS-1A

Figure 4-47 shows the Sensitivity Variation with Frequency data from transponder MS-2. The data is similar to transponder MS-1A with a consistent sensitivity offset of 0.3 dBm with no significant variation with frequency.

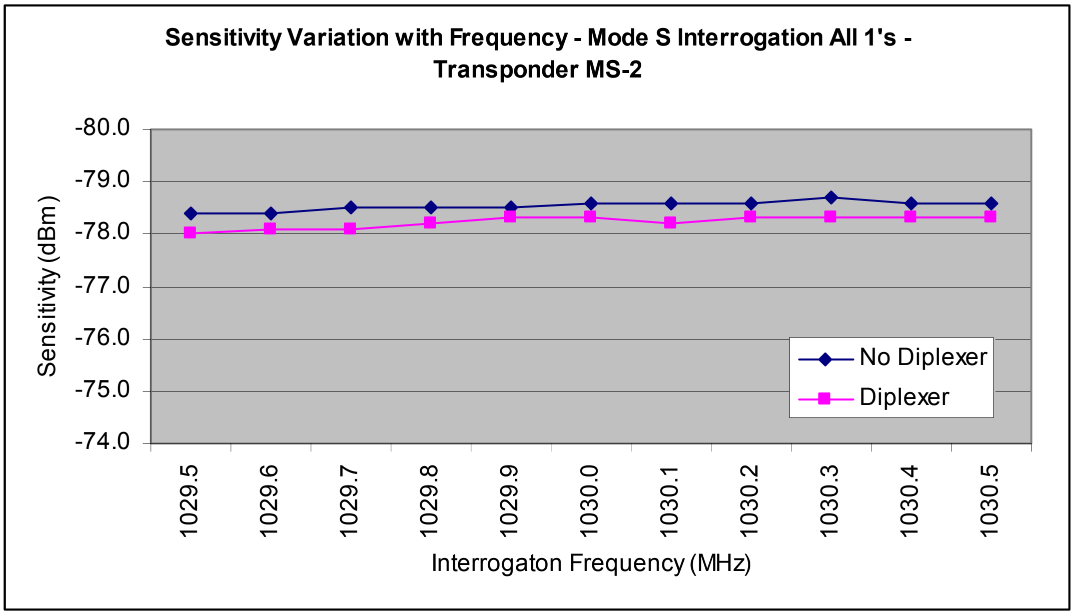

Figure 4-47 – Sensitivity Variation with Frequency, All 1's Interrogation, Transponder MS-2

Figure 4-48 shows the Sensitivity Variation with Frequency data from transponder MS-3A. The data is similar to that of the other 2 transponders with a consistent sensitivity offset of 0.3 dBm. The data point at frequency 1029.5 MHz does deviate from the others, not because of any direct effect from the Diplexer, but because it is near the edge of the transponders bandwidth for Mode S format interrogations. All three transponders exhibit a Mode S interrogation acceptance band of very close to plus or minus 500 kHz. In the case of transponder MS-3A, at 1029.5 MHz the sensitivity is significantly reduced and varies as the test is repeated.

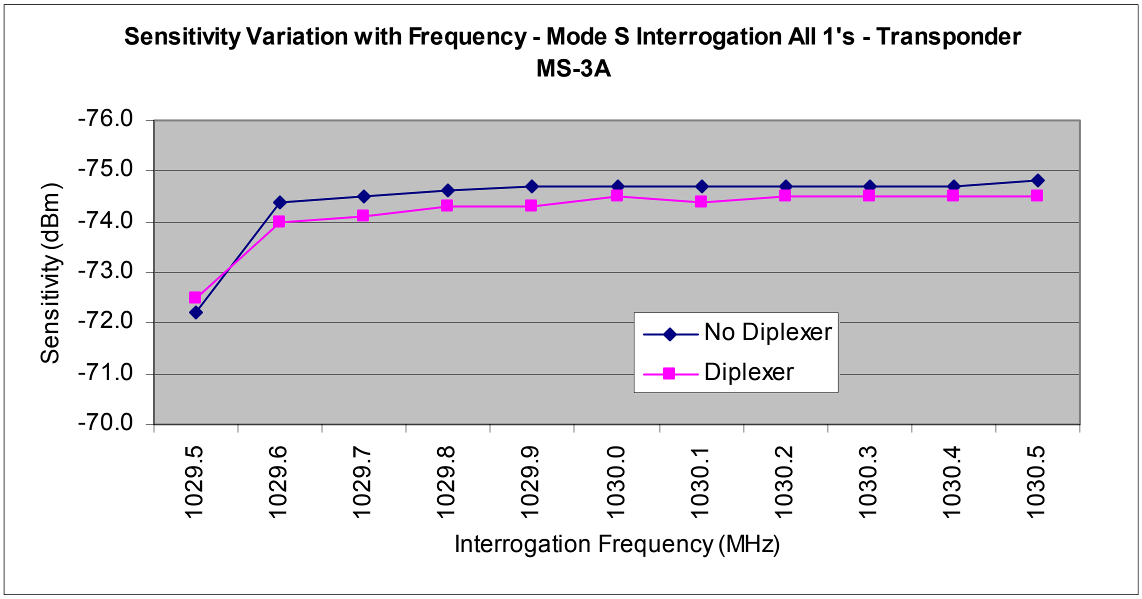

Figure 4-48 – Sensitivity Variation with Frequency, All 1's Interrogation, Transponder MS-3A

The conclusion from running these tests is that there is the expected 0.2 to 0.3 dB reduction in the transponder receiver sensitivity from the Diplexer, but the Mode S sensitivity is not affected as a function of frequency within the operating bandwidth of the transponders.

4.14 Bandwidth

Each transponder's receiver bandwidth was measured by varying the interrogation frequency and measuring the receiver MTL. In this case, a broader frequency range is tested than with that of the sensitivity variation with frequency tests. The bandwidth test range was limited by the maximum transmit power of the test equipment of about –20 dBm. Some transponders had a tighter bandwidth that caused the bandwidth curve to fall sharply before reaching the –20 dBm limit. With each case, the bandwidth tested was sufficient to determine if the Diplexer has an effect on the transponder's receiver bandwidth. A Mode 3/A interrogation was used for these tests. The bandwidth data is presented in the series of graphs from Figure 4-49 through Figure 4-58. There was no significant effect on bandwidth with any of the transponder/Diplexer combinations.

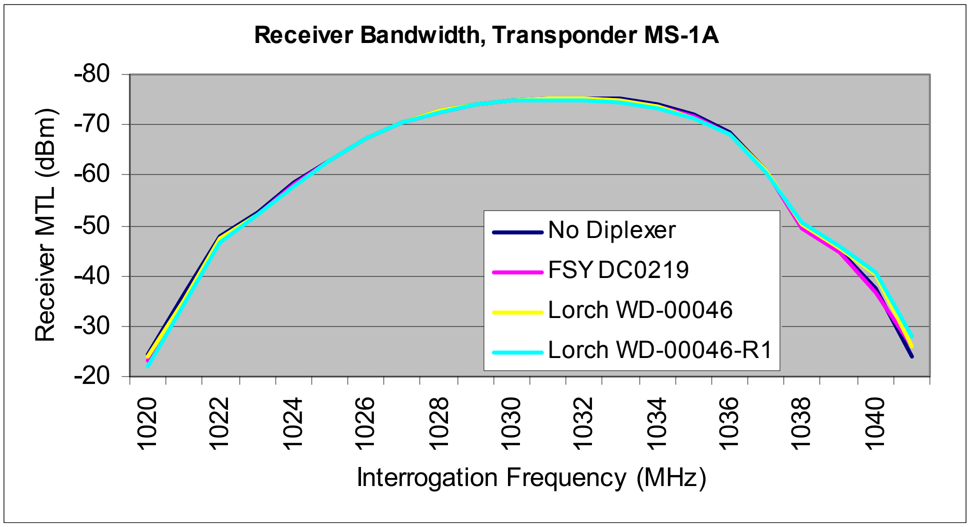

Figure 4-49 – Receiver Bandwidth, Transponder MS-1A

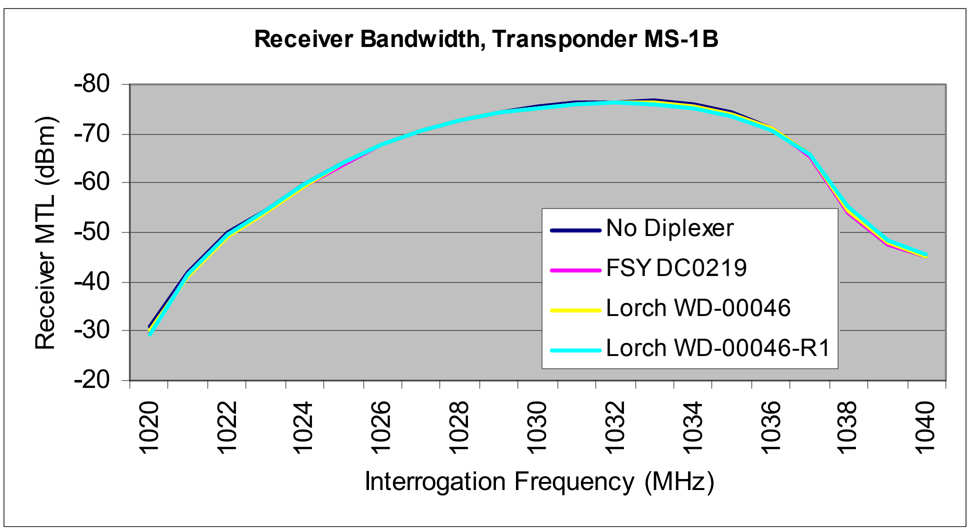

Figure 4-50 – Receiver Bandwidth, Transponder MS-1B

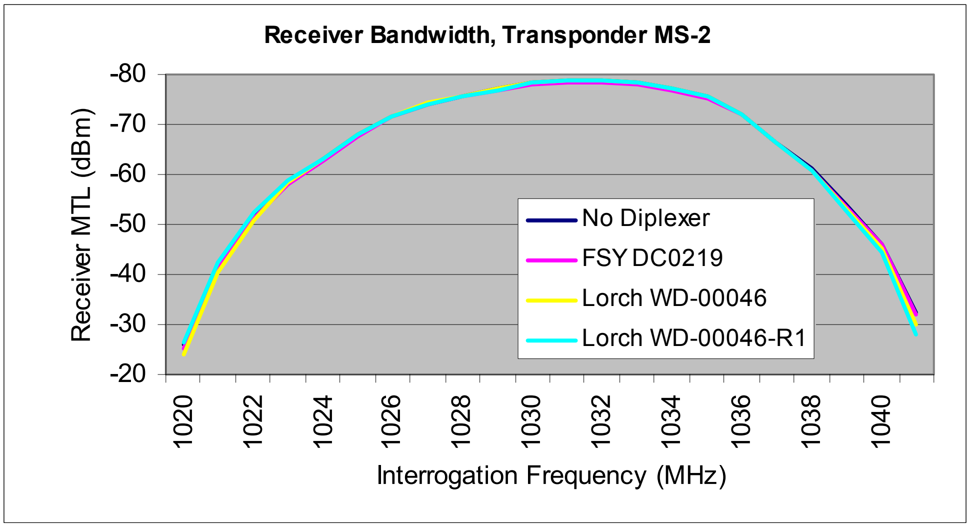

Figure 4-51 – Receiver Bandwidth, Transponder MS-2

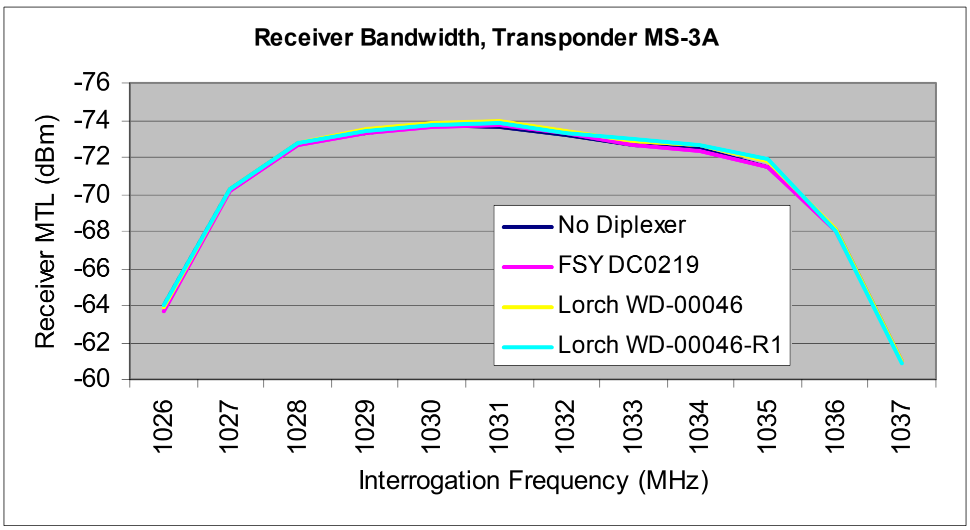

Figure 4-52 – Receiver bandwidth, Transponder MS-3A

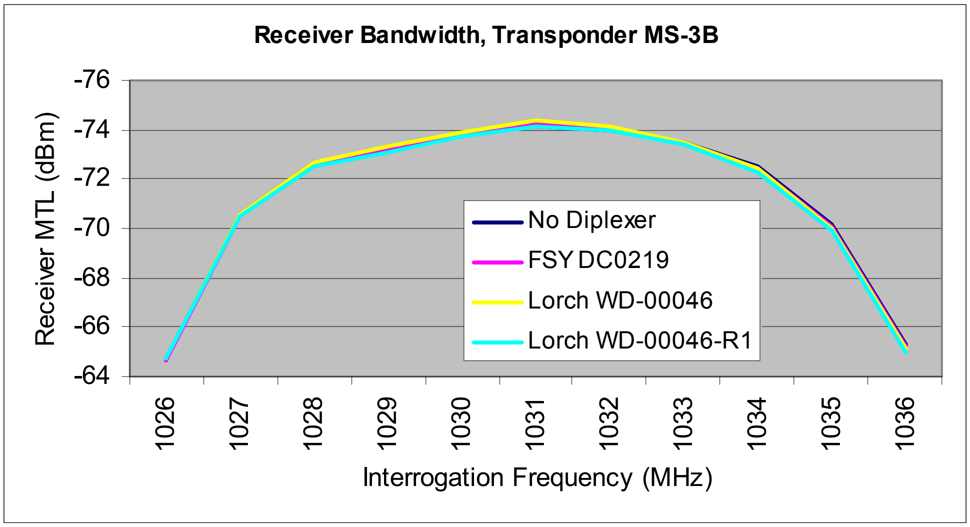

Figure 4-53 – Receiver Bandwidth, Transponder MS-3B

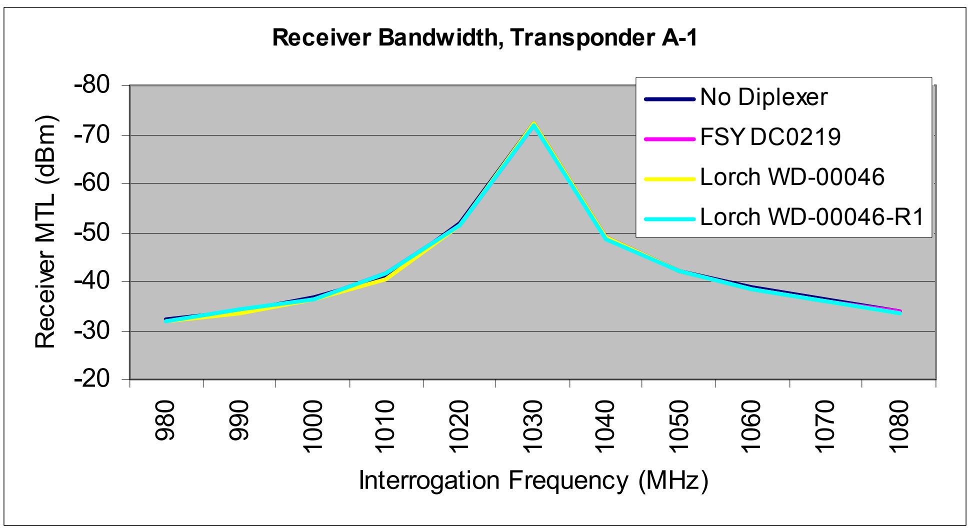

Figure 4-54 – Bandwidth, Transponder A-1

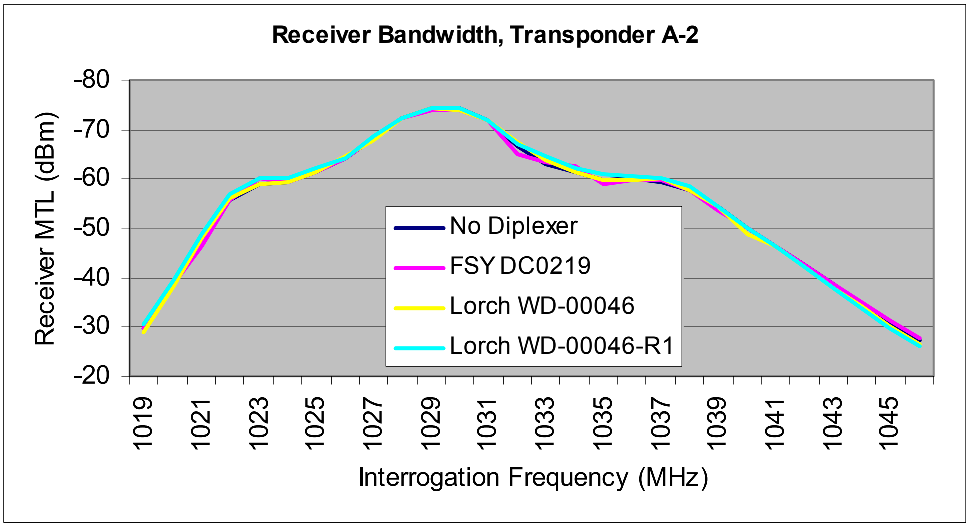

Figure 4-55 – Bandwidth, Transponder A-2

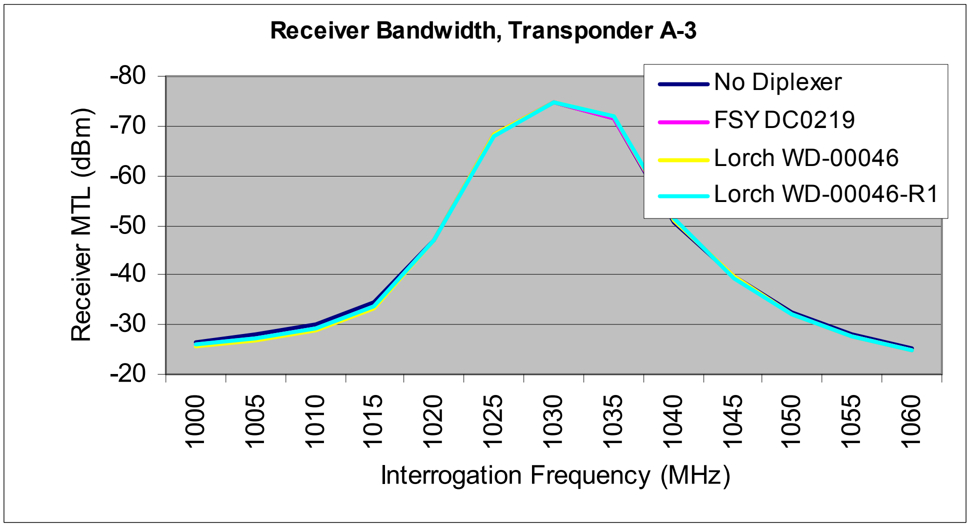

Figure 4-56 – Bandwidth, Transponder A-3

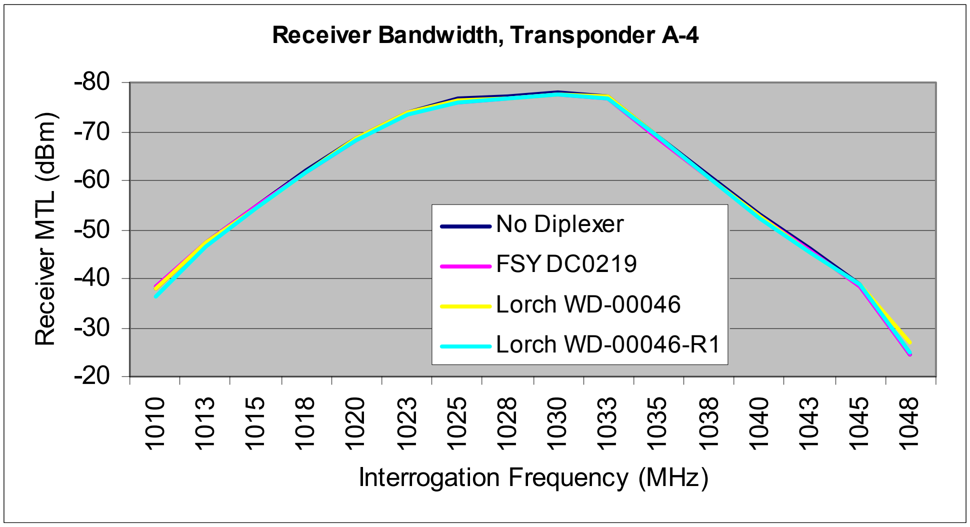

Figure 4-57 – Bandwidth, Transponder A-4

4.15 Mode A/C Pulse Position Tolerance

The Mode A/C pulse position tolerance test is a measure of the transponder's pulse decoder characteristics. The transponder is required to accept the pulse position of ATCRBS interrogations as valid if the spacing between P1 and P3 is within plus or minus 0.2 microseconds of the nominal spacing. Conversely, the transponder is required to reject the pulse position of ATCRBS interrogations if the spacing between P1 and P3 differs from nominal by 1.0 microsecond or more. Tests were conducted to determine if the Diplexer affected the P1 to P3 spacing tolerance or pulse decoding characteristics of the transponders for modes A and C interrogations. Figure 4-58 through Figure 4-75 shows the interrogation pulse decoding performance as the P1 to P3 pulse spacing is varied from 1.2 microseconds short of nominal to 1.2 microseconds beyond the nominal pulse spacing in 0.25 microsecond increments. The decoding performance for both Modes A and C are shown. As indicated by the data, there was no measurable effect on mode A or mode C pulse position decoding.

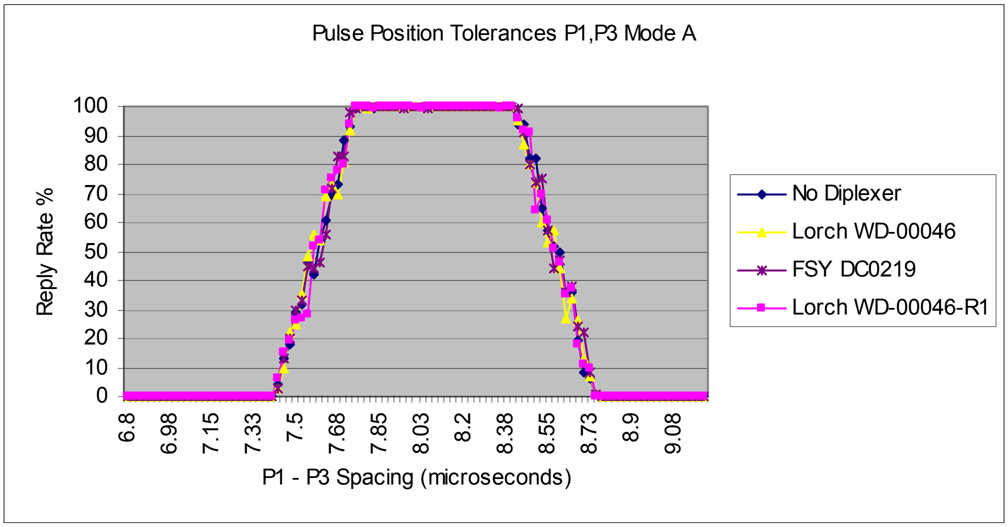

Figure 4-58 – Mode A P1 – P3 Pulse Position Tolerance, Transponder MS-1A

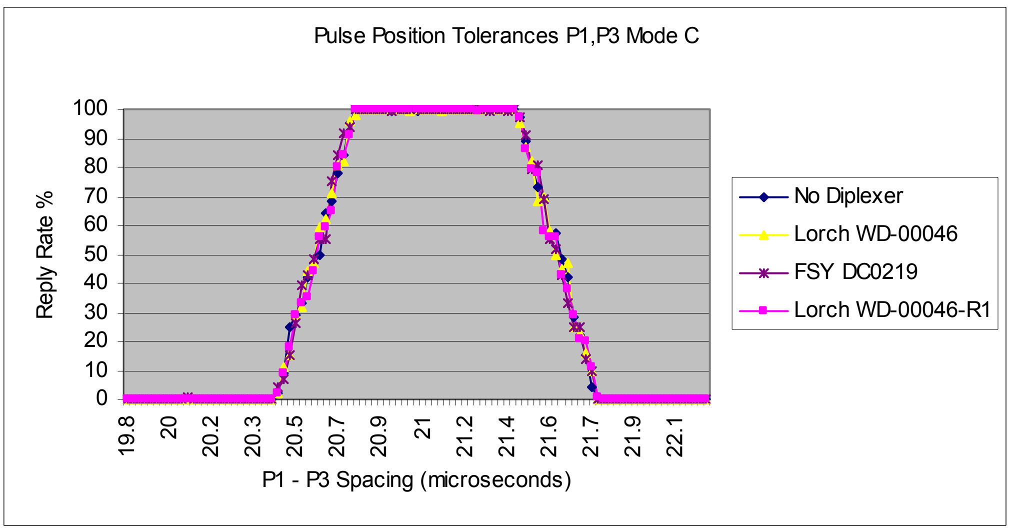

Figure 4-59 – Mode C P1 – P3 Pulse Position Tolerance, Transponder MS-1A

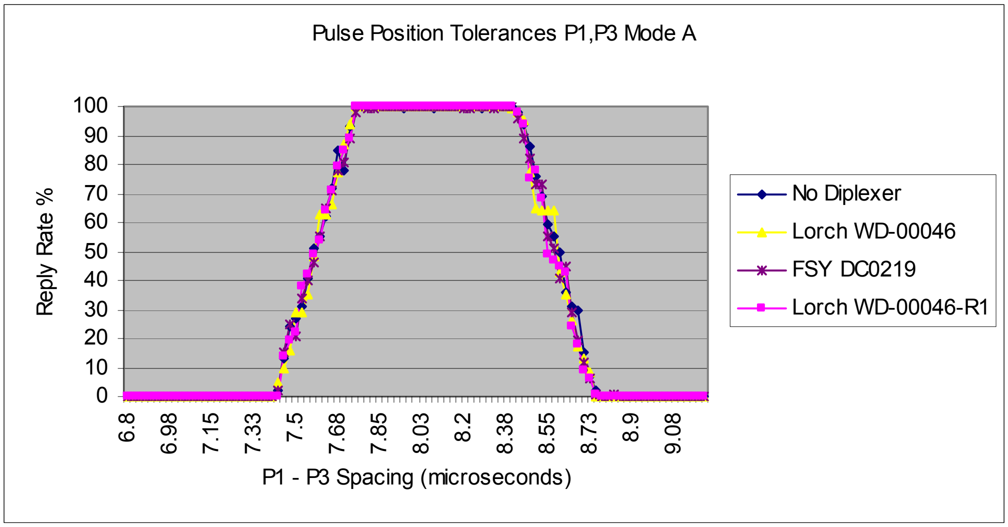

Figure 4-60 – Mode A P1 – P3 Pulse Position Tolerance, Transponder MS-1B

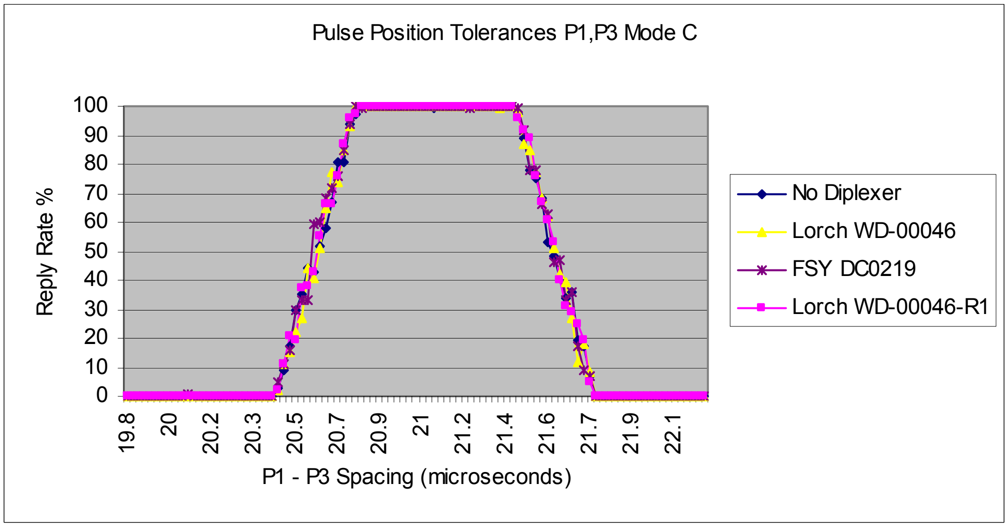

Figure 4-61 – Mode C P1 – P3 Pulse Position Tolerance, Transponder MS-1B

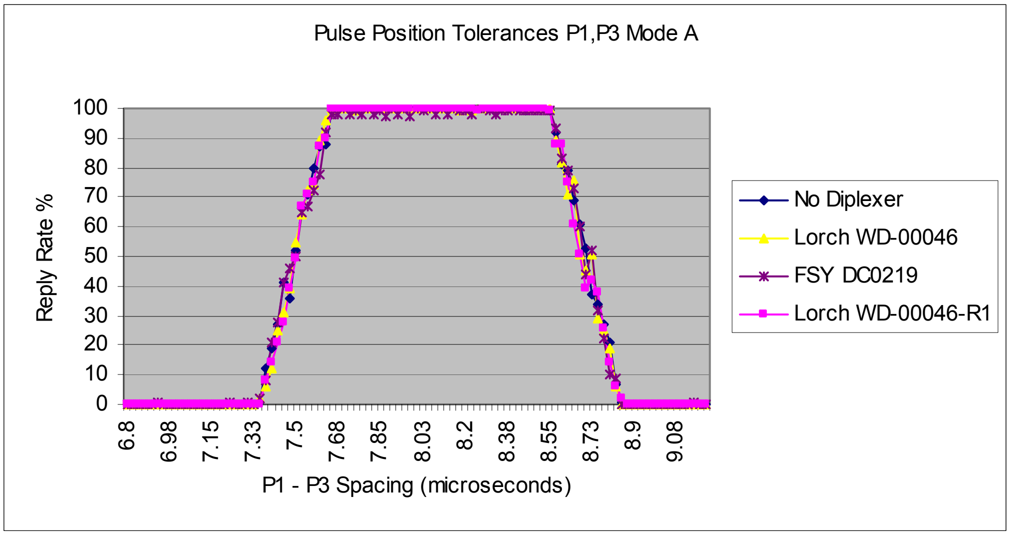

Figure 4-62 – Mode A P1 – P3 Pulse Position Tolerance, Transponder MS-2

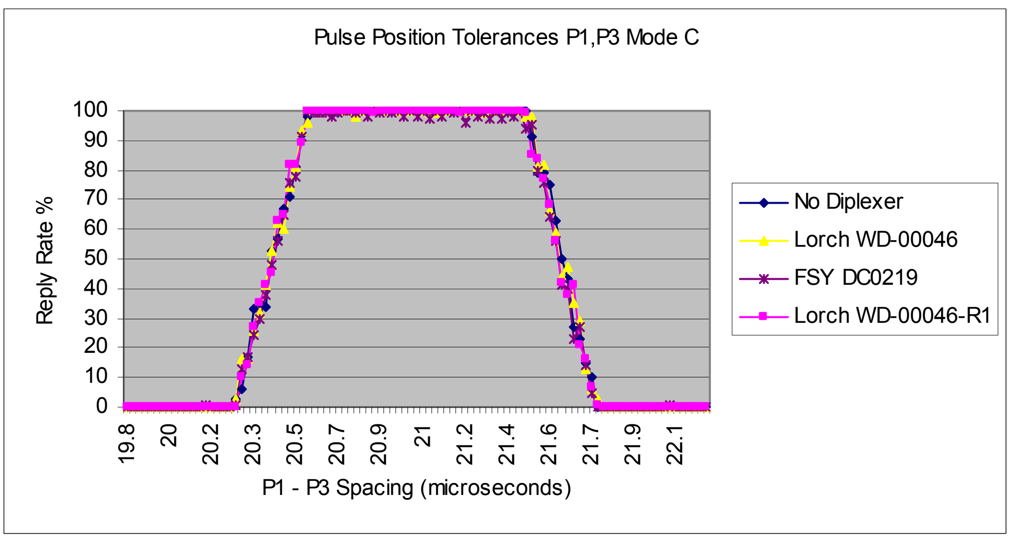

Figure 4-63 – Mode C P1 – P3 Pulse Position Tolerance, Transponder MS-2

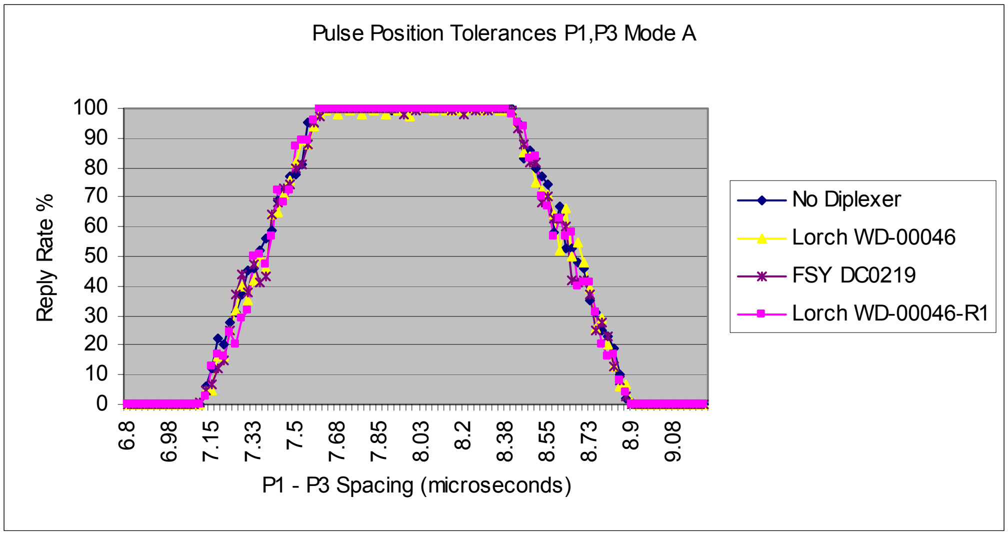

Figure 4-64 – Mode A P1 – P3 Pulse Position Tolerance, Transponder MS-3A

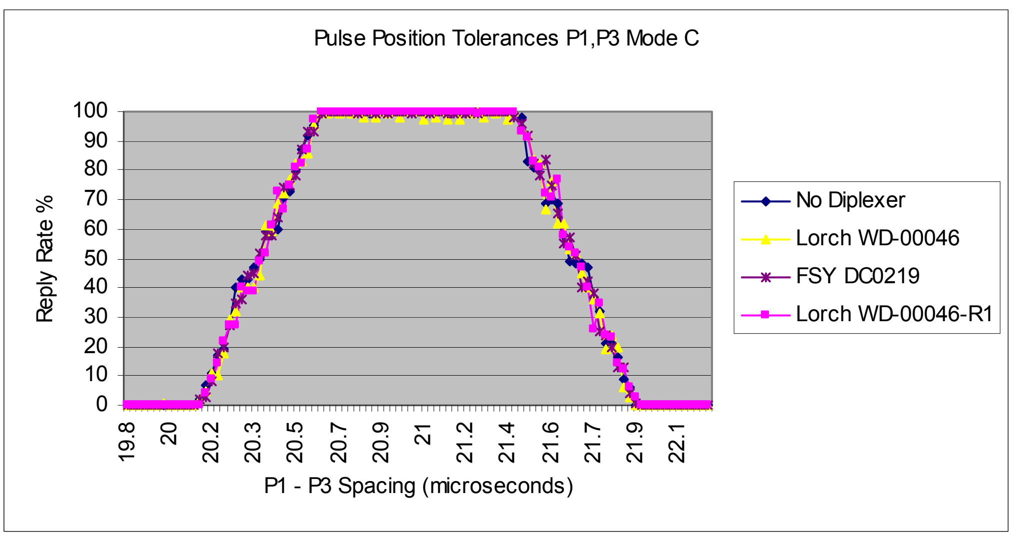

Figure 4-65 – Mode C P1 – P3 Pulse Position Tolerance, Transponder MS-3A

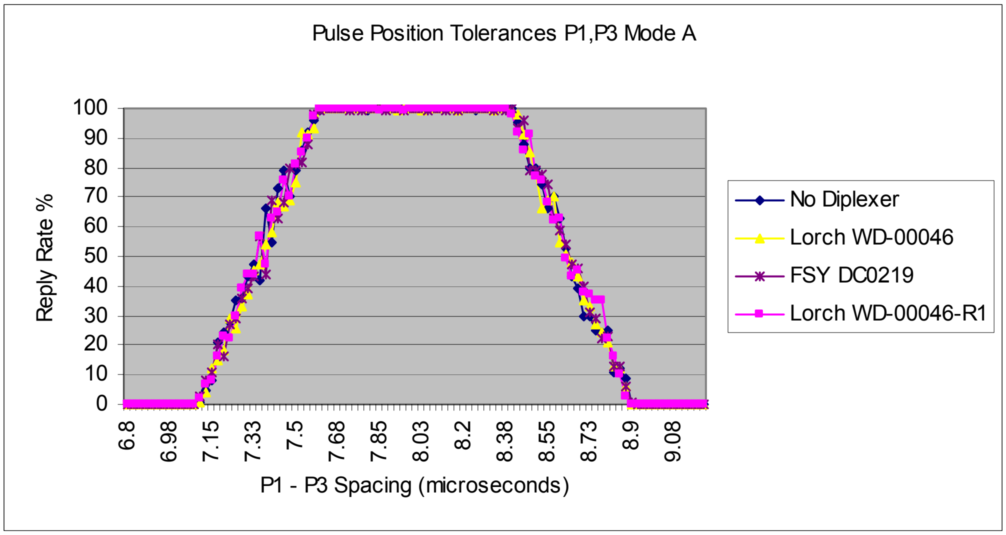

Figure 4-66 – Mode A P1 – P3 Pulse Position Tolerance, Transponder MS-3B

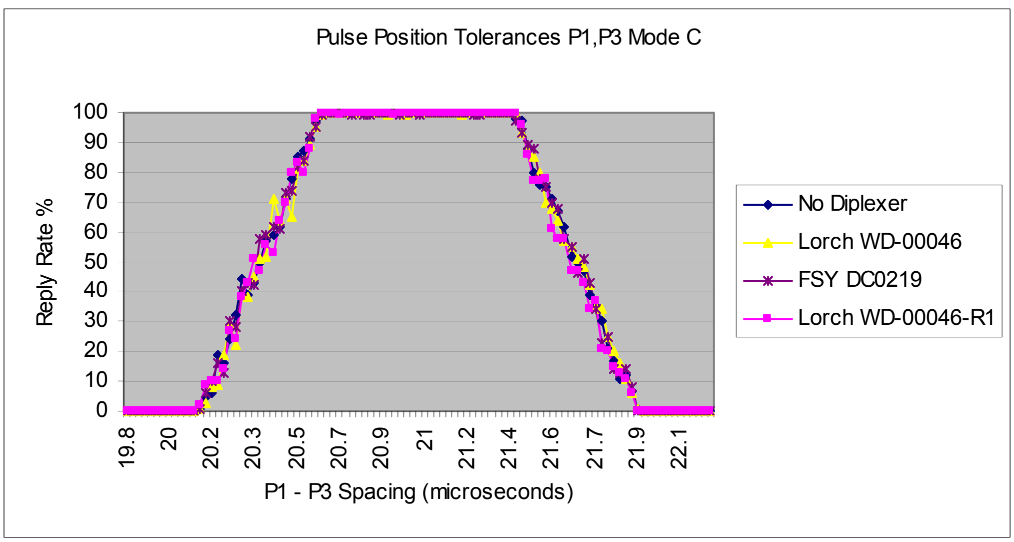

Figure 4-67 – Mode C P1 – P3 Pulse Position Tolerance, Transponder MS-3B

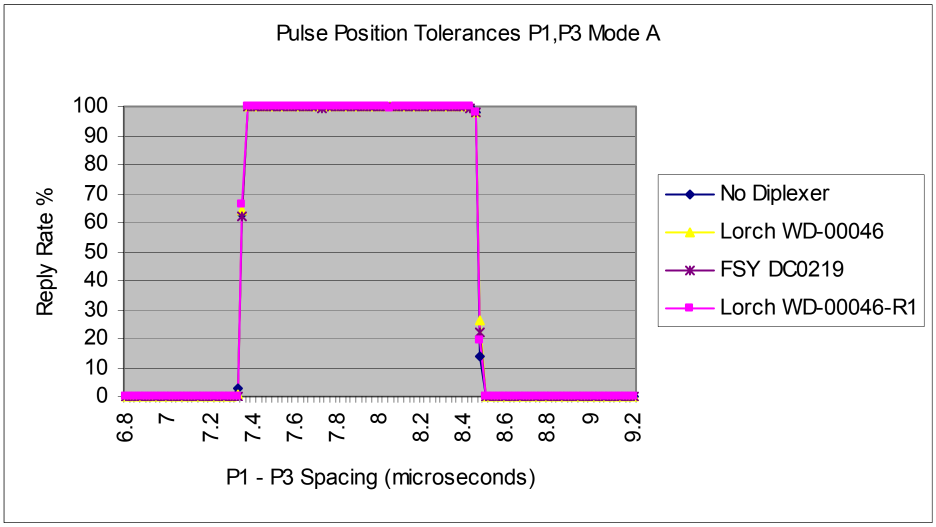

Figure 4-68 – Mode A P1 – P3 Pulse Position Tolerance, Transponder A-1

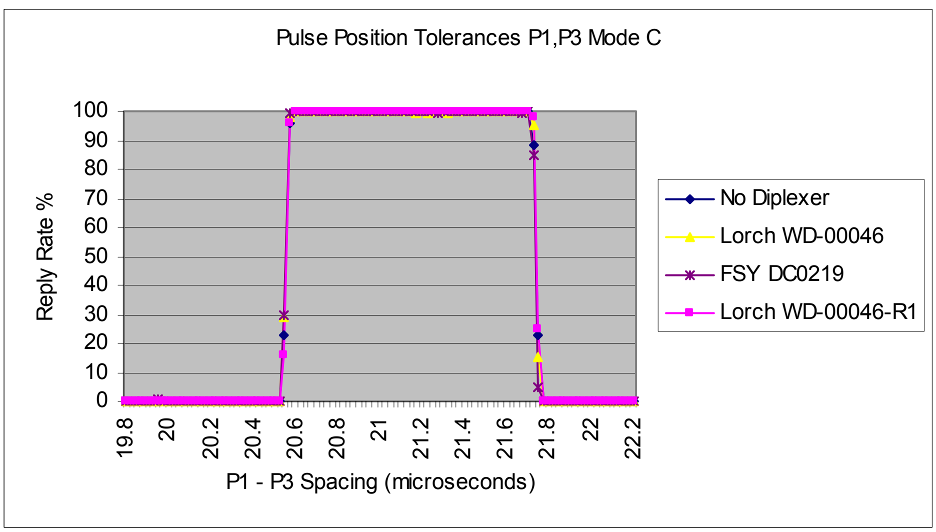

Figure 4-69 – Mode C P1 – P3 Pulse Position Tolerance, Transponder A-1

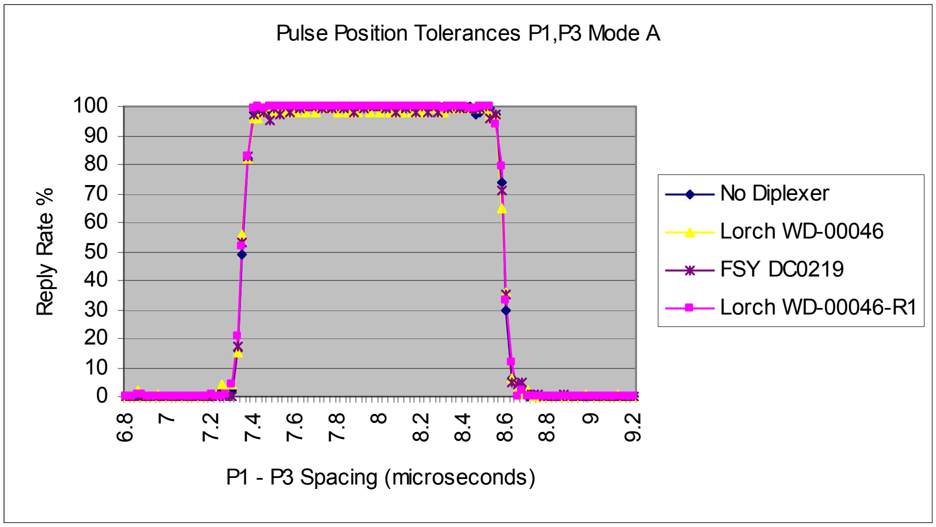

Figure 4-70 – Mode A P1 – P3 Pulse Position Tolerance, Transponder A-2

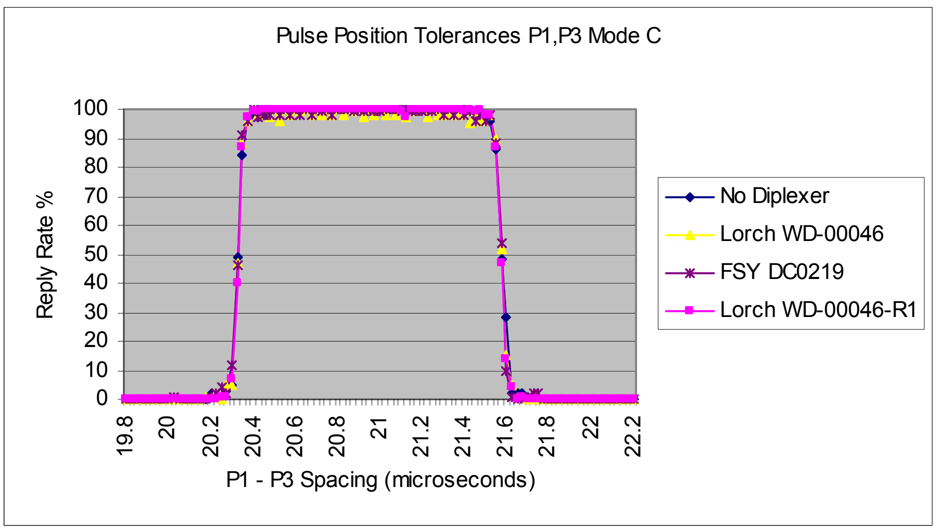

Figure 4-71 – Mode C P1 – P3 Pulse Position Tolerance, Transponder A-2

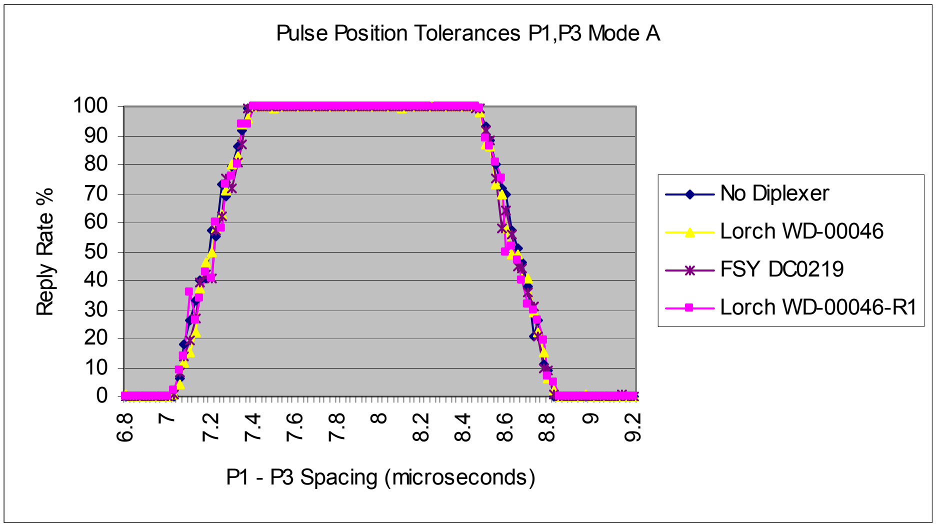

Figure 4-72 – Mode A P1 – P3 Pulse Position Tolerance, Transponder A-3

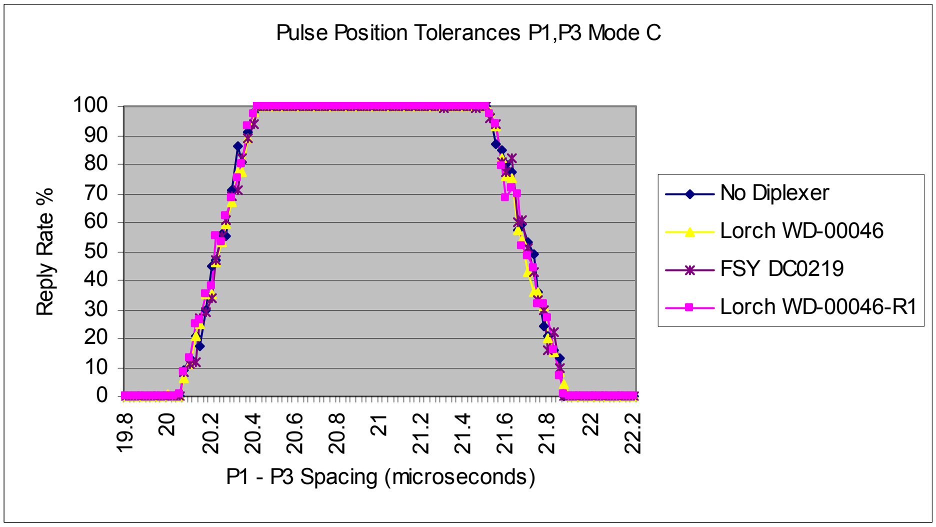

Figure 4-73 – Mode C P1 – P3 Pulse Position Tolerance, Transponder A-3

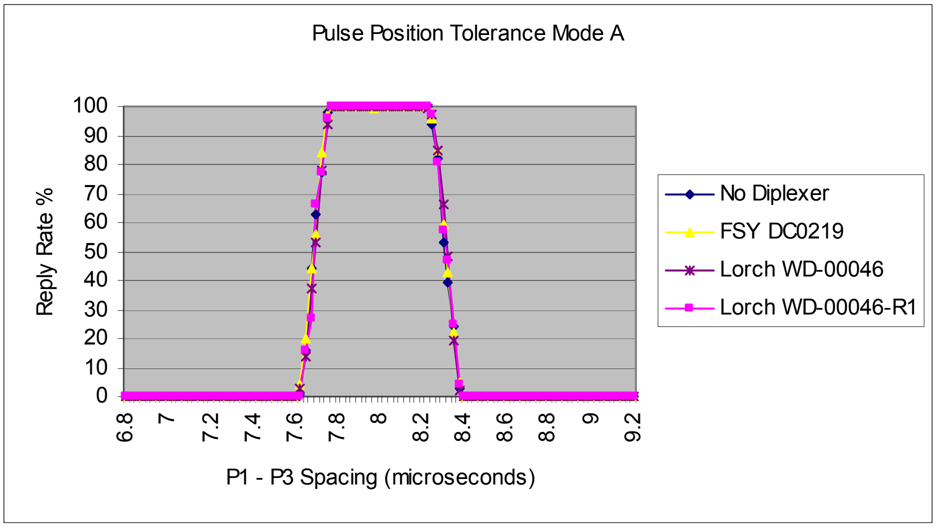

Figure 4-74 – Mode A P1 – P3 Pulse Position Tolerance, Transponder A-4

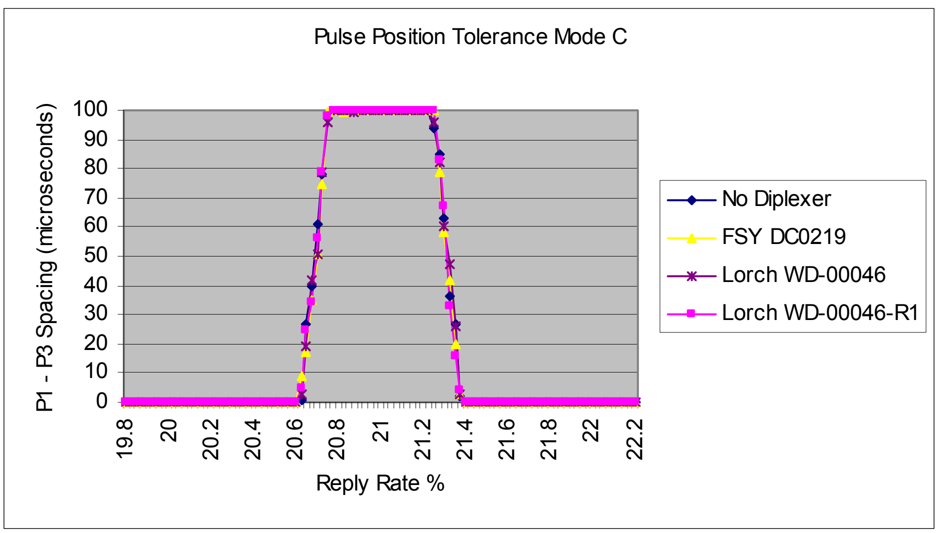

Figure 4-75 – Mode C P1 – P3 Pulse Position Tolerance, Transponder A-4

4.16 ATCRBS/Mode S Pulse Position Tolerance P1 – P3

The ATCRBS/Mode S pulse position tolerance test is a measure of the transponder's pulse decoder characteristics. These tests are similar to the Mode A/C pulse position tolerance tests except in this case the interrogations used include a P4 pulse and were conducted only on the Mode S transponders. The transponder is required to accept the pulse position of ATCRBS/Mode S interrogations as valid if the spacing between P1 and P3 is within plus or minus 0.2 microseconds of the nominal spacing. Conversely, the transponder is required to reject the pulse position of ATCRBS/Mode S interrogations if the spacing between P1 and P3 differs from nominal by 1.0 microsecond or more. Tests were conducted to determine if the Diplexer affected the P1 to P3 spacing tolerance or pulse decoding characteristics of the transponders for ATCRBS/Mode S interrogations. Figure 4-76 through Figure 4-85 shows the interrogation pulse decoding performance as the P1 to P3 pulse spacing is varied from 1.2 microseconds short of nominal to 1.2 microseconds beyond the nominal pulse spacing in 0.25 microsecond increments. The decoding performance for both Mode A/Mode S and Mode C/Mode S are shown. As indicated by the data, there was no measurable effect on the ATCRBS/Mode S P1 to P3 pulse position decoding.

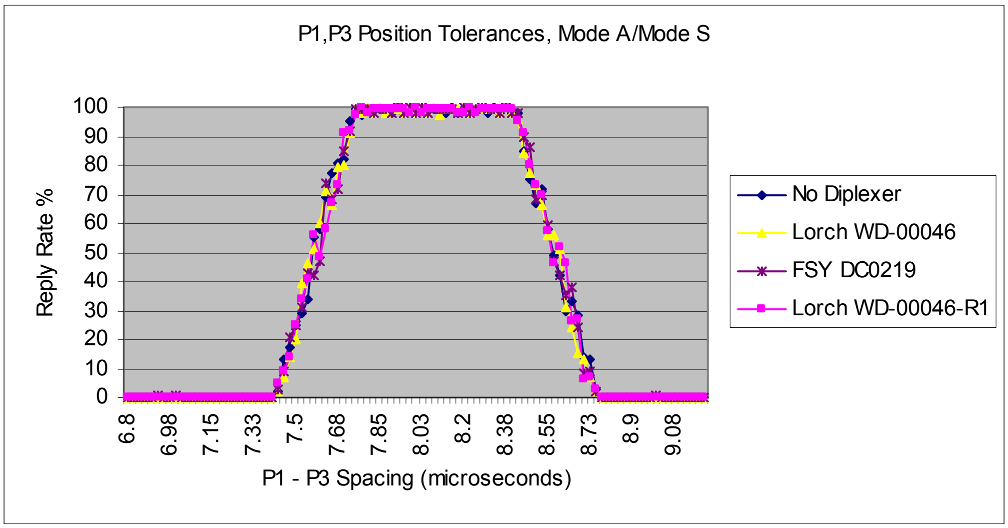

Figure 4-76 – ATCRBS/Mode S (Mode A) P1 – P3 Pulse Position Tolerance, Transponder MS-1A

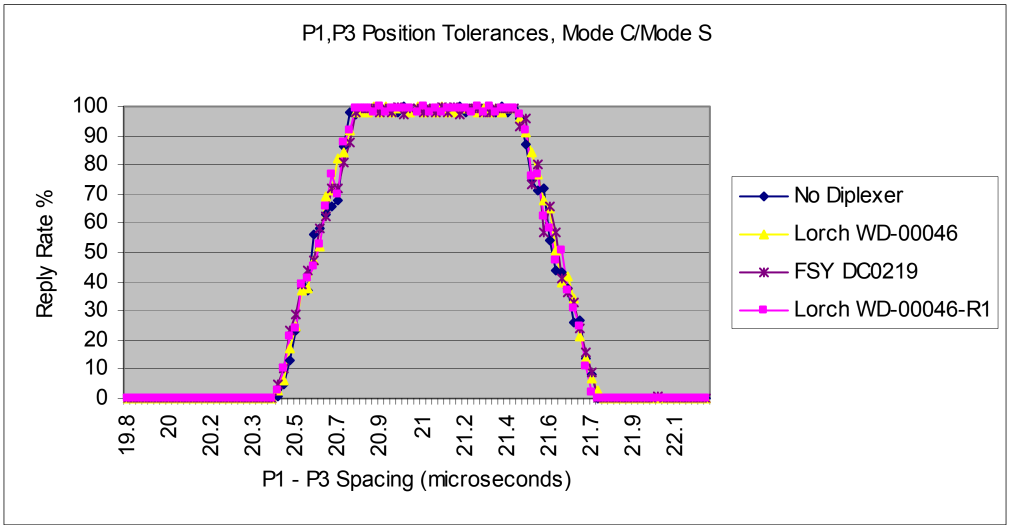

Figure 4-77 – ATCRBS/Mode S (Mode C) P1 – P3 Pulse Position Tolerance, Transponder MS-1A

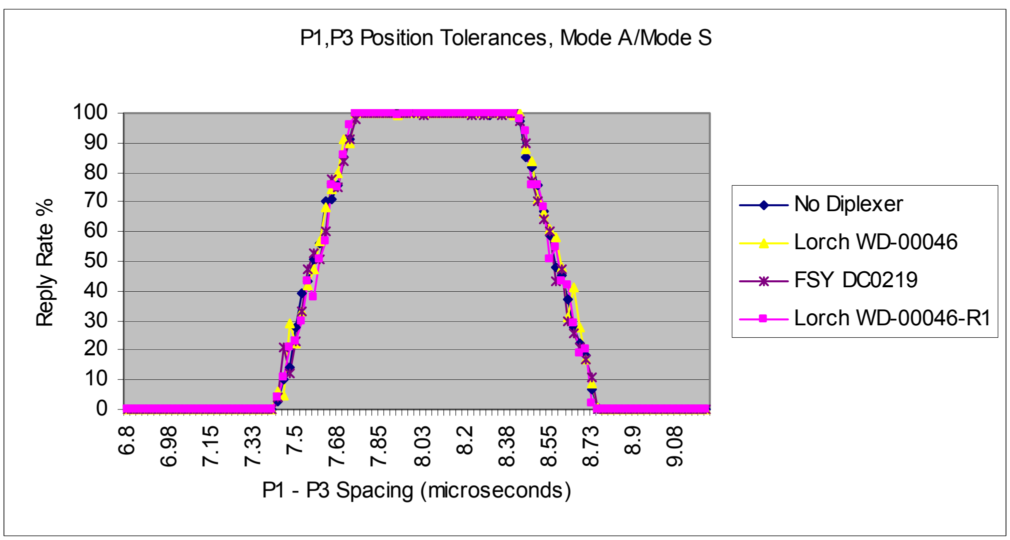

Figure 4-78 – ATCRBS/Mode S (Mode A) P1 – P3 Pulse Position Tolerance, Transponder MS-1B

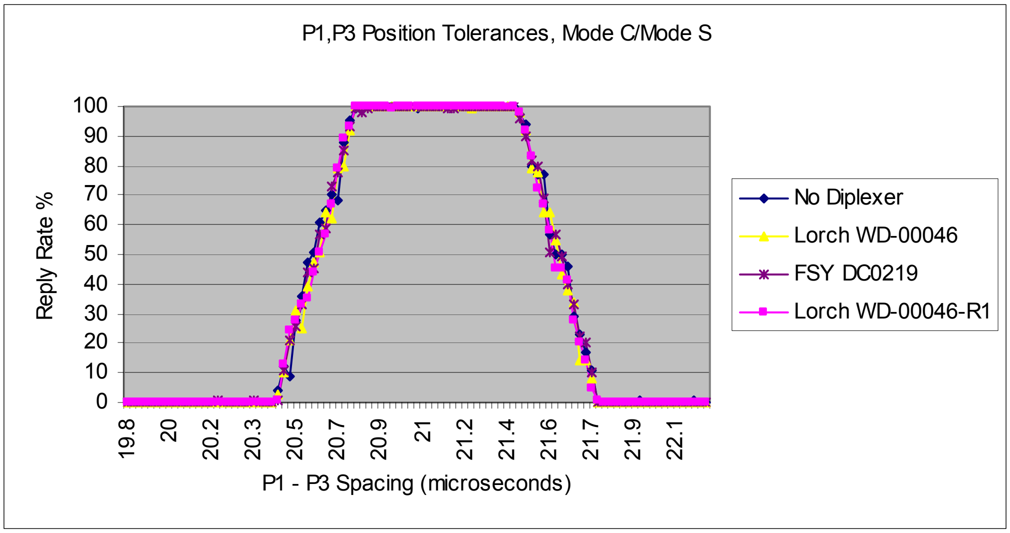

Figure 4-79 – ATCRBS/Mode S (Mode C) P1 – P3 Pulse Position Tolerance, Transponder MS-1B

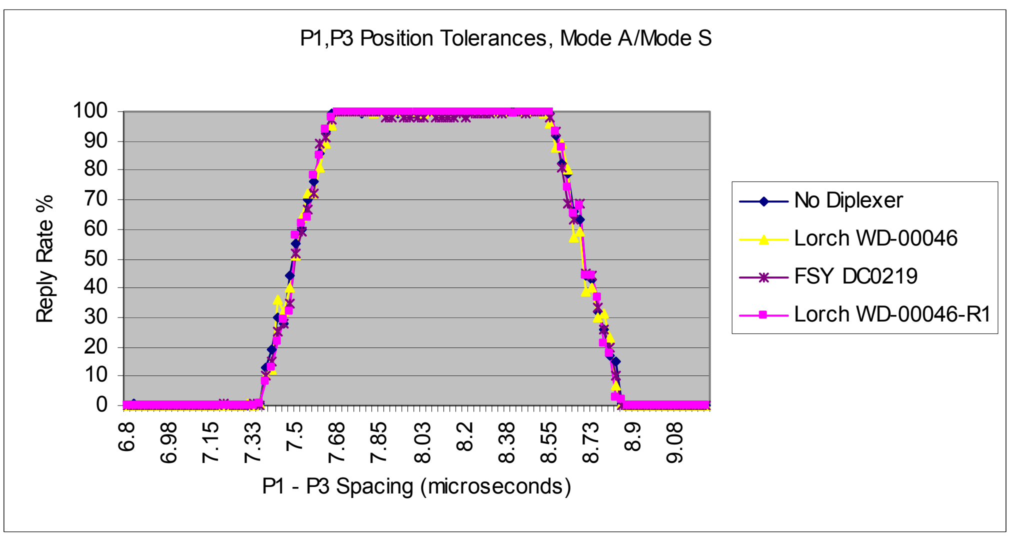

Figure 4-80 – ATCRBS/Mode S (Mode A) P1 – P3 Pulse Position Tolerance, Transponder MS-2

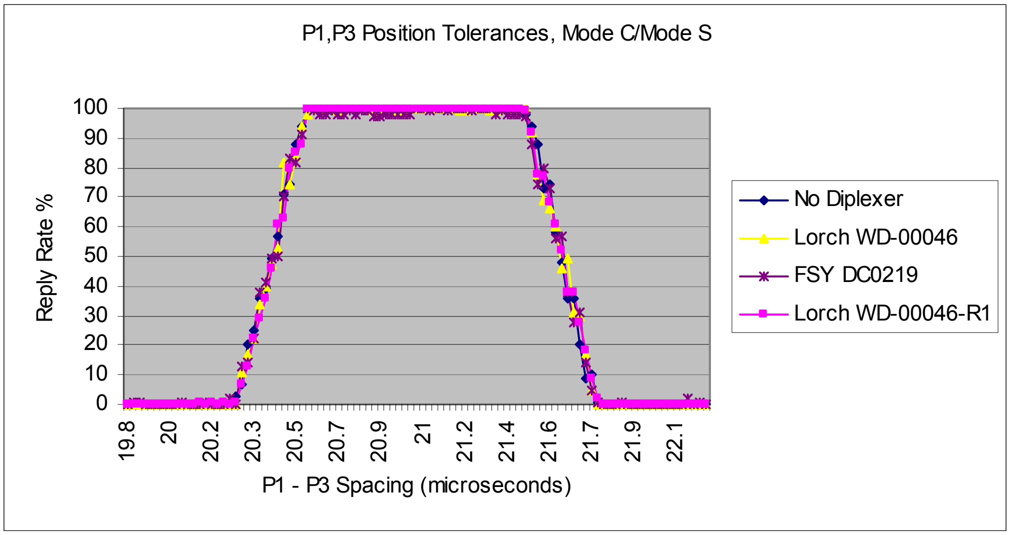

Figure 4-81 – ATCRBS/Mode S (Mode C) P1 – P3 Pulse Position Tolerance, Transponder MS-2

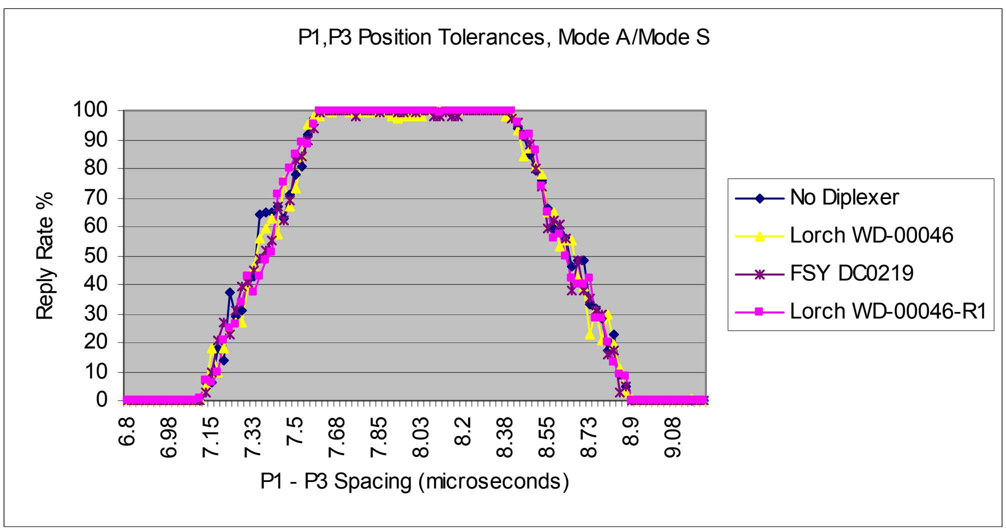

Figure 4-82 – ATCRBS/Mode S (Mode A) P1 – P3 Pulse Position Tolerance, Transponder MS-3A

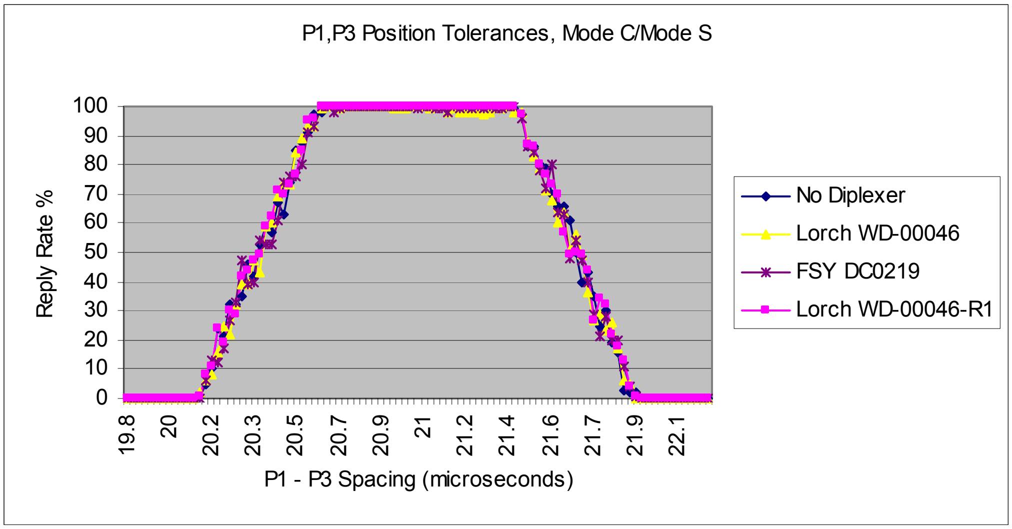

Figure 4-83 – ATCRBS/Mode S (Mode C) P1 – P3 Pulse Position Tolerance, Transponder MS-3A

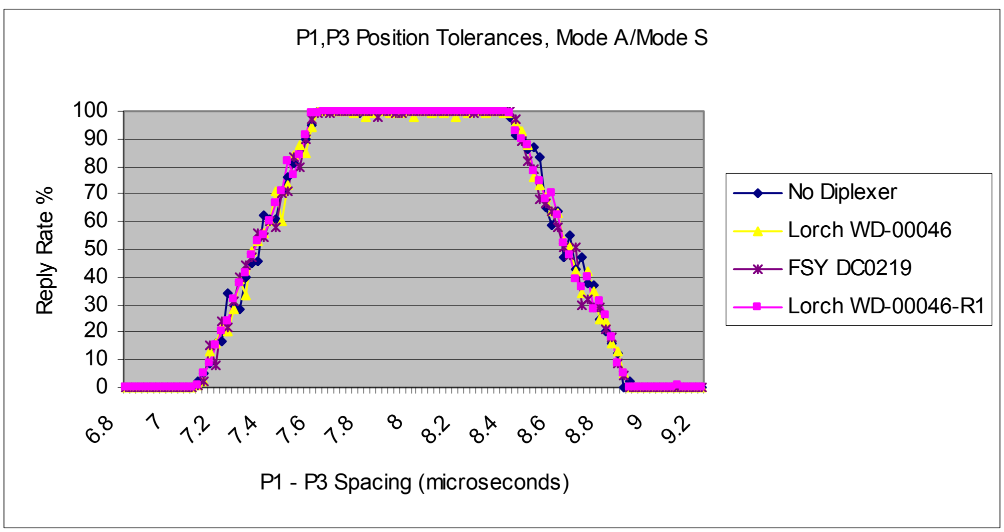

Figure 4-84 – ATCRBS/Mode S (Mode A) P1 – P3 Pulse Position Tolerance, Transponder MS-3B

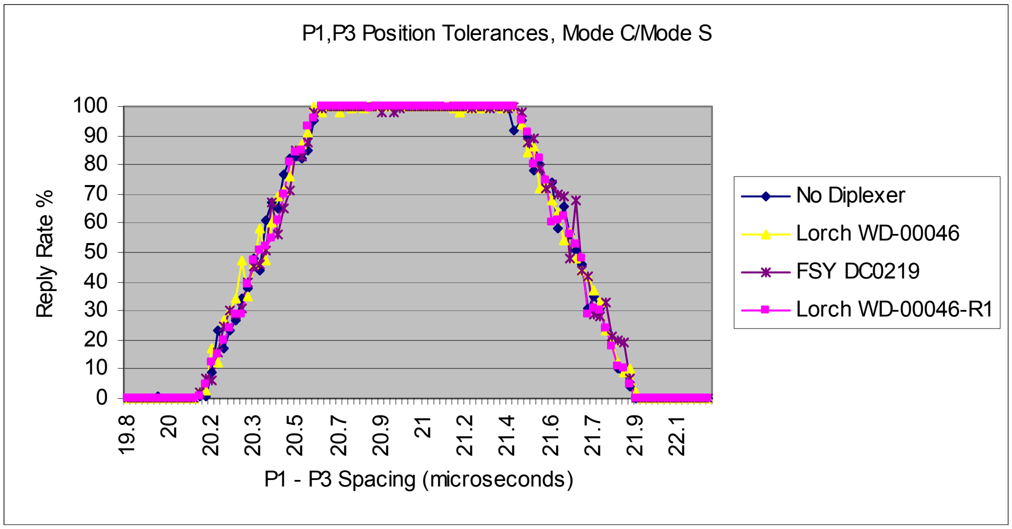

Figure 4-85 – ATCRBS/Mode S (Mode C) P1 – P3 Pulse Position Tolerance, Transponder MS-3B

4.17 ATCRBS/Mode S Pulse Position Tolerance P3 – P4

The ATCRBS/Mode S P4 pulse position tolerance test is a measure of the transponder's pulse decoder characteristics. These tests are similar to the ATCRBS/Mode S pulse position tolerance tests, except in this case the P4 pulse position was varied relative to the P3 pulse position. The transponder is required to accept the pulse position of ATCRBS/Mode S interrogations as valid if the spacing between the P3 and P4 pulses is within plus or minus 0.05 microseconds of the nominal 1.6 microsecond spacing. Conversely, the transponder is required to reject ATCRBS/Mode S interrogations if the spacing between the P3 and P4 pulses differs from nominal by more than 0.3 microseconds. Tests were conducted to determine if the Diplexer affected the P3 to P4 spacing tolerance or pulse decoding characteristics of the transponders for ATCRBS/Mode S interrogations. Figure 4-86 through Figure 4-95 shows the interrogation pulse decoding performance as the P3 to P4 pulse spacing is varied from 1.5 to 2.5 microseconds in 0.25 microsecond increments. The decoding performance for both Mode A/Mode S and Mode C/Mode S are shown. As indicated by the data, there was no measurable effect on the ATCRBS/Mode S P3 to P4 pulse position decoding.

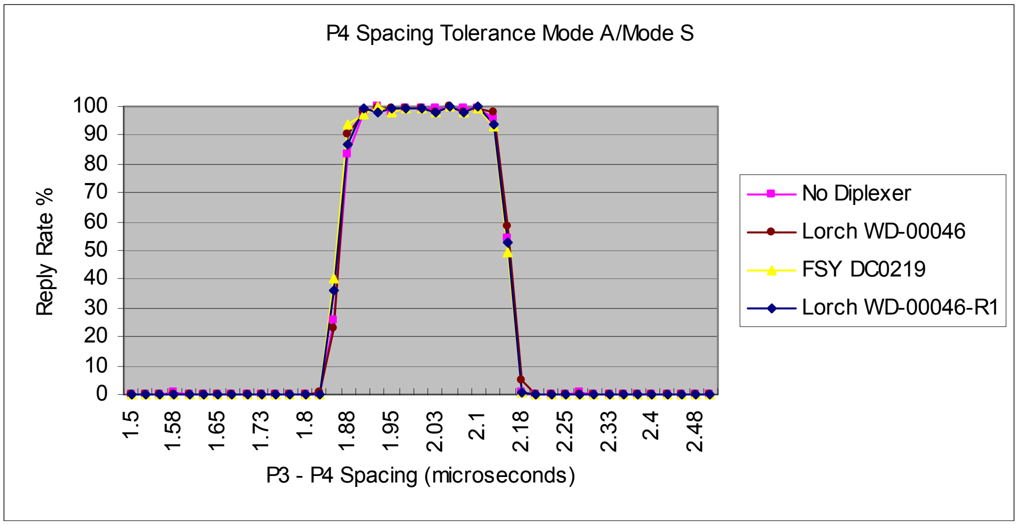

Figure 4-86 – ATCRBS/Mode S (Mode A) P3 – P4 Pulse Position Tolerance, Transponder MS-1A

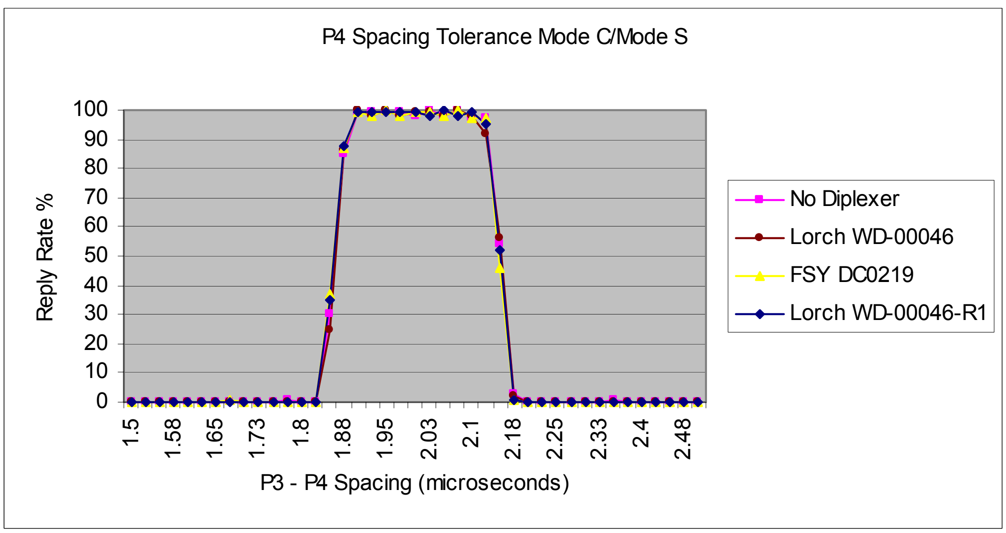

Figure 4-87 – ATCRBS/Mode S (Mode C) P3 – P4 Pulse Position Tolerance, Transponder MS-1A

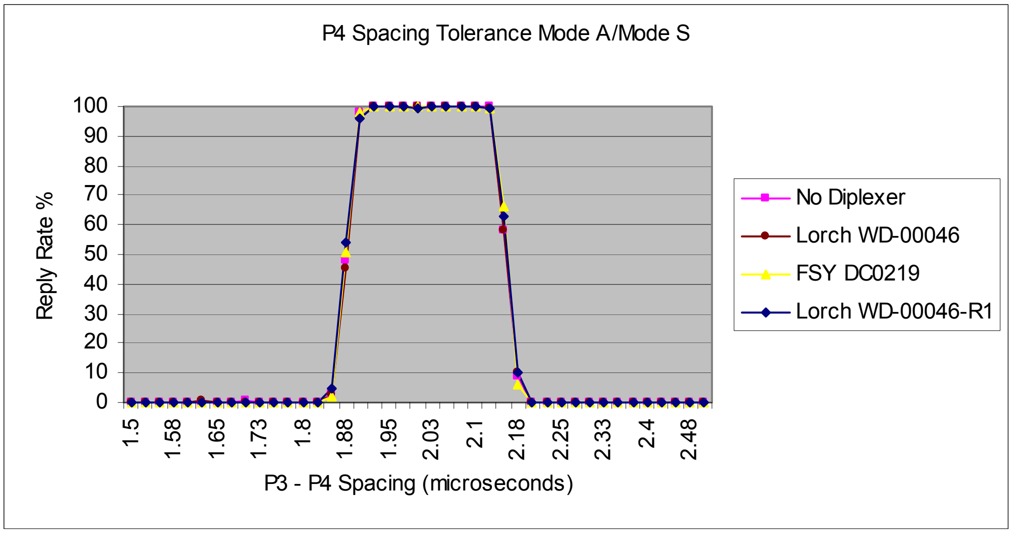

Figure 4-88 – ATCRBS/Mode S (Mode A) P3 – P4 Pulse Position Tolerance, Transponder MS-1B

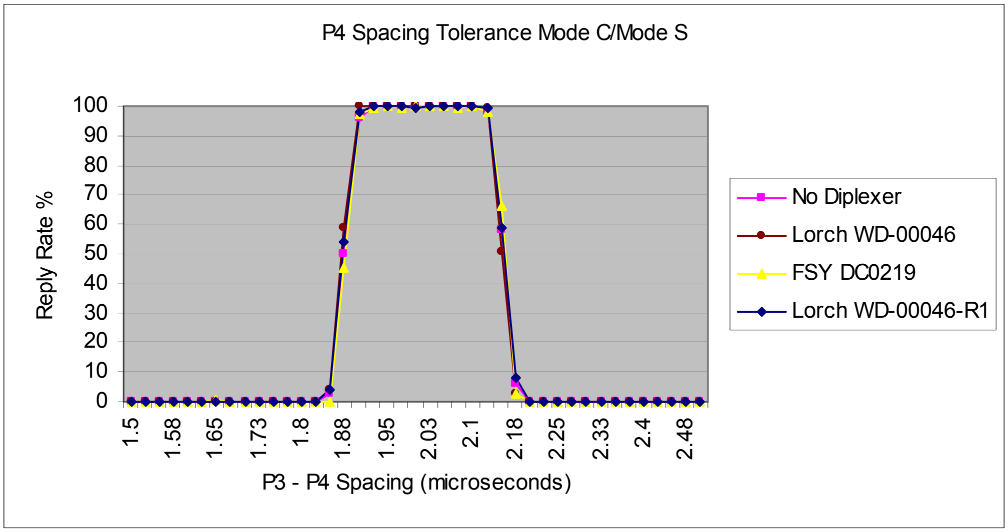

Figure 4-89 – ATCRBS/Mode S (Mode C) P3 – P4 Pulse Position Tolerance, Transponder MS-1B

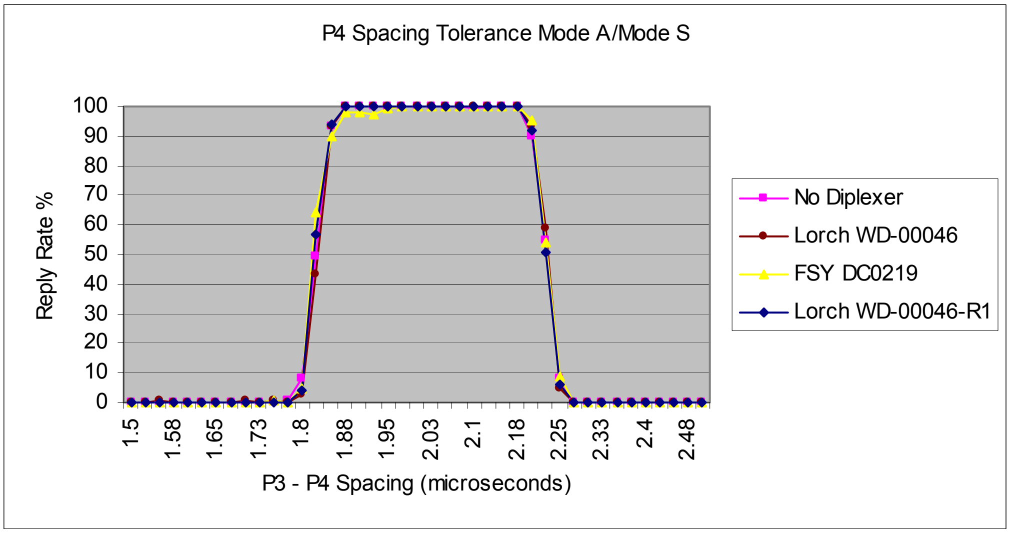

Figure 4-90 – ATCRBS/Mode S (Mode A) P3 – P4 Pulse Position Tolerance, Transponder MS-2

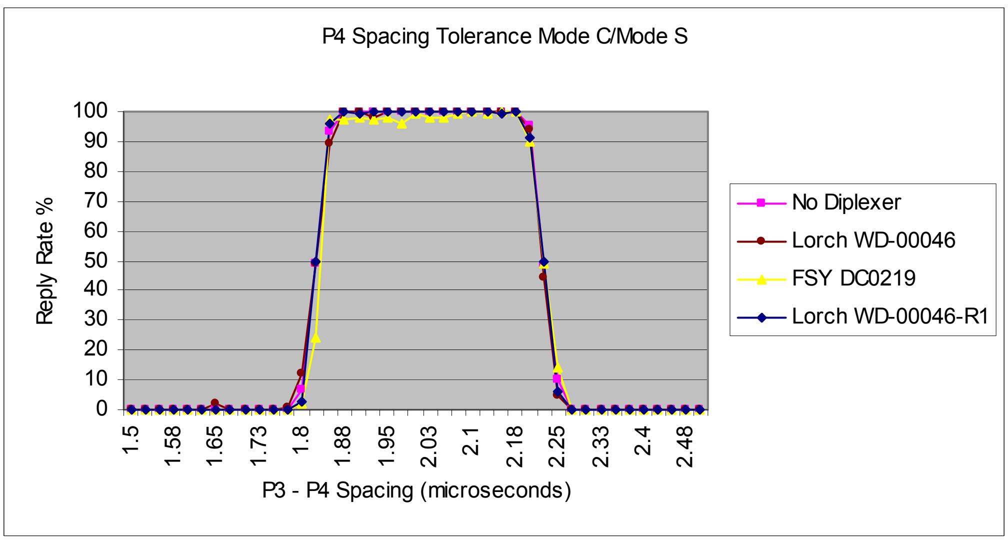

Figure 4-91 – ATCRBS/Mode S (Mode C) P3 – P4 Pulse Position Tolerance, Transponder MS-2

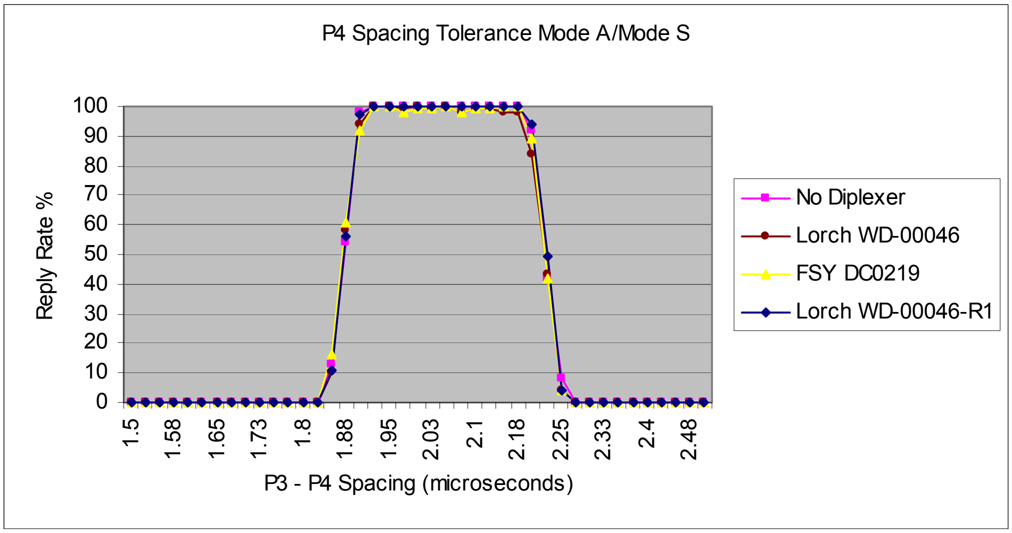

Figure 4-92 – ATCRBS/Mode S (Mode A) P3 – P4 Pulse Position Tolerance, Transponder MS-3A

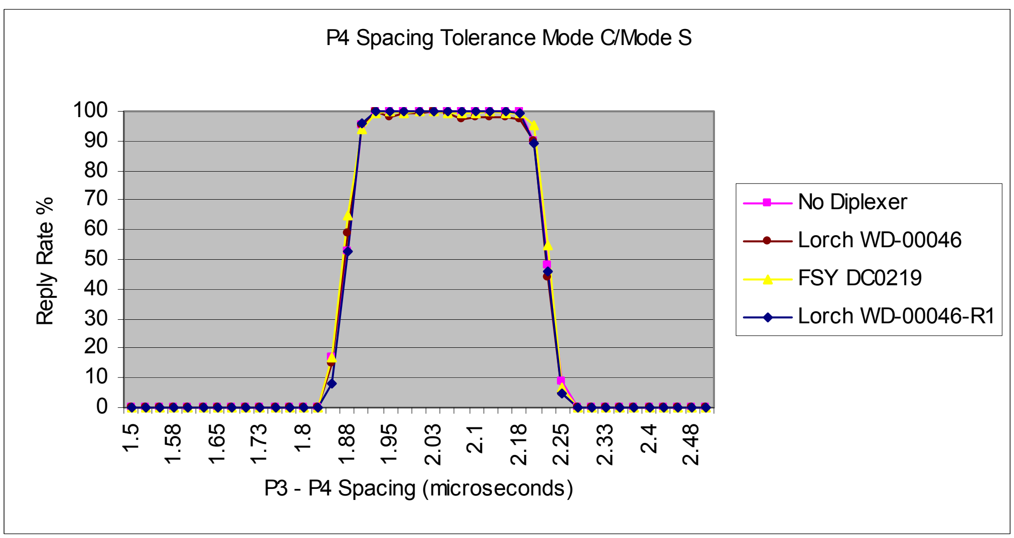

Figure 4-93 – ATCRBS/Mode S (Mode C) P3 – P4 Pulse Position Tolerance, Transponder MS-3A

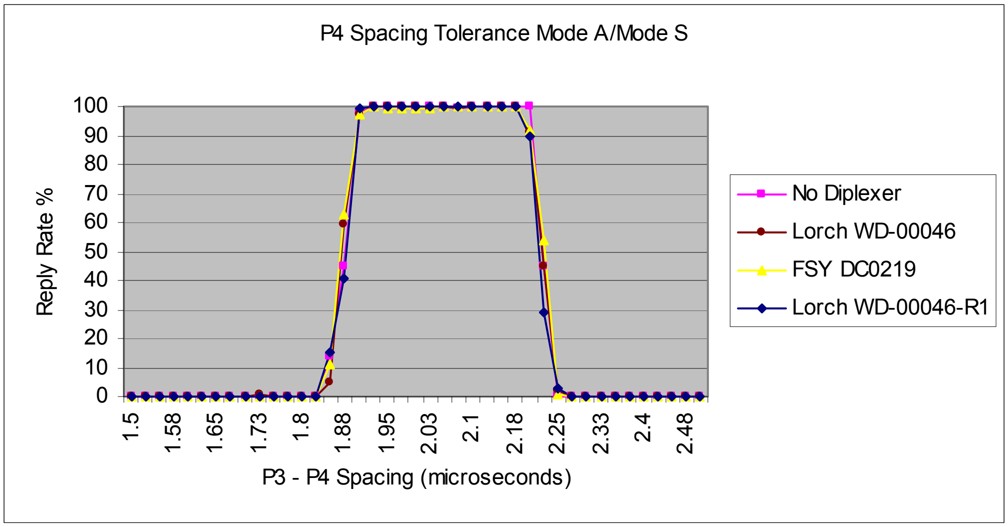

Figure 4-94 – ATCRBS/Mode S (Mode A) P3 – P4 Pulse Position Tolerance, Transponder MS-3B

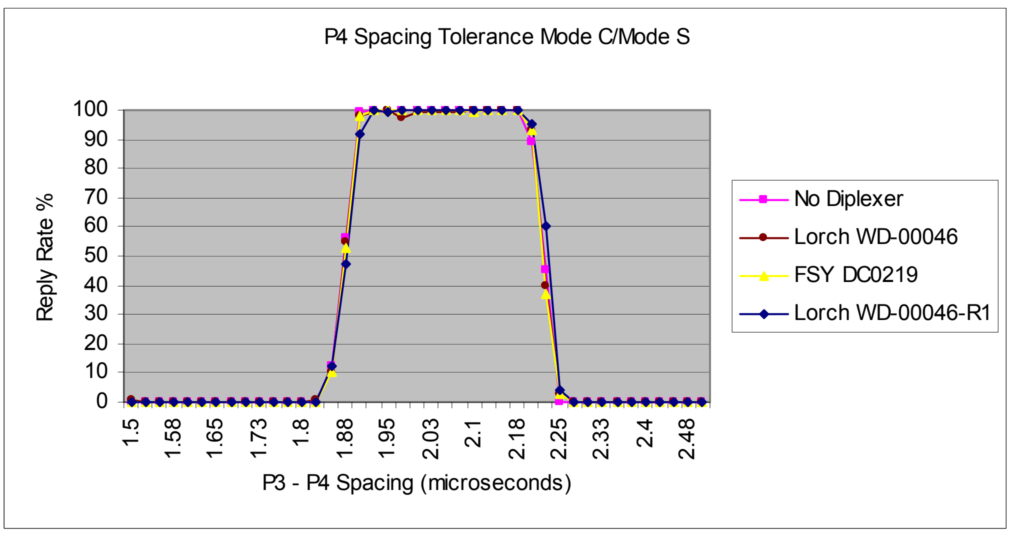

Figure 4-95 – ATCRBS/Mode S (Mode C) P3 – P4 Pulse Position Tolerance, Transponder MS-3B

4.18 Pulse Duration Tolerances, ATCRBS

The ATCRBS pulse duration tolerance test is a measure of the transponder's pulse decoder characteristics. Tests were conducted to determine if the Diplexer affected the pulse duration tolerance of the transponder or the pulse decoding characteristics related to the duration of received pulses. The transponder is required to accept an interrogation as valid if the duration of both P1 and P3 pulses are between 0.7 and 0.9 microseconds. The transponder is required to reply to no more than 10 percent of interrogations if either the P1 or P3 pulse is less than 0.3 microseconds. The tests were conducted using both Mode A and Mode C interrogation types. Since the results are nearly identical for the two modes, only the Mode A plots are presented. Figure 4-96 through Figure 4-113 shows the interrogation pulse decoding performance as the P1 and P3 pulses are independently varied from 0.2 microseconds to 1.0 microseconds in duration. As indicated by the data, there was no measurable effect on the ATCRBS pulse width decoding.

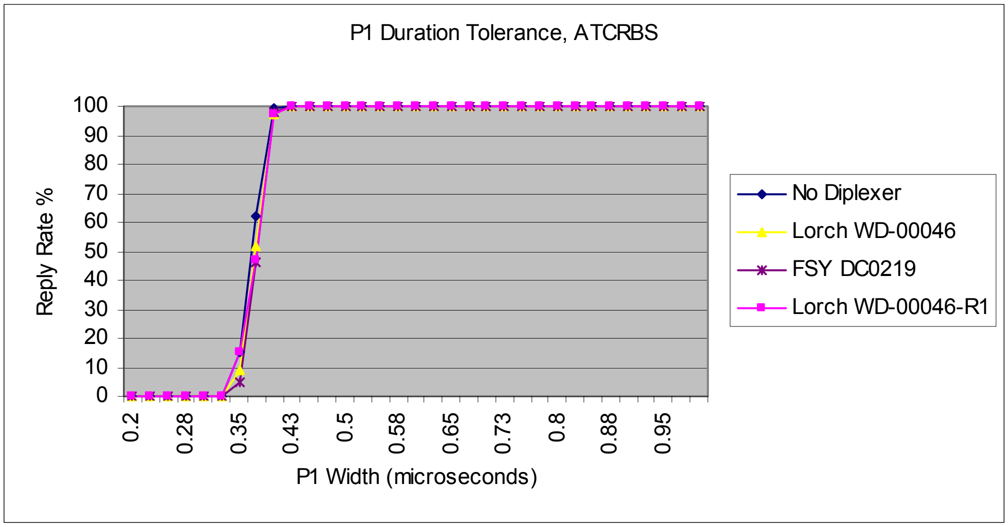

Figure 4-96 – ATCRBS P1 Pulse Duration Tolerance, Transponder MS-1A

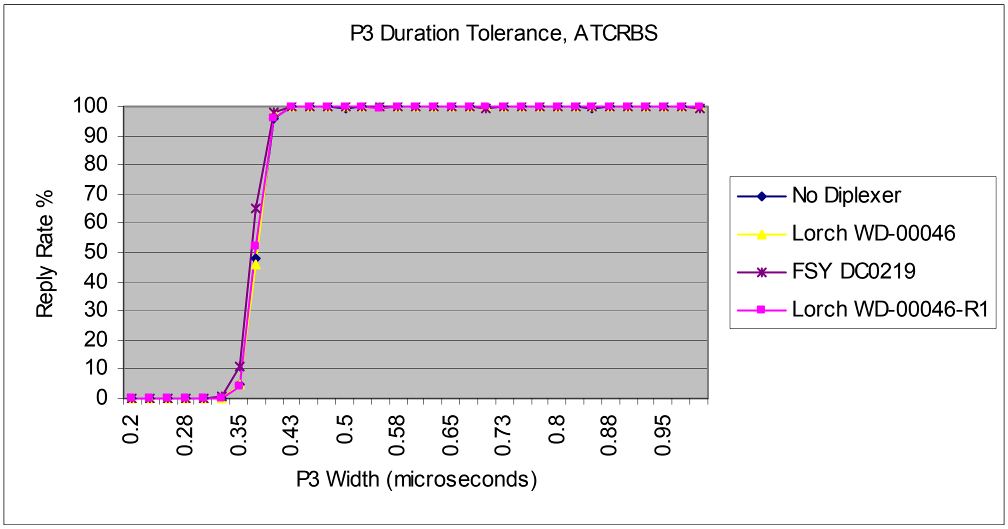

Figure 4-97 – ATCRBS P3 Pulse Duration Tolerance, Transponder MS-1A

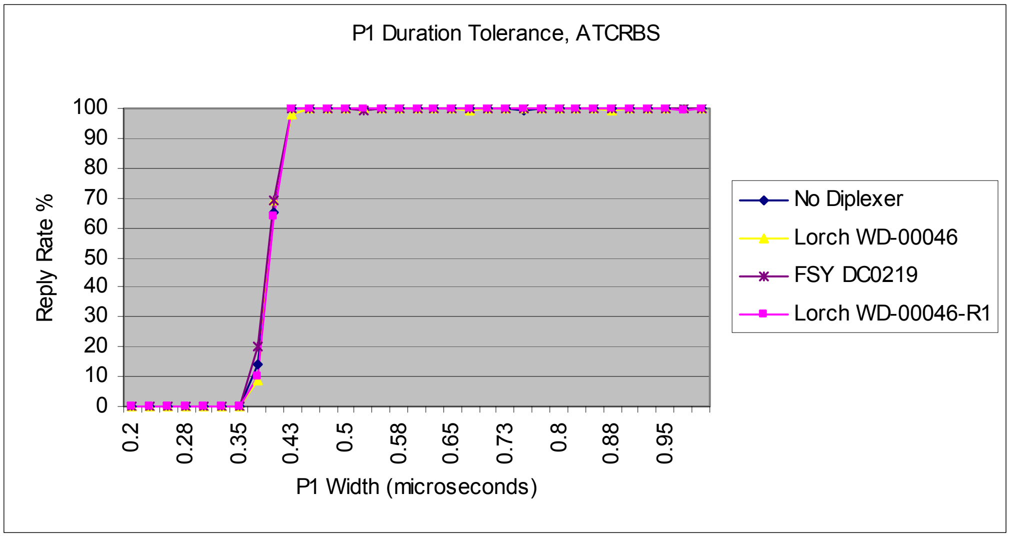

Figure 4-98 – ATCRBS P1 Pulse Duration Tolerance, Transponder MS-1B

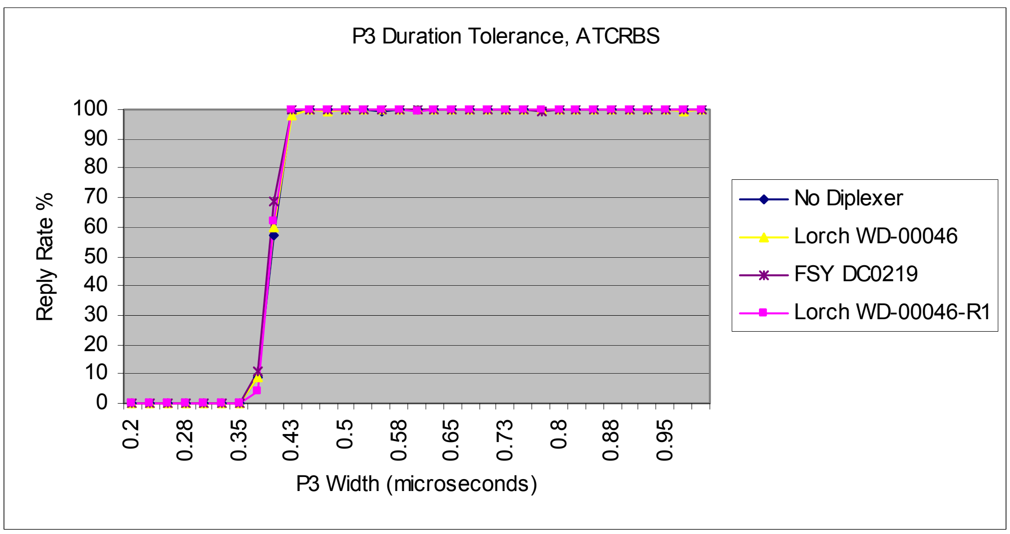

Figure 4-99 – ATCRBS P3 Pulse Duration Tolerance, Transponder MS-1B

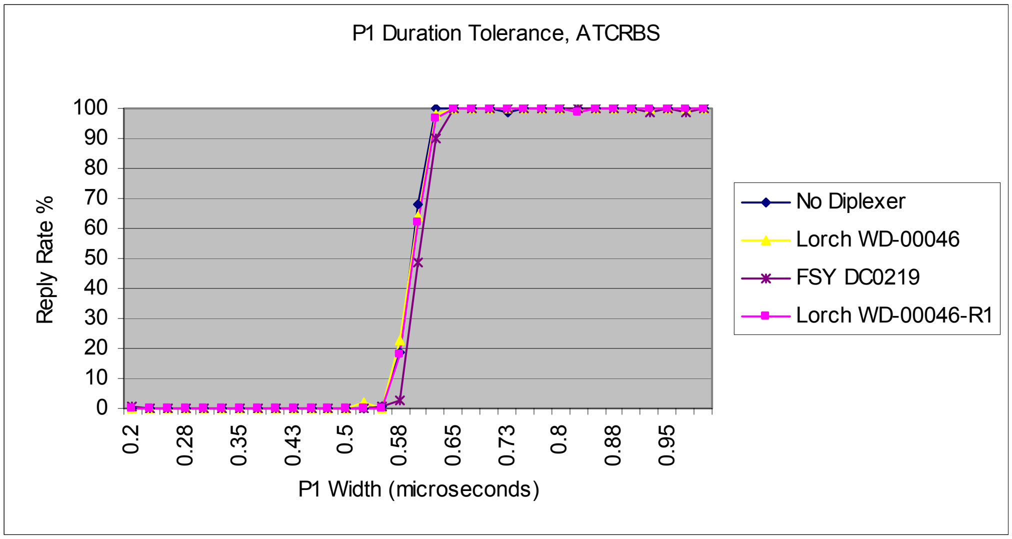

Figure 4-100 – ATCRBS P1 Pulse Duration Tolerance, Transponder MS-2

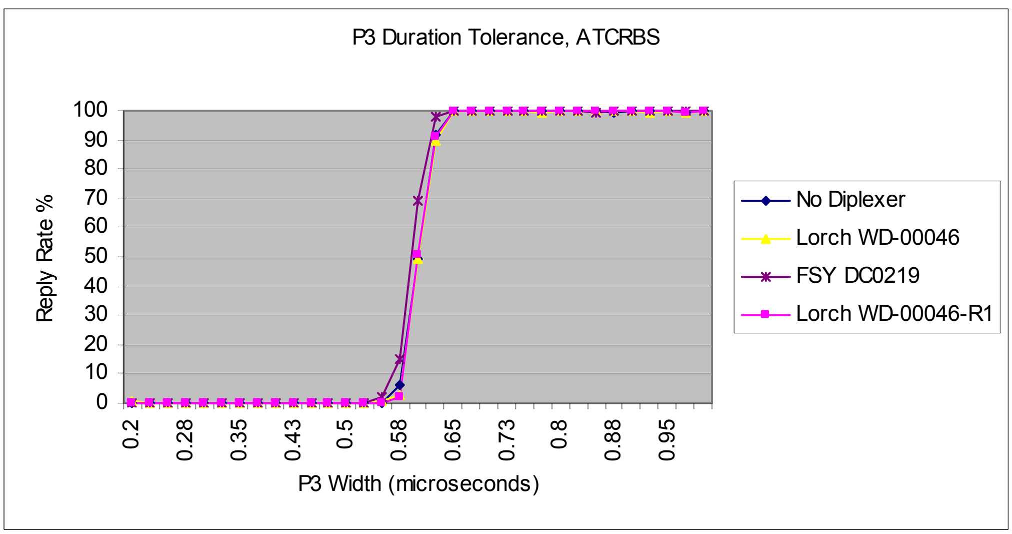

Figure 4-101 – ATCRBS P3 Pulse Duration Tolerance, Transponder MS-2

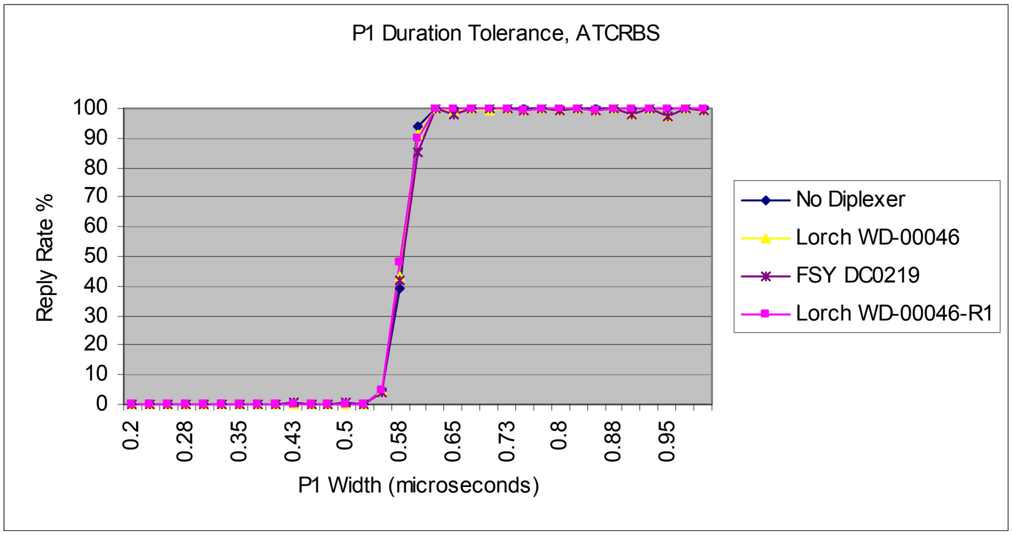

Figure 4-102 – ATCRBS P1 Pulse Duration Tolerance, Transponder MS-3A

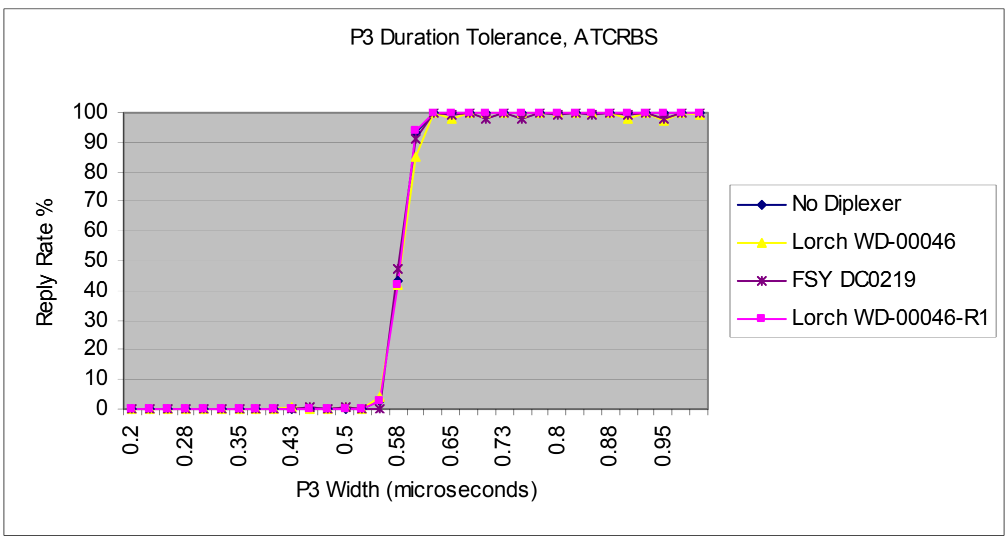

Figure 4-103 – ATCRBS P3 Pulse Duration Tolerance, Transponder MS-3A

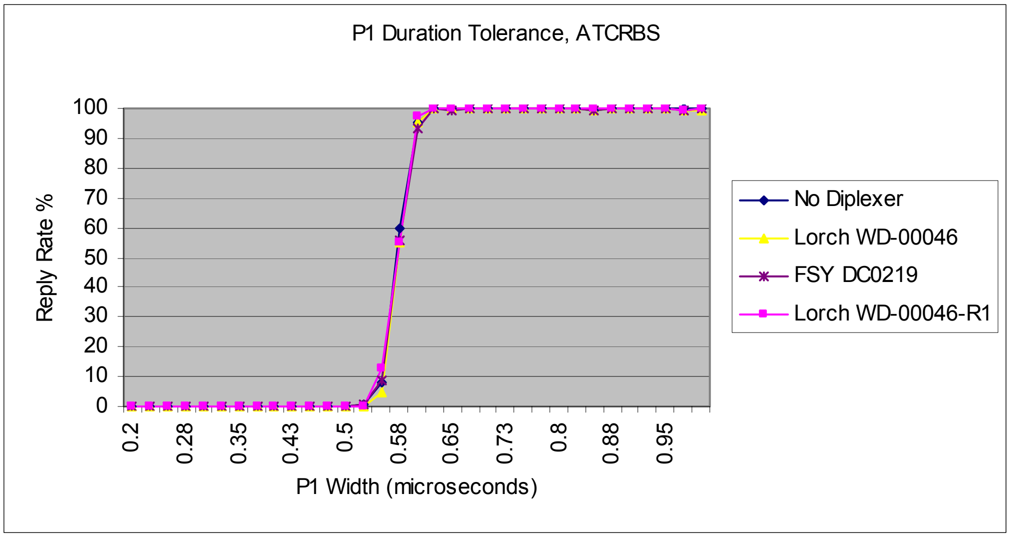

Figure 4-104 – ATCRBS P1 Pulse Duration Tolerance, Transponder MS-3B

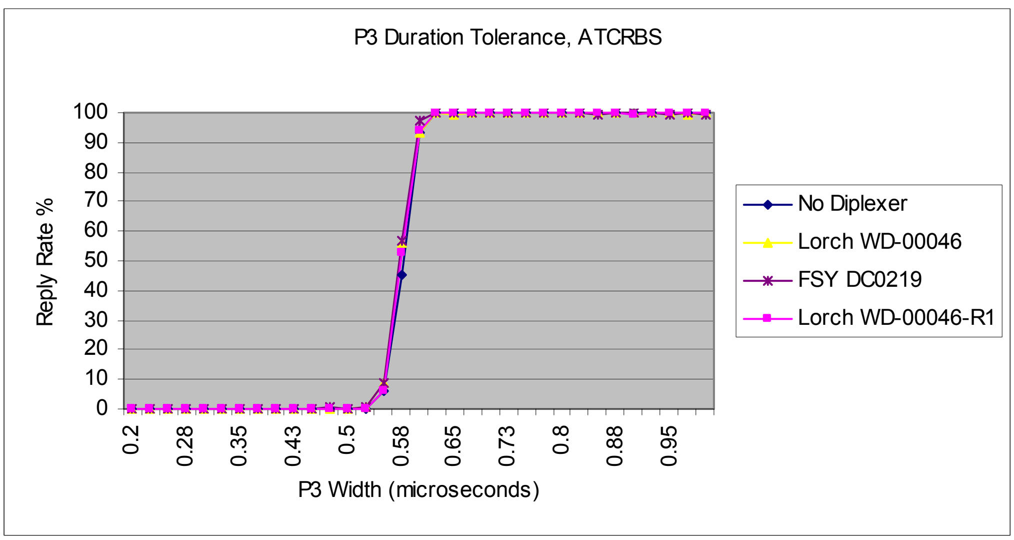

Figure 4-105 – ATCRBS P3 Pulse Duration Tolerance, Transponder MS-3B

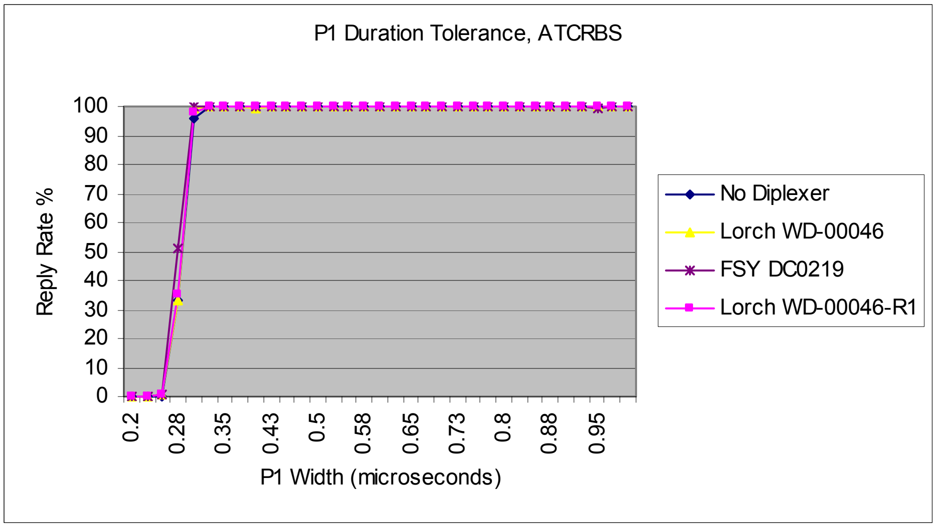

Figure 4-106 – ATCRBS P1 Pulse Duration Tolerance, Transponder A-1

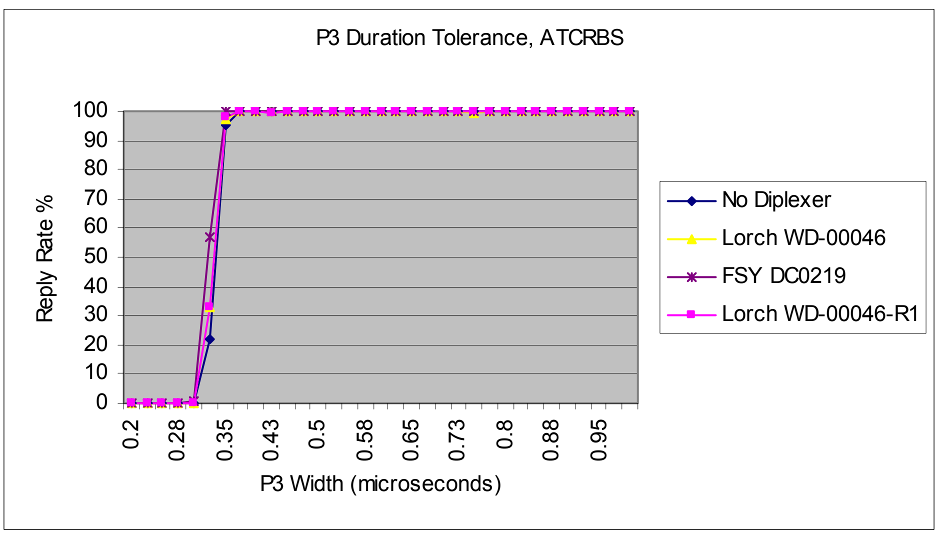

Figure 4-107 – ATCRBS P3 Pulse Duration Tolerance, Transponder A-1

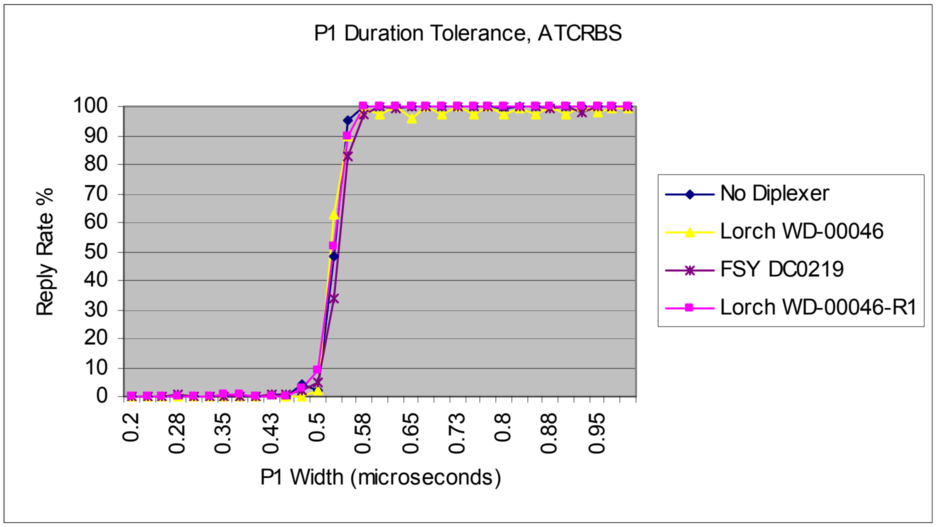

Figure 4-108 – ATCRBS P1 Pulse Duration Tolerance, Transponder A-2

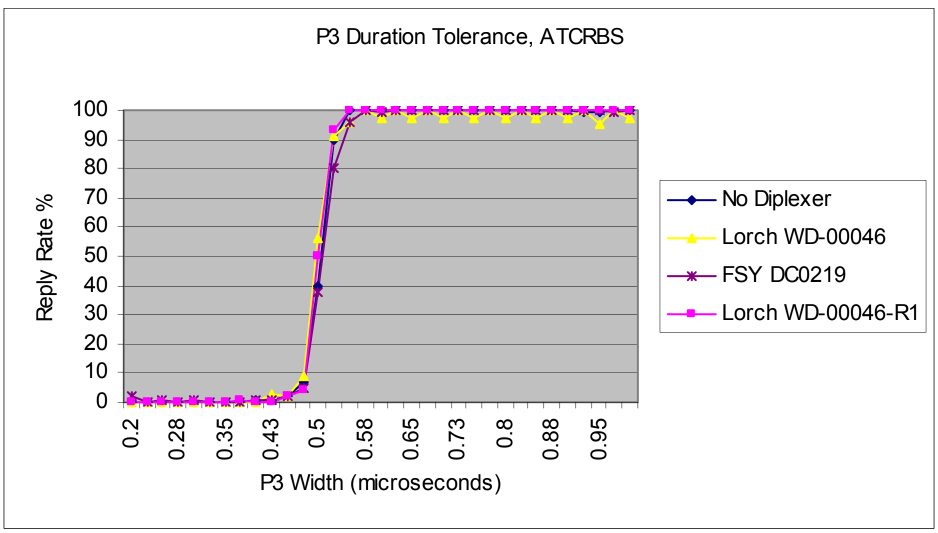

Figure 4-109 – ATCRBS P3 Pulse Duration Tolerance, Transponder A-2

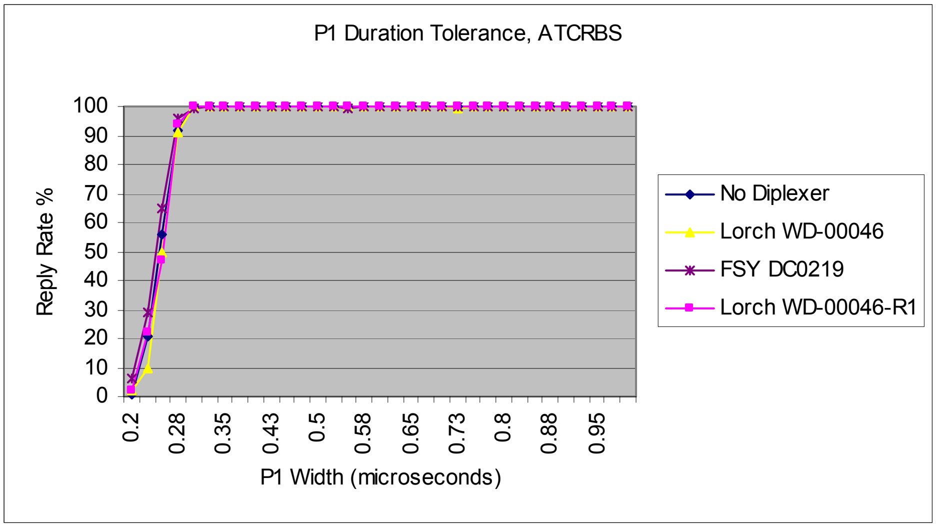

Figure 4-110 – ATCRBS P1 Pulse Duration Tolerance, Transponder A-3

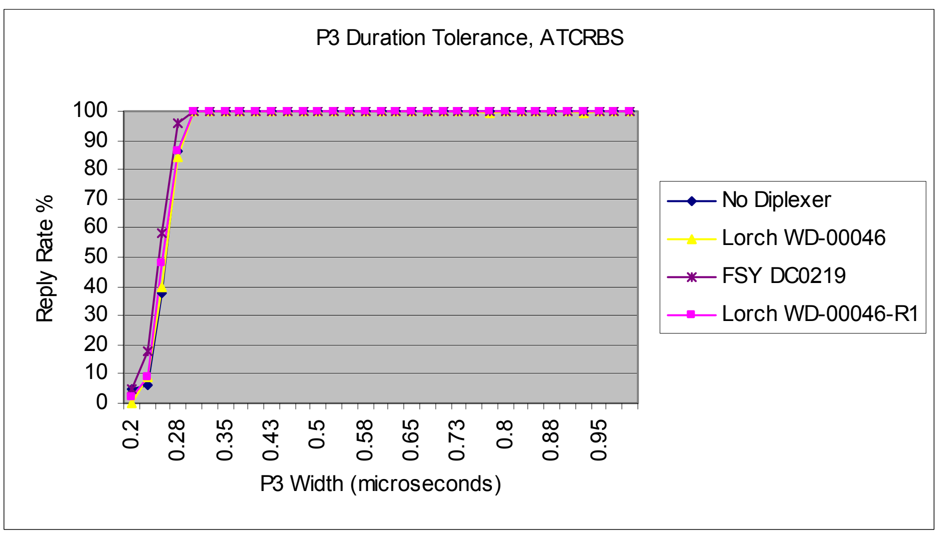

Figure 4-111 – ATCRBS P3 Pulse Duration Tolerance, Transponder A-3

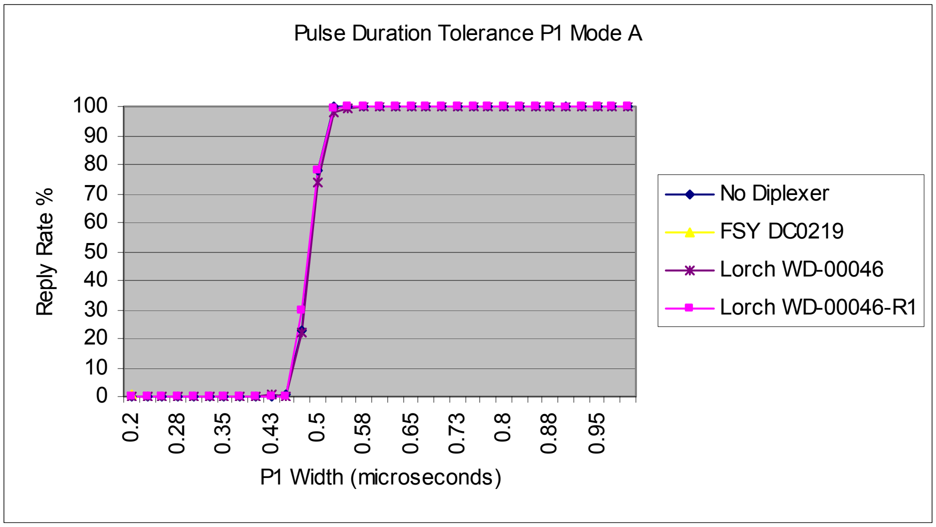

Figure 4-112 – ATCRBS P1 Pulse Duration Tolerance, Transponder A-4

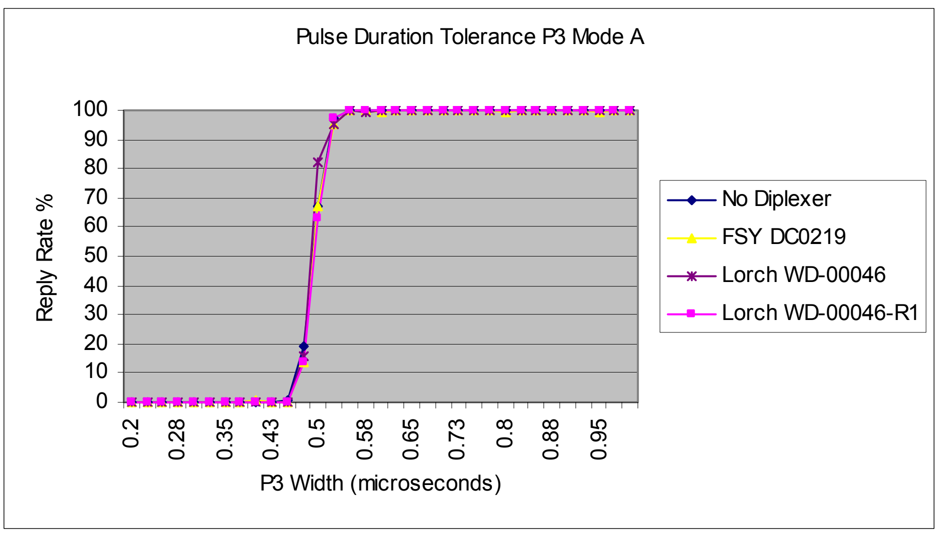

Figure 4-113 – ATCRBS P3 Pulse Duration Tolerance, Transponder A-4

4.19 Pulse Duration Tolerances, ATCRBS/Mode S

The ATCRBS/Mode S pulse duration tolerance test is a measure of the transponder's pulse decoder characteristics. Tests were conducted to determine if the Diplexer affected the pulse duration tolerance of the transponder or the pulse decoding characteristics related to the duration of received pulses. These tests are similar to the ATCRBS pulse duration tolerance tests except in this case, ATCRBS/Mode S interrogation formats are used and the duration of the P1, P3 and P4 pulses are varied. The transponder is required to accept an ATCRBS/Mode S interrogation as valid if the duration of both P1 and P3 pulses are between 0.7 and 0.9 microseconds and the duration of P4 is between 1.5 and 1.7 microseconds. The transponder is required to reply to no more than 10 percent of interrogations that have either P1 or P3 pulses less than 0.3 microseconds. The transponder must not accept an interrogation if the P4 duration is outside the range between 1.2 and 2.5 microseconds.

The tests were conducted using both Mode A and Mode C ATCRBS/Mode S interrogation types. Since the results are nearly identical for the two modes, only the Mode A/Mode S plots are presented. Figure 4-114 through Figure 4-128 shows the interrogation pulse decoding performance as the P1 and P3 pulses are independently varied from 0.1 microseconds to 1.5 microseconds in duration and the P4 pulse is varied from 0.9 microseconds to 2.3 microseconds in duration. As indicated by the data, there was no measurable effect on the ATCRBS pulse width decoding.

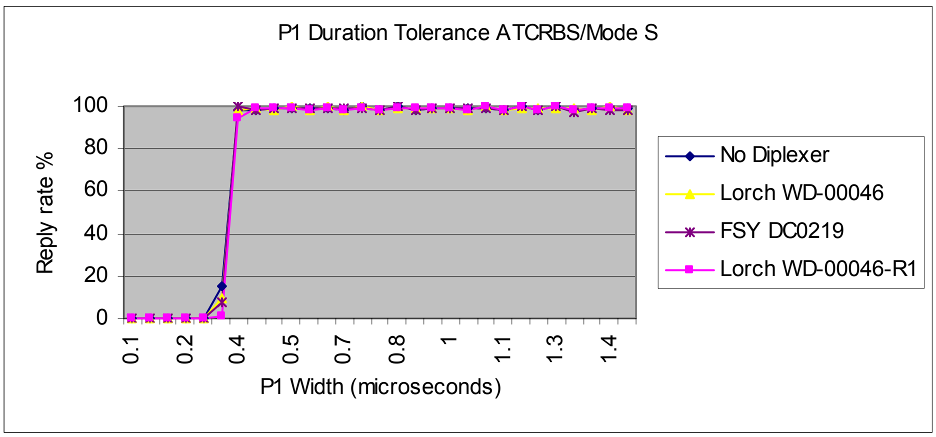

Figure 4-114 – ATCRBS/Mode S P1 Pulse Duration Tolerance, Transponder MS-1A

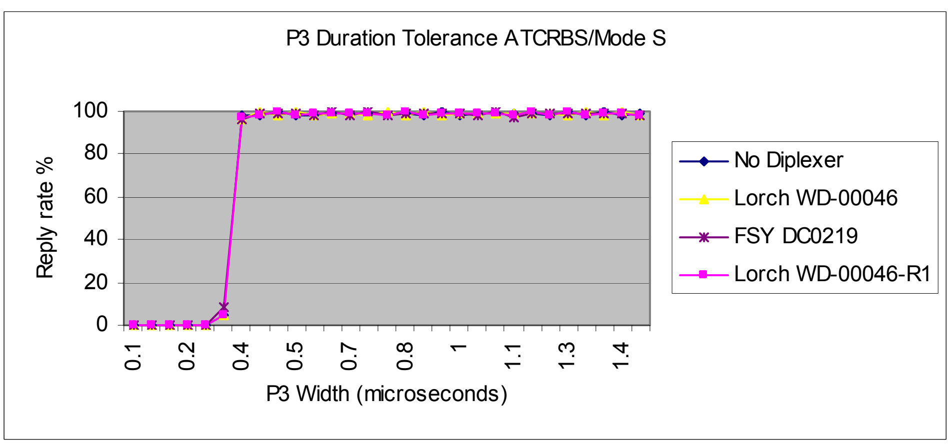

Figure 4-115 – ATCRBS/Mode S P3 Pulse Duration Tolerance, Transponder MS-1A

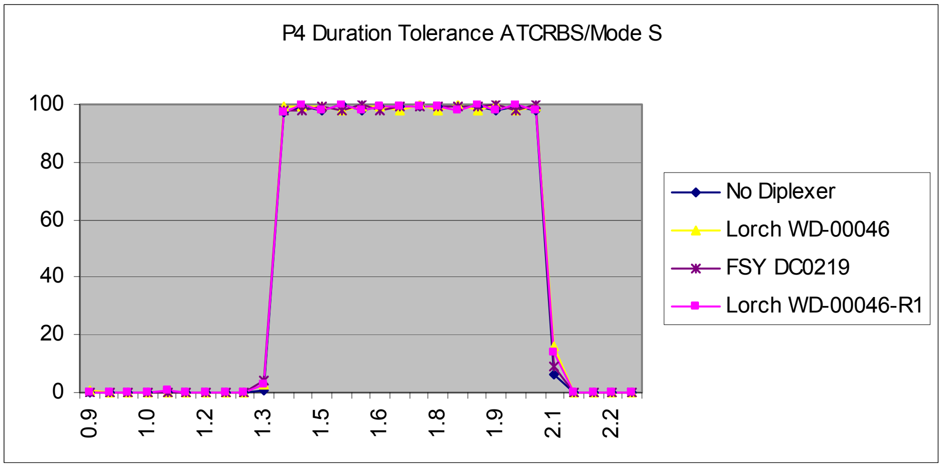

Figure 4-116 – ATCRBS/Mode S P4 Pulse Duration Tolerance, Transponder MS-1A

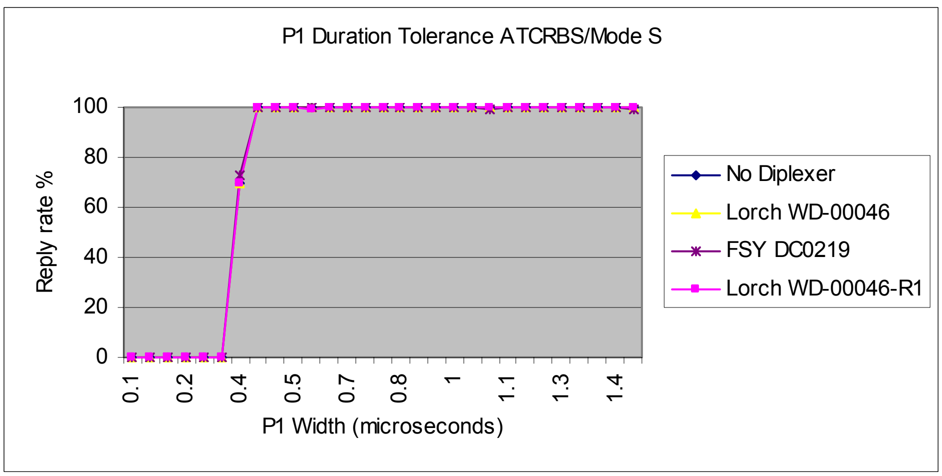

Figure 4-117 – ATCRBS/Mode S P1 Pulse Duration Tolerance, Transponder MS-1B

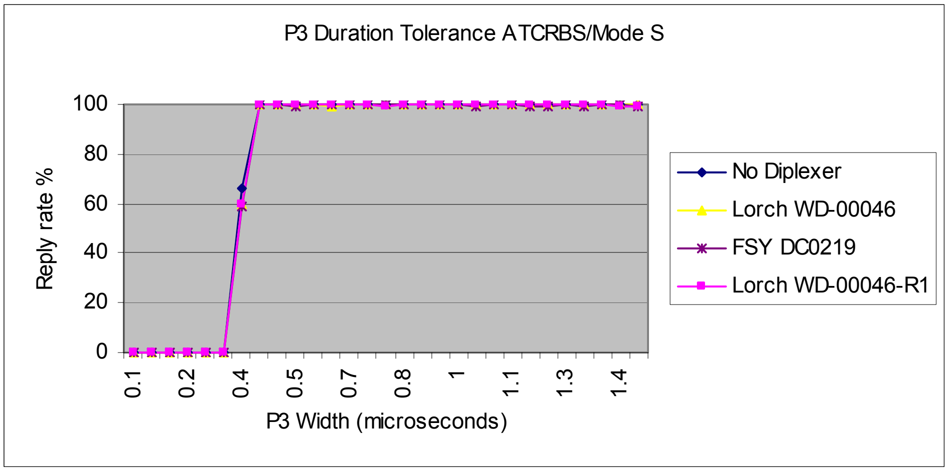

Figure 4-118 – ATCRBS/Mode S P3 Pulse Duration Tolerance, Transponder MS-1B

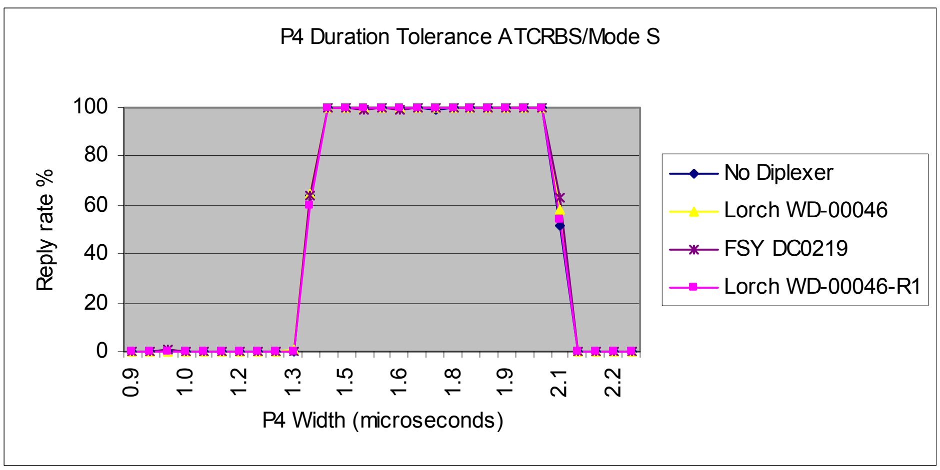

Figure 4-119 – ATCRBS/Mode S P4 Pulse Duration Tolerance, Transponder MS-1B

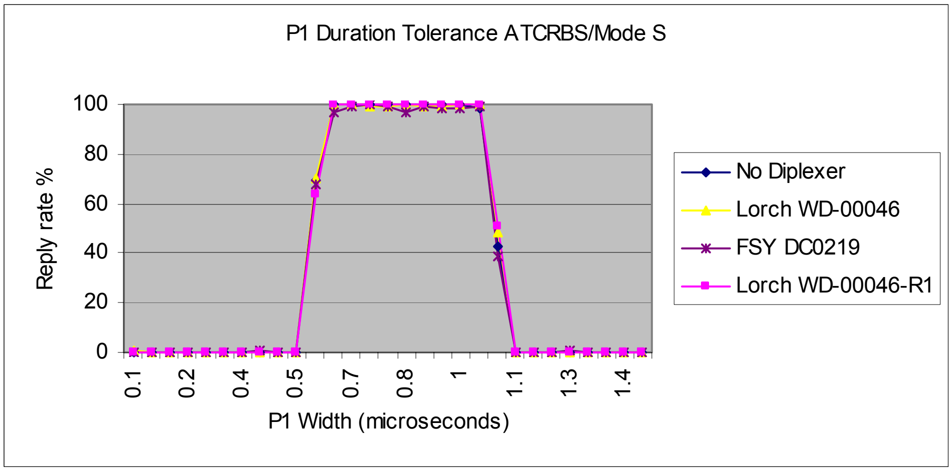

Figure 4-120 – ATCRBS/Mode S P1 Pulse Duration Tolerance, Transponder MS-2

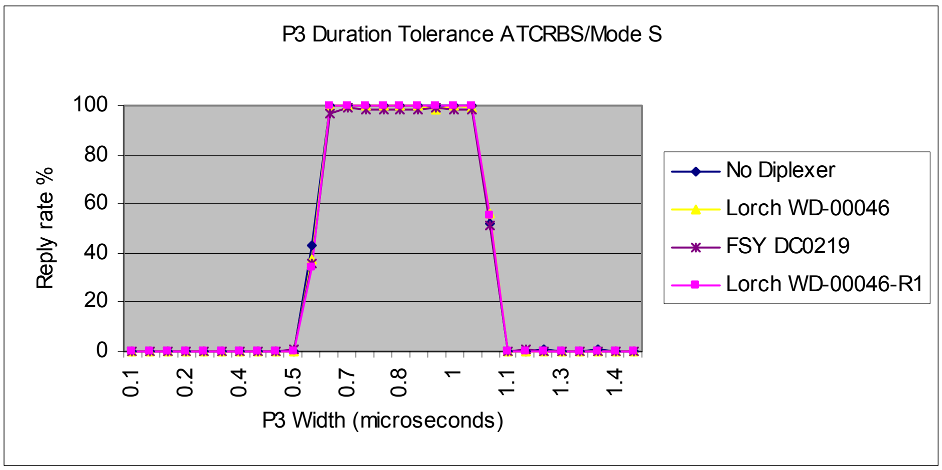

Figure 4-121 – ATCRBS/Mode S P3 Pulse Duration Tolerance, Transponder MS-2

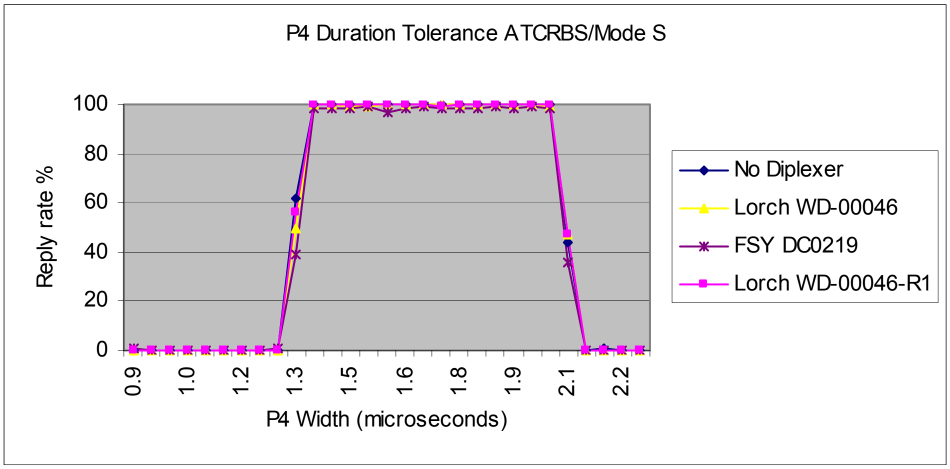

Figure 4-122 – ATCRBS/Mode S P4 Pulse Duration Tolerance, Transponder MS-2

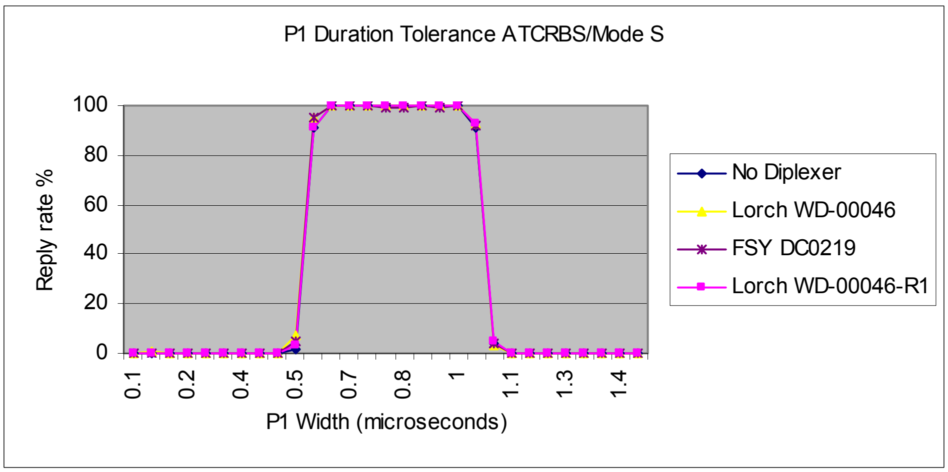

Figure 4-123 – ATCRBS/Mode S P1 Pulse Duration Tolerance, Transponder MS-3A

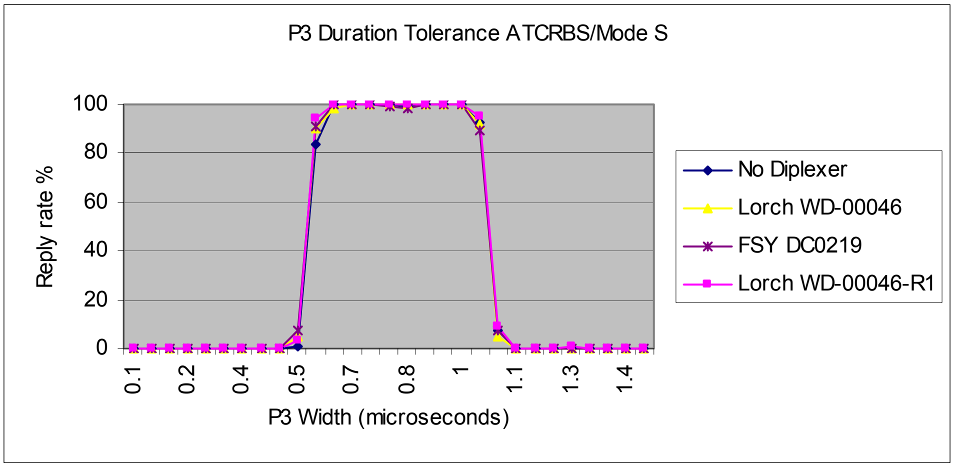

Figure 4-124 – ATCRBS/Mode S P3 Pulse Duration Tolerance, Transponder MS-3A

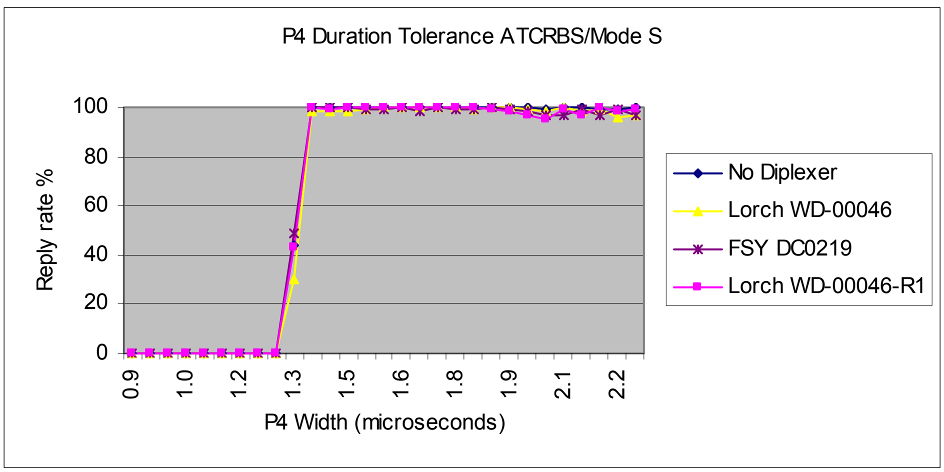

Figure 4-125 – ATCRBS/Mode S P4 Pulse Duration Tolerance, Transponder MS-3A

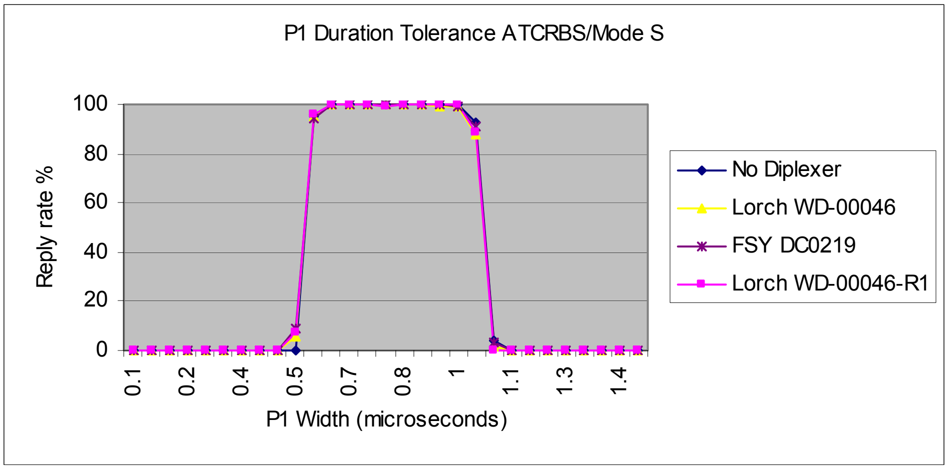

Figure 4-126 – ATCRBS/Mode S P1 Pulse Duration Tolerance, Transponder MS-3B

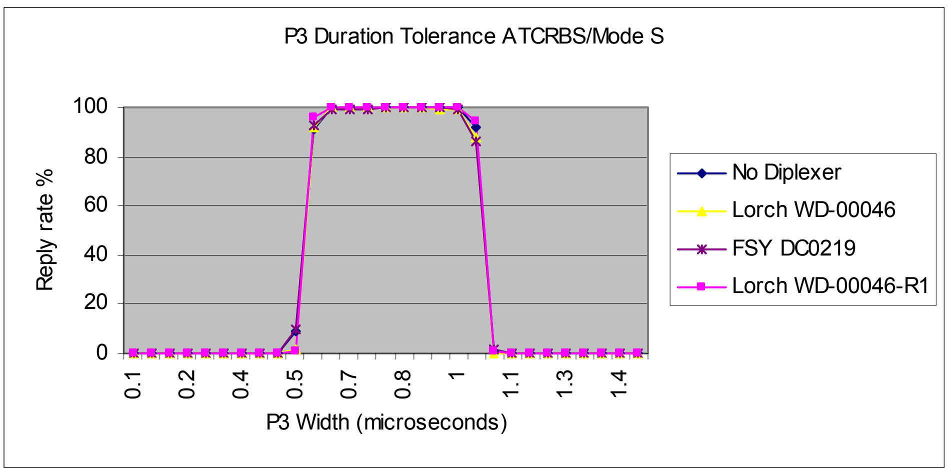

Figure 4-127 – ATCRBS/Mode S P3 Pulse Duration Tolerance, Transponder MS-3B

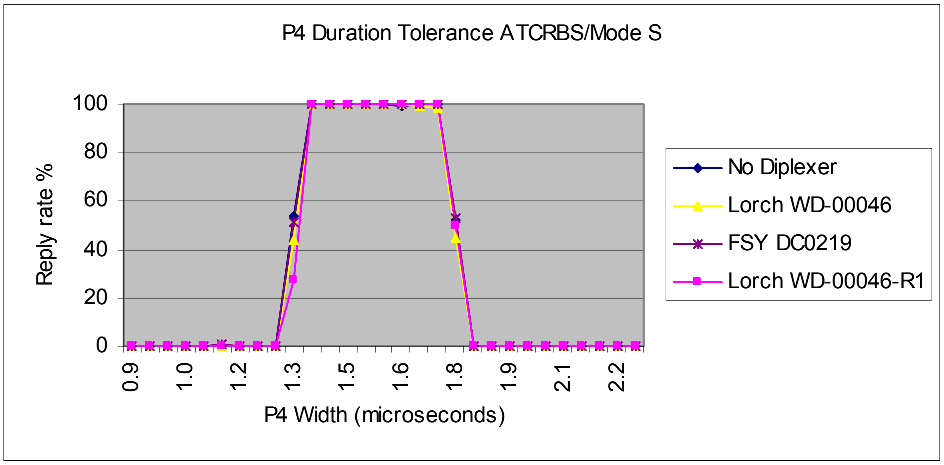

Figure 4-128 – ATCRBS/Mode S P4 Pulse Duration Tolerance, Transponder MS-3B

4.20 Pulse Level Tolerances, ATCRBS/Mode S All-Call

The ATCRBS/Mode S All-Call pulse level tolerance test is a measure of the transponder's pulse decoder characteristics. Tests were conducted to determine if the Diplexer affected the pulse level tolerance of the transponder or the pulse decoding characteristics related to the level of received pulses. The transponder is required to accept an interrogation as an ATCRBS/Mode S All-Call as valid if the amplitude of the P4 pulse is greater than the amplitude of P3 minus 1 dB. The transponder is required to accept an interrogation as a valid ATCRBS interrogation if the amplitude of the P4 pulse is less than the amplitude of P3 minus 6 dB. Tests were conducted to measure the P4 level acceptance with each test configuration. The test procedure measured the reply format (either ATCRBS or Mode S) as the level of the P4 pulse was varied from minus 10 dB to equal in relative amplitude to the P1 and P3 pulses of the interrogation. As indicated in the graphs, there is a transition from an ATCRBS reply to a Mode S reply as the level of the P4 pulse approaches that of the other pulses. Of interest here is whether the addition of the Diplexer introduces any pulse distortions that are revealed when conducting this test. Figure 4-129 through Figure 4-133 shows that there is no significant effect from the Diplexers on the P4 pulse level decoding characteristics.

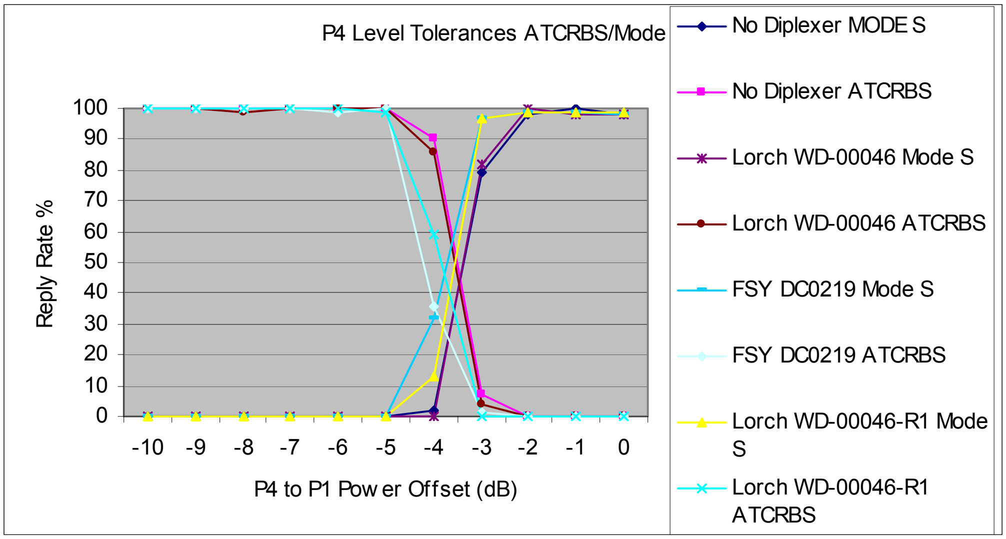

Figure 4-129 – ATCRBS/Mode S P4 Pulse Level Tolerance, Transponder MS-1A

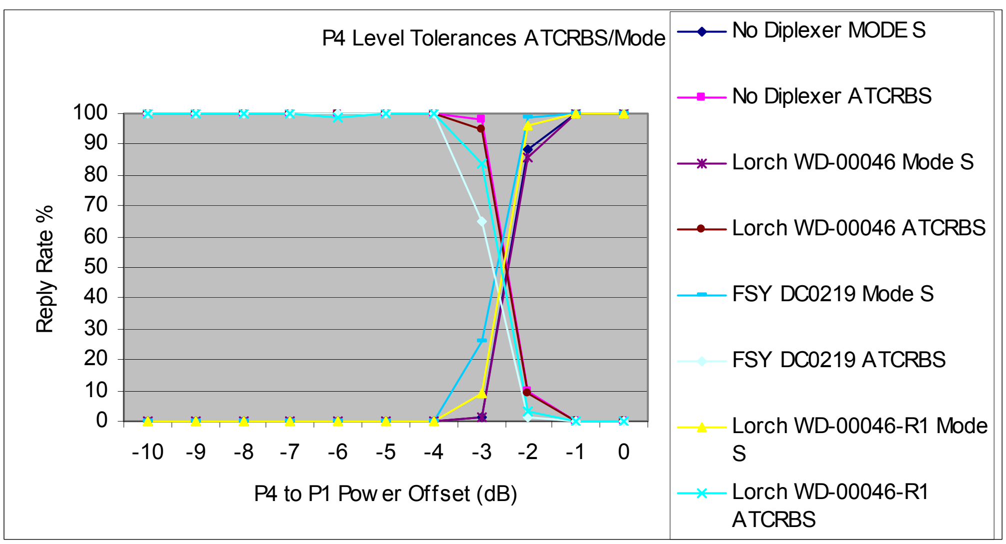

Figure 4-130 – ATCRBS/Mode S P4 Pulse Level Tolerance, Transponder MS-1B

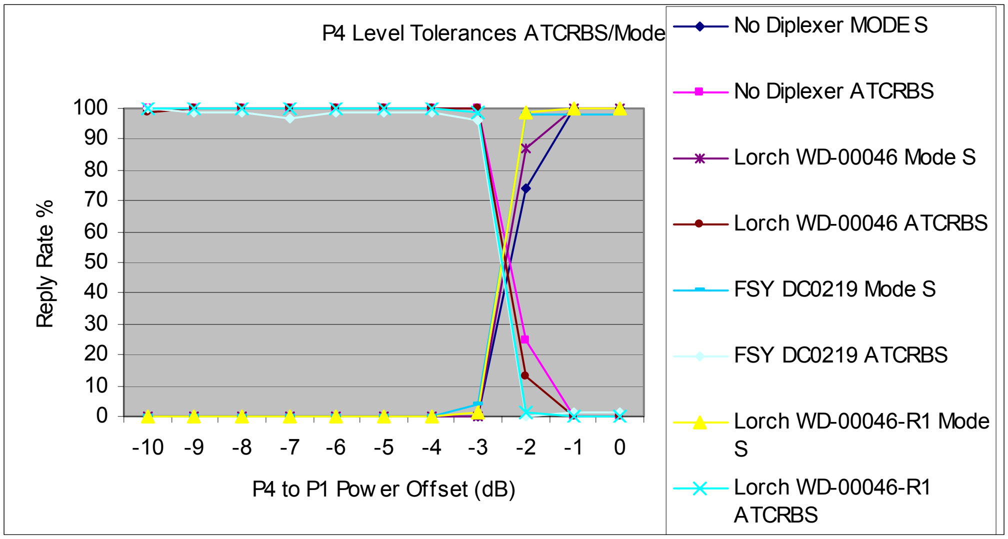

Figure 4-131 – ATCRBS/Mode S P4 Pulse Level Tolerance, Transponder MS-2

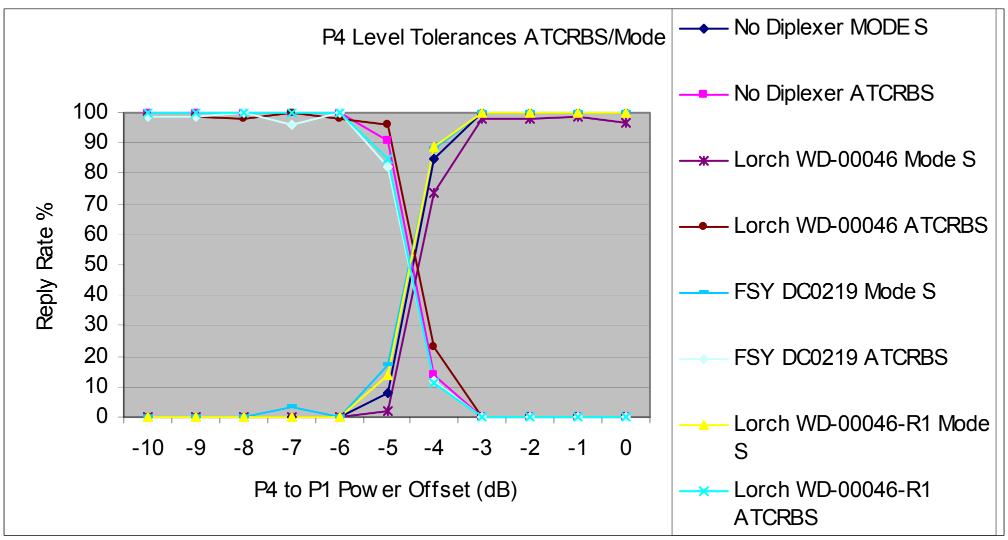

Figure 4-132 – ATCRBS/Mode S P4 Pulse Level Tolerance, Transponder MS-3A

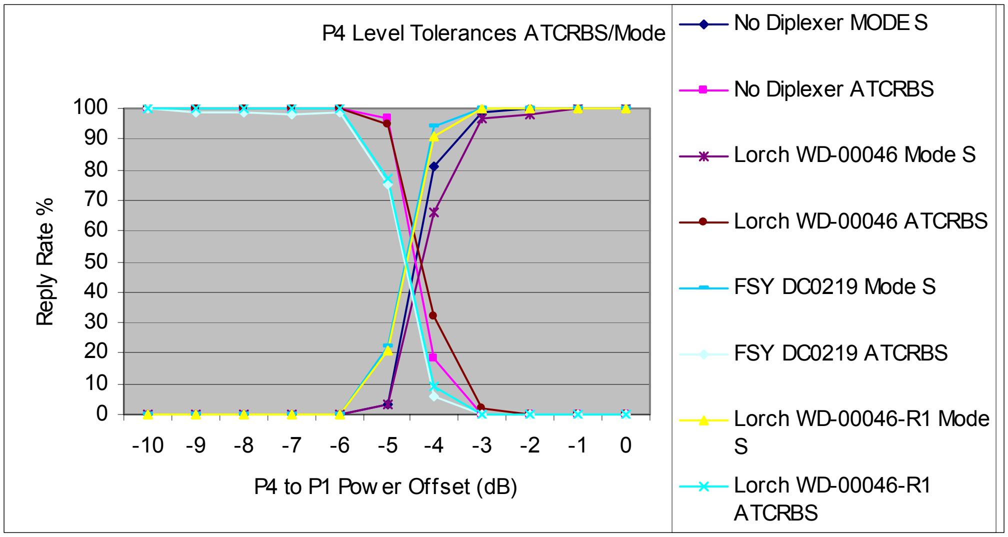

Figure 4-133 – ATCRBS/Mode S P4 Pulse Level Tolerance, Transponder MS-3B

4.21 Sync Phase Reversal Position Tolerance

The sync phase reversal position tolerance test is a measure of a Mode S transponder's pulse decoder characteristics. Tests were conducted to determine if the Diplexer affected the sync phase position tolerance of the transponder. Mode S transponders are required to accept interrogations as valid if the sync phase reversal is received within the interval from 1.2 to 1.3 microseconds following the leading edge of P6. The interrogation is to be rejected if the sync phase is received outside the interval from 1.05 to 1.45 microseconds after the leading edge of P6. Figure 4-134 through Figure 4-138 shows that the Diplexers had no effect on the sync phase reversal position tolerance parameter.

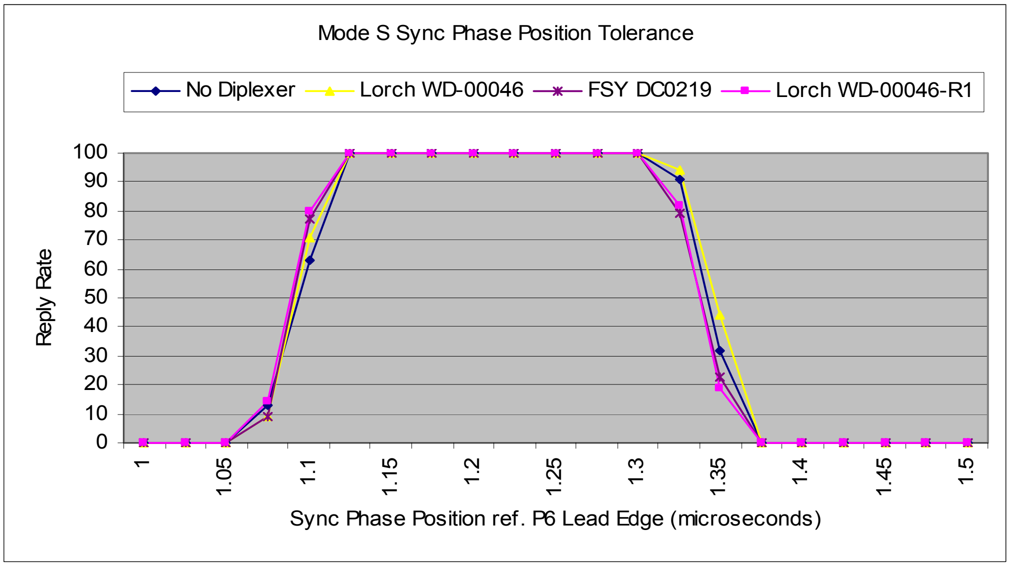

Figure 4-134 – Mode S Sync Phase Position Tolerance, Transponder MS-1A

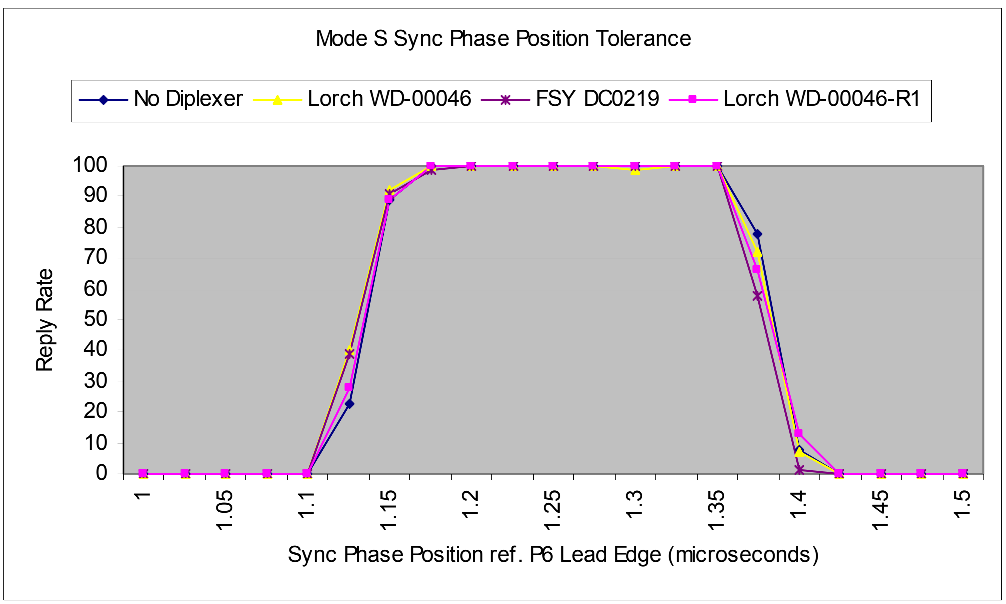

Figure 4-135 – Mode S Sync Phase Position Tolerance, Transponder MS-1B

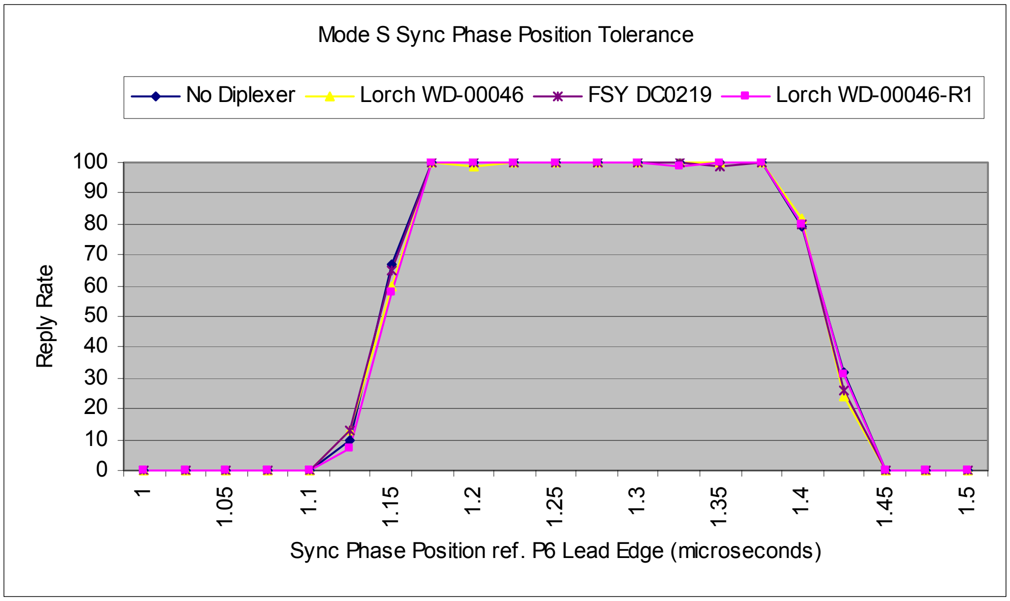

Figure 4-136 – Mode S Sync Phase Position Tolerance, Transponder MS-2

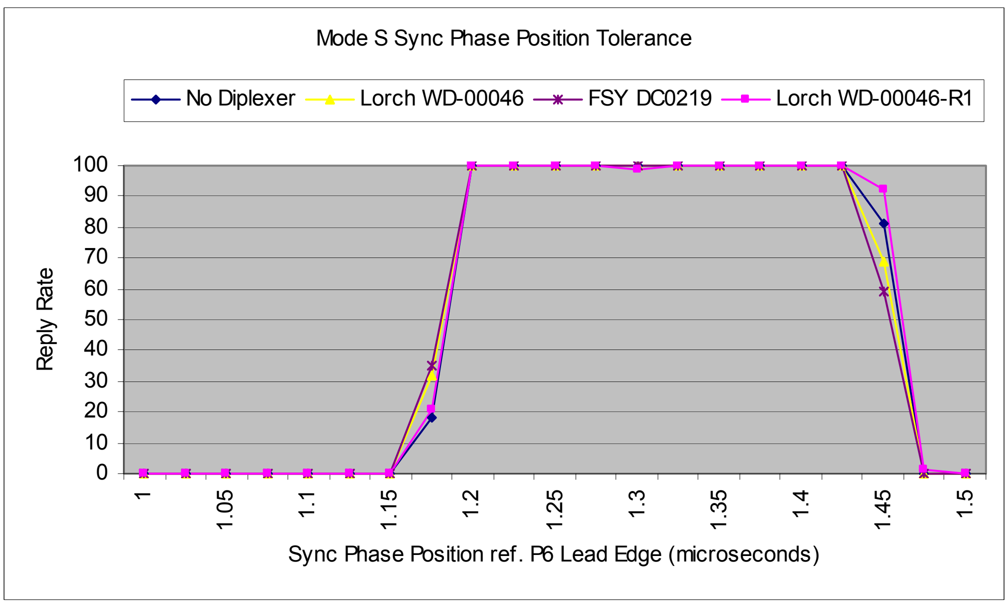

Figure 4-137 – Mode S Sync Phase Position Tolerance, Transponder MS-3A

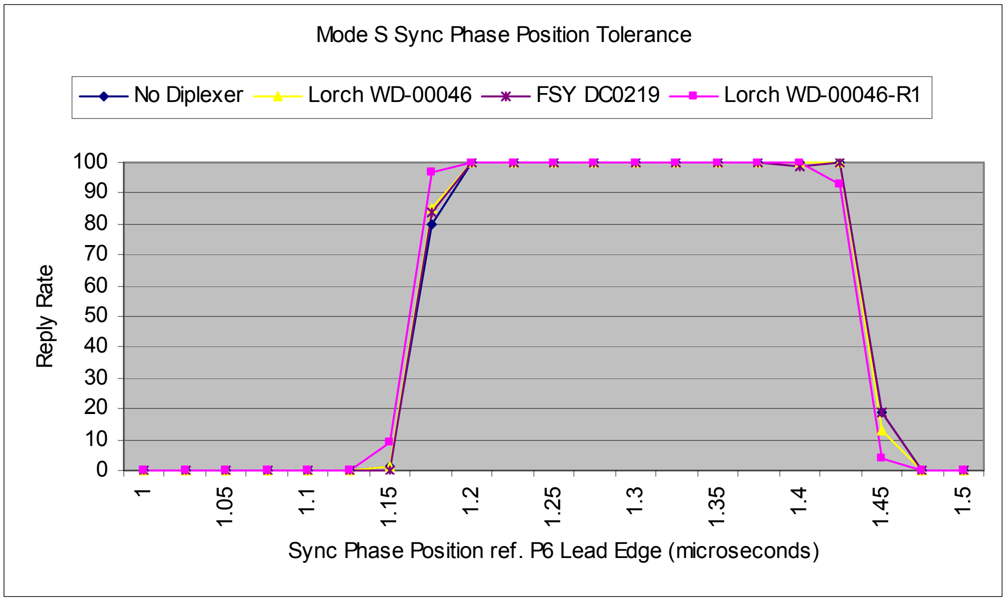

Figure 4-138 – Mode S Sync Phase Position Tolerance, Transponder MS-3B

4.22 Side Lobe Suppression (SLS) Decoding

Tests were conducted to determine if the Diplexers had an effect on the decoding of the P2 Side Lobe Suppression (SLS) pulse with ATCRBS interrogations. The transponder is required to suppress when a valid suppression pulse of equal or greater amplitude to P1 is received in the interval between 1.85 to 2.15 microseconds from P1. The transponder is required to reply to at least 90 percent of interrogations when no suppression pulse is received within the interval from 1.3 to 2.7 microseconds. The SLS decoding tests measured the transponders reply rate as the suppression pulse position was varied from 1.0 microsecond to 3.0 microseconds from the P1 pulse leading edge position. Figure 4-139 through Figure 4-147 shows that there was no measurable effect on SLS decoding.

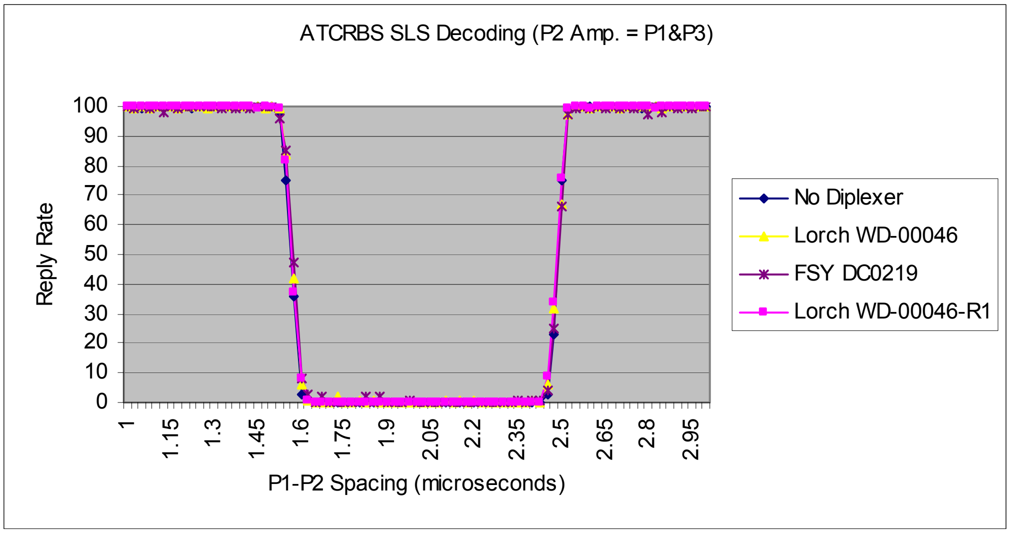

Figure 4-139 – SLS Decoding, Transponder MS-1A

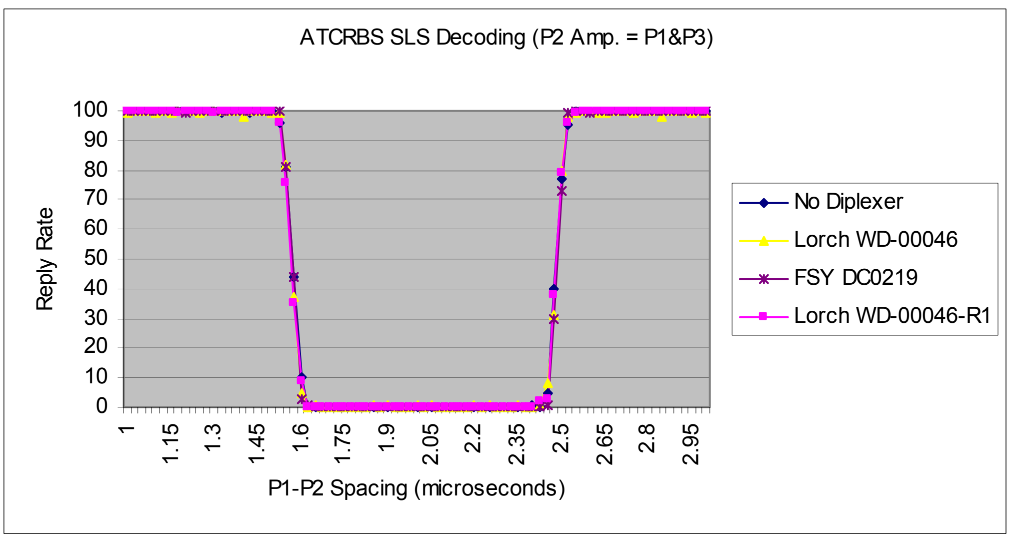

Figure 4-140 – SLS Decoding, Transponder MS-1B

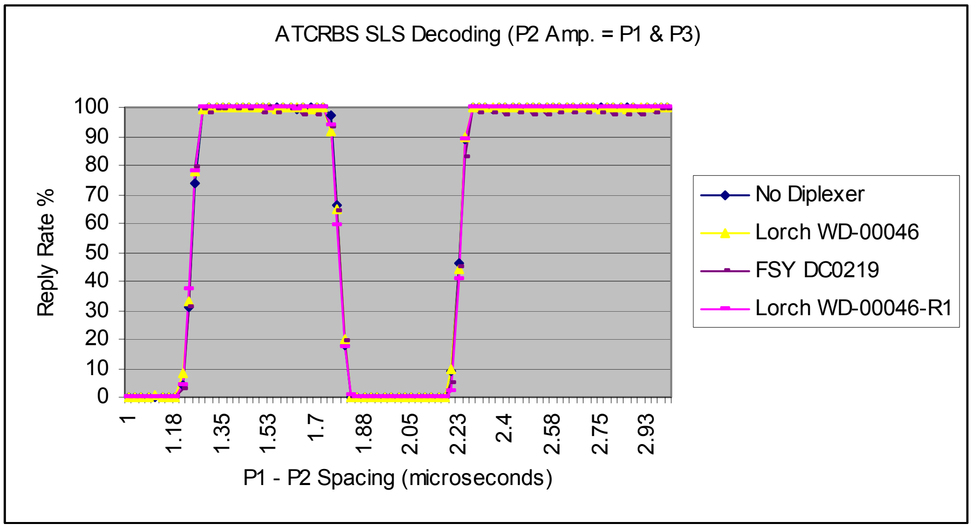

Figure 4-141 – SLS Decoding, Transponder MS-2

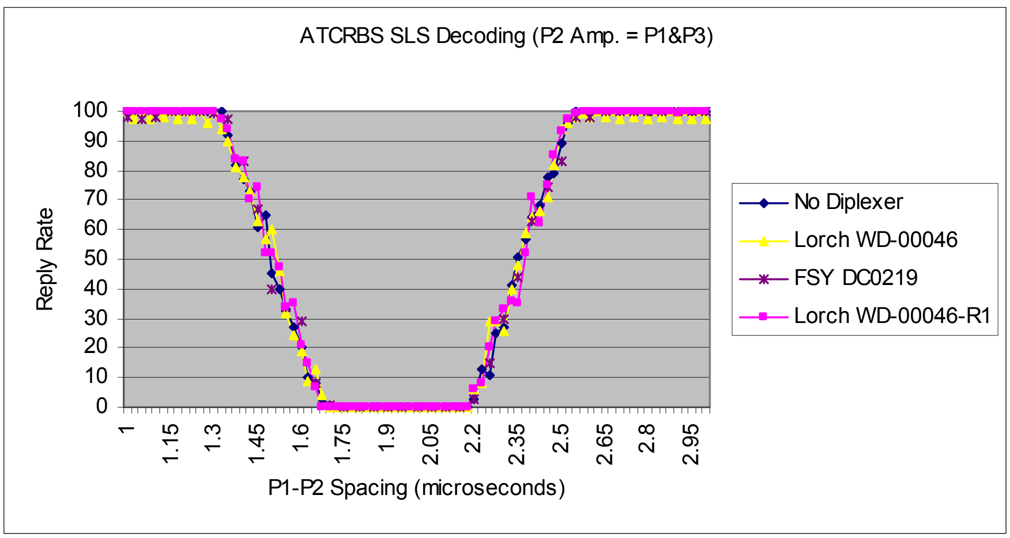

Figure 4-142 – SLS Decoding, Transponder MS-3A

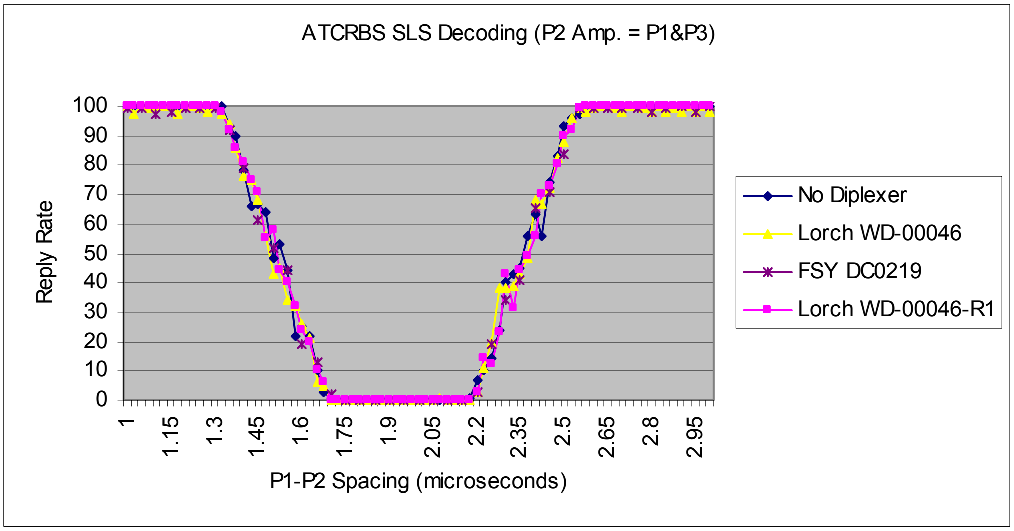

Figure 4-143 – SLS Decoding, Transponder MS-3B

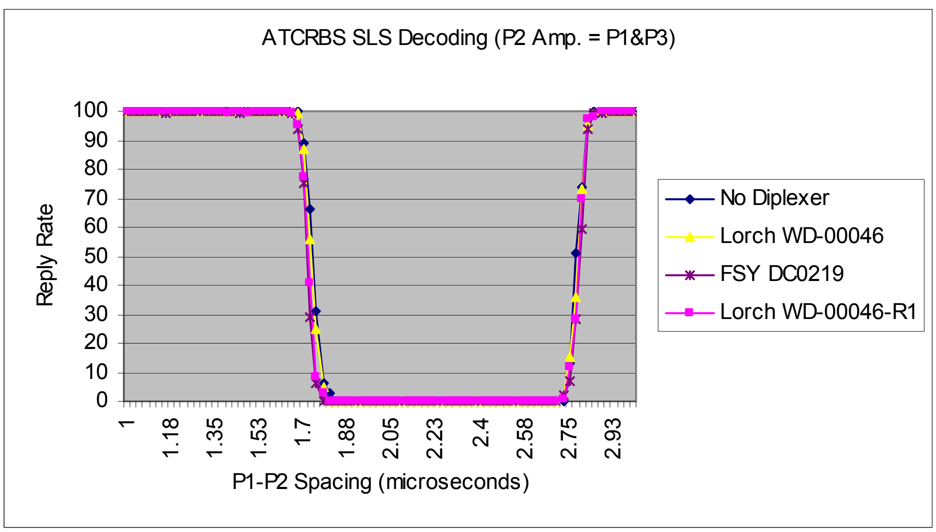

Figure 4-144 – SLS Decoding, Transponder A-1

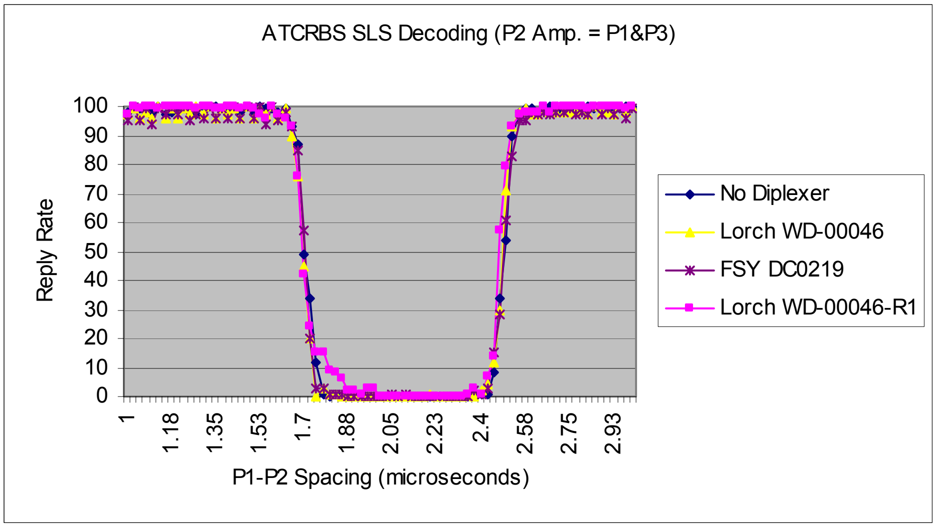

Figure 4-145 – SLS Decoding, Transponder A-2

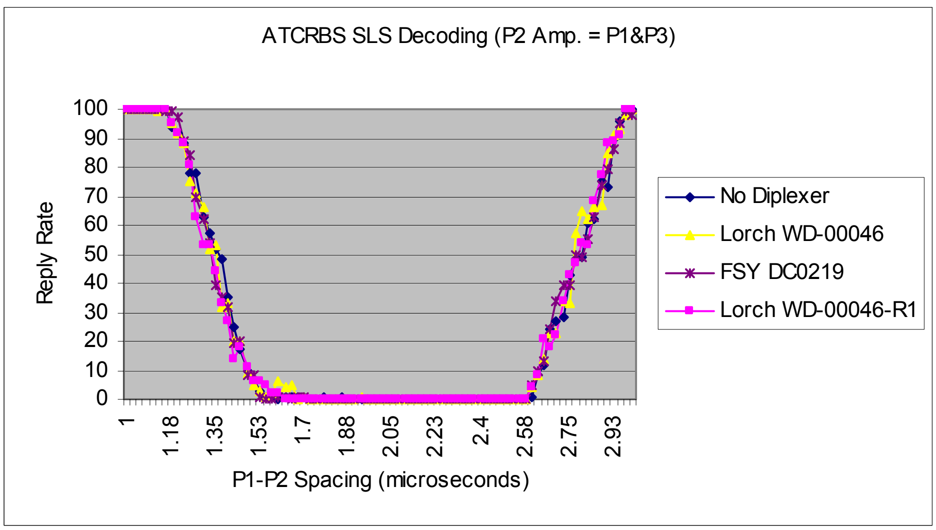

Figure 4-146 – SLS Decoding, Transponder A-3

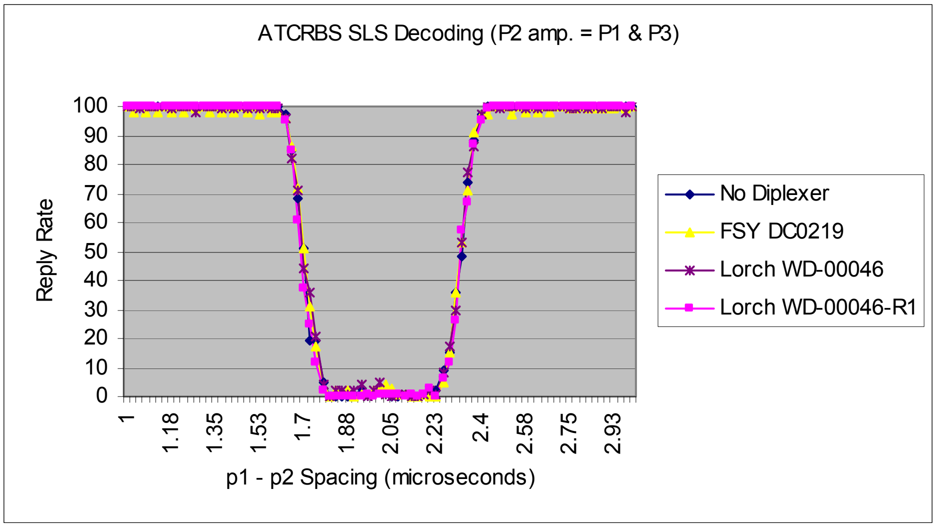

Figure 4-147 – SLS Decoding, Transponder A-4

4.23 SLS Decoding ATCRBS/Mode S

Tests were conducted to determine if the Diplexers had an effect on the decoding of the P2 SLS pulse with ATCRBS/Mode S interrogations. The transponder is required to suppress when a valid suppression pulse of equal or greater amplitude to P1 is received in the interval between 1.85 to 2.15 microseconds from P1. The transponder is required to reply to at least 90 percent of interrogations when no suppression pulse is received within the interval from 1.3 to 2.7 microseconds. The SLS decoding tests measured the transponders reply rate as the suppression pulse position was varied from 1.0 microsecond to 3.0 microseconds from the P1 pulse leading edge position. Figure 4-148 through Figure 4-152 shows that there was no measurable effect on SLS decoding with ATCRBS/Mode S interrogations.

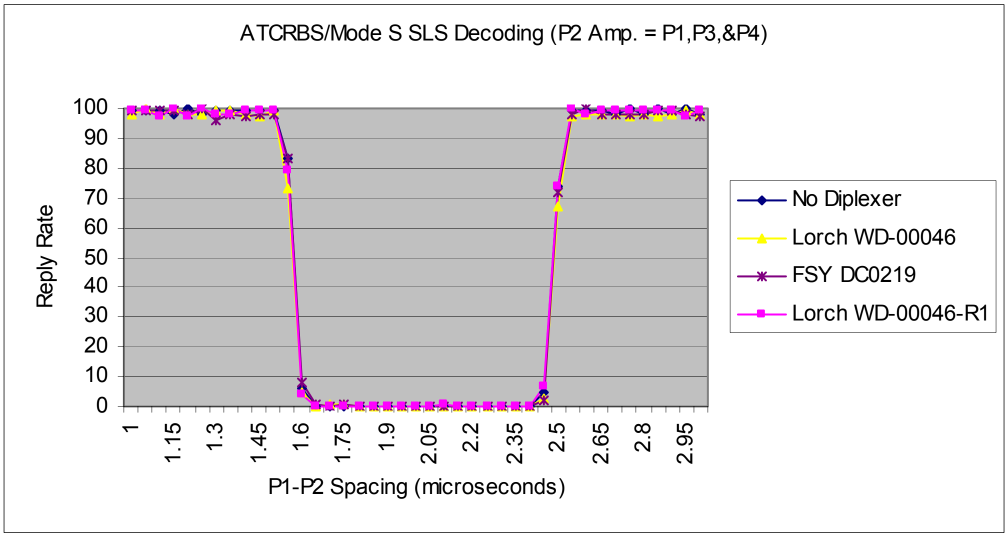

Figure 4-148 – SLS Decoding, ATCRBS/Mode S Transponder MS-1A

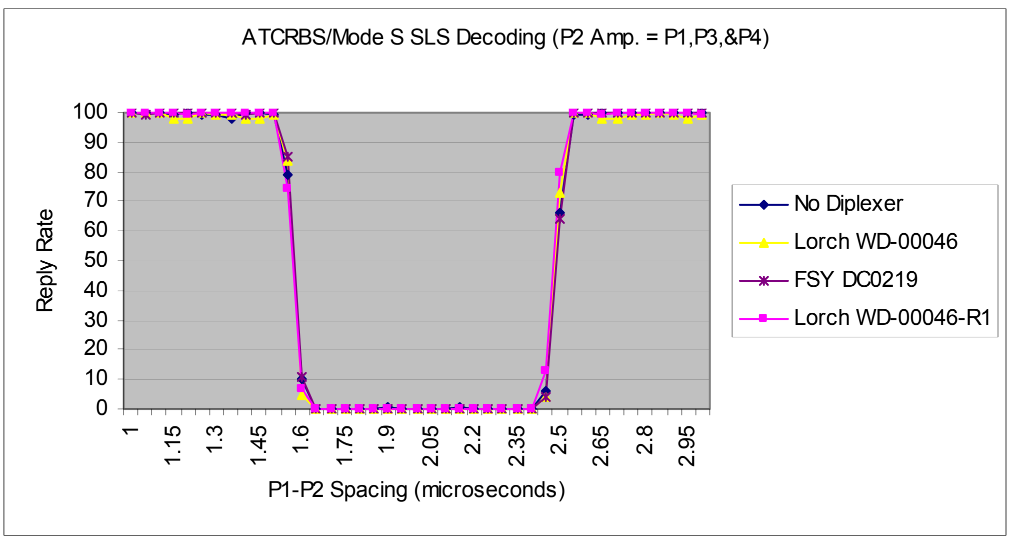

Figure 4-149 – SLS Decoding, ATCRBS/Mode S Transponder MS-1B

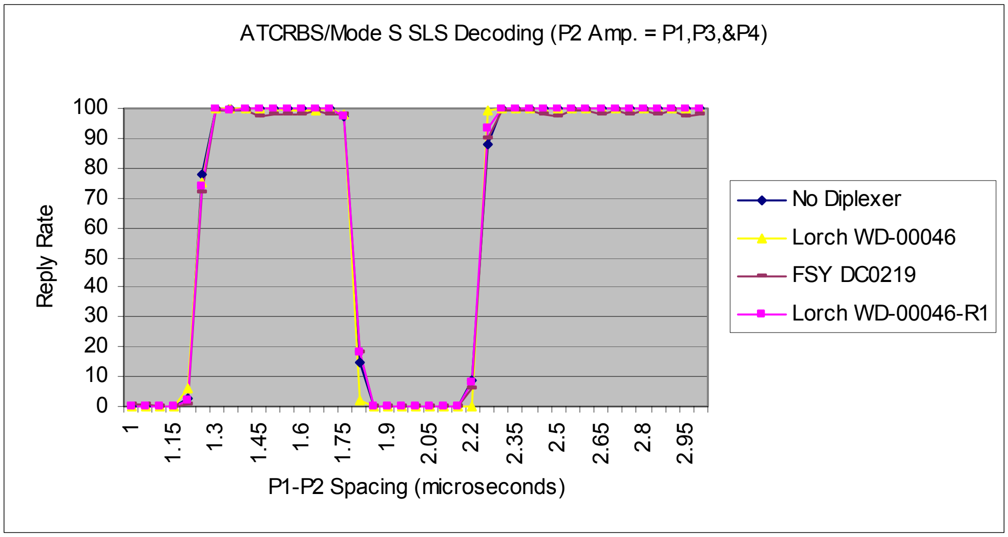

Figure 4-150 – SLS Decoding, ATCRBS/Mode S Transponder MS-2

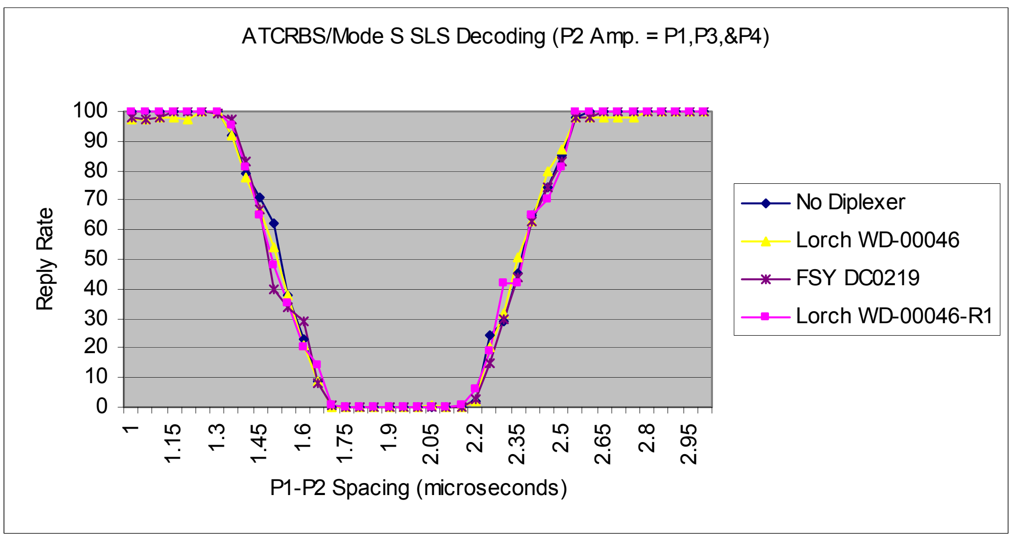

Figure 4-151 – SLS Decoding, ATCRBS/Mode S Transponder MS-3A

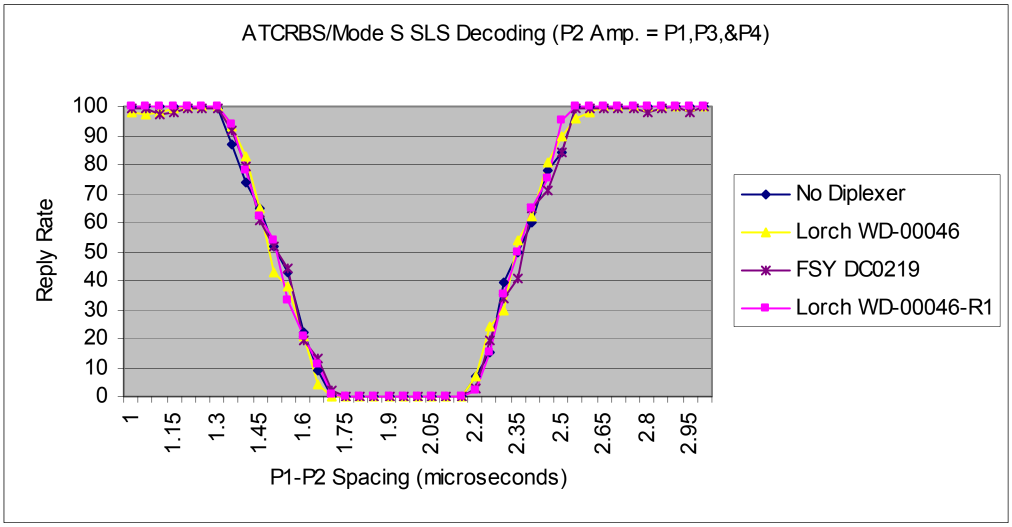

Figure 4-152 – SLS Decoding, ATCRBS/Mode S Transponder MS-3B

4.24 SLS Pulse Ratio

Tests were conducted to determine if the Diplexers had an effect on the Side Lobe Suppression pulse ratio with ATCRBS format interrogations. The transponder shall not be suppressed if the level of P1 exceeds the level of P2 by 9 dB or more. For the SLS pulse ratio tests, the P2 pulse power level was set to 9 dB below that of the P1 and P3 pulse levels. The reply rate was measured as the position of the P2 pulse was varied from 1.0 microsecond to 3.0 microseconds from the P1 pulse leading edge. Figure 4-153 through Figure 4-161 shows that there was no measurable effect on the SLS pulse ratio with ATCRBS interrogations.

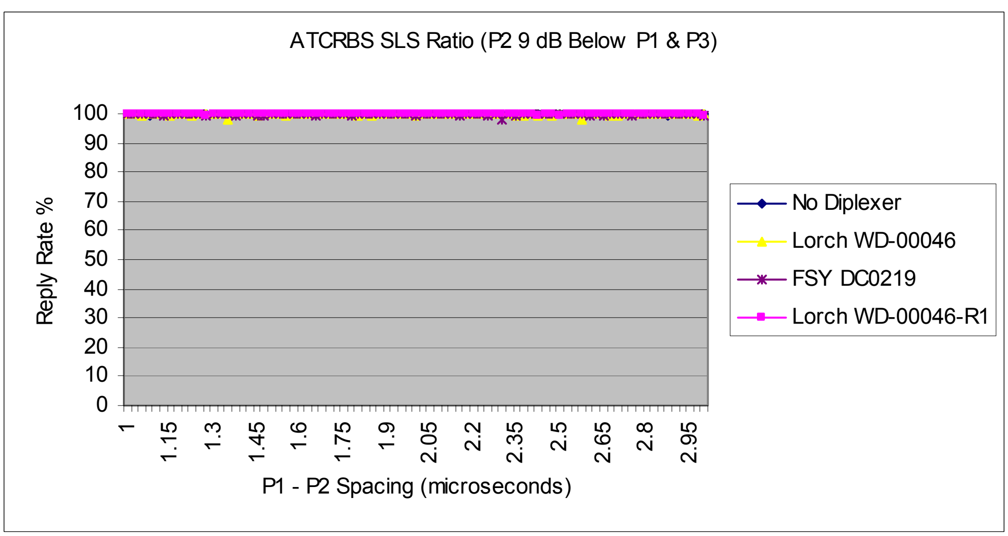

Figure 4-153 – SLS Ratio, ATCRBS, Transponder MS-1A

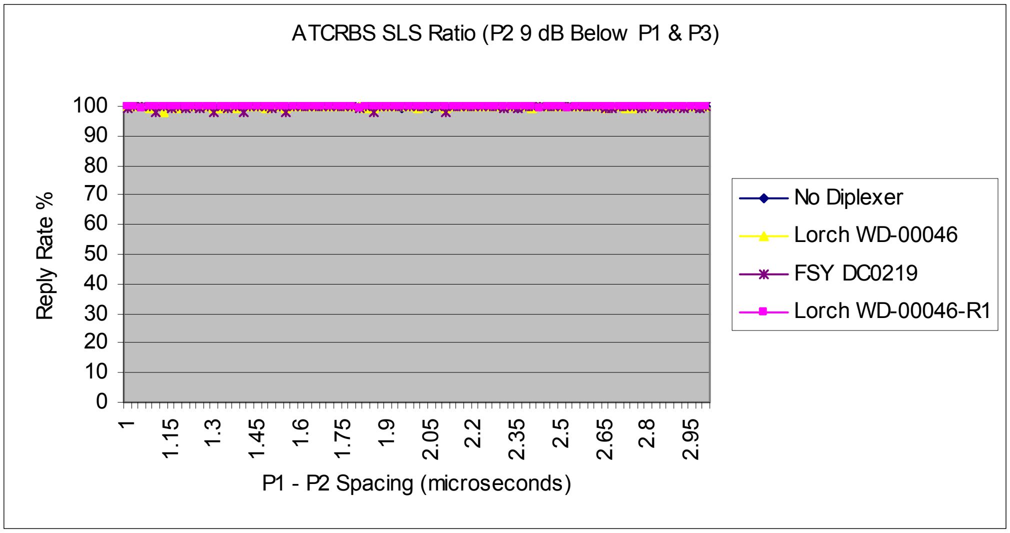

Figure 4-154 – SLS Ratio, ATCRBS, Transponder MS-1B

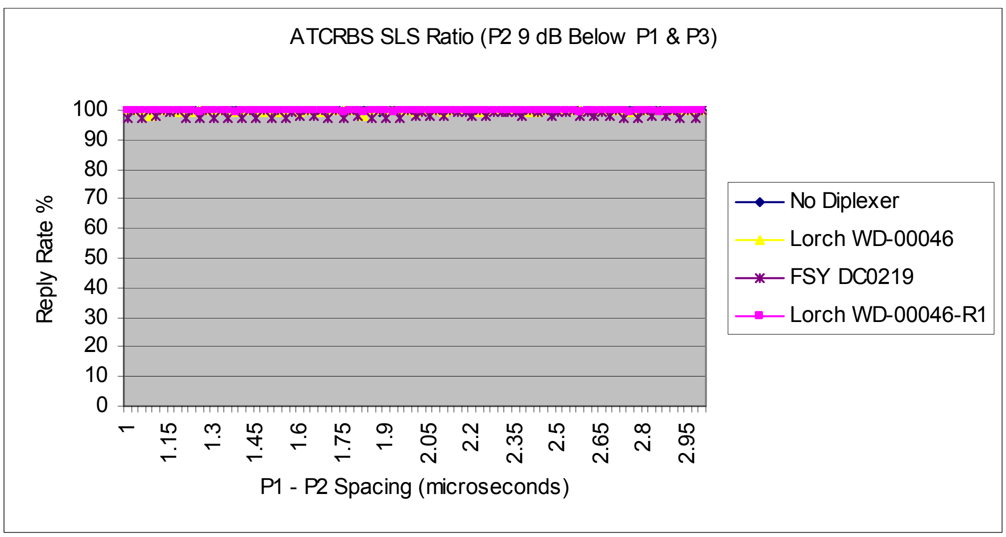

Figure 4-155 – SLS Ratio, ATCRBS, Transponder MS-2

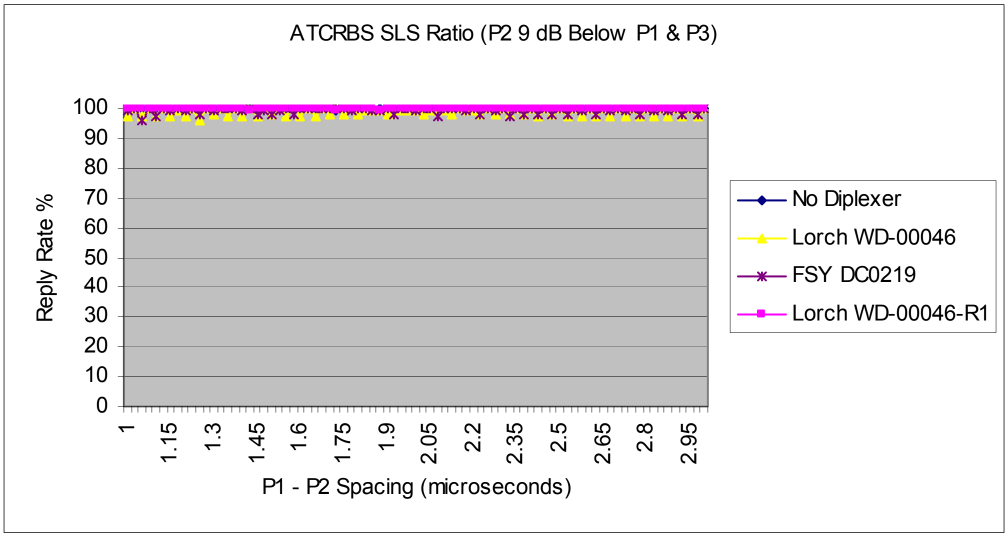

Figure 4-156 – SLS Ratio, ATCRBS, Transponder MS-3A

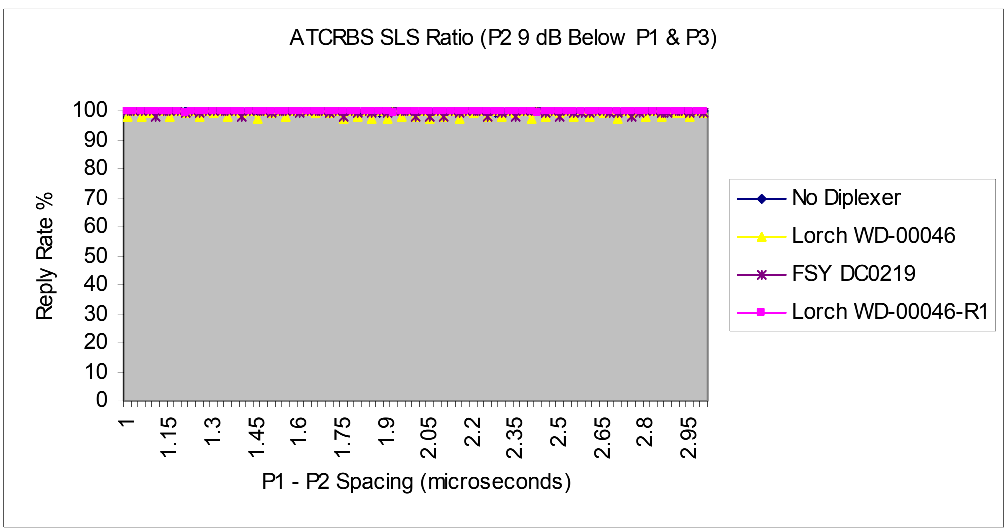

Figure 4-157 – SLS Ratio, ATCRBS, Transponder MS-3B

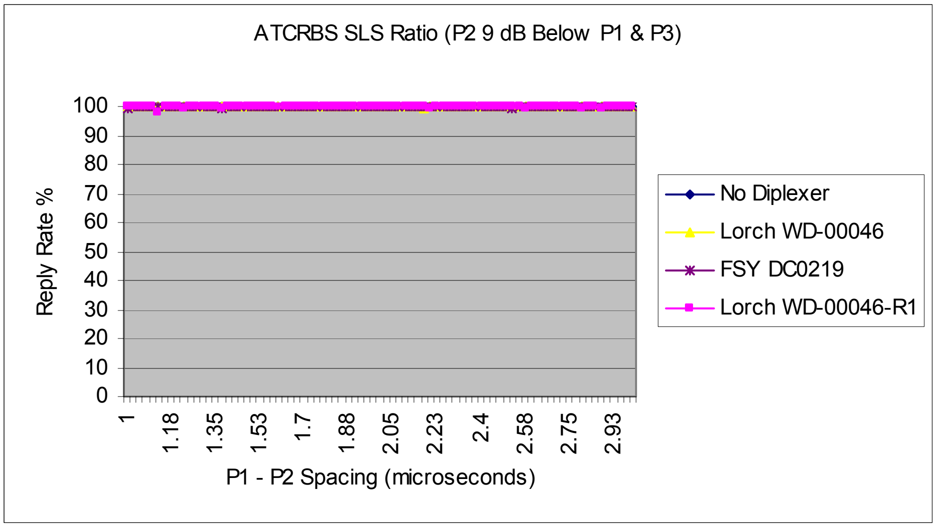

Figure 4-158 – SLS Ratio, ATCRBS, Transponder A-1

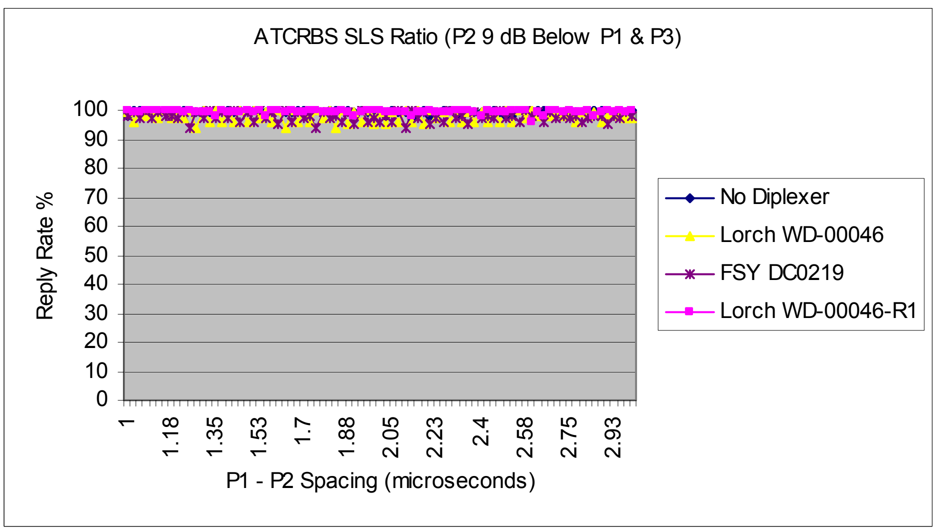

Figure 4-159 – SLS Ratio, ATCRBS, Transponder A-2

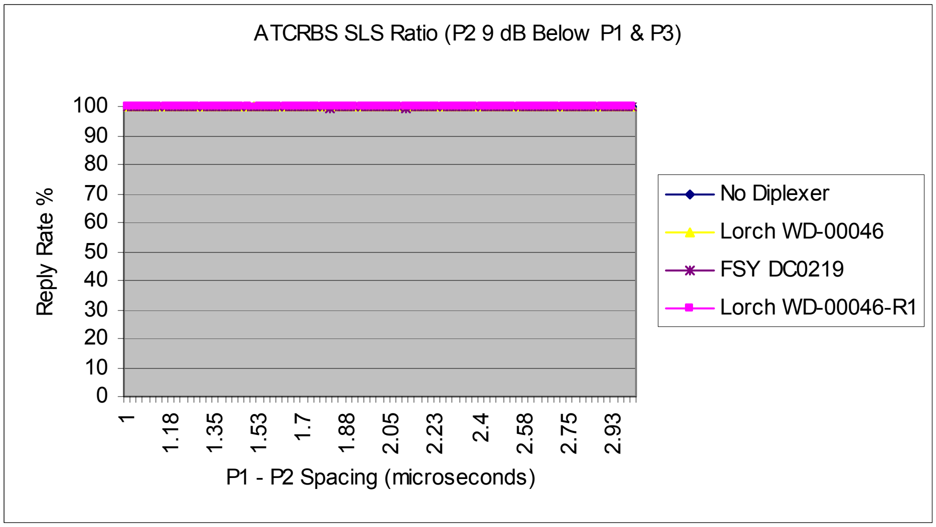

Figure 4-160 – SLS Ratio, ATCRBS, Transponder A-3

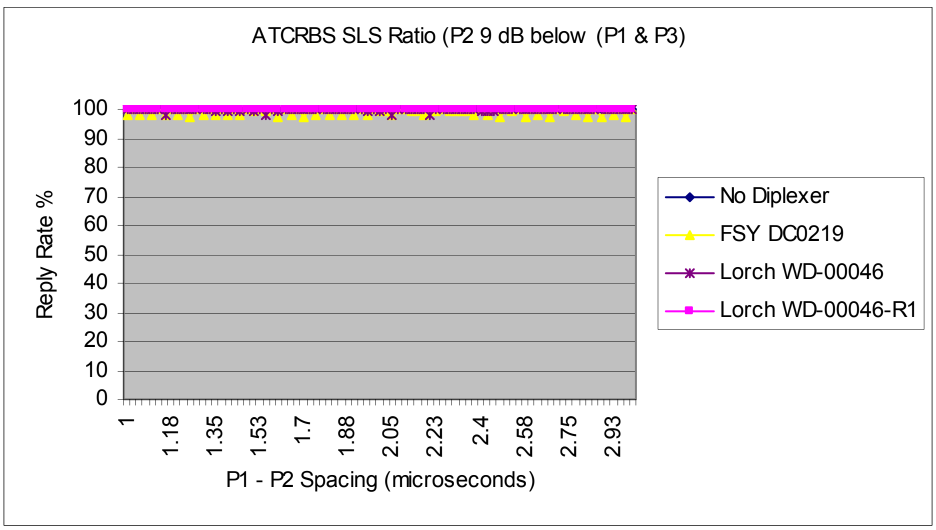

Figure 4-161 – SLS Ratio, ATCRBS, Transponder A-4

4.25 SLS Ratio ATCRBS/Mode S

Tests were conducted to determine if the Diplexers had an effect on the Side Lobe Suppression pulse ratio with ATCRBS/Mode S format interrogations. The transponder shall not be suppressed if the level of P1 exceeds the level of P2 by 9 dB or more. For the SLS pulse ratio tests, the P2 pulse power level was set to 9 dB below that of the P1 and P3 pulse levels. The reply rate was measured as the position of the P2 pulse was varied from 1.0 microsecond to 3.0 microseconds from the P1 pulse leading edge. Figure 4-162 through Figure 4-166 shows that there was no measurable effect on the SLS pulse ratio with ATCRBS/Mode S interrogations.

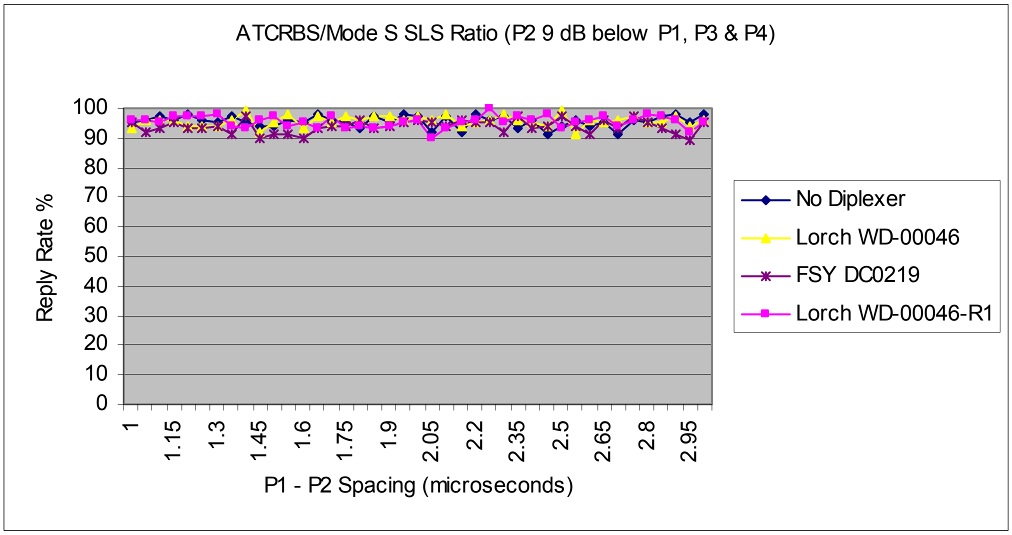

Figure 4-162 – SLS Ratio, ATCRBS/Mode S, Transponder MS-1A

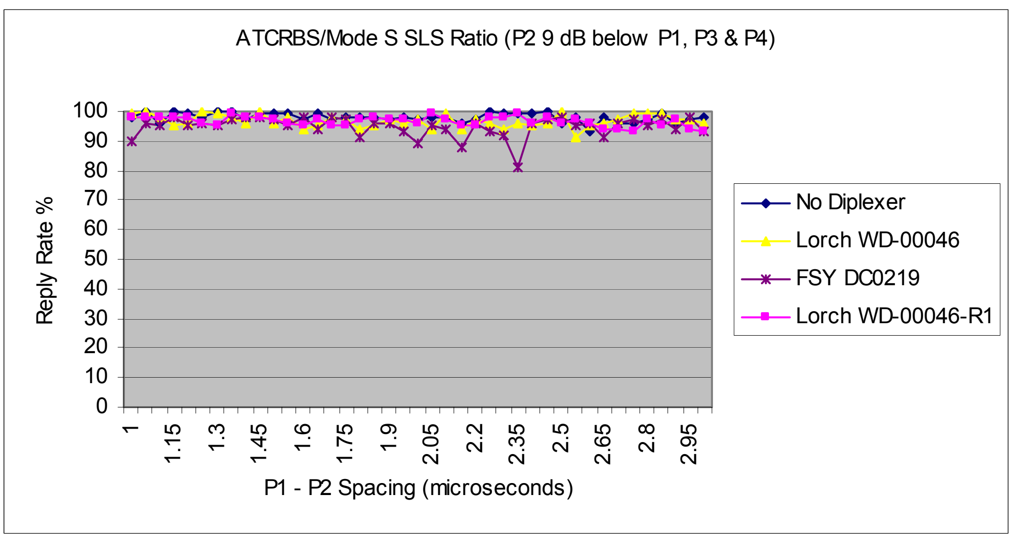

Figure 4-163 – SLS Ratio, ATCRBS/Mode S, Transponder MS-1B

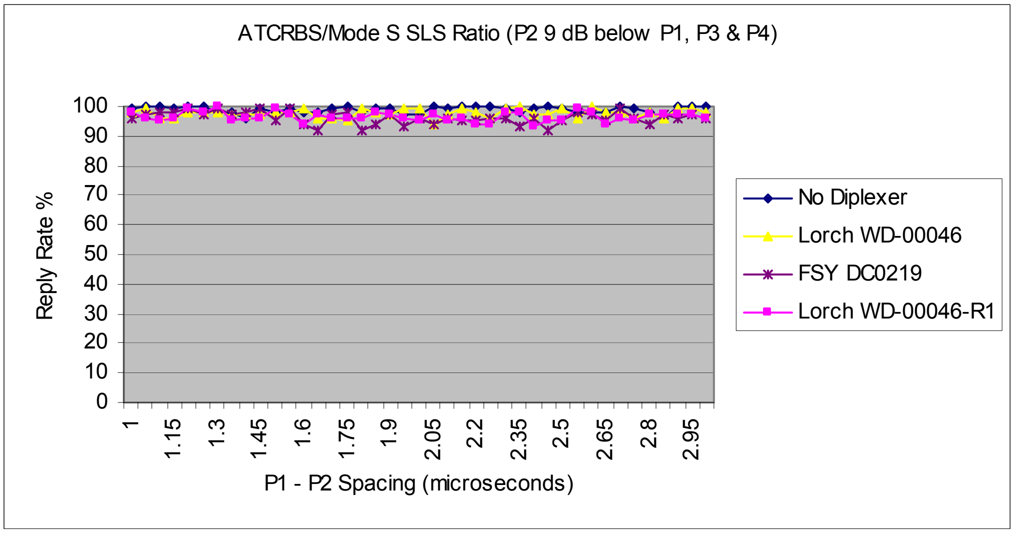

Figure 4-164 – SLS Ratio, ATCRBS/Mode S, Transponder MS-2

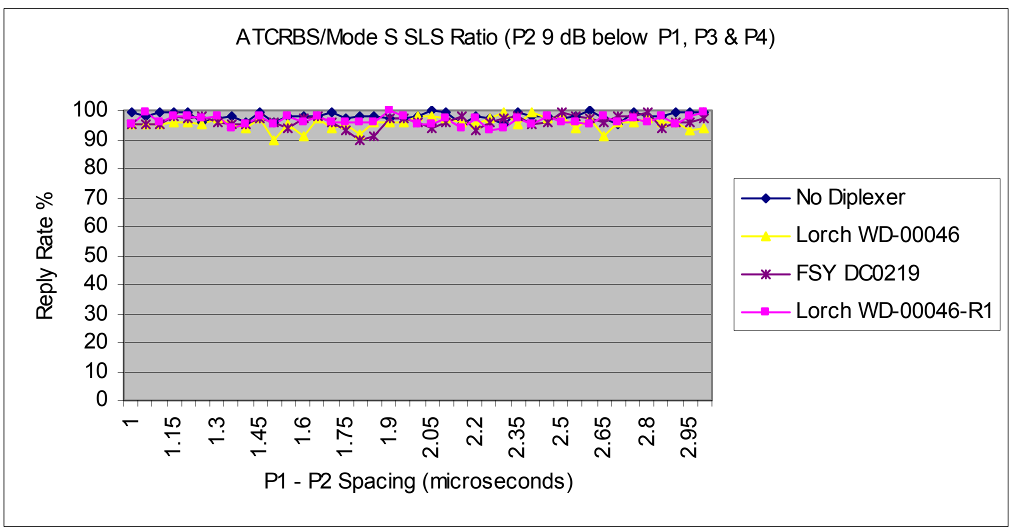

Figure 4-165 – SLS Ratio, ATCRBS/Mode S, Transponder MS-3A

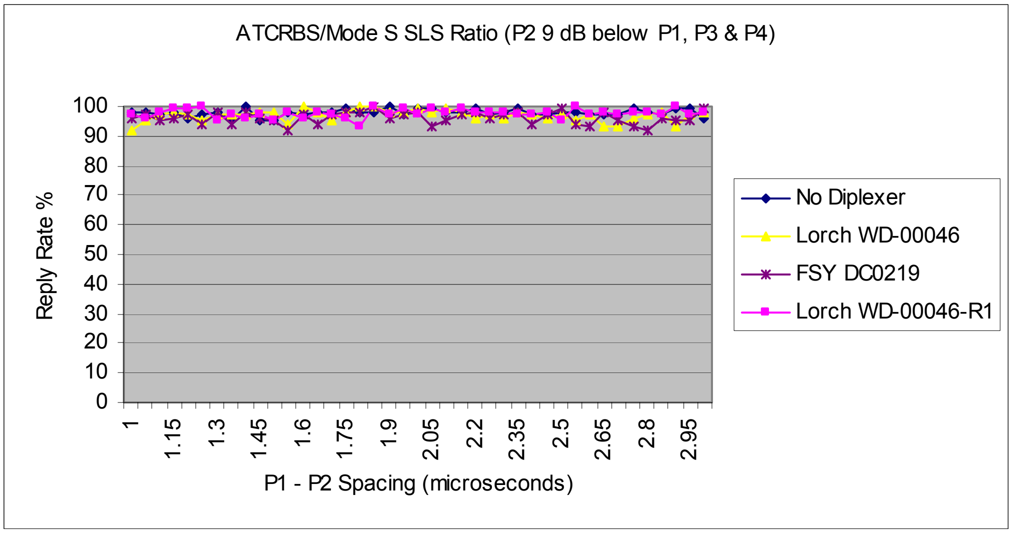

Figure 4-166 – SLS Ratio, ATCRBS/Mode S, Transponder MS-3B

4.26 Suppression Duration

The suppression duration is the time interval between the leading edges of a P2 pulse of a suppression pair and the P1 pulse of the earliest subsequent interrogation to which the transponder replies. The suppression duration is required to be between 25 and 45 microseconds. The suppression duration was measured for each transponder with each Diplexer configuration. Both Mode A and Mode C suppression duration was measured and in all cases the Mode A and Mode C suppression duration was virtually identical. For this reason, only the Mode A suppression duration plots are presented here. Figure 4-167 through Figure 4-175 shows that there was no effect from the Diplexers in suppression duration.

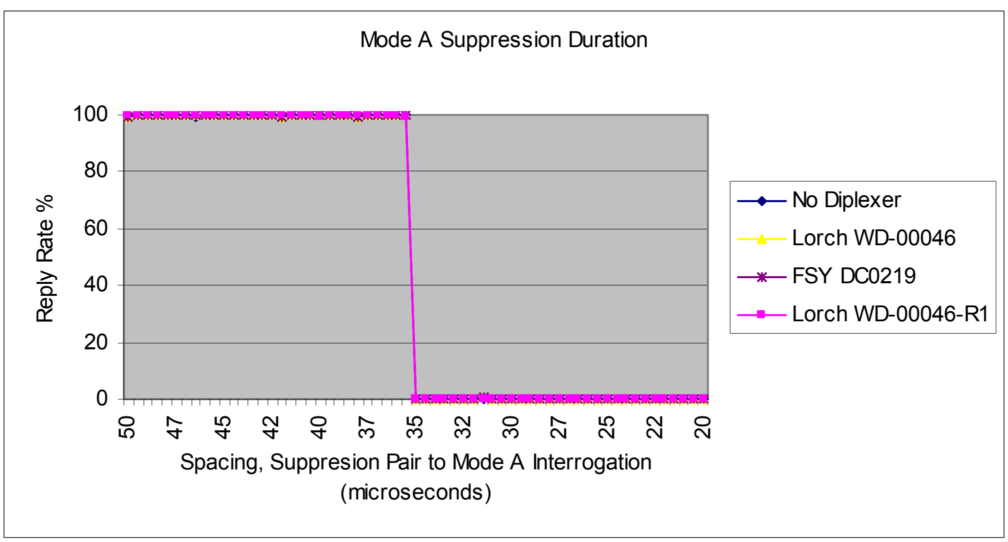

Figure 4-167 – Mode A Suppression Duration, Transponder MS-1A

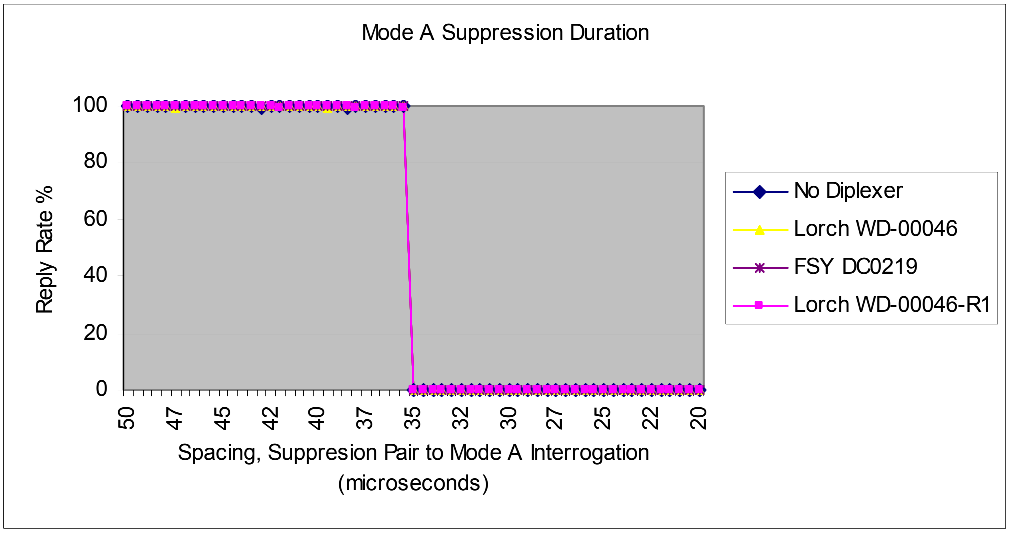

Figure 4-168 – Mode A Suppression Duration, Transponder MS-1B

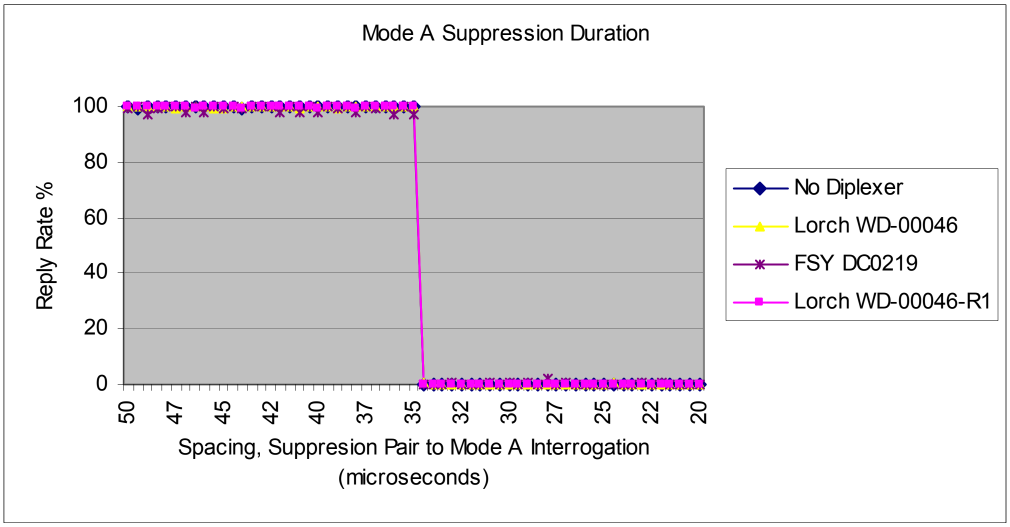

Figure 4-169 – Mode A Suppression Duration, Transponder MS-2

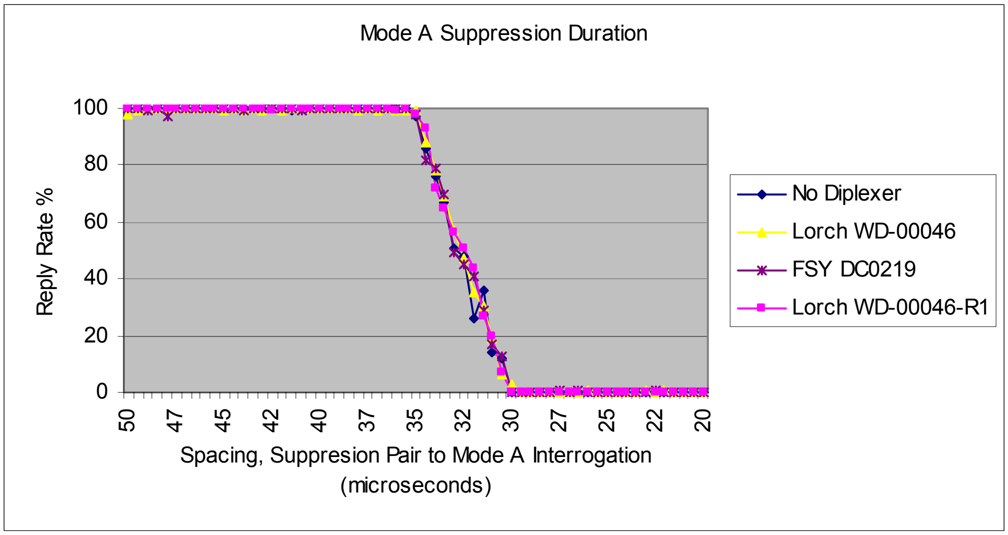

Figure 4-170 – Mode A Suppression Duration, Transponder MS-3A

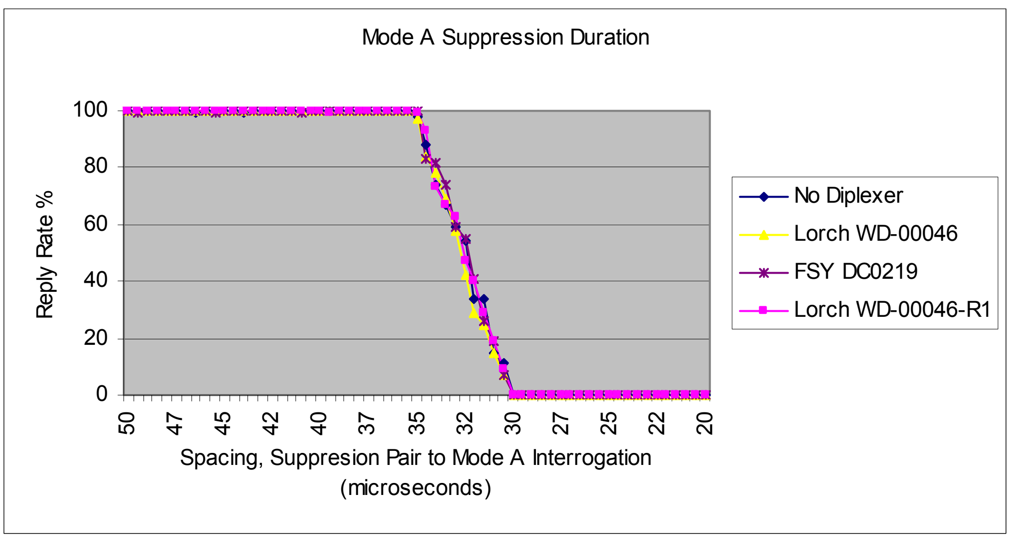

Figure 4-171 – Mode A Suppression Duration, Transponder MS-3B

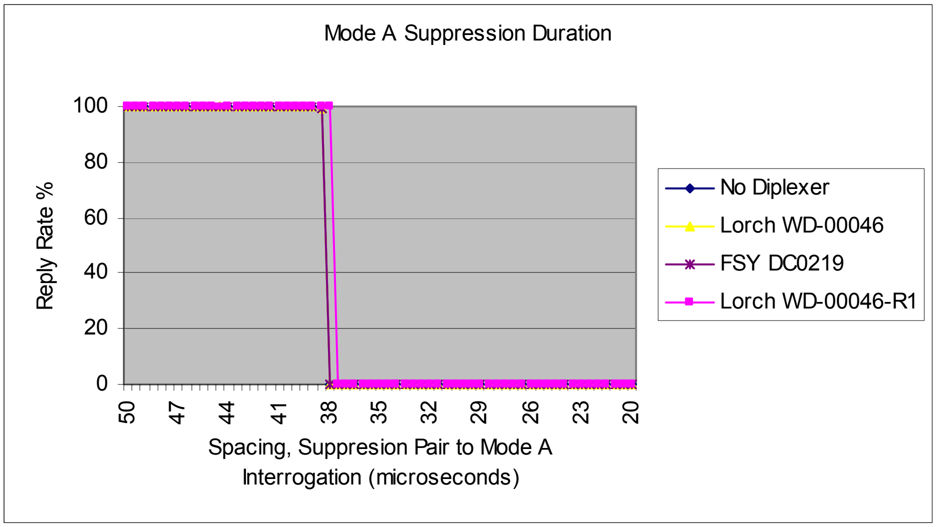

Figure 4-172 – Mode A Suppression Duration, Transponder A-1

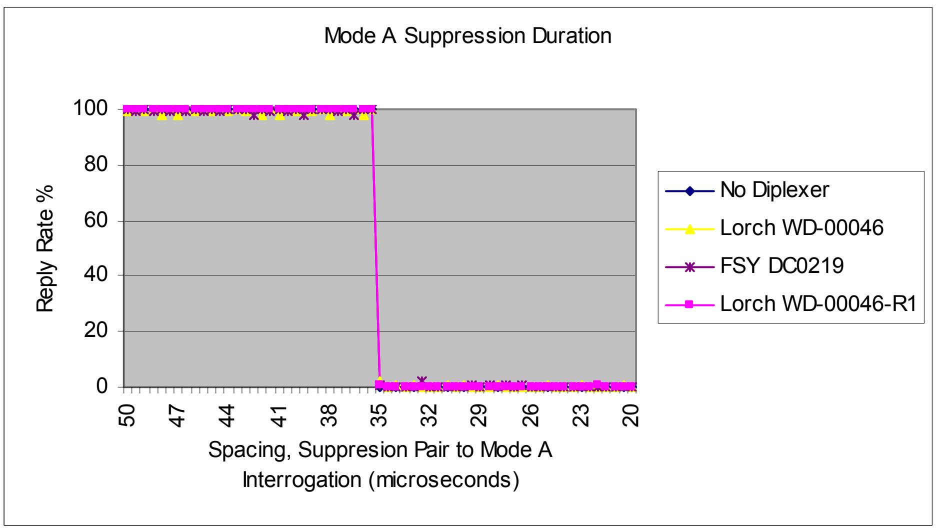

Figure 4-173 – Mode A Suppression Duration, Transponder A-2

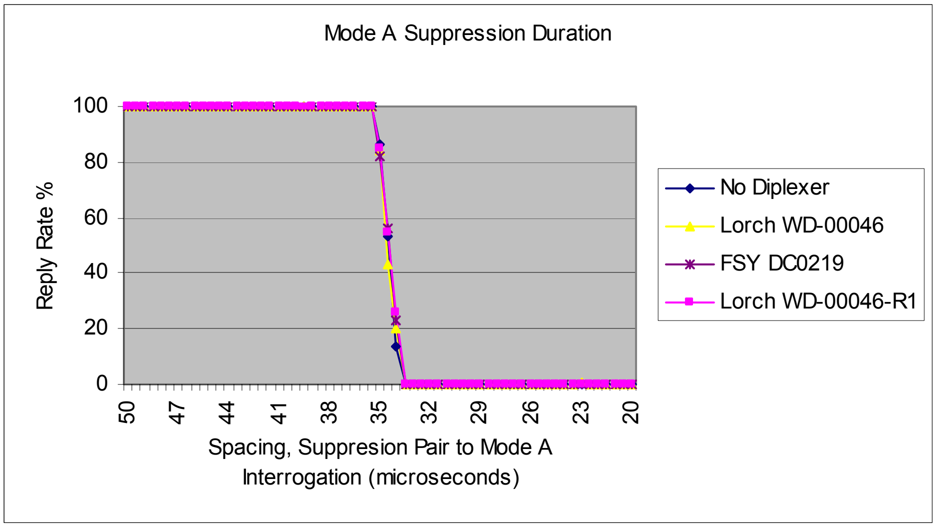

Figure 4-174 – Mode A Suppression Duration, Transponder A-3

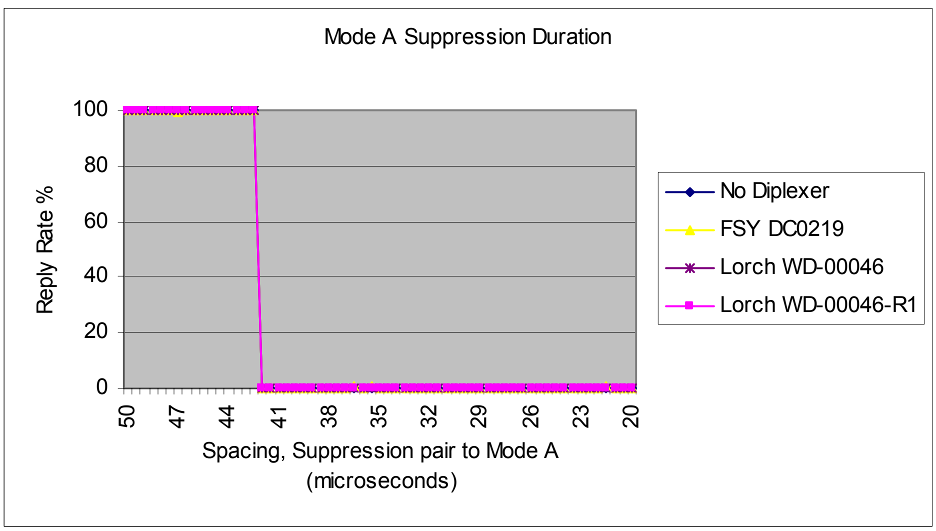

Figure 4-175 – Mode A Suppression Duration, Transponder A-4

4.27 Suppression Reinitiation

The transponder is required to have the capability to reinitiate a suppression period within two microseconds of the end of a suppression period. Suppression reinitiation was tested by measuring the suppression duration that was initiated by a suppression pair positioned two microseconds after the end of a suppression period. Figure 4-176 through Figure 167 shows that the Diplexers had no effect on suppression reinitiation.

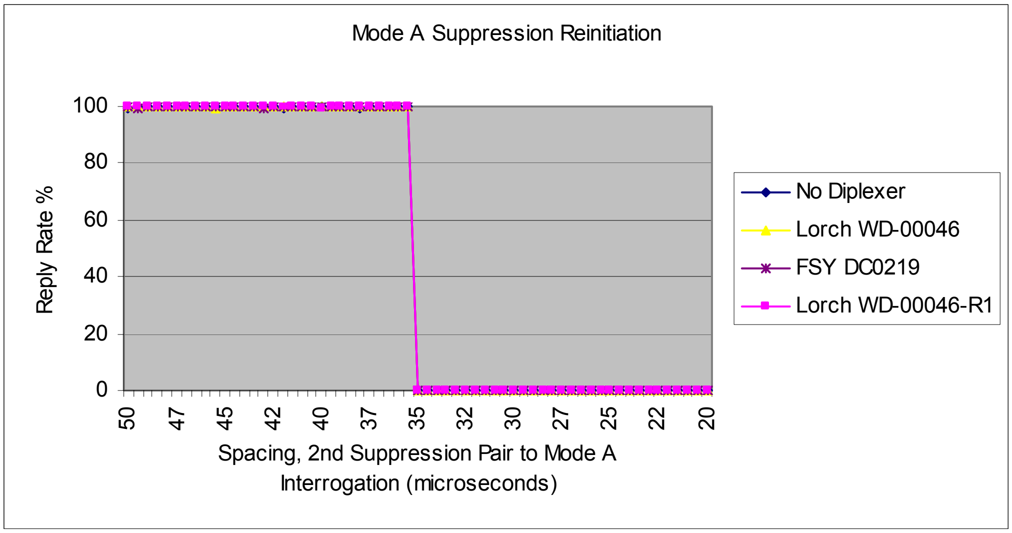

Figure 4-176 – Mode A Suppression Reinitiation, Transponder MS-1A

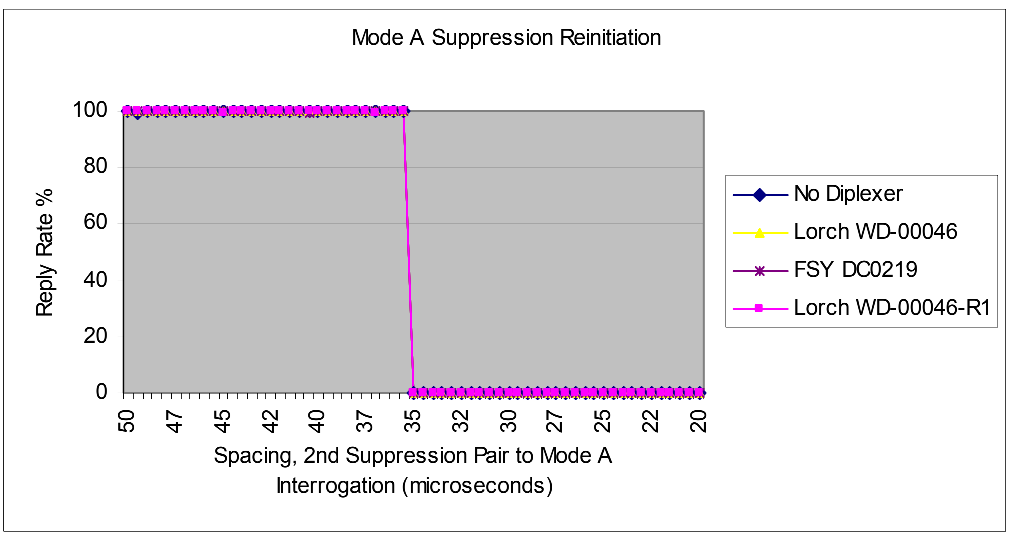

Figure 4-177 – Mode A Suppression Reinitiation, Transponder MS-1B

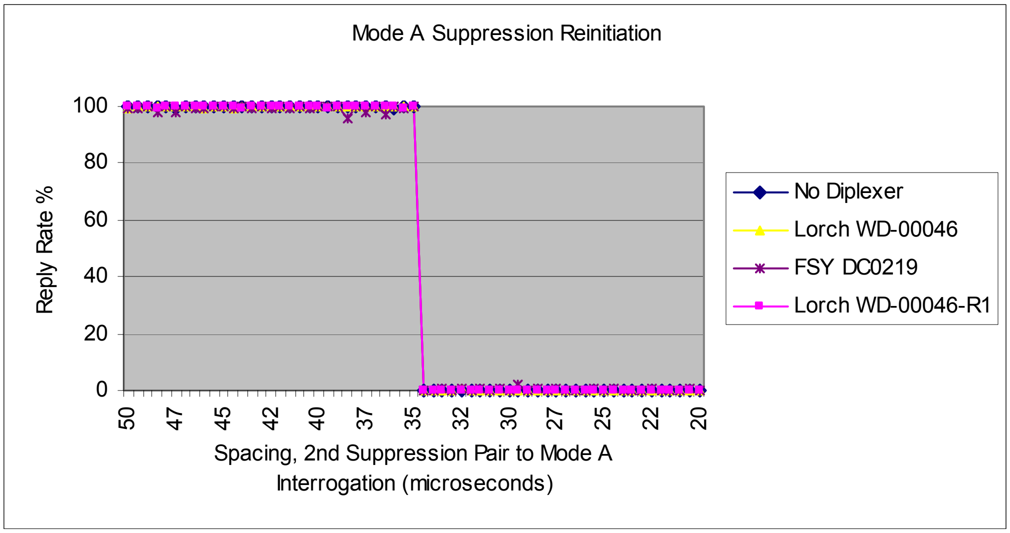

Figure 4-178 – Mode A Suppression Reinitiation, Transponder MS-2

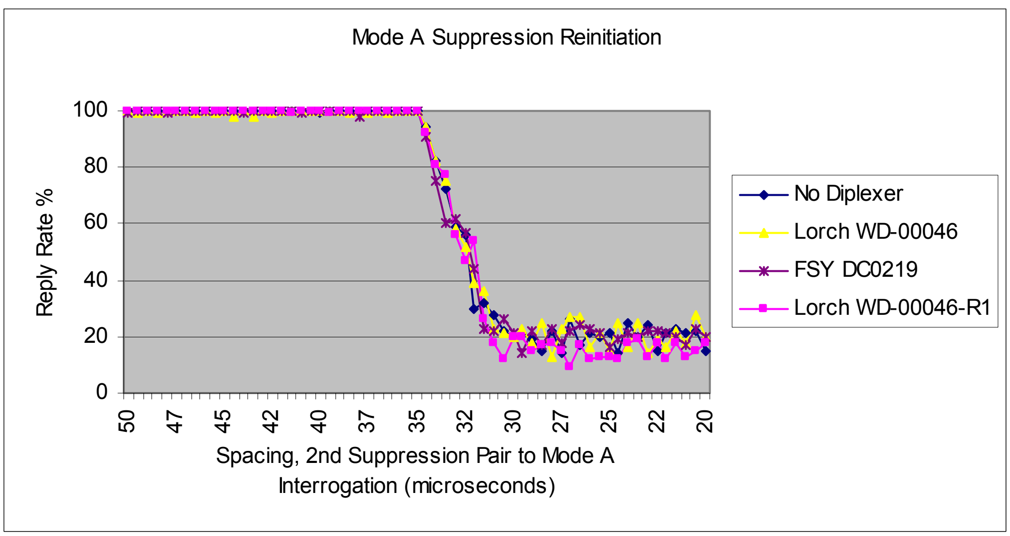

Figure 4-179 – Mode A Suppression Reinitiation, Transponder MS-3A

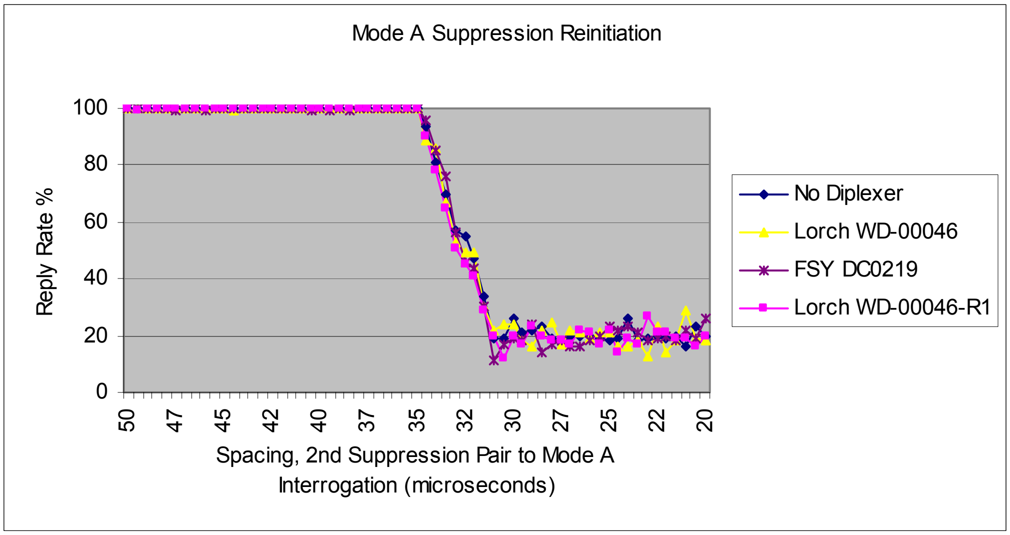

Figure 4-180 – Mode A Suppression Reinitiation, Transponder MS-3B

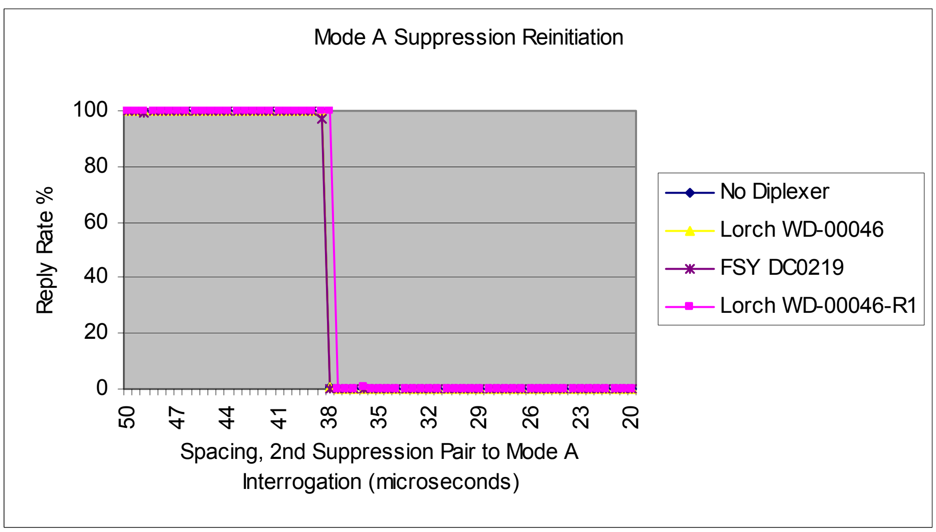

Figure 4-181 – Mode A Suppression Reinitiation, Transponder A-1

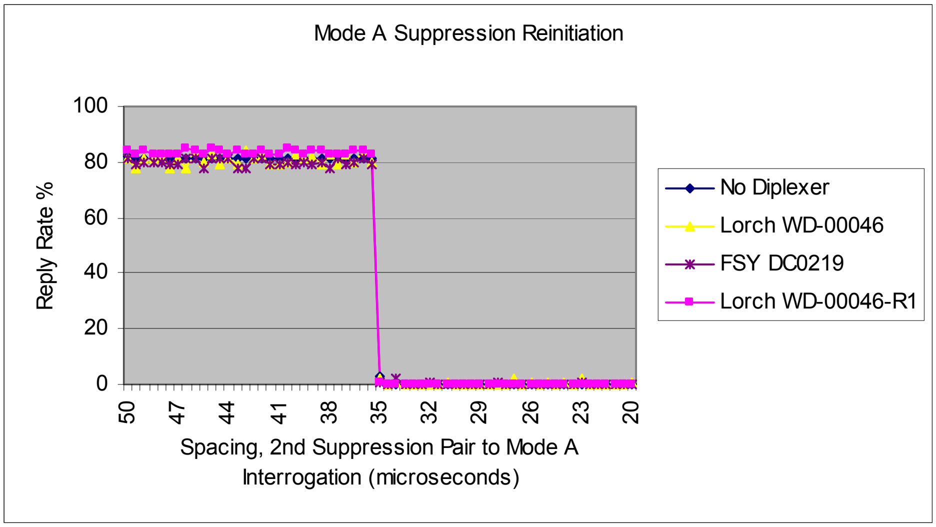

Figure 4-182 – Mode A Suppression Reinitiation, Transponder A-2

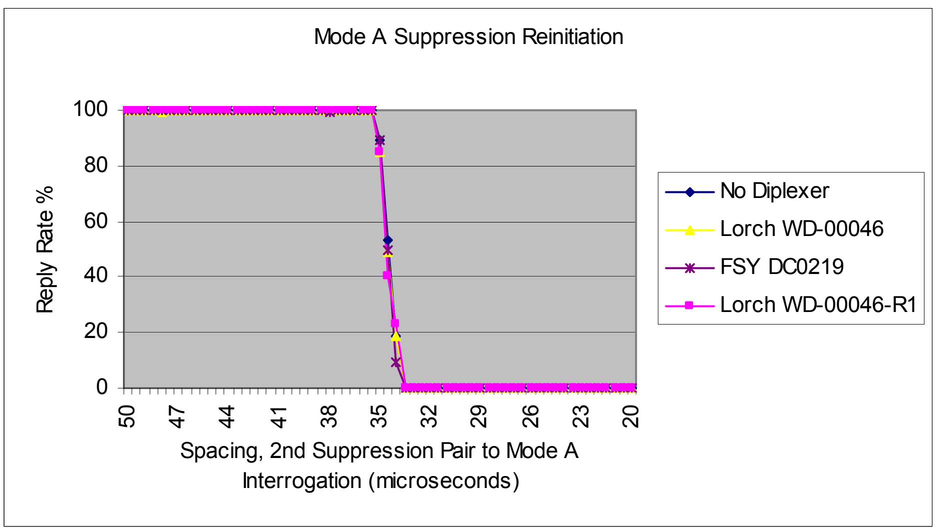

Figure 4-183 – Mode A Suppression Reinitiation, Transponder A-3

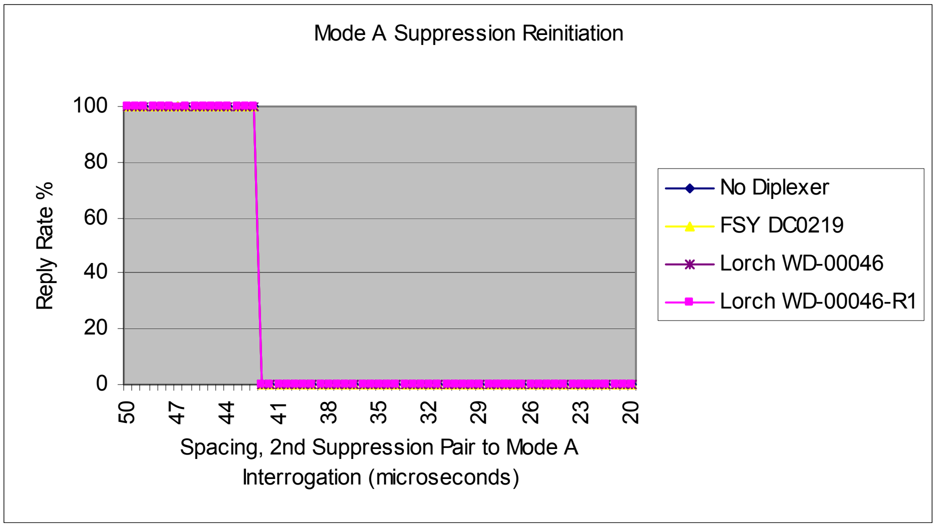

Figure 4-184 – Mode A Suppression Reinitiation, Transponder A-4

4.28 Recovery From Suppression

The transponder receiver sensitivity is required to be at MTL no later than one microsecond after the end of the suppression period. Suppression recovery was measured by measuring suppression duration with the Mode A interrogation at MTL following the suppression pair. Figure 4-185 through Figure 4-193 shows that there was no effect from the Diplexers on suppression recovery.

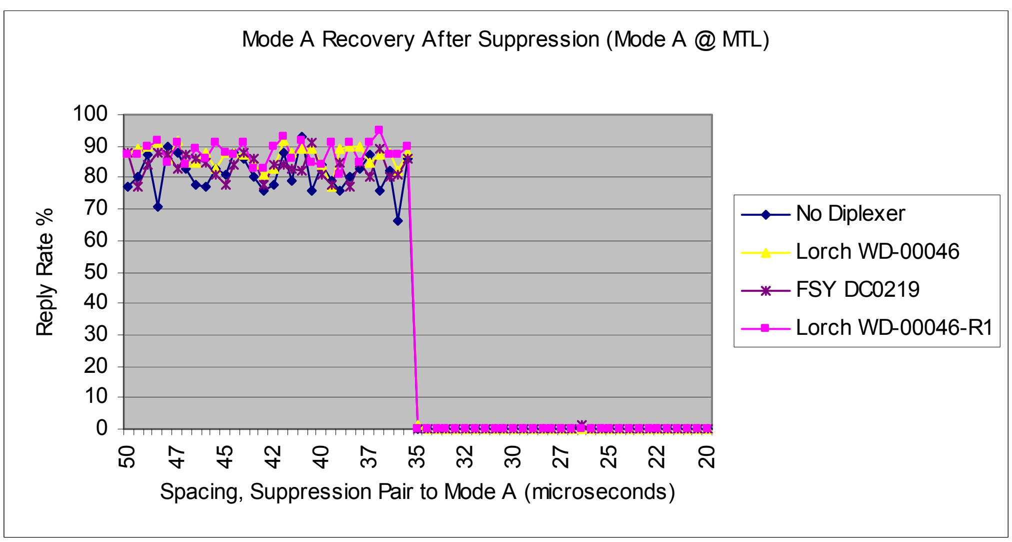

Figure 4-185 – Recovery After Suppression, Transponder MS-1A

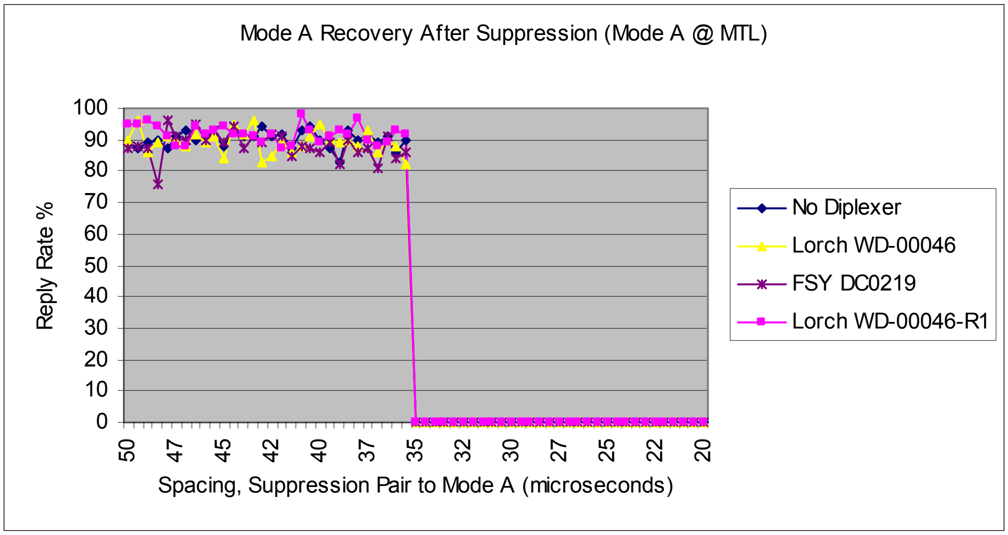

Figure 4-186 – Recovery After Suppression, Transponder MS-1B

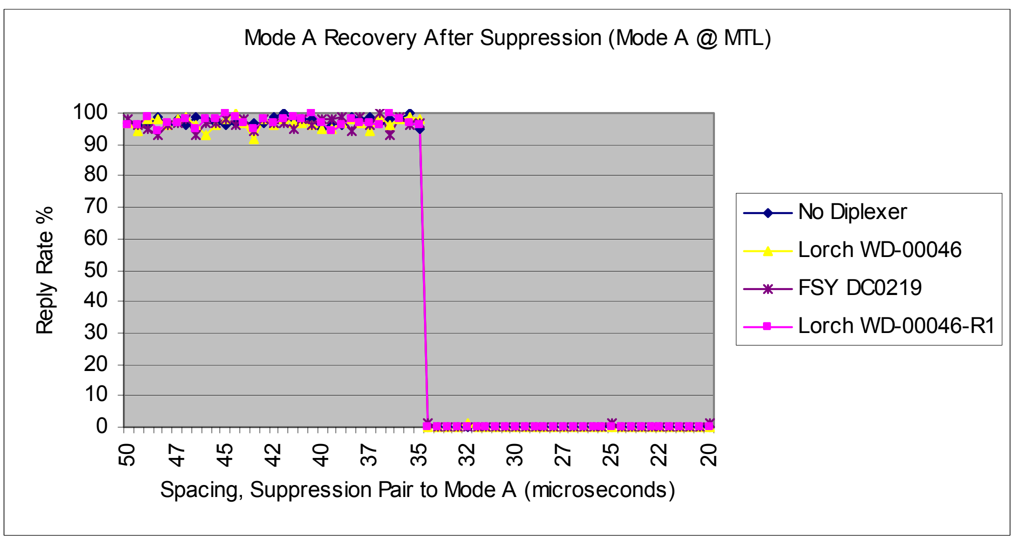

Figure 4-187 – Recovery After Suppression, Transponder MS-2

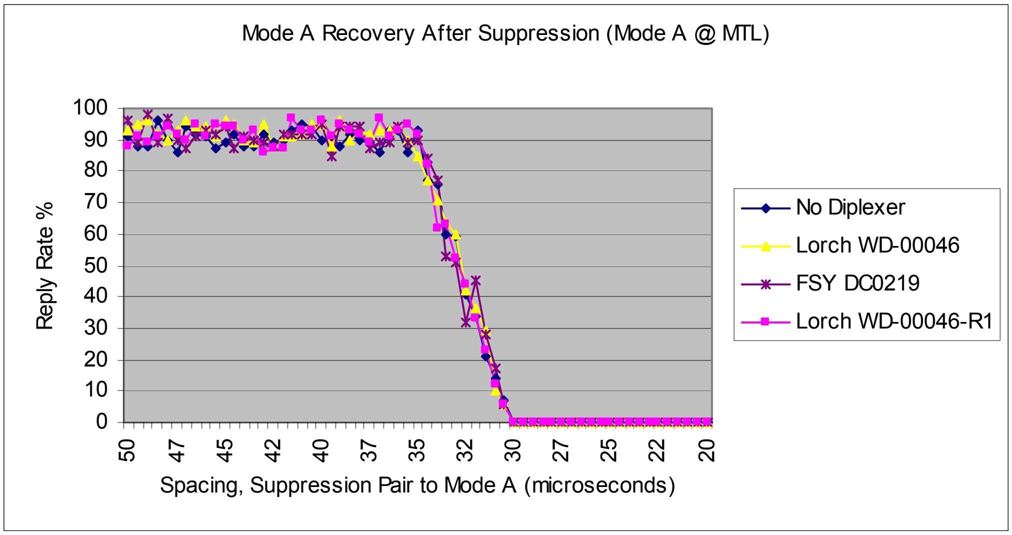

Figure 4-188 – Recovery After Suppression, Transponder MS-3A

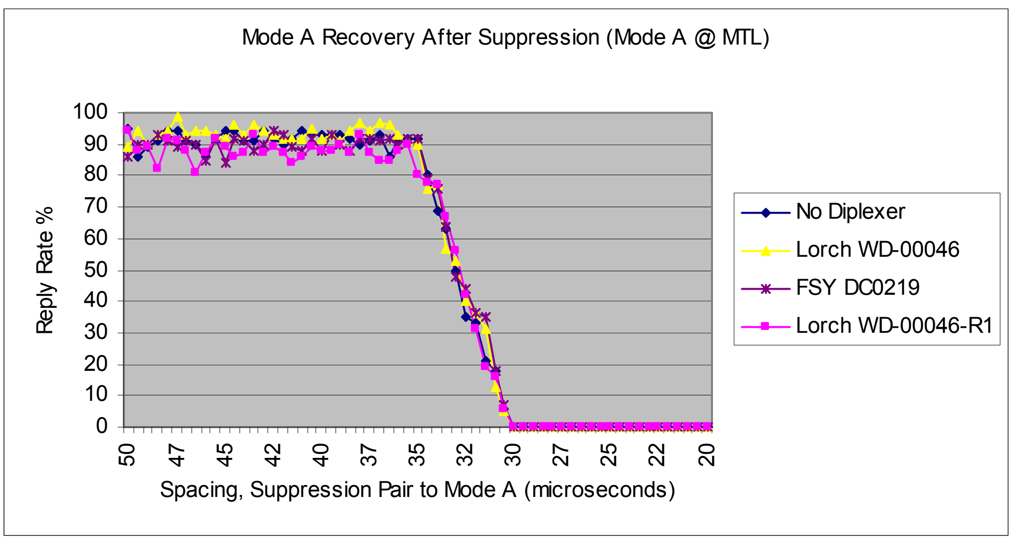

Figure 4-189 – Recovery After Suppression, Transponder MS-3B

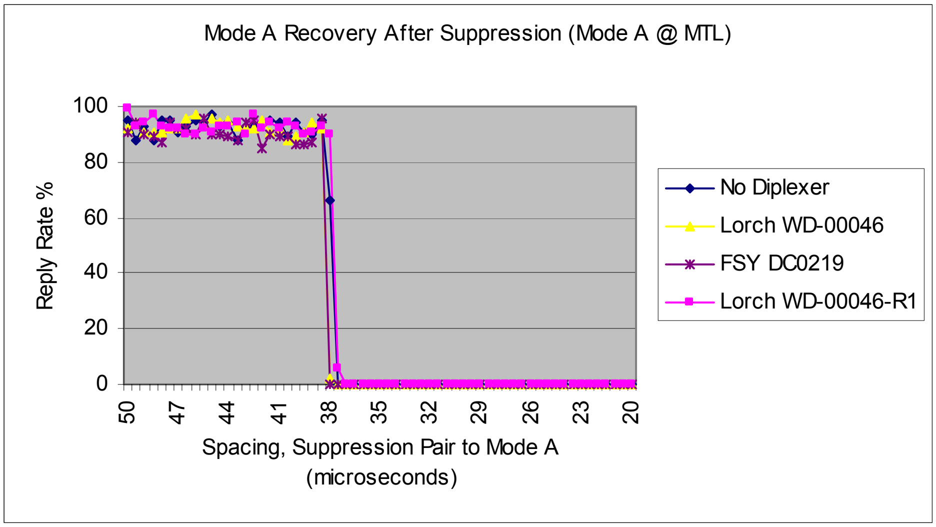

Figure 4-190 – Recovery After Suppression, Transponder A-1

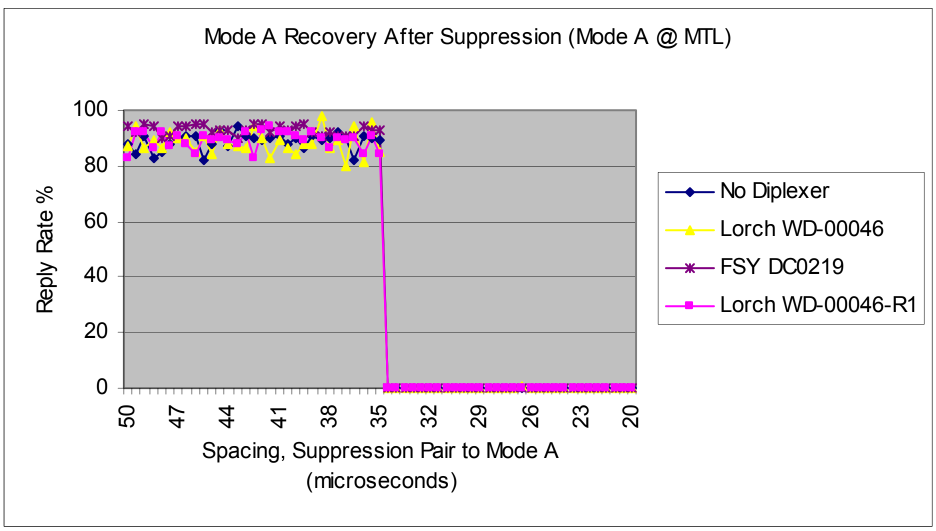

Figure 4-191 – Recovery After Suppression, Transponder A-2

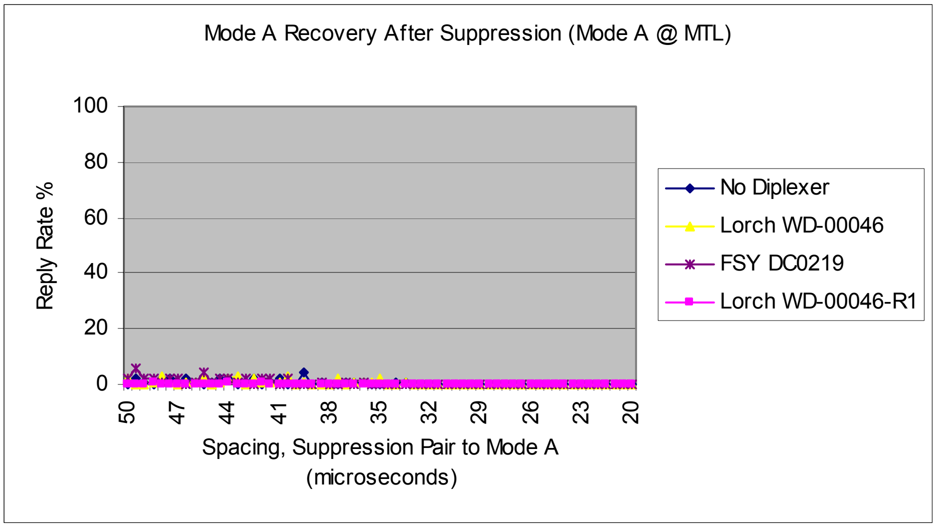

Figure 4-192 – Recovery After Suppression, Transponder A-3

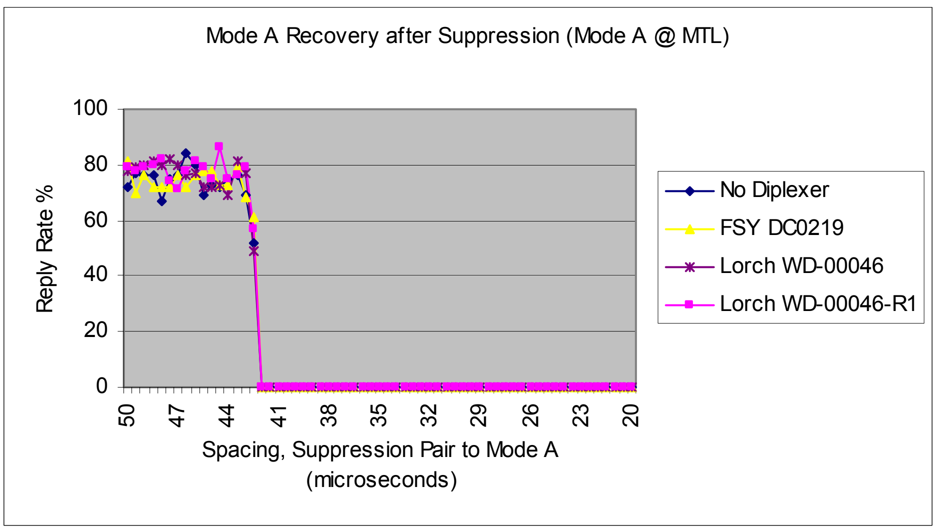

Figure 4-193 – Recovery After Suppression, Transponder A-4

4.29 Mode S SLS

The transponder is required to suppress replies to Mode S format interrogations when a P5 pulse, overlaying the sync phase reversal of P6 exceeds the amplitude of P6 by 3 dB or more. The reply ratio is required to be at least 99 percent if the amplitude of P6 exceeds that of P5 by 12 dB or more. Mode S SLS decoding was tested for the 5 Mode S transponders and compared to that measured with each Diplexer type. Figure 4-194 through Figure 4-198 shows that the Diplexers had no effect on Mode S SLS decoding.

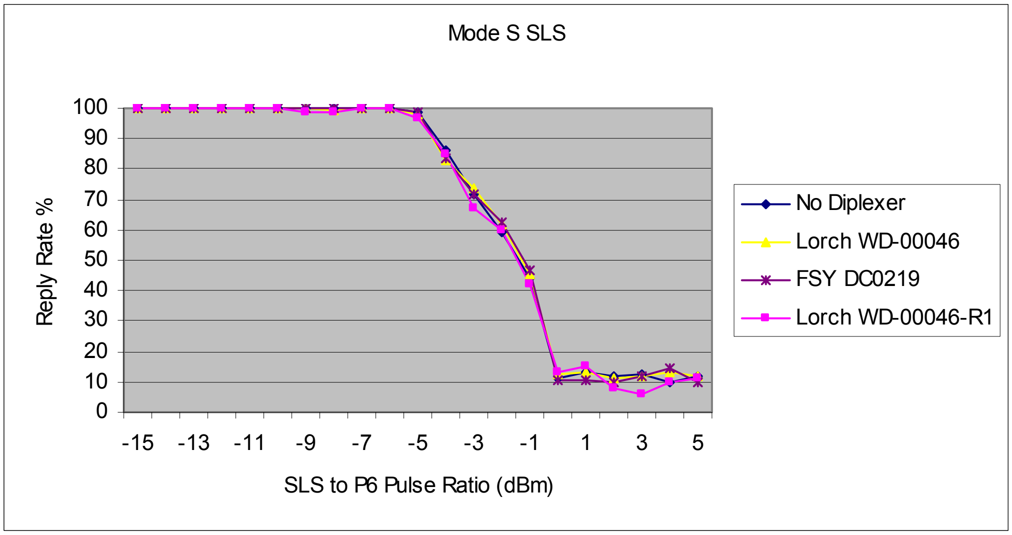

Figure 4-194 – Mode S Side Lobe Suppression, Transponder MS-1A

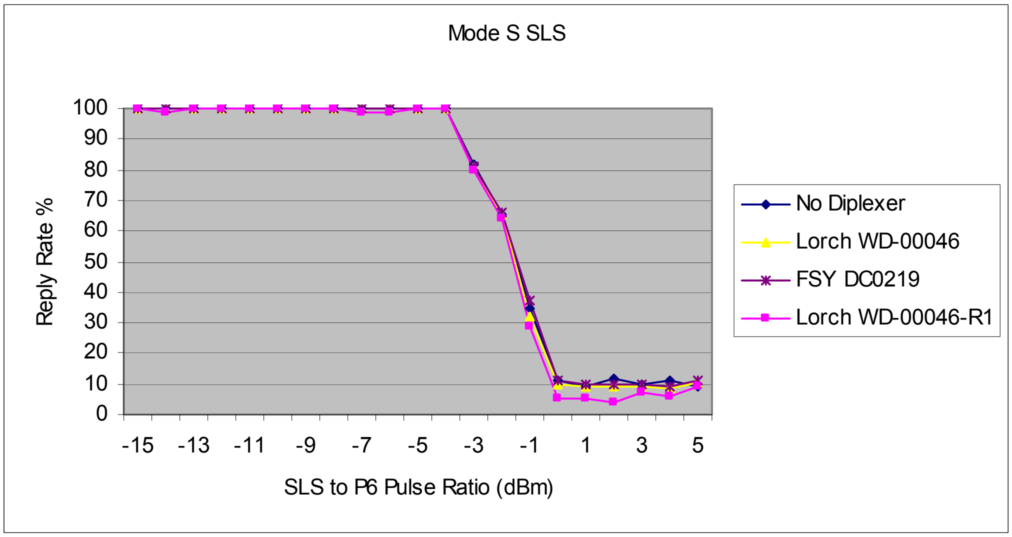

Figure 4-195 – Mode S Side Lobe Suppression, Transponder MS-1B

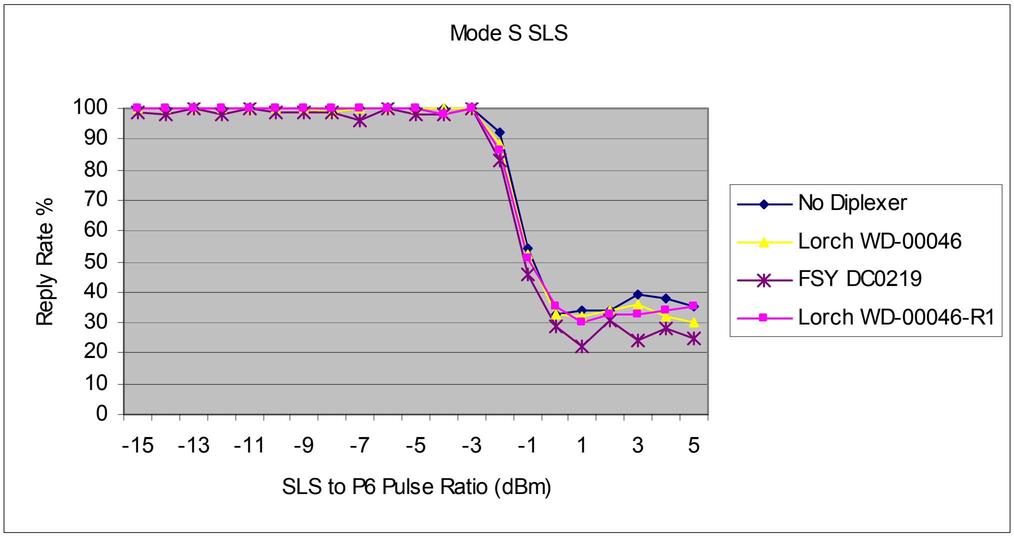

Figure 4-196 – Mode S Side Lobe Suppression, Transponder MS-2

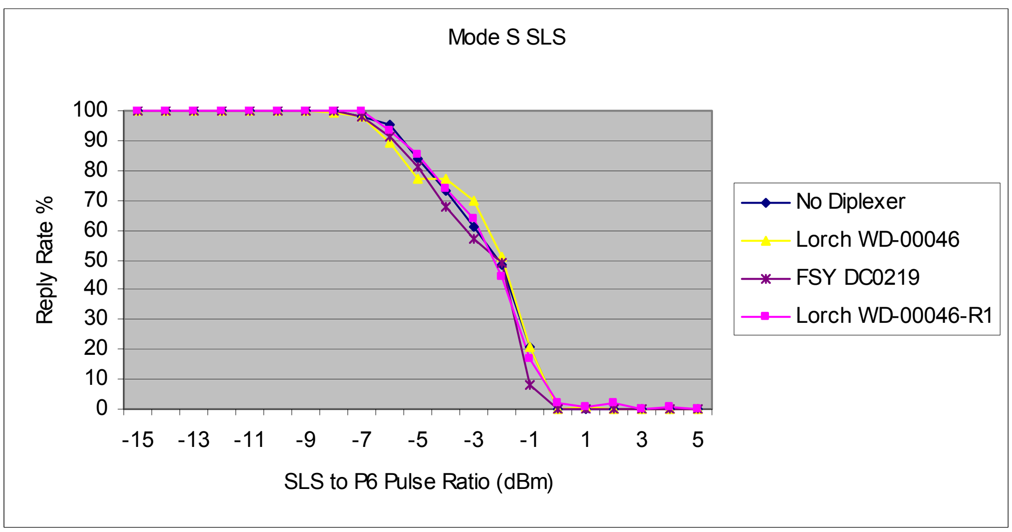

Figure 4-197 – Mode S Side Lobe Suppression, Transponder MS-3A

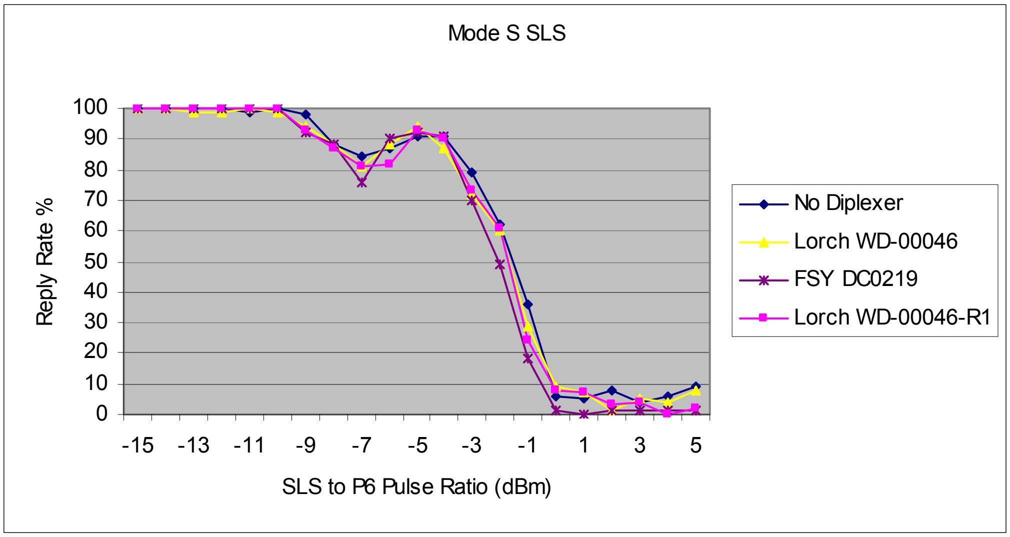

Figure 4-198 – Mode S Side Lobe Suppression, Transponder MS-3B

4.30 ATCRBS Desensitization Pulse and Recovery

When a transponder receives a pulse of more than 0.7 microseconds in duration, it is required to be desensitized temporarily by raising the receiver threshold. Immediately after the desensitizing pulse, the sensitivity is reduced to somewhere between the level of the desensitizing pulse and 9 dB below that. Following desensitization, the transponder is required to recover sensitivity to within 3 dB of MTL within 15 microseconds of the trailing edge of the desensitizing pulse. Tests were conducted to measure desensitization and recovery for each transponder/Diplexer configuration. Figure 4-199 through Figure 4-207 shows that there was no effect from the Diplexers.

Note: *When the desensitizing pulse combines with P1 at or near 8 or 21 microseconds, the transponder decodes the desensitizing pulse and P1 pulse combination as a valid ATCRBS interrogation and replies outside of the reply detection window of the test equipment. The apparent sudden loss in sensitivity at these points along the curve are actually due to the resulting lack of a reply in the reply detection window.*

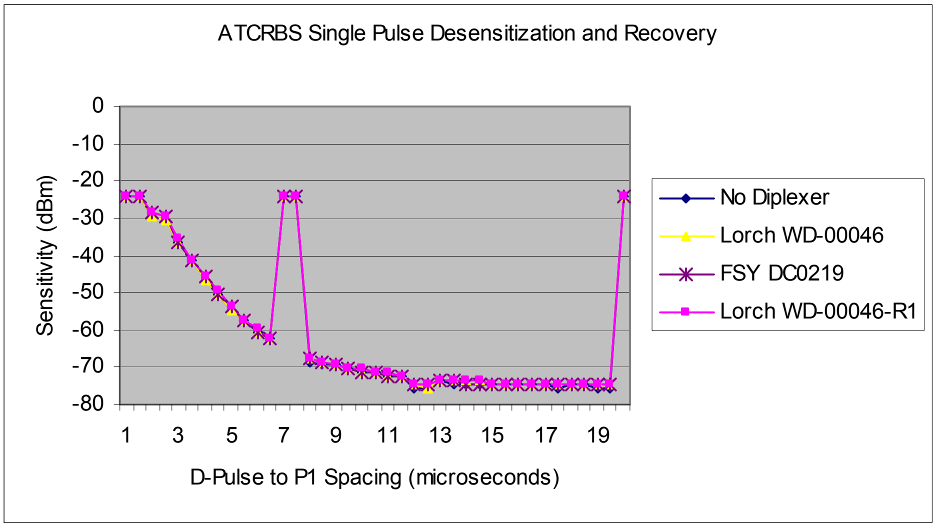

Figure 4-199 – ATCRBS Single Pulse Desensitization and Recovery, Transponder MS-1A

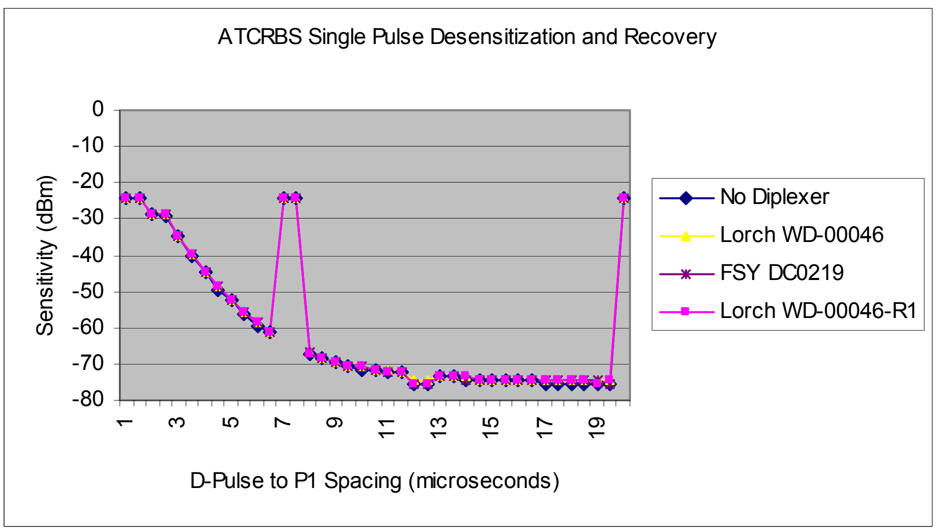

Figure 4-200 – ATCRBS Single Pulse Desensitization and Recovery, Transponder MS-1B

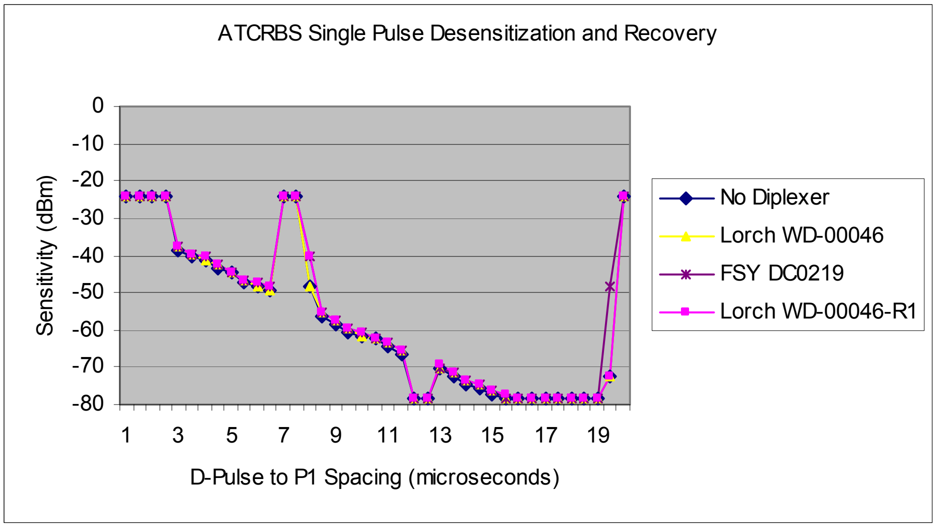

Figure 4-201 – ATCRBS Single Pulse Desensitization and Recovery, Transponder MS-2

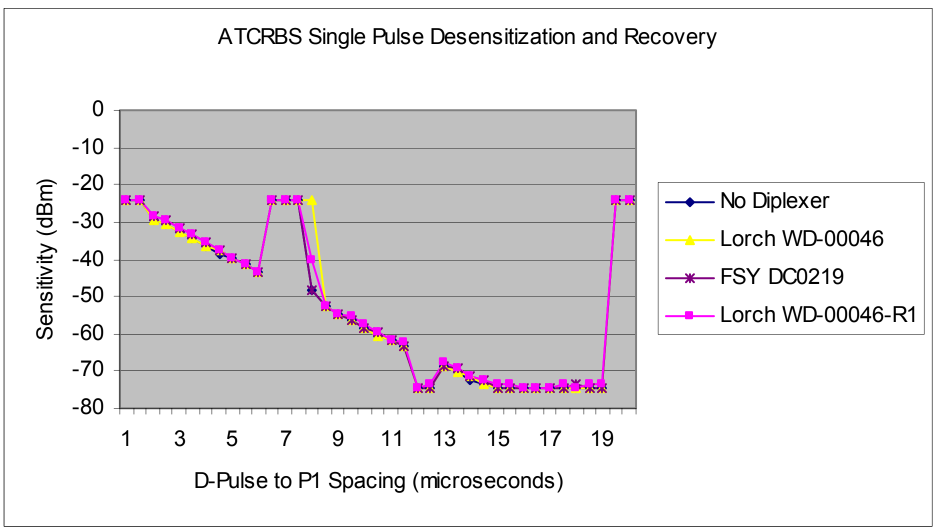

Figure 4-202 – ATCRBS Single Pulse Desensitization and Recovery, Transponder MS-3A

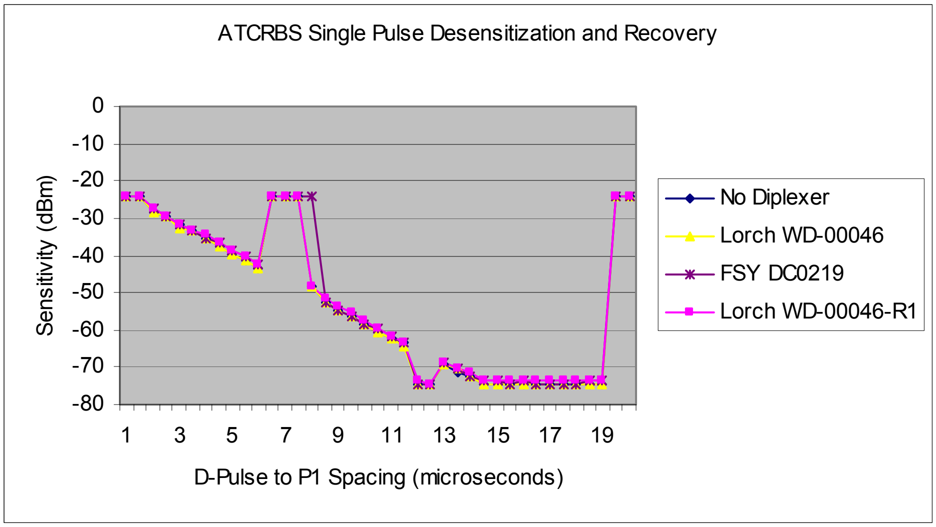

Figure 4-203 – ATCRBS Single Pulse Desensitization and Recovery, Transponder MS-3B

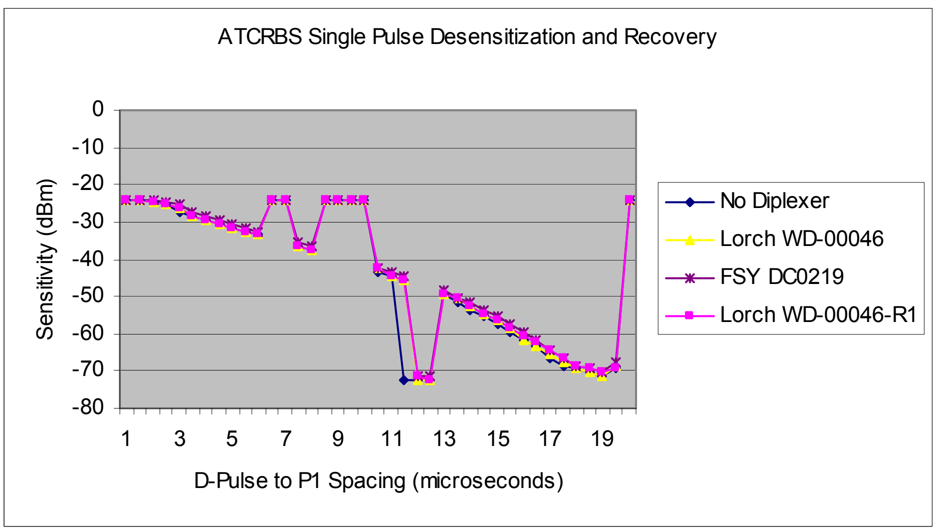

Figure 4-204 – ATCRBS Single Pulse Desensitization and Recovery, Transponder A-1

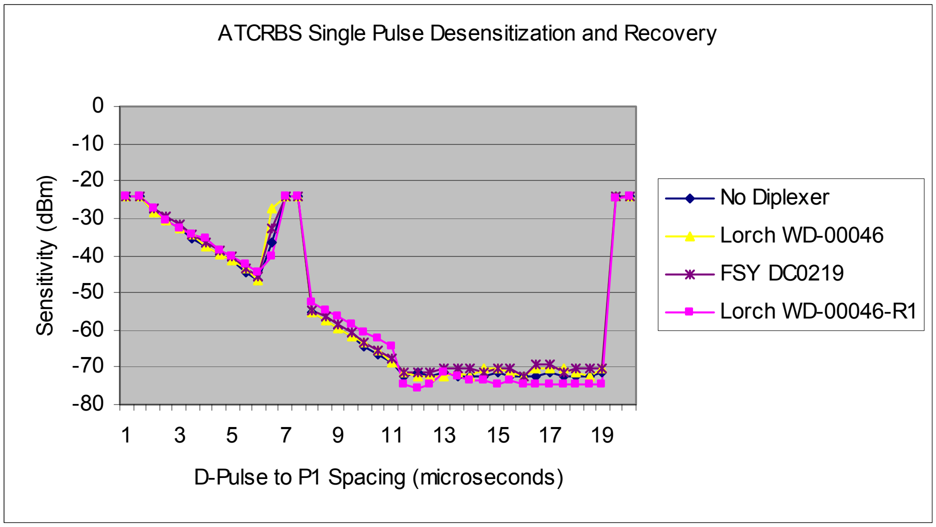

Figure 4-205 – ATCRBS Single Pulse Desensitization and Recovery, Transponder A-2

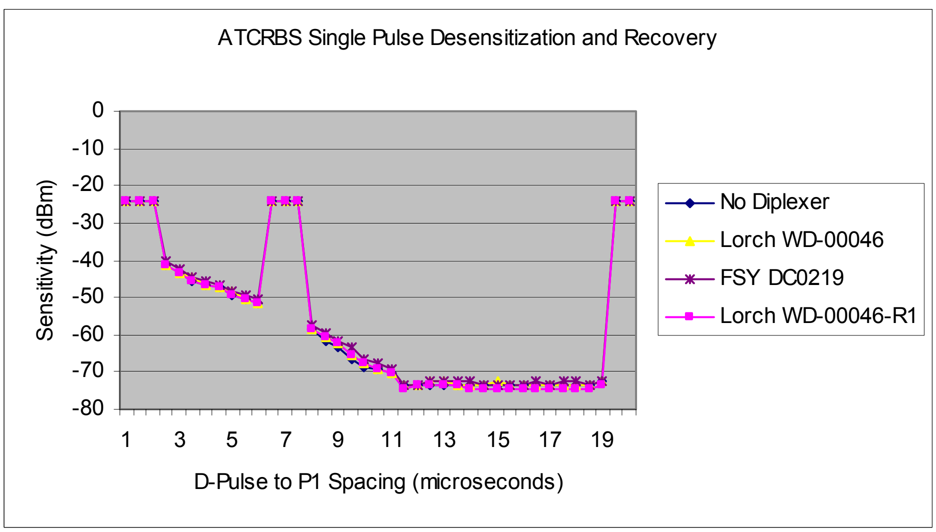

Figure 4-206 – ATCRBS Single Pulse Desensitization and Recovery, Transponder A-3

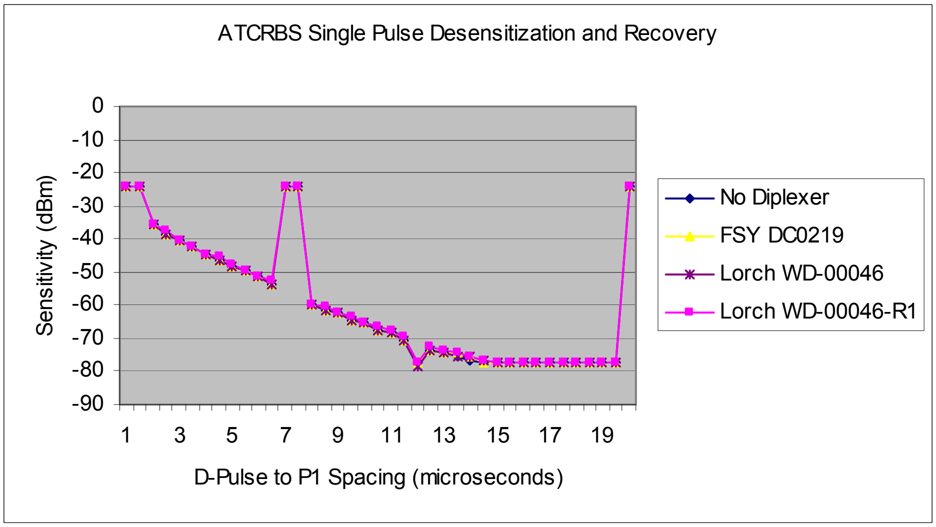

Figure 4-207 – ATCRBS Single Pulse Desensitization and Recovery, Transponder A-4

5 SIMULATED UAT FAILURE TESTS

Additional tests were run to test the effect if any on the performance of the SSR transponders under simulated extreme failure conditions with the UAT. Those conditions are an open and a short on the UAT input to the Diplexer. Using both the FSY and Lorch WD-00046 Diplexers, the SSR transponder sensitivity and transmit power were measured with the UAT input both an open circuit and shorted to ground. These measurements were compared to the sensitivity and power measurements that were made with the UAT input properly terminated. The tests were run on both Mode S and ATCRBS type transponders. The test showed there was no difference in either transmit power or receiver sensitivity with any of the transponders with either Diplexer.

6 DIPLEXER INSTALLATION GUIDANCE

The test data presented in this report support the conclusion that the use of a Diplexer that meets the specified requirements for installing UAT equipment aboard an aircraft that currently has an ATCRBS or Mode S SSR transponder is a viable option. It is anticipated that the use of a Diplexer for this purpose will be feasible in most cases. A data sample from a major air-transport carrier indicates that with the SSR transponder installations, the average cable loss is much less than the allowed 3 dB. However, prior to installation it should be first verified that the existing SSR transponder cable loss budget allows for the 0.5 dB maximum additional loss that could be introduced with the Diplexer.

The existing cable loss can be determined in one of the following ways:

1. The cable loss can be calculated if the length of the cable from the transponder to the antenna is known. The table below gives the losses for a few standard cables. The loss is measured at 1090MHz.

Cable	Loss per 100 feet (dB)	Cable	Loss per 100 feet (dB)
Belden 8237(RG-8)	7.8	Belden 9913 (RG-8)	4.6
Belden 9258(RG-8X)	15.117	Belden 8219 (RG-58A)	18.9
Belden 9201(RG-58)	17.4	Belden 8259 (RG-58C)	24.08
RG-62	9.1	RG213, RG214	8.6

2. The cable loss can be measured by using a Transmission Line analyzer. If the total measured loss is within the allowable antenna to equipment loss allocation by at least an amount that can absorb the additional loss that will be experienced by the addition of the Diplexer, connectors and additional cable, then the installation is a candidate for using a Diplexer.

3. If a Transmission Line analyzer is not available, the power can be measured at both ends of the transmission line between the transponder and the antenna. Using the transponder reply as the signal source, measure the power at the output port of the transponder. At the antenna end of the cable from the transponder, measure the power. The difference between these two readings is the cable loss.

In all cases, the addition of the Diplexer must also consider the losses through additional connectors and cable that are required to install the Diplexer. Also, the total cable loss through the Diplexer to the UAT equipment must be calculated to insure that the loss allocation required by the UAT equipment is not exceeded. Typically, the same 3 dB allocation to the loss between equipment and antenna applies to the UAT equipment, but the UAT Installation Manual should be referenced to verify the allowable loss. There are transponder installations that may not allow the typical cable loss allocation of 3 dB. Manufacturers sometimes rely on less loss to enable design to a less stringent transmit power or receiver sensitivity. Installation Manuals should be referenced to determine the loss allocation allowed for a particular transponder model. In the cases where the loss allowed is less than 3 dB, the loss allocation must be decreased by .5 dB to compensate for the Diplexer loss.

7 CONCLUSIONS

The results of the extensive testing of SSR transponder and UAT performance verify that the use of a Diplexer to share the SSR antenna with UAT equipment on an aircraft is an acceptable configuration.

The performance of the SSR transponder with a Diplexer is consistent with the performance of an SSR transponder without a Diplexer. The Diplexer introduces a maximum of 0.5 dB loss across either the SSR transponder equipment to antenna path or the UAT equipment to antenna path. The Diplexer introduces up to a 10 nanosecond delay across either path. The loss across the Diplexer would have to be factored into an installation where the loss allocation between the box and antenna is normally 3 dB.

The characteristics of the prototype Diplexer used in this testing were recommended and adopted in the relevant UAT MOPS document (RTCA/DO-282A). The testing performed herein provides verification that a Diplexer meeting the specifications of the prototype Diplexer tested insures compatibility with SSR transponder operation.

It is important to note that the tests were conducted using available production ATCRBS and Mode S transponders. Use of a Diplexer with SSR transponders requires verifying that the off frequency power that the equipment will be subjected to at the input of the equipment can be tolerated. UAT equipment designs must also factor the off frequency power that the equipment would be subjected to through the use of a Diplexer. These same issues would need to be addressed without a Diplexer as the co-site of UAT, SSR and TCAS equipment require these same power considerations to be factored into their design. The use of a Diplexer designed to the specifications defined in the UAT MOPS (RTCA/DO-282A) will not require additional tests to be conducted and submitted to FAA certification authorities to verify operation of the SSR transponder and UAT with the use of a Diplexer.