APPLICATION NOTE

Tower Mounted Amplifiers, Diagnostics and Isolation Measurements

Site Master™ S251C

Introduction

The use of Tower Mounted Amplifiers (TMAs) in cellular, PCS, GSM and 3G Base Stations has offered significant improvements to carriers to minimize call drops, loss of communication, and provide a more reliable service to customers in both outdoor and indoor coverage. Their use with any new installation is another way to provide better coverage and increase the number of subscribers without deploying new Base Stations in the same geographic area.

This application note will focus on testing of TMAs before and after installation and provide diagnostic tests like Cable Loss and DTF-Load Sweep to help determine the performance of transmission lines and tower mounted amplifiers.

Site Master S251C simplifies performance verification of TMAs prior to installation, thus reducing trouble shooting time and future diagnostics checks. Its easy calibration, high dynamic range, user-friendly menu, and optional bias tee provides a simple method of measuring gain of tower mounted amplifiers in the field.

Improve System Performance and Coverage with Site Master S251C

SiteMaster

An example of how TMA usage increases coverage at the PCS Base Station is shown in Figures 1 and 2. The low noise amplifier provides better coverage to the subscriber by minimizing fading in the communication system. This reduces call drop outs and extends battery life to the cell phone subscriber as the transmit power required is decreased because the Base Station becomes more sensitive to weaker signals.

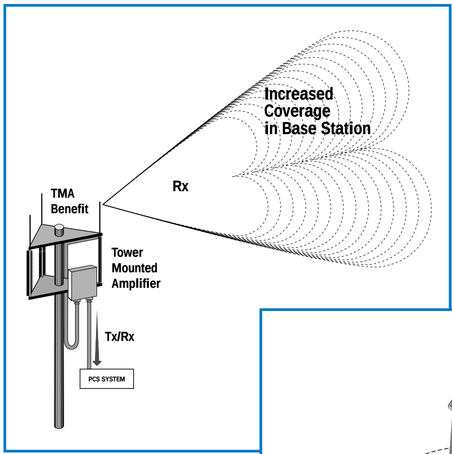


Figure 1. Tower Mounted Amplifier

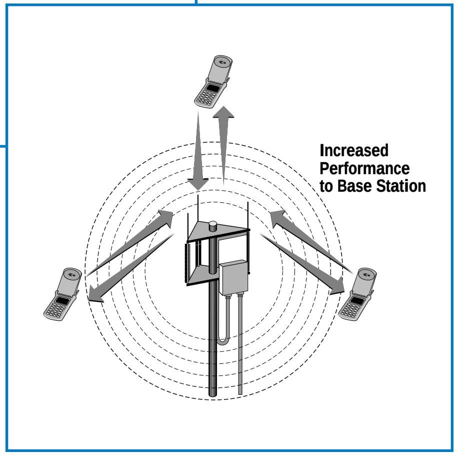
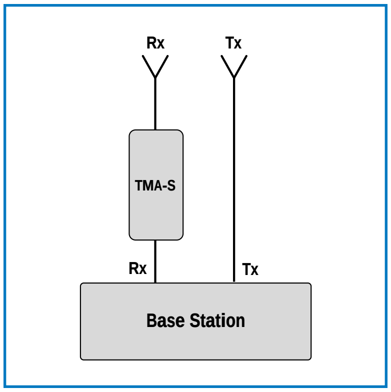


Figure 2. Larger Coverage Area

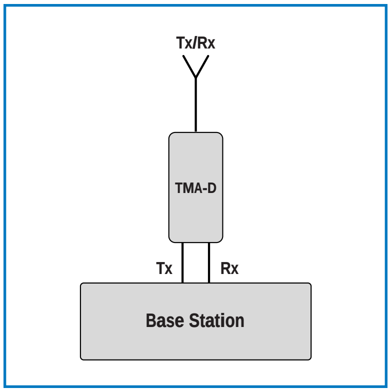
Applications of Tower Mounted Amplifiers

Manufacturers of Tower Mounted Amplifiers have accommodated the Base Station equipment providers with different types of TMAs to meet system requirements. Three types commonly used are shown below.

The **TMA-S** is a Rx-receive only tower mounted amplifier that connects between the Rx-receive antenna and the radio. Its purpose is to boost weak signals from the subscriber. This configuration is specific to systems that use separate antennas for Tx-transmit and Rx-receive.

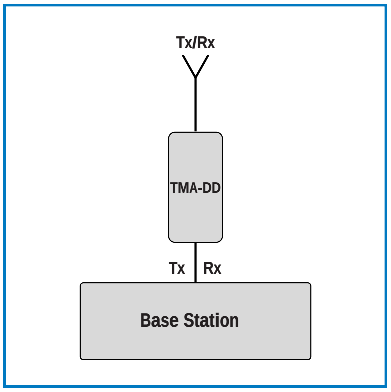


Tower Mounted Amplifier-Single (TMA-S)



Tower Mounted Amplifier-Duplex (TMA-D)

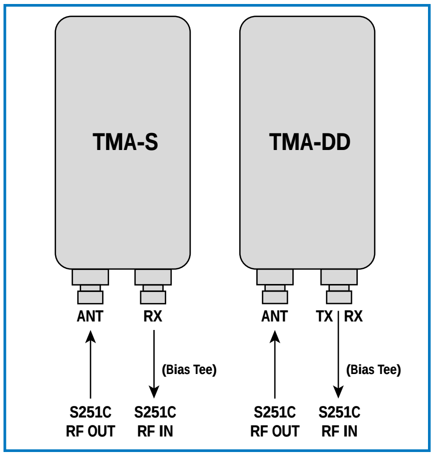
The **TMA-DD** is a dual duplex tower mounted amplifier that combines Tx-transmit and Rx-receive ports from the Base Station with a single transmission line. This configuration is specific to systems that can utilize a single antenna configuration.



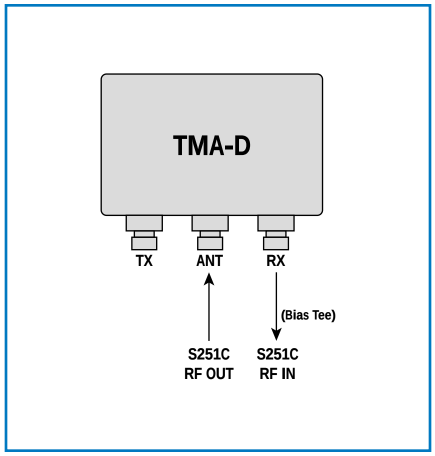
Tower Mounted Amplifier-Dual Duplex (TMA-DD)

The **TMA-D** is a duplex tower mounted amplifier that is used for the Base Station with a single antenna port connection for Tx-transmit and Rx-receive. These systems are commonly called transceivers.

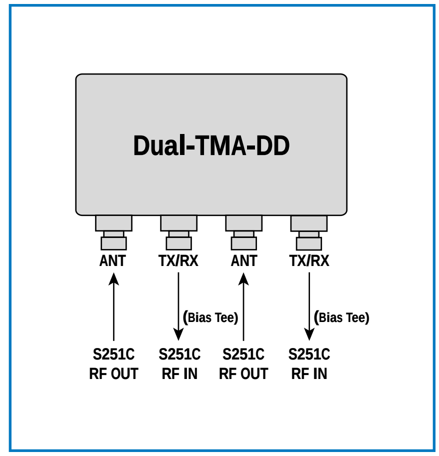
Types of Tower Mounted Amplifiers



Two-Port Tower Mounted Amplifier

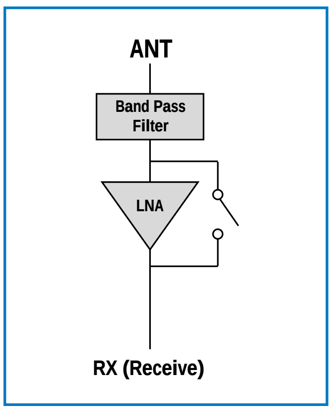


Three-Port Tower Mounted Amplifier

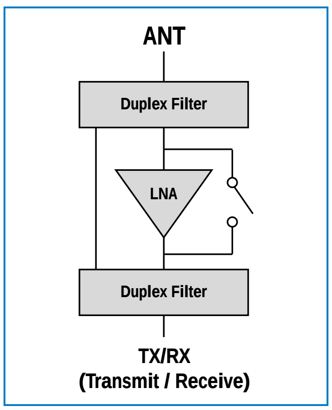


Four-Port Tower Mounted Amplifier
Dual-Duplex with NON Bypass

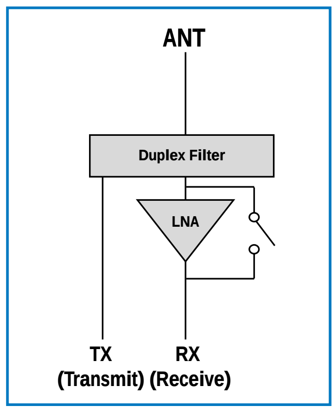
Internal Components and Frequency Response of TMAs



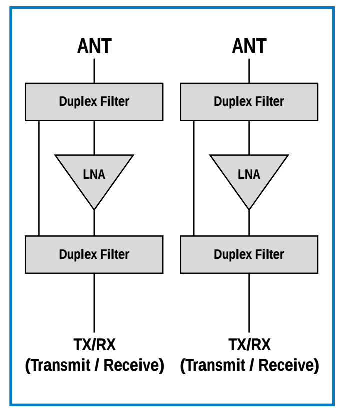
Two-Port RX Only/LNA with Bypass Switch



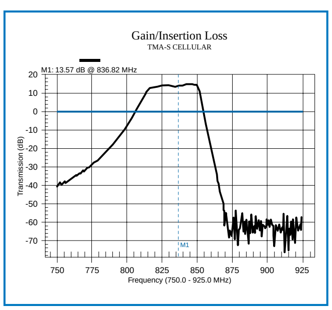
Two-Port Dual-Duplex/LNA with Bypass Switch

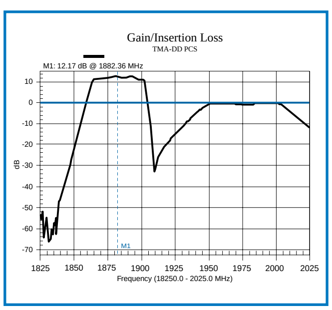


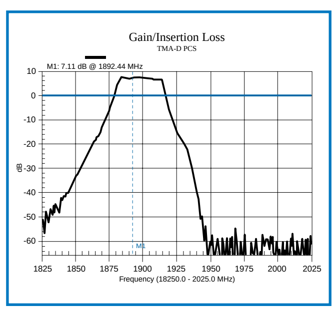
Three-Port Duplex/LNA with Bypass Switch

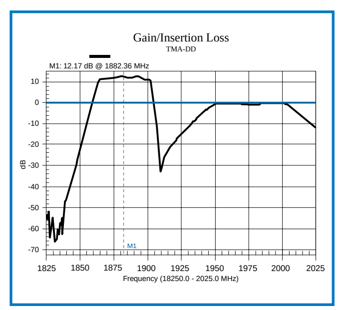


Four-Port with Two Dual-Duplex/LNA without Bypass Switch









Measuring Tower Mounted Amplifiers prior to installation

Setting the Site Master S251C to Insertion Gain Mode

Set the Site Master S251C to insertion gain mode when testing the tower-mounted amplifier prior to installation. The Power Level of insertion loss mode (+6 dBm) may cause LNA saturation and can damage the front end of the Site Master receiver. The insertion gain mode (–30 dBm) output level keeps the LNA in the linear range and provides an accurate gain reading without saturating the output. For 3G applications when measuring Dual-TMA-DD, use insertion loss (+6 dBm) mode.

Site Master S251C User Setups

Operation Mode	System
Insertion Gain (–30 dBm)	Cellular
Insertion Gain (–30 dBm)	PCS
Insertion Gain (–30 dBm)	GSM

Press **MODE** button. Move the cursor to select Insertion Gain Mode (–30 dBm output) and Press **ENTER**.

Step 1. Prior to any tests, select the appropriate frequency range of the TMA system under test.

For example, when measuring the TMA-DD in the PCS Band, set the frequency range from 1850 MHz to 1990 MHz; F1 = 1850.0 MHz and F2 = 1990.0 MHz.

Step 2. Press the **FREQ/DIST** button and the frequency limits. **F1** and **F2** are the start and stop frequencies.

Performing a Full two port calibration in the Site Master S251C

A full two-port calibration is required when making either insertion loss or insertion gain measurements in the frequency range of the system (Cellular, PCS, GSM and 3G).

Connect Test Port Extension cables to Site Master RF In and RF Out and press **START CAL** button to perform a two-port calibration on the Site Master S251C.

Follow the Site Master instructions displayed on the screen. After a full two-port calibration has been completed, a 0 dB reference level is established as shown in figure 3 by the heavy blue line.

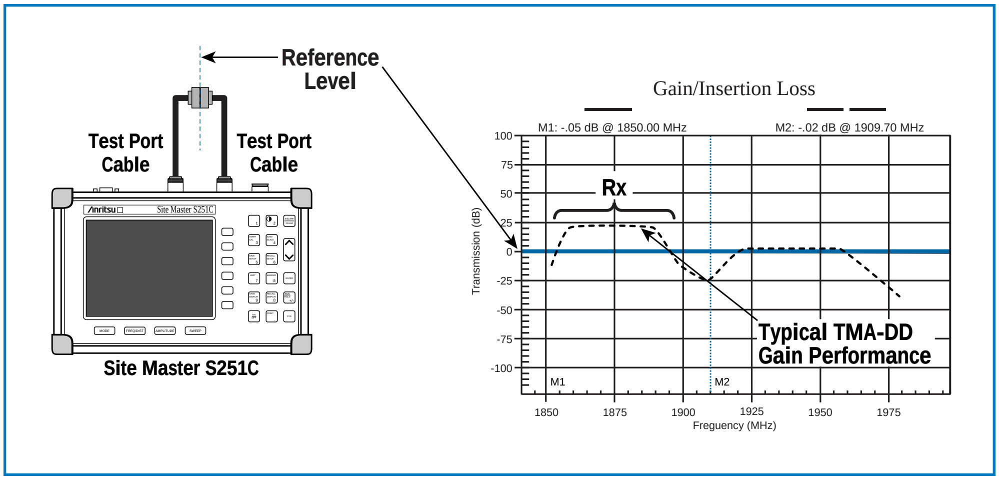


Figure 3. Site Master S251C after Calibration

Measuring gain in a two-port TMA-DD (Tx/Rx) using the Site Master S251C.

Step 1. Connect the RF Out port of the Site Master S251C to the ANT (antenna) port of the TMA-DD and connect the RF In port of the Site Master S251C to the Tx/Rx (transmit/receive) port of the TMA-DD.

Step 2. The gain measurement is made when the Bias Tee Option (240 mA max.) in the Site Master S251C is turned "On".

The optional bias tee gets its power through the AC/DC converter or battery.

Step 3. To activate the Bias Tee option menu on the Site Master S251C, press the **SYS, OPTIONS, BIAS TEE** buttons. The Bias Tee menu has ON/OFF, Low/High Voltage (15V or 12V) and Low/High Current (1A surge/650 mA steady state or 460 mA surge/244 mA steady state.) Press the soft keys to toggle between the appropriate parameters.

Note: When the Option 10B Bias Tee is switched ON and the user presses the START CAL button, the following warning message will appear on the display: "Bias Tee has been turned OFF for Calibration. Don't Turn Bias Tee ON before removing calibration components." After the calibration the user must switch the Bias Tee Option on in order to perform TMA gain measurement.

Step 4. Measure the gain of the tower mounted amplifier between the RF Out and RF In ports of the Site Master S251C. Typical values for gain are between 10-20 dB. Consult your TMA manufacturers specification for exact values.

Step 5. Adjust the scale either manually or using the AUTO SCALE button to center gain level in the middle of the display.

Step 6. Set up the markers M1 = 1880 MHz and M2 = 1910 MHz to identify the receive portion of the PCS Band.

The TMA-DD measurement is swept across the entire frequency range, which includes Tx-transmit (1960-1990 MHz) and Rx-receive (1850-1910 MHz) bands. Markers M1 and M2 highlight the signal level in Rx-receive band of the tower-mounted amplifier where gain is measured. For all TMA types the gain is measured by connecting the RF Out of the S251C to the antenna port and RF In of the S251C to the Rx-receive port of the tower mounted amplifier (TMA-S, TMA-DD, TMA-D, and Dual-TMA-DD). Gain measurements are typically between 10 dB to 20 dB above the 0 dB reference level established during full 2-port calibration.

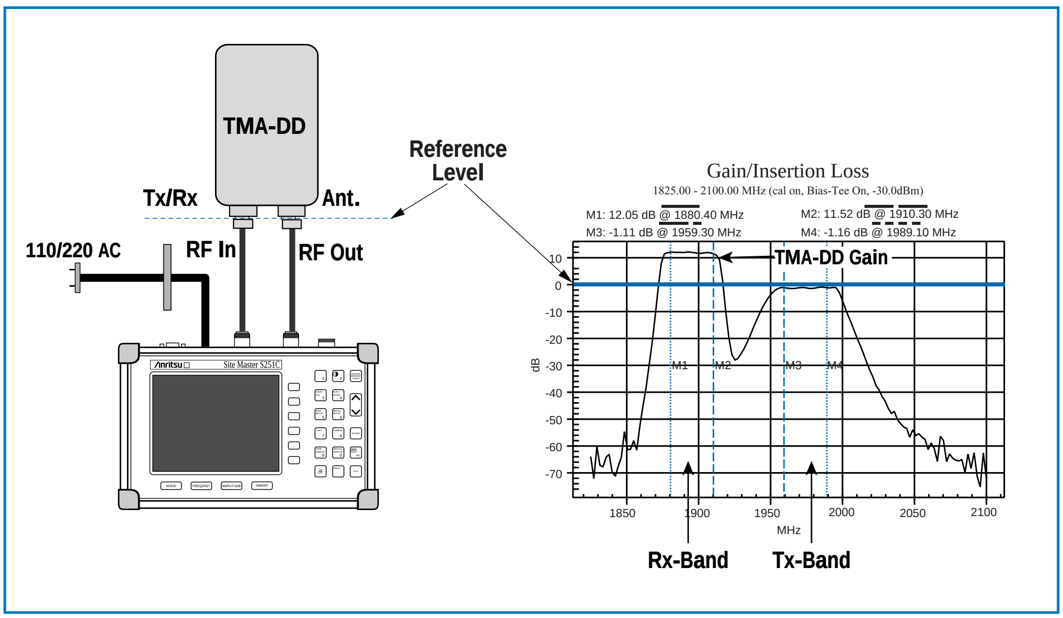


Figure 4. TMA-DD Gain with Site Master S251C

TMA Isolation Measurement–Relative Gain

An alternative method of testing the TMA gain after installation is to perform a TMA Isolation test. A signal is sent from an available Tx-transmit antenna to the Rx-receive antenna of tower mounted amplifier. Accessing an unused Tx-transmit antenna may be difficult during normal business hours and must be conducted during the maintenance window.

This test is very similar to an antenna-to-antenna isolation measurement (see page 11). The RF output signal of the S251C is connected to the Tx-transmit antenna and the RF input is connected to the Rx port of the TMA (TMA-S, TMA-DD, TMA-D, and Dual-TMA-DD).

This test measures relative gain levels of the tower-mounted amplifier for verification and operation, but does not provide absolute levels in tenths of dB. The gain is measured by comparing the relative signal changes between the non-active / bypass and active gain when the Bias Tee is turned OFF and ON. The signal level measured helps to identify problems in the tower mounted amplifier and how it affects Base Station performance.

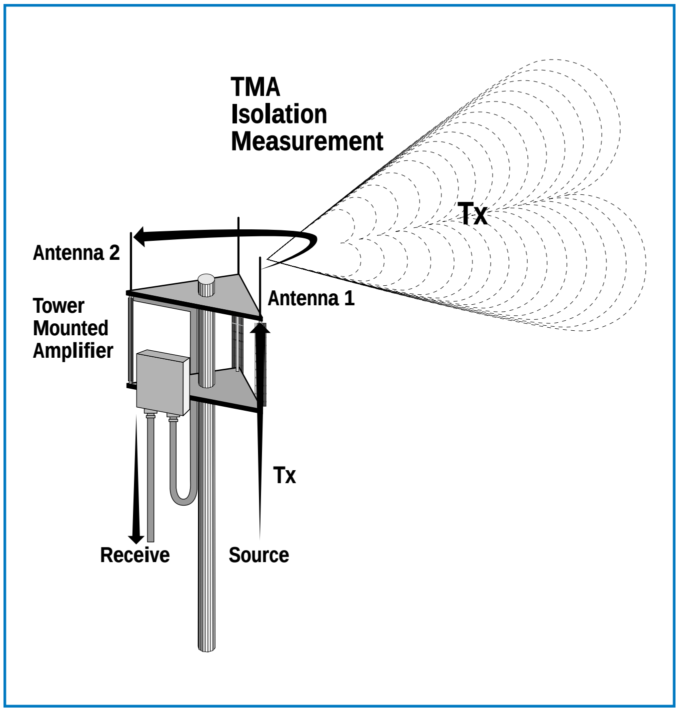


Figure 5. Tower Mounted Amplifier

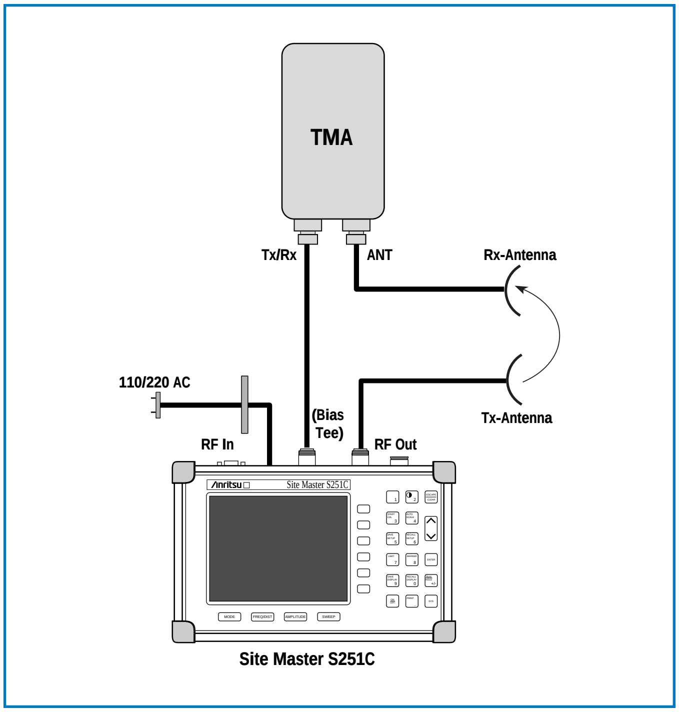


Figure 6. TMA Isolation Measurement

Test Procedure

Step 1. Set the Site Master S251C to Insertion Loss Mode (+6 dBm)

Insertion Loss Mode is required when using the TMA Isolation Test Method and when testing 3G Dual-TMA-DD applications. The Insertion Gain Mode (-30 dBm) output level is too low to send a signal from antenna-to-antenna.

Press the **MODE** button. Move the cursor to select INSERTION LOSS (+6 dBm level) **MODE** and Press **ENTER.**

Step 2. Select the frequency range on the Site Master based on the TMA frequency range.

Performing a Full two port calibration in the Site Master S251C.

Step 3. Connect the Test Port Extension Cables to the Site Master RF In and RF Out ports and press the **START CAL** button to perform a two-port calibration and follow the display instructions.

Step 4. Press **SAVE SETUP** to save the calibration set up.

Performing a TMA Isolation Test

Step 1. Disconnect the Tx-transmit antenna coax from the antenna. Connect the RF Out port of the Site Master S251C to the transmit coax and connect the Rx-receive coax from TMA-DD to the RF In port of the Site Master S251C.

Step 2. Measure the signal level between the RF Out and RF In ports of the Site Master S251C with the Bias Tee "OFF".

Step 3. Save the display to the Site Master's S251C memory.

Press the **SAVE DISPLAY** key to activate the alpha-numeric menu button to store the signal level plot with a descriptive name. Use the soft keys to name the trace.

For example, to save the display with the name "TMA_Duplex Insertion Gain", press the soft key group that contains the letter "T" and then press the "**T**" soft key. Repeat this sequence until the entire name has been entered through the soft key menu. Press the **ENTER** key to save the display.

Step 4. Measure the signal level between the RF Out and RF In ports of the Site Master S251C with the Bias Tee "ON".

Step 5. Press the **SYS, OPTIONS, BIAS TEE** buttons to toggle the Bias Tee On. The Bias Tee menu has ON/OFF, Low/High Voltage (15V or 12V) and Low/High Current (1A surge/650 mA steady state or 460 mA surge/244 mA steady state.) Press the soft keys to toggle between the appropriate parameters.

Step 6. **TRACE OVERLAY**-Comparison of two measurements by using the trace overlay feature of the S251C provides an easy verification of the operation of the TMA when the bias tee is activated. Press **SWEEP**, **TRACE OVERLAY**, and **ON/OFF** buttons. Select the trace that was saved with the Bias Tee OFF from the Site Master S251C's memory. Using the **UP/DOWN** arrow key to highlight the appropriate trace name and press the **ENTER** key to overlay the trace.

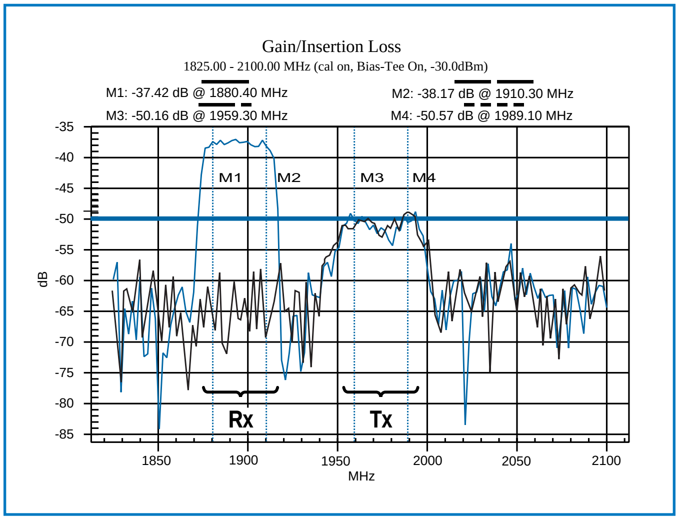
Step 7. Adjust the contrast in the display such that both the active trace (bias tee "ON") and the trace from memory (non-bias tee trace) can be viewed on the screen.

Step 8. Set up the markers M1 = 1880 MHz and M2 = 1910 MHz to identify the Rx-receive frequency of the PCS Band.

Step 9. The isolation level of –50 dB is indicated by the blue line and is the total loss of cables and path loss between the two antennas. This signal level is 50 dB below the 0 dB reference established during calibration. The TMA-DD relative gain measurement is approximately 12 dB above the isolation signal level. (TMA gain –38 dB–(–50 dB) = 12 dB).

ANALYSIS OF TMA-DD GAIN

The relative gain measurement of the TMA after installation is very similar to the other gain measurements with the exception of signal level offsets due to the cable losses and system isolation level shown by the blue line. Two plots are compared with the S251C trace overlay feature. The black plot is non-active bias tee and the blue plot gain is when the bias tee is applied to the TMA. As previously discussed, the comparison of the amplifier plots before and after the bias tee activation will not produce the accuracy to tenths of dB, but will provide a good test for operation and verification of the TMA-DD, TMA-D, TMA-S and Dual-TMA-DD. The graph indicates TMA gain of about 12 dB which is very close to the specified TMA gain of 14 dB.



Measurement: TMA Isolation Test

Diagnostics–Identifying Problems in a TMA System

Insertion Loss and DTF-Load sweep are two tests that help determine the integrity of the transmission line in a TMA (Tower Mounted Amplifier) system that is suspected of having problems.

Cable Loss Measurement after TMA Installation

Cable Loss is one of the key measurements to verify system performance of the transmission line in Base Stations. Cable Loss becomes especially important for installations that incorporate tower mounted amplifiers. The purpose of the tower mounted amplifier is to boost signal and to provide better coverage to areas that conventional antenna orientations cannot service.

A transmission line measured with Cable Loss of 6 dB is approximately 2 dB above an acceptable level of 3-4 dB loss for 150 ft. cable run and may reduce coverage of the Base Station.

It is very difficult to determine which components within the system are causing system failure after the TMA is installed. A common method of troubleshooting the system is to remove the tower mounted amplifier from the configuration and perform an end-to-end Cable Loss measurement on the entire transmission line which includes jumpers, main feeder, and adapters.

This test identifies changes in the transmission line assembly by measuring the total Cable Loss of the system without the TMA connected. Cable Loss provides valuable information about signal level coverage and whether the output level of the transmitter has been compromised due to excessive signal loss in either the jumpers or the main feeder.

Figure 8 shows the TMA removed from the system configuration. The Site Master S251C performs a Cable Loss measurement of the entire transmission line system. The dotted lines indicate where the TMA and the antenna are removed from the configuration. Cable Loss is measured when a precision short is connected to the end of the transmission line.

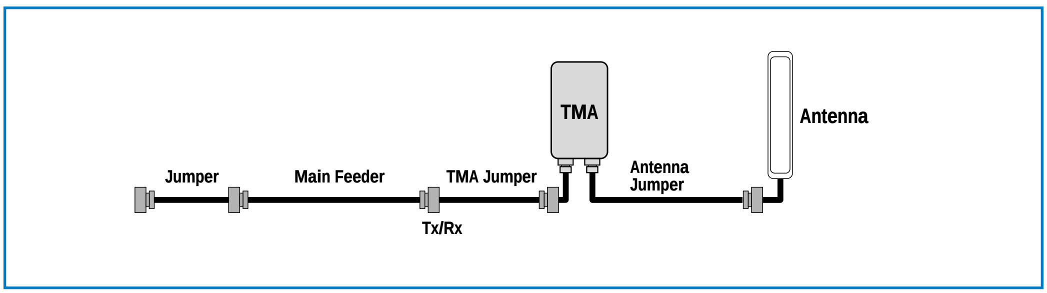


Figure 7. TMA Installation

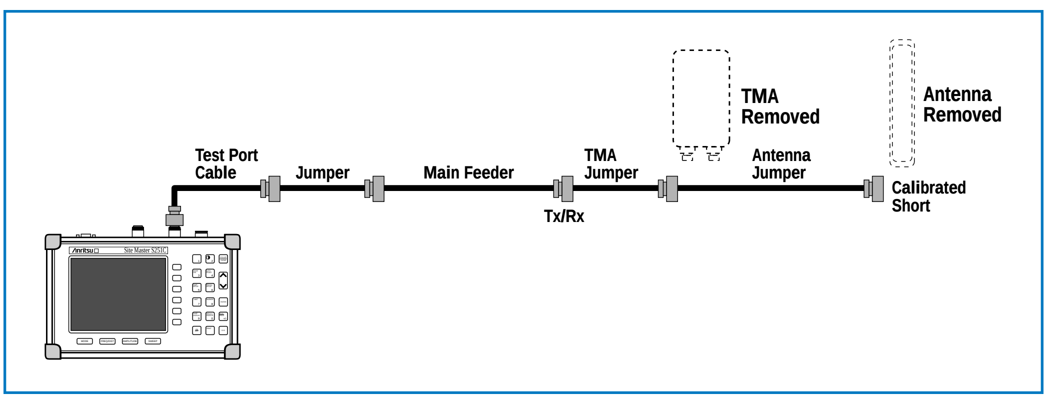


Figure 8. Insertion Loss Measurement without TMA

Test Procedure

Cable Loss Mode

Step 1. Press the **MODE** key.

Step 2. Select FREQ-CABLE LOSS using the Up/Down arrow key and press **ENTER**.

Step 3. Set the start and stop frequencies, F1 and F2, F1 = 1850 and F2 = 1990.

Step 4. Connect the Test Port Extension cable to the RF Out port and press **START CAL** to calibrate the Site Master.

Step 5. Follow the Site Master instructions on the screen and press **SAVE SETUP** to save the calibration.

Step 6. Connect the jumper to the Site Master phase stable Test Port Extension cable and connect short at the end of antenna jumper. A trace will be displayed on the screen as long as the Site Master is in sweep mode.

Step 7. Press the **AMPLITUDE** key and set the TOP and BOTTOM values of the display. In the example below, the TOP is set to 1, and the BOTTOM is set to 6.

Step 8. Press the **MARKER** key.

Step 9. Set M1 to MARKER TO PEAK.

Step 10. Set M2 to MARKER TO VALLEY.

Step 11. Calculate the measured insertion loss by averaging M1 (marker to peak) and M2 (marker to valley) as follows:

Step 12. $\textit{Insertion Loss} = \dfrac{M1+M2}{2} = \dfrac{-3.25\ -4.07}{2} = \dfrac{-7.32}{2} = -3.66\ \text{dB}$

Step 13. Press **SAVE DISPLAY**, name the trace, and press **ENTER**.

Calculate Transmission Line Insertion Loss Example

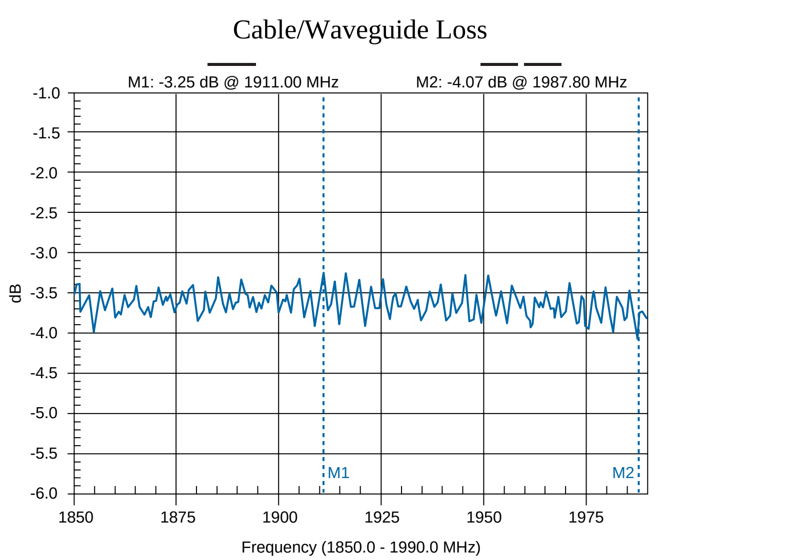
	Type	Attenuation (dB/ft)	Length (ft)	Loss (dB)
1st_Jumper	LDF4-50A	0.0325 X	20	= 0.65
Main_Feeder	LDF5-50A	0.0186 X	150	= 2.79
TMA_Jumper	LDF4-50A	0.0325 X	10	= 0.325
Antenna_Jumper	LDF4-50A	0.0325 X	10	= 0.325
Connector Pairs	Connector Loss (dB)			Insertion Loss
4 X	0.14 =			0.42

Calculated Insertion Loss

= 0.65+2.79+0.325+0.325+0.42

= 4.515 dB

Verify the measured cable loss with the calculated cable loss.



Cable Loss

Result of Insertion Loss

The measured insertion loss of –3.66 dB is less than the calculated –4.515 dB and the system meets specification.

Distance-To-Fault (DTF) Measurements

DTF-Load Sweep is a test to locate the faults in the transmission line that the Cable Loss measurement may not identify. A DTF test verifies proper operation of the transmission line that may degrade over time and may be manifested as a signal reflection.

Test Procedure

DTF-Return Loss Mode

Step 1. Press the **MODE** key.

Step 2. Select DTF-RETURN LOSS using the Up/Down arrow key and press **ENTER**.

Step 3. Set the start and stop frequencies, F1 and F2, F1 = 1850 and F2 = 1990.

Step 4. Connect the Test Port Extension cable to the RF Out port and press **START CAL** to calibrate the Site Master.

Step 5. Follow the Site Master instructions on the screen and press **SAVE SETUP** to save the calibration.

Step 6. Connect the jumper to the Site Master phase stable Test Port Extension cable and connect load to the antenna jumper.

Step 7. Press the FREQ/DIST key.

Step 8. Set the D1 = 0 and D2 = 110 ft values. The Site Master default for D1 is zero.

Step 9. Press the **DTF AID** soft key and select the appropriate CABLE TYPE to set the correct propagation velocity and attenuation factor.

> *NOTE: Selecting the right propagation velocity, attenuation factor and distance is very important for accurate measurements, otherwise the faults cannot be identified accurately and insertion loss will be incorrect.*

Step 10. Press **SAVE DISPLAY**, name the trace, and press **ENTER**.

Step 11. Record the connector transitions.

Analysis of DTF-Load Sweep

Carrier specifications for DTF-Return Loss plots are typically –30 dB for connectors and –45 dB for the cable/transmission line. In figure 10, all markers (M1-M4) are below the –30 dB level indicating that the connectors and the transmission line meet specification. Markers M3 and M4, the TMA jumper does not indicate a problem because the readings are below –30 dB. Therefore, the problems must be with the tower-mounted amplifier.

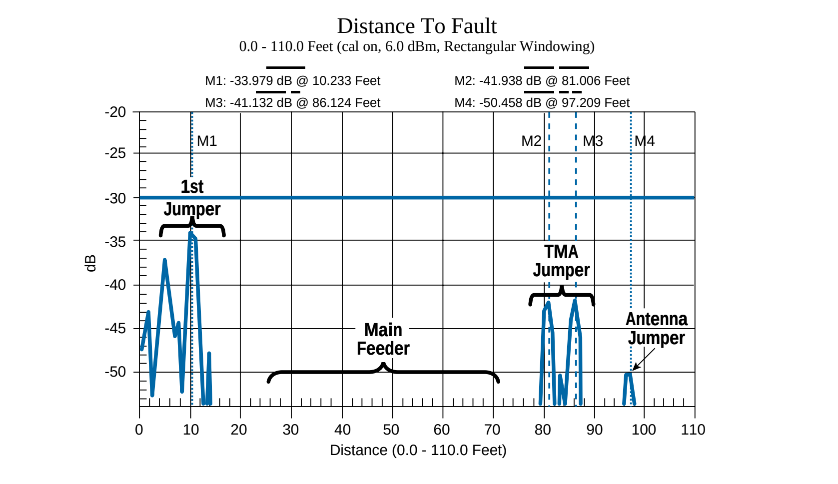


Figure 10. DTF-Return Loss Load Sweep

Antenna-to-Antenna Isolation with the Site Master S251C

Measuring Antenna-to-Antenna Isolation between adjacent systems is very important when deploying multiple systems on the same tower. It helps to determine the potential threat of interfering signals and maximizes capacity of the Base Station. Site Master S251C simplifies this by indicating the isolation between systems without the need of calculating coaxial losses and antenna gains.

An example of adjacent PCS systems is shown in Figure 11. System 1 transmits signal in a specific direction, but some of the signal is received by antenna 2. Any excessive signal level from transmitter 1 will cause poor performance, loss of communication, and system degradation in the adjacent system. Antenna-to-Antenna isolation (more commonly known as the system isolation) is the difference between the output level transmitted by system 1 and the signal level received by system 2. The system isolation is equivalent to the reduction of signal level (attenuation) of Transmitter 1. Typical levels for isolation between systems can vary from 50 dB to 100 dB.

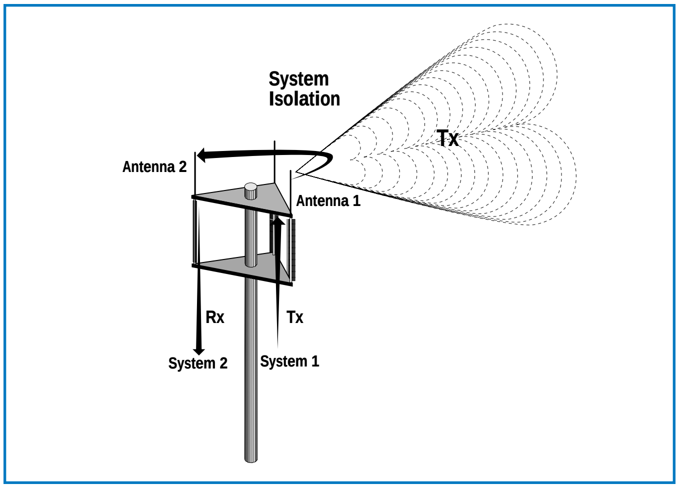


Figure 11. System Isolation

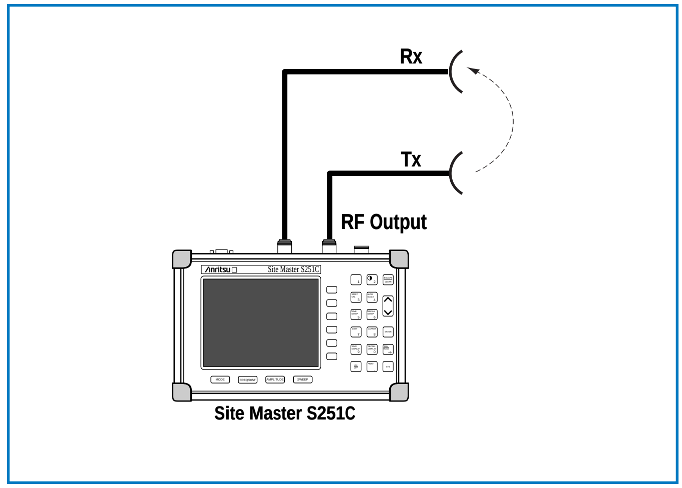


Figure 12. Antenna Isolation with Site Master S251C

Setting the Site Master S251C to Insertion Loss Mode (+6 dBm)

Insertion Loss Mode (+6 dBm) is required to drive the signal level large enough to be detected by the second antenna system. The Insertion Gain Mode (–30 dBm level) does not output enough power to provide an accurate measurement reading.

Press **MODE** button. Move the cursor to select INSERTION LOSS (+6 dBm level) MODE and Press **ENTER**.

Setting the Frequency range for the antenna system.

The table below indicates frequency settings for common systems.

Operation Mode	System	Frequency Start (MHz)	Frequency Stop (MHz)
Insertion Loss +6 dBm	Cellular PCS GSM	F1 = 806 F1 = 1850 F1 = 1800	F2 = 960 F2 = 1990 F2 = 1900

Select the appropriate frequency range to measure the isolation of a PCS system. Set the frequency range from 1850 MHz to 1990 MHz, F1 = 1850.0 MHz and F2 = 1990.0 MHz.

Performing a Full two port calibration in the Site Master S251C

A full two port calibration is required when making antenna-to-antenna isolation measurements in the appropriate frequency range for the system (Cellular, PCS, GSM, and 3G).

Connect test Port Extension cables to Site Master RF In and RF Out and press **START CAL** button to perform a two-port calibration on the Site Master S251C.

Follow the Site Master instructions shown on the display. After performing a two port calibration, a 0 dB reference level is established shown in figure 13 by the heavy blue line.

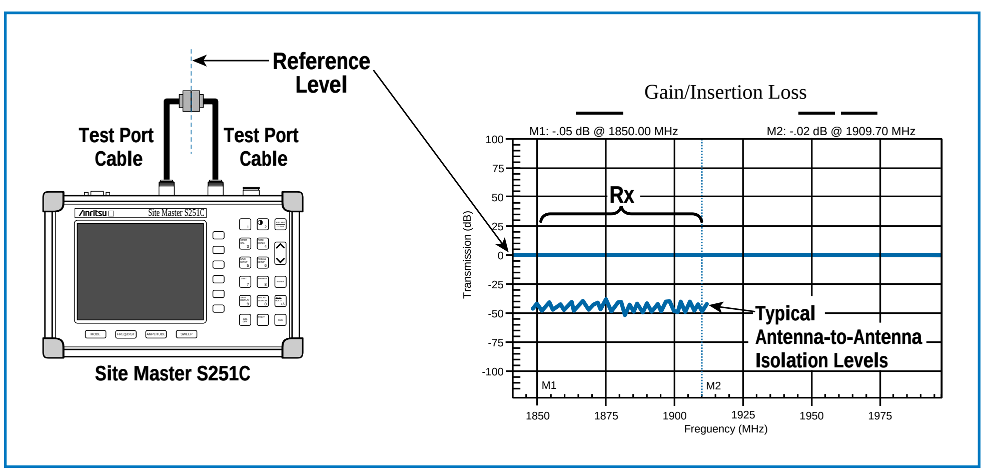


Figure 13. Site Master S251C after Calibration

Measuring Antenna-to-Antenna isolation using the Site Master S251C

Step 1. Disconnect the Tx (Transmit) antenna coax from System 1 in figure 11 and connect it to the RF Out port of the Site Master S251C. Disconnect the Rx (Receive) coax from System 2 in figure 11 and connect it to the RF In port of the Site Master S251C.

Step 2. Measure the total isolation level between the RF Out (Tx, Transmit) and RF In (Rx, Receive) ports of the Site Master S251C.

Step 3. Adjust the scale either manually or using the **AUTO SCALE** button to display isolation level to center of the display.

Step 4. Set up the markers M1 = 1880 MHz and M2 = 1910 MHz to identify the receive portion of the PCS Band.

Step 5. Measurement values are between –85 dB and –92.5 dB with average antenna isolation level at –89 dB. Set up the limit line to the estimated average signal level. The isolation level measurement includes all the cable loss of both systems, antenna gains, and insertion losses.

Typical antenna-to antenna isolation measurements are made in between –50 dB and –100 dB below the 0 dB reference line established by the full 2-port calibration.

The measurement is swept across the entire frequency range that includes both transmit (1960-1990 MHz) and receive (1850-1910 MHz) bands. Markers M1 and M2 highlight the signal level measured in the receive band because this power level will affect the performance of the receiver of system 2 in figure 11 and identifies the signal level from an unwanted source (another transmitter).

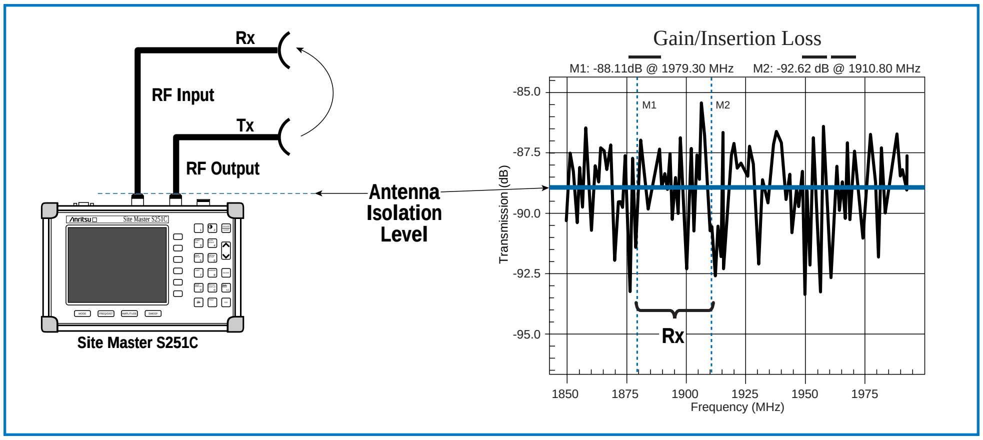


Figure 14. Antenna Isolation with Site Master S251C

When the isolation level measured is more negative, there is a better chance of co-location without system degradation. An isolation level of –89 dB is very good. RF System engineers/technicians must decide what is an acceptable level for their particular system. If the antenna-to-antenna isolation measured is closer to –60 dB, then re-alignment of the antennas may be necessary until the isolation becomes better. In some cases, alternative channel plans must be used to assure that all the systems at the same location can operate successfully.

Conclusion

For all TMA types (TMA-S, TMA-DD, TMA-D and Dual-TMA-D) and manufacturers, the gain is measured by connecting the RF Out of S251C to the antenna port and the RF In to the Rx-receive port of the TMA. When TMAs deployed in the field do not have bypass switches, then the recommended test is to activate the bias tee of the S251C and measure the gain referenced to the 0 dB level (established during calibration). Test methods verifying the operation and performance of a TMA after installation is dependent on the carrier specifications and test procedures. Removal of the TMA from the system configuration and testing the transmission line and TMA independently is the method that provides the most confidence to the field technician. However, the TMA Isolation test is an alternative method that measures relative gain to confirm correct operation and performance of the TMA.

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