RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS (DO-282), Revision A

Meeting #19

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Proposed Changes to DO-282 for the Diplexer

With Revision 1 editorial changes

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SUMMARY
This Working Paper contains what is hoped to be the final set of proposed changes to the UAT MOPS related to the addition of materials for the Diplexer. This Working Paper contains materials for requirements in section 2.2, with test procedures in section 2.4 and proposed changes to section 3. Additionally, there are proposed changes to Appendix E.

1.0 Purpose And Scope

2.0 Equipment Performance Requirements and Test Procedures

2.1 General Requirements

2.2 Equipment Performance – Standard Conditions

2.2.1 Definition of Standard Conditions

2.2.2 ADS-B Transmitter Characteristics

2.2.3 Broadcast Message Characteristics

2.2.4 The ADS-B Message Payload

2.2.5 Procedures for Processing of Time Data

2.2.6 Procedures for ADS-B Message Transmission

2.2.7 UAT Transmitter Message Data Characteristics

2.2.8 Receiver Characteristics

2.2.9 Report Assembly Requirements

2.2.10 Receiver Subsystem Capacity and Throughput Requirements

2.2.11 Special Requirements for Transceiver Implementations

2.2.12 Suppression Requirements

2.2.13 Self Test and Monitors

2.2.14 Antenna System

2.2.14.1 Polarization

2.2.14.2 Antenna Voltage Standing Wave Ratio (VSWR)

2.2.14.3 Optional Diplexer Requirements

An option to use a frequency diplexer is provided to allow sharing of a single antenna between the ATCRBS/Mode S Transponder and the UAT unit is provided herein. Sharing a common antenna between the two systems may be desirable in aircraft to minimize antenna installation cost and complexity. The diplexer specified herein is a 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 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. Other installation issues are discussed in §3.2.1.10 along with further guidance to insure proper installation and operation of the systems. Additional diplexer information is available in Appendix E. The use of the diplexer does not preclude the UAT from driving the suppression bus during UAT transmissions. Diplexer installations must include connection and use of the suppression bus driven by the UAT and received by the Transponder as specified in §2.2.12.

2.2.14.3.1 Diplexer RF Requirements

2.2.14.3.1.1 UAT Channel

The diplexer **shall** include a UAT Channel that conveys UAT signals without distortion of the waveform. The UAT Channel **shall** convey UAT Basic, Long and Ground Uplink Messages while maintaining the modulation accuracy of the input UAT signals as specified in §2.2.2.4 and produce no more than 0.5 dB amplitude attenuation and no more than 10 nanoseconds in propagation delay. The UAT Channel **shall** provide a passband from no greater than 977 MHz to no less than 979 MHz (2.0 MHz minimum) and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband **shall** be different by no greater than 0.20 dB. The UAT port of the diplexer **shall** be capable of peak power transmissions according to the appropriate aircraft equipage class given by Table 2-1. The VSWR produced by the diplexer at the UAT port, when the other two ports are terminated in a 50 ohm load, **shall** not exceed 1.3:1 for frequencies within the passband.

2.2.14.3.1.2 Transponder Channel

The diplexer **shall** include a Transponder Channel that conveys 1030 MHz interrogation and 1090 MHz reply signals without distortion of the waveform. The Transponder Channel **shall** convey pulses that are amplitude modulated on either 1030 MHz or 1090 MHz and having rise and fall times of 50 nanoseconds or more and produce no more than 0.5 dB amplitude attenuation and no more than 10 nanoseconds delay while retaining the pulse rise and fall times and pulse width of the input pulses. The Transponder Channel **shall** provide a passband from no greater than 1015 MHz to no less than 1105 MHz (90 MHz minimum) and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband **shall** be different by no greater than 0.20 dB. The Transponder port **shall** be capable of handling 1000 Watts instantaneous power. The VSWR produced by the diplexer at the Transponder port, when the other two ports are terminated in a 50 ohm load, **shall** not exceed 1.3:1 for frequencies within the passband. If required by the transponder installation, the diplexer **shall** support DC coupling from the Transponder port to the antenna port as required by the electrical characteristics of the installed equipment.

2.2.14.3.1.3 Channel to Channel Isolation

The diplexer **shall** provide RF isolation between the UAT Channel and the Transponder Channel. The diplexer **shall** provide a minimum of 55 dB of isolation between these ports at 1090 MHz. Additionally, the diplexer **shall** provide a minimum isolation of 40 dB between the UAT and Transponder ports of the diplexer at 1030 MHz. The diplexer **shall** provide a minimum of 25 dB of isolation between the ports at 978 MHz.

Note: *Installations that incorporate the diplexer must insure that the off frequency power seen by the front end of the UAT equipment and the ATCRBS/Mode S transponders through the diplexer are within the design tolerances of each unit to insure proper operation. It has been determined that the isolations provided above should insure safe operation for most transponder designs with respect to off frequency effects. The design of the UAT needs to consider the power seen at the input from the transponder and it should be verified that the transponder design can handle the UAT power through the isolation provided.*

2.3 Equipment Performance – Environmental Conditions

2.3.1 Environmental Test Conditions

2.3.2 Detailed Environmental Test Procedures

2.4 Equipment Test Procedures

2.4.1 Definition of Standard Conditions of Test

2.4.2 Verification of ADS-B Transmitter Characteristics (§2.2.2)

2.4.3 Verification of Broadcast Message Characteristics (§2.2.3)

2.4.4 Verification of The ADS-B Message Payload (§2.2.4)

2.4.5 Verification of Procedures for Processing of Time Data (§2.2.5)

2.4.6 Verification of Procedures for ADS-B Message Transmission (§2.2.6)

2.4.7 Verification of UAT Transmitter Message Data Characteristics (§2.2.7)

2.4.8 Verification of Receiver Characteristics (§2.2.8)

2.4.9 Verification of Report Assembly Requirements (§2.2.9)

2.4.10 Verification of Receiver Subsystem Capacity and Throughput Requirements (§2.2.10)

2.4.11 Verification of Special Requirements for Transceiver Implementations (§2.2.11)

2.4.12 Verification of Suppression Requirements (§2.2.12)

2.4.13 Verification of Self Test and Monitors (§2.2.13)

2.4.14 Verification of Antenna System (§2.2.14)

2.4.14.1 Verification of Polarization (§2.2.14.1)

2.4.14.2 Verification of Antenna Voltage Standing Wave Ratio (VSWR) (§2.2.14.2)

2.4.14.3 Verification of Optional Diplexer Requirements (§2.2.14.3)

2.4.14.3.1 Verification of Diplexer RF Requirements

2.4.14.3.1.1 Verification of UAT Channel

Purpose/Introduction:

The diplexer **shall** include a UAT Channel that conveys UAT signals without distortion of the waveform. The UAT Channel **shall** convey UAT Basic, Long and Ground Uplink Messages while maintaining the modulation accuracy of the input UAT signals as specified in §2.2.2.4 and produce no more than 0.5 dB amplitude attenuation and no more than 10 nanoseconds in propagation delay. The UAT Channel **shall** provide a passband from no greater than 977 MHz to no less than 979 MHz (2.0 MHz minimum) and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband **shall** be different by no greater than 0.20 dB. The UAT port of the diplexer **shall** be capable of peak power transmissions according to the appropriate aircraft equipage class given by Table 2-1. The VSWR produced by the diplexer at the UAT port, when the other two ports are terminated in a 50 ohm load, **shall** not exceed 1.3:1 for frequencies within the passband.

Equipment Required:

The tests performed in this subparagraph require the diplexer under test, equipment as described in §2.2.8.2.3.a and §2.2.8.2.3.b, two lengths of 50 ohm cable of known loss and connector adaptors, as necessary, a 50 ohm termination, 20 to 30 dB of power attenuation, and a High Power UAT message source that meets the maximum RF power requirements of the equipage class under test. Provide a means for measurement of VSWR.

Measurement Procedures:

Step 1: Equipment Setup (§2.2.14.3.1.1)

Connect both cables in series directly between the Signal Generator and the Vector Signal Analyzer temporarily bypassing the diplexer. Configure the Signal Generator to sweep CW RF with a sweep range of 3 MHz centered at 978 MHz. Configure the Vector Signal Analyzer to display the continuous peak hold of a RF spectrum 3 MHz wide centered at 978 MHz and signal levels between –29.9 and –31.9 dBm.

Step 2: Test Setup (§2.2.14.3.1.1)

Adjust the Signal Generator so that the Vector Signal Analyzer measures a level of –30 dBm, and insure that the difference between the maximum and minimum level across the 3 MHz band is less than 0.05 dB. Insert the diplexer between the two cables at the UAT and Antenna ports, and terminate the Transponder port in 50 ohms.

Step 3: Maximum UAT Channel Passband Attenuation and Ripple (§2.2.14.3.1.1)

Allow the Vector Signal Analyzer to record the results of a number of sweeps sufficient to show smooth results, and verify 1) that the minimum signal level in the 978 MHz +/- 1 MHz range is no less than –30.5 dBm, and 2) that the maximum minus minimum level in the 3 MHz band is no greater than 0.2 dB.

Step 4: UAT Signal Verification (§2.2.14.3.1.1)

Get ready to replace the Signal Generator with the UAT message source, place attenuation between the diplexer and the Vector Signal Analyzer to limit the power into the Vector Signal Analyzer to less than +25 dBm, replace the Signal Generator with the UAT message source, set it to the maximum power for the equipage class under test.

Setup the Vector Signal Analyzer as described in §2.4.2.4 except adjust for the signal levels specified above in this test, and verify that the measured "Eye Diagram" is similar to the one measured in §2.4.2.4, Step 2, and that it shows no distortion of the UAT waveform.

Step 5: UAT Signal Verification - Loss and Delay (§2.2.14.3.1.1)

Determine the power loss of the pulse from the UAT port to the Antenna port, and verify that the loss is no more than 0.5 dB.

Determine the pulse delay measured from the lead edge time of the pulse at the UAT port to the lead edge of the pulse at the Antenna port, and verify that the delay introduced by the diplexer is no more than 10 nanoseconds.

Step 6: VSWR at 978 MHz (§2.2.14.3.1.1)

Verify that the VSWR at the UAT port, with the other two ports terminated in 50 ohms, is no more than 1.3:1 at 978 1030 MHz.

2.4.14.3.1.2 Verification of Transponder Channel

Purpose/Introduction:

The diplexer **shall** include a Transponder Channel that conveys 1030 MHz interrogation and 1090 MHz reply signals without distortion of the waveform. The Transponder Channel **shall** convey pulses that are amplitude modulated on either 1030 MHz or 1090 MHz and having rise and fall times of 50 nanoseconds or more and produce no more than 0.5 dB amplitude attenuation and no more than 10 nanoseconds delay while retaining the pulse rise and fall times and pulse width of the input pulses. The Transponder Channel **shall** provide a passband from no greater than 1015 MHz to no less than 1105 MHz (90 MHz minimum) and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband **shall** be different by no greater than 0.20 dB. The Transponder port **shall** be capable of handling 1000 Watts instantaneous power. The VSWR produced by the diplexer at the Transponder port, when the other two ports are terminated in a 50 ohm load, **shall** not exceed 1.3:1 for frequencies within the passband. If required by the transponder installation, the diplexer **shall** support DC coupling from the Transponder port to the antenna port as required by the electrical characteristics of the installed equipment.

Equipment Required:

The tests performed in this subparagraph require the diplexer under test, equipment as described in §2.2.8.2.3.a and §2.2.8.2.3.b, two lengths of 50 ohm cable with connector adaptors, a 50 ohm termination, at least 35 dB of power attenuation, and an RF Signal Source with Pulse Amplitude Modulation at both 1030 and 1090 MHz Carrier Frequencies and at least 1000 Watts of power output. Also, provide a means for measurement of VSWR.

Measurement Procedures:

Step 1: Equipment Setup (§2.2.14.3.1.2)

Connect both cables in series directly between the Signal Generator and the Vector Signal Analyzer temporarily bypassing the diplexer. Configure the Signal Generator to sweep CW RF with a sweep range of 100 MHz centered at 1060 MHz. Configure the Vector Signal Analyzer to display the continuous peak hold of a RF spectrum 100 MHz wide centered at 1060 MHz and signal levels between –29.9 and –31.9 dBm.

Step 2: Test Setup (§2.2.14.3.1.2)

Adjust the Signal Generator so that the Vector Signal Analyzer measures a level of –30 dBm, and insure that the difference between the maximum and minimum level across the 100 MHz band is less than 0.05 dB. Insert the diplexer between the two cables at the Transponder and Antenna ports, and terminate the UAT port in 50 ohms.

Step 3: Maximum Transponder Channel Passband Attenuation and Ripple (§2.2.14.3.1.2)

Allow the Vector Signal Analyzer to record the results of a number of sweeps sufficient to show smooth results, and verify 1) that the minimum signal level in the 1015 to 1105 MHz (central 90 MHz) range is no less than –30.5 dBm, and 2) that the maximum minus minimum level in the central 90 MHz band is no greater than 0.2 dB.

Step 4: Pulse Input Verification (§2.2.14.3.1.2)

Get ready to replace the Signal Generator with the RF source providing a 450 nanosecond pulse with 50 nanosecond rise and fall times pulse modulated at 1030 MHz. Place attenuation between the diplexer and the Vector Signal Analyzer to limit the power into the Vector Signal Analyzer to less than +25 dBm, and replace the Signal Generator with the RF source.

Setup the Vector Signal Analyzer in vector mode in order to measure the envelope of the RF pulse, and verify that the measured pulse has a 450 nanosecond pulse width and 50 nanosecond rise and fall times.

Step 5: RF Pulse Input Verification – Loss and Delay (§2.2.14.3.1.2)

Determine the power loss of the pulse from the Transponder port to the Antenna port, and verify that the loss is no more than 0.5 dB.

Determine the pulse delay measured from the lead edge time of the pulse at the Transponder port to the lead edge of the pulse at the Antenna port, and verify that the delay introduced by the diplexer is no more than 10 nanoseconds.

Step 6: RF Pulse Input Verification at 1090 MHz (§2.2.14.3.1.2)

Repeat Steps 4 and 5 above with the input RF signal source set at 1090 MHz.

Step 7: VSWR at 1030 MHz and 1090 MHz (§2.2.14.3.1.2)

Verify that the VSWR at the Transponder port, with the other two ports terminated in 50 ohms, is no more than 1.3:1 for both 1030 MHz and 1090 MHz.

2.4.14.3.1.3 Verification of Channel to Channel Isolation

Purpose/Introduction:

The diplexer **shall** provide RF isolation between the UAT Channel and the Transponder Channel. The diplexer **shall** provide a minimum of 55 dB of isolation between these ports at 1090 MHz. Additionally, the diplexer **shall** provide a minimum isolation of 40 dB between the UAT and Transponder ports of the diplexer at 1030 MHz. The diplexer **shall** provide a minimum of 25 dB of isolation between the ports at 978 MHz.

Equipment Required:

The tests performed in this subparagraph require the diplexer under test, equipment as described in §2.2.8.2.3.a and §2.2.8.2.3.b, two lengths of 50 ohm cable with connector adaptors, and a 50 ohm termination.

Measurement Procedures:

Step 1: Equipment Setup (§2.2.14.3.1.3)

Connect both cables in series directly between the Signal Generator and the Vector Signal Analyzer temporarily bypassing the diplexer. Configure the Signal Generator to sweep CW RF with a sweep range of 150 MHz centered at 1035 MHz. Configure the Vector Signal Analyzer to display the continuous peak hold of a RF spectrum 150 MHz wide centered at 1035 MHz and signal levels between –29.9 and –31.9 dBm.

Step 2: Test Setup (§2.2.14.3.1.3)

Adjust the Signal Generator so that the Vector Signal Analyzer measures a level of –30 dBm, and insure that the difference between the maximum and minimum level across the 150 MHz band is less than 0.05 dB. Insert the diplexer between the two cables at the UAT and Transponder ports, and terminate the Antenna port in 50 ohms.

Step 3: Minimum UAT and Transponder Channel Isolation (§2.2.14.3.1.3)

Allow the Vector Signal Analyzer to record the results of a number of sweeps sufficient to show smooth results, and verify 1) that the maximum signal level at 978 MHz is no greater than –55.0 dBm, 2) that the maximum signal level at 1030 MHz is no greater than –70.0 dBm, and 3) that the maximum signal level at 1090 MHz is no greater than –85.0 dBm.

3.0

3.1

3.1.1

3.1.2

3.1.3

3.1.4

3.1.5

3.1.6

3.1.7

3.1.8

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3.1.10

3.1.11 Mutual Suppression

UAT ADS-B equipment is not required to interface with mutual suppression systems.

Replace with:

UAT ADS-B equipment **shall** interface to the mutual suppression bus. The UAT **shall** drive the mutual suppression bus during UAT transmissions so that other L Band systems installed in the aircraft can desensitize their receivers during UAT transmissions. Installations with ATCRBS or Mode S transponders **shall** insure that the transponder is connected to the mutual suppression bus to prevent unsolicited replies from being generated by the transponder during UAT transmissions. UAT equipment **shall** not receive from the mutual suppression bus.

3.2

3.2.1 Antenna Installation

3.2.1.1 General Considerations

Antenna gain and pattern characteristics are major contributors to the system data link performance. The location and number of antennas required for aircraft ADS-B systems is determined by the equipage class. Classes A1L, A1H, A2, and A3 require antenna diversity and must have transmit and receiving capability on both the top and bottom of the aircraft. Exceptions may be made for installations on radio-transparent airframes. Class A0 installations do not require antenna diversity. Compliance of the installed antennas with the requirements of §2.1.11 may be demonstrated by analysis.

If the ADS-B Transmitting Subsystem shares antennas with a Mode-S transponder, the antennas **shall** comply with the requirements of RTCA Document Number DO-181B.

Delete above two-line paragraph and replace with:

If the ADS-B Transceiver shares antennas with a Mode S or ATCRBS transponder, the antennas **shall** additionally comply with the requirements of the applicable transponder standards (currently for Mode S – RTCA Document Number DO-181C, and for ATCRBS, TSO-C74C), and the diplexer **shall** comply with the requirements of §2.2.14.3 of this document.

3.2.1.2

3.2.1.3

3.2.1.4

3.2.1.5

3.2.1.6

3.2.1.7

3.2.1.8

3.2.1.9

3.2.1.10 Antenna Diplexer

An antenna diplexer may be utilized in installations with SSR ATCRBS transponders or Mode S transponders to allow antenna sharing of the UAT equipment and the transponder. The use of a diplexer may be considered in all classes of UAT equipage classes. When installed with the diplexer, the ATCRBS or Mode S transponder **shall** continue to conform to the appropriate standards. The installation of a diplexer must consider the impact to the transponder and UAT equipment. The loss of signal power through the diplexer must be factored into the cable loss allocation between the antenna and the transponder and the antenna and the UAT equipment. The signal delay through the diplexer must also be considered and if diversity is supported, the use of a diplexer on the top, bottom or both antenna must insure that the diversity delay tolerances between top and bottom antenna are met for both the transponder and UAT equipment.

Note: *The characteristics of the diplexer contained in these MOPS should insure proper operation of UAT equipment with the majority of existing models of ATCRBS and Mode S transponders. Extensive testing was performed with* *current representative ATCRBS and Mode S transponders and prototype diplexers to verify proper operation of the transponders and UAT equipment with the use of a diplexer. Results of these tests were utilized to produce and validate the diplexer requirements contained in this document. The assumptions used to derive diplexer characteristics have taken into consideration existing installations of ATCRBS and Mode S transponders. The loss budget for cable loss between the antenna and equipment in most installations should readily absorb the loss allocated to the diplexer.*

Variation in diplexer characteristics from the requirements contained in this document must insure that the transponder and UAT equipment meet the requirements of the appropriate applicable standards. Verification that the isolation requirements of the transponder are satisfied and receiver tolerance to high power off frequency signals need to be factors in consideration of use of a diplexer in installations.

Appendix E

Aircraft Antenna Characteristics

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E. Aircraft Antenna Characteristics

E.1 Antenna Characteristics

E.1.1 General Characteristics

The UAT System is expected to be able to utilize any standard transponder/DME antenna. Potential sharing of existing transponder antennas is discussed in Section E.3 below. The antenna must be suitable to receive and transmit vertically polarized signals at 978 MHz. The VSWR produced by the antenna into a manufacturer specified load must not exceed 1.7:1 at 978 MHz +/- 1 MHz.

E.1.2 Radiation Patterns

Performance of the UAT ADS-B System was estimated using a model of antenna gain that was developed for the FAA Safe Flight – 21 (SF-21) Technical Link Assessment Team (TLAT) Report. See Appendix K of this document. In practice, equipment designers assume 0.5 dB less average gain in the azimuth plane than that given in the TLAT Antenna Gain Model. However, in data links such as UAT, which are interference limited, this difference should not be expected to affect the performance presented in Appendix K of this document.

E.1.3 Directional Gain Radiation Patterns

For some applications (such as applications specific to Class A3 equipment), it may be suitable to use antennas with directional gain patterns to increase the range in the forward direction. Limitations on such directional gain antennas include not creating undesired nulls in the azimuth pattern, maintaining the minimum air-to-air range in the aft direction, and ensuring that any future requirements for minimum air-to-ground range are met. This subparagraph contains some examples of antennas that can achieve these goals.

The Figure E-1 shows the azimuth pattern of an antenna that has been evaluated through the development of RTCA DO-260A. This antenna achieves its gain through use of passive reflector elements. The antenna has a peak gain of 7.5 dBi, and a F/B ratio of 5 dB. This antenna could be easily scaled for 978 MHz, or undergo additional investigation to determine its characteristics as a combined antenna for both 978 and 1090 MHz.

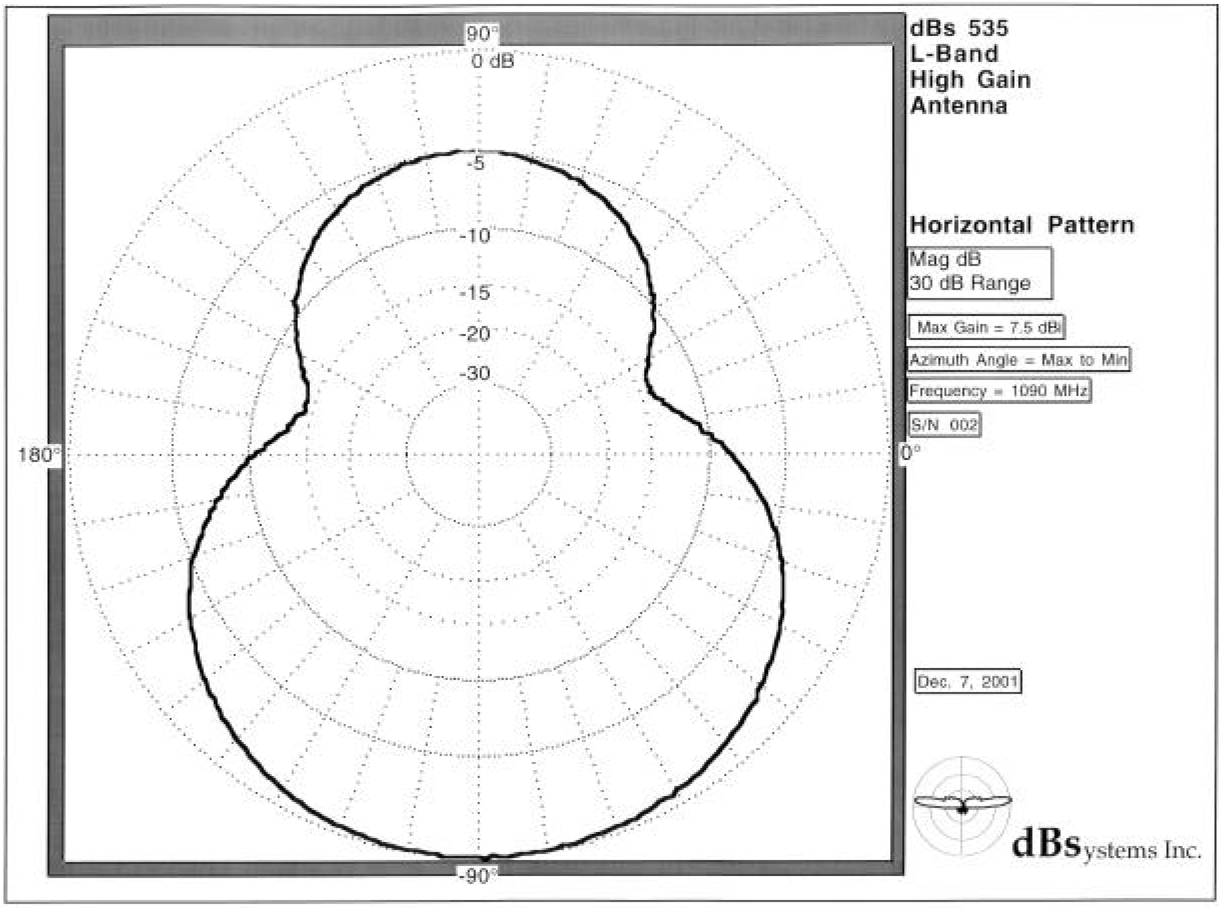
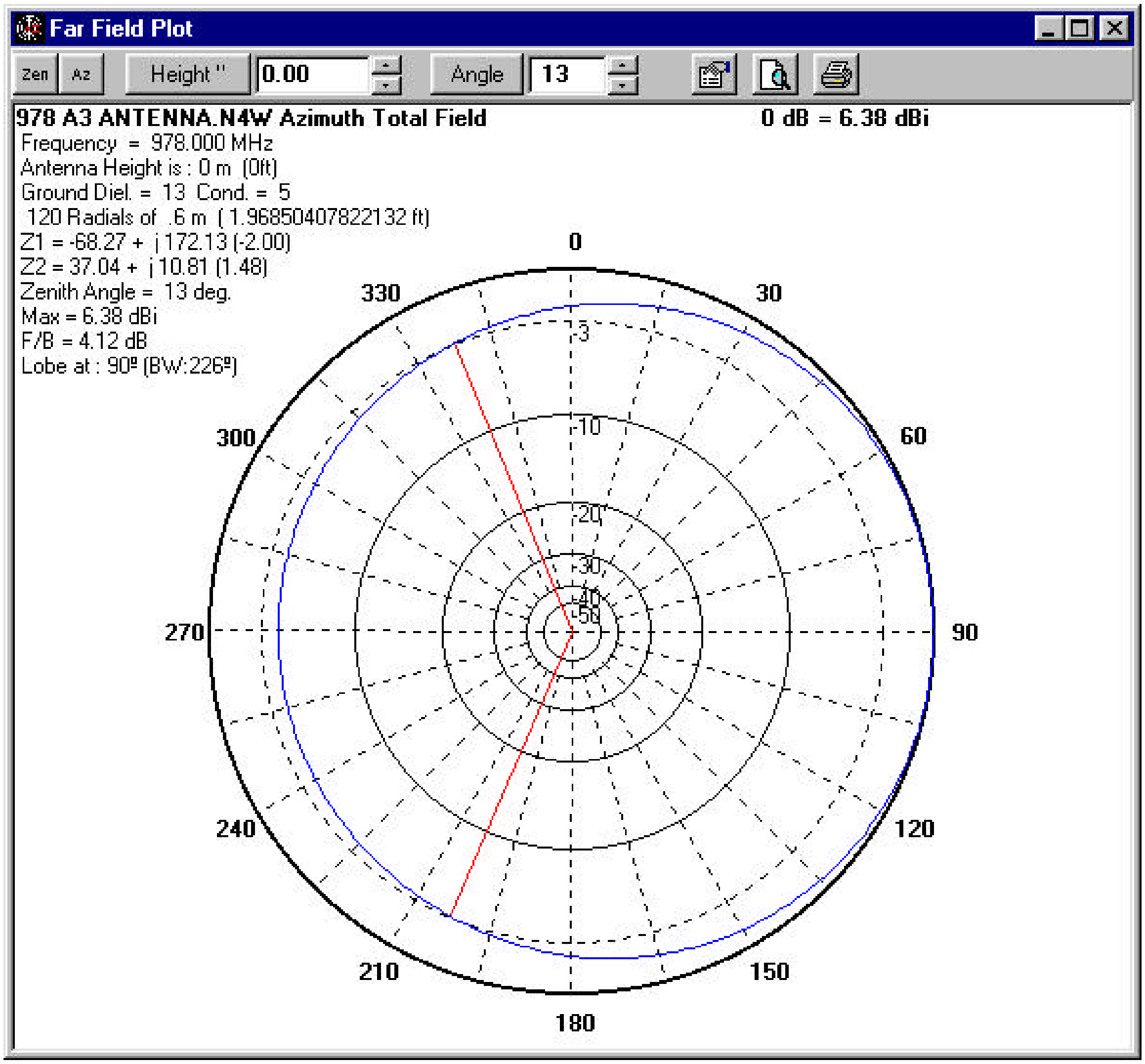


Figure E-1: L-Band Passive Gain Antenna

Figure E-2 shows a theoretical antenna that uses a pair of active driven elements to achieve directional gain while creating a uniform pattern. This antenna consists of a pair of quarter-wave resonant elements spaced at 1/8 wavelength, and driven 45 degrees out of phase.

This antenna design achieves 6.4 dBi of gain at an elevation angle of 13 degrees, with a F/B ratio of 4 dB.



<u>Figure E-2:</u> Gain Array Antenna Azimuth Pattern

E.2 Typical VSWR Measurements of Existing Transponder / DME Antennas

There are several varieties of existing antennas that are suitable for use with the UAT datalink. These are summarized in Table E-1 below.

Table E-1: Typical Antennas

FAA TSO	RTCA	Equipment Type	VSWR & Frequency
TSO-C66c	DO-189C	DME	2:1 from 960-1215
TSO-C74c	DO-144	Transponder	1.5:1 on 1030, 1090
TSO-C112	DO-181C	ATCRBS Mode S	1.5:1 from 1030-1090

Typically, antennas that comply with TSO-C112 are specified with VSWR < 1.5:1 from 1030 to 1090 MHz, and VSWR < 1.7:1 over the remainder of the band from 978 to 1215 MHz. Certain types of transponder antennas that utilize very thin radiator elements are only intended for use at 1030 and 1090 MHz. These types of antennas should be evaluated on a model-by-model basis to determine their suitability as UAT datalink antennas.

Note that RF system performance is not strongly affected by VSWR values. A VSWR value as high as 2:1 does not increase the losses in the transmitted signal by more than 0.5 dB. This lack of sensitivity in system performance to VSWR values should be kept in mind when evaluating antennas for UAT applications.

The following subparagraphs illustrate these VSWR characteristics for specific antenna models. These measurements were performed with the antenna mounted in the center of a 4-foot diameter conductive ground plane.

E.2.1 Sensor Systems L Band Blade Antenna P/N S65-5366-7L

This antenna is typical of those found on jet transport aircraft, and is rated for TSO C66b, C74c, and C112. This antenna would be suitable as a UAT antenna.

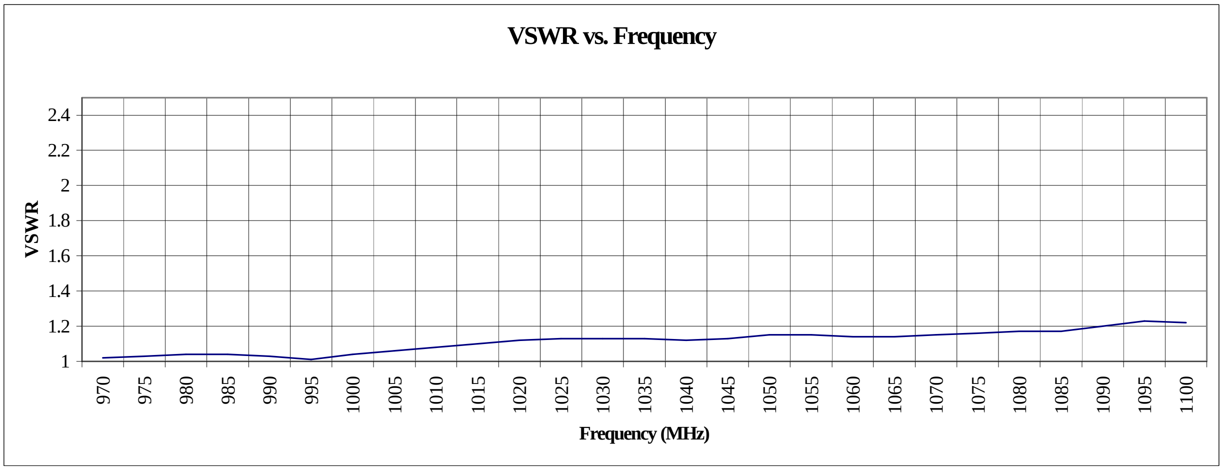


Figure E-3: Jet Transport Antenna

E.2.2 AeroAntenna P/N AT-130-1

This antenna was designed for the FAA Capstone program as a dedicated UAT antenna.

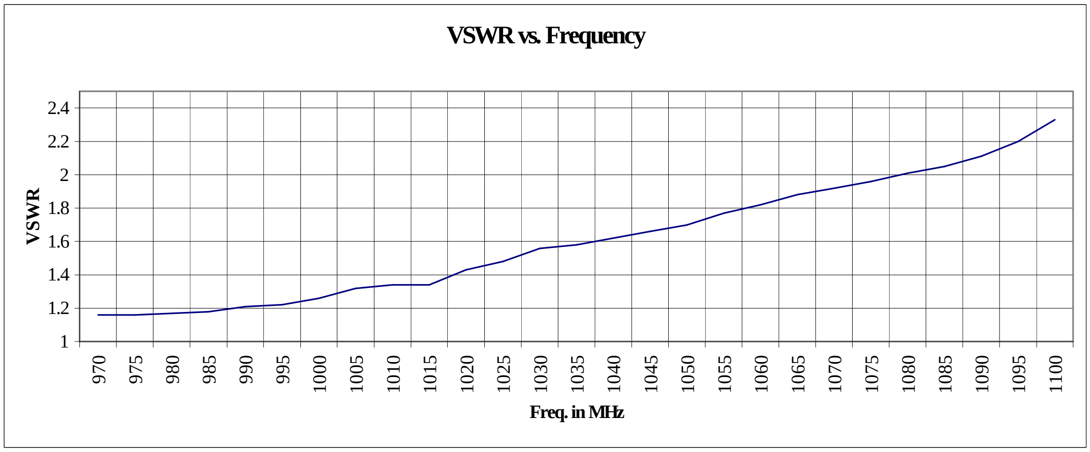


Figure E-4: Capstone Antenna

E.2.3 ¼ Wave Whip Antenna

This data represents a typical GA-application thin whip antenna, such as a RAMI Model AV-22 (TSO C-74c). Note that although not specified for performance outside of the 1030 to 1090 MHz range, it actually performs best at frequencies lower than 1030 MHz.

This antenna would be a suitable UAT datalink antenna, and illustrates the need to look at the characteristics of each candidate antenna closely.

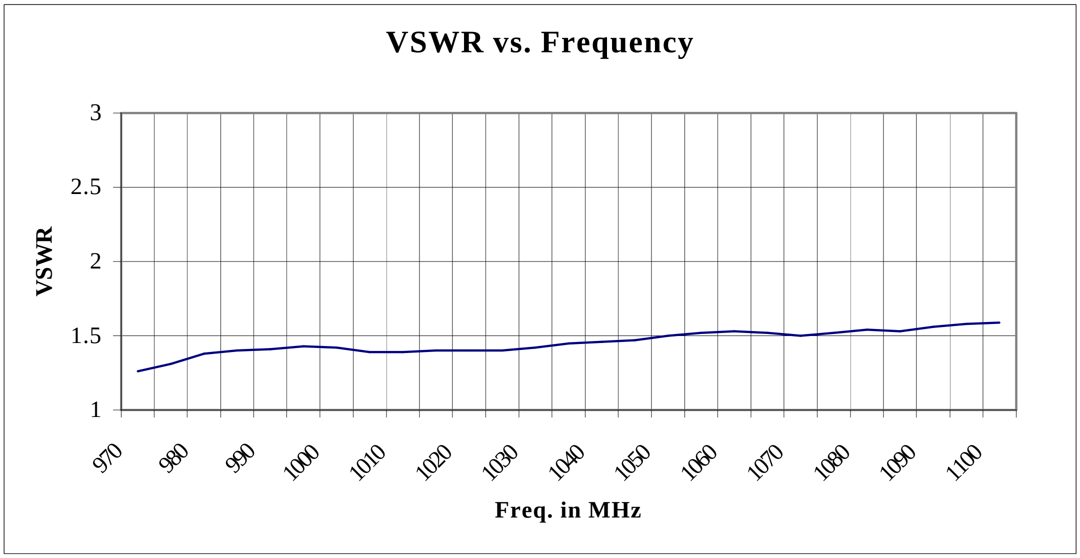


Figure E-5: **¼ Wave Whip Antenna**

E.3 Antenna ~~A Potential Method of Sharing Antennas with Existing Transponder Installations~~Diplexer Characteristics

A potential method of providing an antenna for the UAT is to use a frequency diplexer that is installed between an existing transponder and its antenna. ~~While the techniques described below look promising, further~~Allowing the use of a diplexer to operate UAT equipment and the on-board SSR transponder required extensive validation ~~investigation of those techniques will be required in order to validate that TCAS/ACAS operation is not adversely affected~~ to verify that the use of a diplexer would not degrade the operation of either system. A test effort utilizing a prototype diplexer conforming to the requirements of section 2.2.14.3 was utilized to conduct the necessary testing.

Upon initial investigation into the concept of antenna sharing by use of a diplexer, certain characteristics were critical to enable use of a diplexer. The power loss across the diplexer was an important consideration. The typical loss that installations allow between the transponder and antenna is 3 dB. The diplexer can not use up a significant portion of this allocation without eliminating most existing transponder installations as candidates for UAT antenna sharing. The requirement that the diplexer loss can not exceed .5 dB is expected to enable most existing installations to use a diplexer and share the transponder antenna. The goals of the diplexer design were to support a transponder port that would~~To minimize impact on the transponder installation, t~~ minimize the~~he~~ insertion loss in the 1090 / 1030 MHz band and possessing adequate passband so that 1030 MHz interrogation signals and 1090 MHz reply signals were unaffected by the diplexer. ~~is minimized.~~ An optional DC path in the diplexer's transponder channel is allowed so that installations that require antenna sensing can maintain the capability to sense the presence of an antenna. The diplexer's transponder channel will attenuate signals at 978 MHz, providing isolation from the UAT. In some cases, diplexer isolation actually exceeds the level of isolation obtained by using separate transponder and UAT antennas. The latter is a function of distance between antennas. The UAT's diplexer port can provide minimal insertion loss to the antenna at 978 MHz while manifesting a high impedance at the 1030 / 1090 MHz band.

E.3.1 Antenna Diplexer TestingPrototype L-Band Diplexer Characteristics

Tests were conducted to validate the performance of ATC transponders sharing an aircraft antenna with a UAT by incorporating a diplexer into the installation. The purpose of the tests was to insure that both the UAT equipment and transponders perform according to the applicable standards and that the diplexer does not introduce any signal distortions on the 978 MHz frequency of UAT and the 1030/1090 MHz frequencies of ATC transponders. A selected set of tests was performed to measure any potential degradation of equipment performance due to the diplexer installation. The tests measured the effect of both the UAT/diplexer on the performance of the transponder and the effect of the transponder/diplexer on the performance of the UAT system.

E.3.1.1 SSR Transponder Testing

Tests were conducted to measure the effect of the diplexer installation on the performance of ATC transponders. Two prototype diplexers built by two different manufacturers were tested. Each diplexer was tested with seven different transponders including 3 Mode S, and 4 ATCRBS only transponders.

A comprehensive set of tests were run on each transponder to measure transmitter and receiver characteristics, reply pulse characteristics, side lobe suppression, undesired replies, and pulse decoder characteristics. Each test was performed both with and without the diplexer installed to measure the relative effects of the diplexer. Where appropriate, with the diplexer installation, the UAT system was connected and transmitting.

Table E-2 shows a summary of the test results. Parameters labeled "none" under measured effects showed no measurable effect within the accuracy of the test system. The test system measurement accuracy either met or exceeded the specified test conditions in the appropriate MOPS.

Table E-2: Diplexer Testing with ATC Transponders

TEST PARAMETER	MEASURED EFFECT
Reply Power	0.2 to 0.4 dB loss
Reply Frequency	None
Reply Delay (ATCRBS & Mode S)	Increased 0.01 to 0.018 microseconds
Reply Delay Jitter (ATCRBS & Mode S)	None
Reply Pulse Spacing (ATCRBS & Mode S)	None
Reply Pulse Shape (ATCRBS & Mode S)	None
Undesired Replies	UAT transmission triggered ATCRBS replies with some units
Sensitivity (ATCRBS & Mode S)	0.25 to 0.35 dB loss
Dynamic Range	None
Sensitivity Variation with Frequency	None
Bandwidth	None
Pulse Position Tolerance (ATCRBS & ATCRBS/Mode S)	None
Pulse Duration Tolerance (ATCRBS & ATCRBS/Mode S)	None
Pulse Level Tolerance P4 (ATCRBS/Mode S)	None
Sync Phase Reversal Position Tolerance (Mode S)	None
SLS Decoding (ATCRBS & ATCRBS Mode S)	None
SLS Pulse Ratio (ATCRBS & ATCRBS/Mode S)	None
Suppression Duration	None
Suppression Reinitiation	None
Recovery From Suppression	None
Mode S SLS	None
ATCRBS Desensitization Pulse and Recovery	None

The Reply Power and Receiver Sensitivity of the transponders were reduced a fraction of a dB through the diplexer. This is expected due to the insertion loss of the transponder channel of the diplexer that is specified to be 0.5 dB maximum. This should not be a detriment to proper operation as long as the installation accounts for the additional loss.

The reply delay showed an increase of about 10 to almost 20 nanoseconds average for all diplexer and transponder combinations. This is an effect of the sum of the 1030 MHz interrogation and the subsequent 1090 MHz reply each being delayed through the diplexer about 5 to 10 nanoseconds.

The Undesired reply rate was measured by monitoring ATCRBS and Mode S reply transmissions without interrogating the transponder. With the diplexer and UAT installed and operating with the transponder, some of the transponder/diplexer combinations resulted in unsolicited ATCRBS replies. This was caused by the low-level UAT signal leakage into the transponder channel of the diplexer. This occurred significantly more with one of the diplexers than with the other and it varied with the transponder type. The worst case measured was at an average rate of about 0.75

ATCRBS per UAT transmission. There were no unsolicited Mode S replies with any of the test configurations. 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 MOPS for Airborne ATC Transponder Systems (DO-144) requires that the random triggering rate not exceed 30 replies per second. This latter requirement is after installation with all possible interfering equipment operating. Although the undesired reply rate caused by the UAT transmissions were within the requirements, it was not desirable to trigger transponder emissions by the UAT signal. This issue was not solely a diplexer issue, since depending upon UAT antenna and transponder antenna proximity in an installation, UAT transmissions could cause transponder responses during UAT transmissions without a diplexer. For this reason, UAt equipment is required to output a suppression pulse to the transponder to inhibit the transponder receiver during UAT transmissions.

Measurements also indicated that the diplexer installation does affect VSWR. With ATCRBS transponders, the change in VSWR altered the transponder reply frequency. Mode S transponders were more immune to VSWR variations. Proper tuning of the installed cabling and adjusting for VSWR as specified in section 3.2.1.2 of this document for UAT installation, and for the transponder, as required by the applicable standard, is required..

E.3.1.1Specifications

UAT Channel:	Passband	977 to 979 MHz Min.
	Passband Insertion Loss	0.5 dB Max.
	DC coupling	None
Transponder Channel:	Passband	1015 MHz to 1105 MHz Min.
	Passband insertion Loss	0.4 dB Max.
	DC Coupled to antenna port	28 VDC @ 500 mA Max.
Both Channels	Channel-to-Channel isolation: 978-to-1090 MHz	50 dB min.
	Channel-to-Channel isolation: 978-to-1030 MHz	30 dB min
	Passband return loss	17 dB (all ports)
	Impedance	50 ohms (all ports)
	Power rating (Max.)	5 watts CW, 1000 watts peak
	Temperature range	-30 deg to +70 deg C
	Connectors	TNC female (all ports)

E.3.1.2 UAT Diplexer Testing

A variety of tests were conducted to determine the effects of UAT signals through a diplexer. Testing was facilitated using nine different configurations to test various combinations of remote or onboard UAT receivers, remote Ground Uplink transmissions, interference to UAT from remote or onboard Mode S or ATCRBS transponders, as well as onboard transponder leakage, in circuit with an implemented antenna diplexer.

Since no performance difference was measured looking at UAT reception at the on-board UAT receiver nor remotely when looking at UAT signals from the on-board transmitter through the diplexer, the severe case of onboard interference from Mode S or ATCRBS transmissions through the transponder port of a diplexer to a UAT receiver, was investigated. Even though the assumptions for the UAT performance model assume no UAT receptions when UAT signals are overlapped by on-board SSR transmissions, the test results show that the diplexer provides sufficient isolation from the on-board 1030 MHz and 1090 MHz transmissions to enable a high probability of successful reception of low level UAT messages. In all of the test cases where Mode S or ATCRBS transmissions interfered with UAT message receptions, the test was particularly severe. The transponder transmissions were overlaid in time with the UAT messages 100 % of the time, yet the UAT receiver, isolated by the antenna diplexer, performed with no significant degradation

~~E.3.1.2~~Prototype Diplexer Performance

E.3.1.3

The following figures show measured data obtained from a prototype L-band diplexer.

Figure E-6 shows the performance between the Antenna and UAT ports.

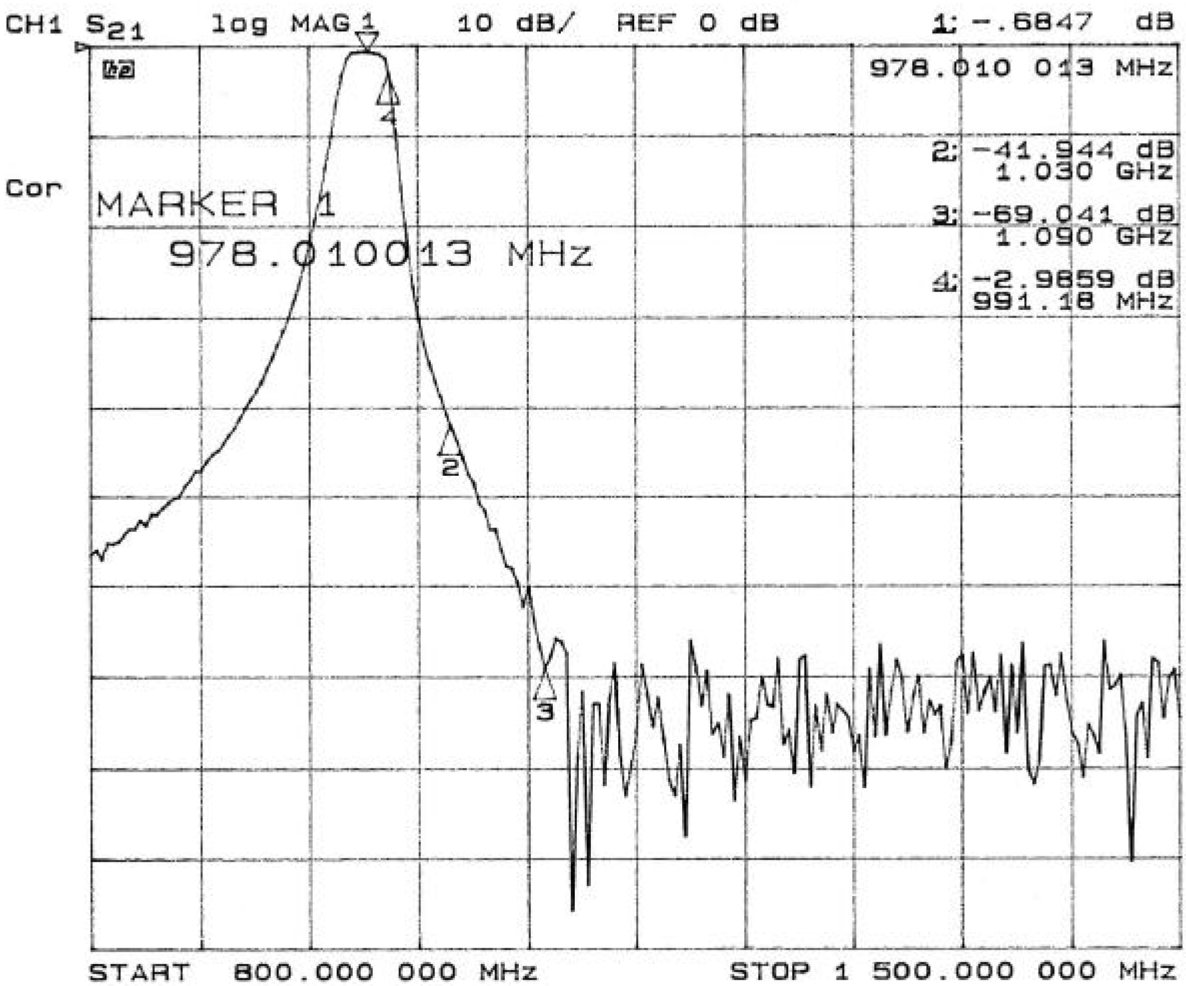


Figure E-6: Diplexer UAT Port

Figure E-7 shows the performance between the Antenna and Transponder ports.

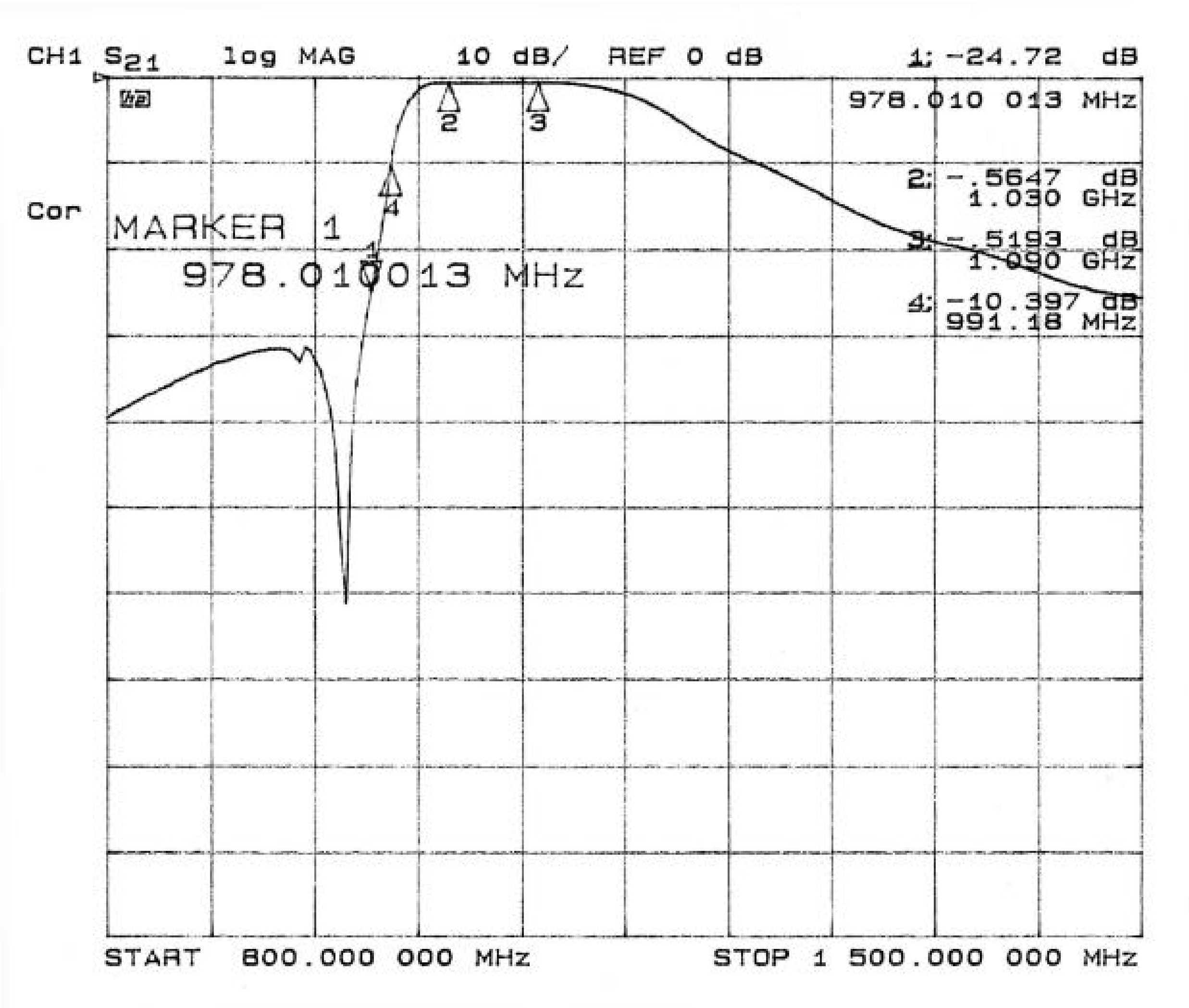


Figure E-7: **Diplexer Transponder Port**

Figure E-8 shows the isolation between the UAT and Transponder ports. Note that the isolation between the ports at the UAT frequency is 25 dB, and the isolation at the Transponder frequencies are 42 dB at 1030 MHz, and 64 dB at 1090 MHz.

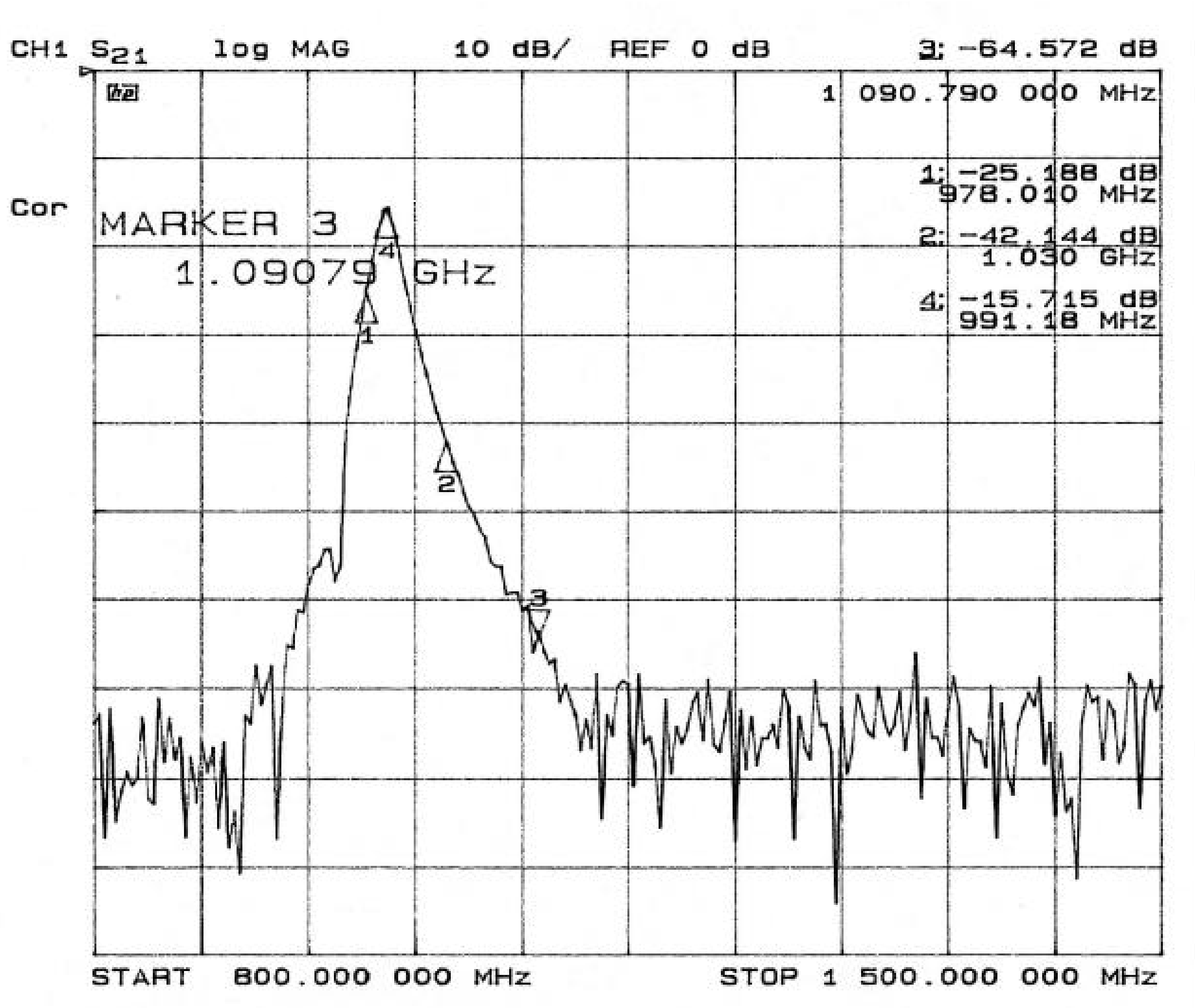


Figure E-8: **Diplexer UAT-to-Transponder Port Isolation**

E.3.2 Typical Installation Diagram

Figure E-9 illustrates how a UAT might be added to a typical existing transponder installation by using frequency diplexer/combiner. Shaded boxes indicate the new components added to the existing installation. The diplexer can be added anywhere in the antenna's feedline. The most logical place for this addition would be in the aircraft's equipment bay in close proximity to both the UAT and transponder units. This way, existing feedlines would not have to be re-routed or altered.

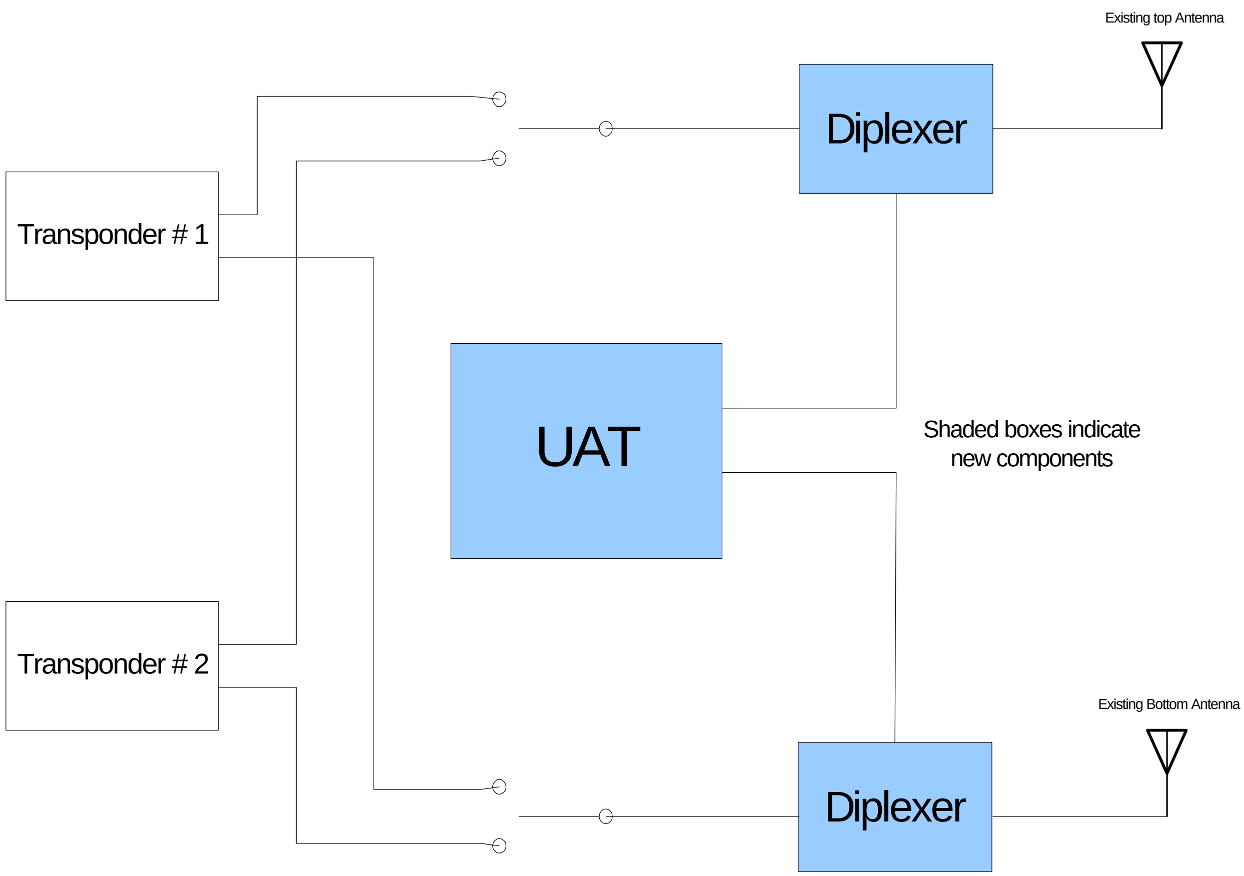


Figure E-9: Diplexer Installation

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