

In today's competitive environment, it is very easy for mobile subscribers to change their provider. This makes customer satisfaction very important for every network operator. Network stability needs to be high and dropped calls need to be minimized. On the other hand, to reduce investment, it is important to use a large cell size, where possible, and still have good coverage. Tower Mounted Amplifiers (TMAs or receiver preamplifiers) or Mast Head Amplifiers (MHAs) allow the best sensitivity when larger cells and weak handset signals are prevalent. To be most beneficial, TMAs or MHAs need to be mounted as close to the receive antenna as possible.

This application note describes how to test Antenna systems with tower mounted amplifiers. You will learn about typical TMA/HMA configurations and their effects on reflection measurements. A special focus will be set on the Insertion Gain and Insertion Loss while performing gain measurements of tower mounted amplifier and antenna isolation measurements.



Application Note

#### Introduction

Antenna systems are commonly tested from the ground level of base transceiver stations (BTS) by using an antenna sweeper, such as the YBA250.

With the growing demand for higher data rate applications, there is a critical need to improve the uplink (Rx) sensitivity of new networks. Tower mounted amplifiers (TMA) or masthead amplifiers (MHA) are installed near the receiver antenna, at the top of the cell tower, in order to increase the uplink sensitivity and improve the reception of weak signals. Other benefits are the extension of coverage area, the reduction of dropped calls, and an increment of handset battery life. The relative easy installation of the TMA makes it even suitable for upgrading existing base transceiver stations (BTS). Figure 1 shows an example of an antenna system with TMA.

In an antenna system without TMA, a return loss (or VSWR) sweep indicates how well the antenna transmits power by measuring the power that it reflects compared to the power that it receives. With the insertion of a TMA, the reflected power might not come from the antenna itself but from one of the components of the TMA. Because of this, it is important to understand the TMA's configuration and basic operation to properly test antennas with TMA.

The inclusion of a TMA not only introduces new challenges when testing antenna systems but also introduces the need to test the TMA itself. The YBA250 offers Insertion Gain/Loss measurement that, in conjunction with the YBT250, suits this need. Insertion Loss measurement can also be used to perform antenna-to-antenna isolation measurements which is becoming more important as more antennas are located on one tower.



► Figure 1. Antenna system with TMA.

In this application note you will first learn about typical configurations of tower mounted amplifiers, the role of bias-tees and duplexers, as well as the effects that amplifiers and filters have on reflection measurements. We will then describe the procedure to sweep antennas with TMAs and how to properly use the distance to fault measurement (DTF) to locate faults. Then, we will move to specific gain measurements of tower mounted amplifiers and antenna isolation using two-port measurements.

### **Common TMA Configurations**

A TMA (or HMA) is used to amplify the (weak) uplink signal. There are several configurations depending on the BTS requirements; the most common are:

- Received only or simplex configuration (S)
- Single duplex configuration (D)
- Dual Duplex configuration (DD)

These configurations are illustrated in Figure 2.

#### Received only or simplex configuration (S)

This configuration is used in antenna systems that have separate Rx and TX antennas, and separate Rx and TX feed lines to the BTS. The TMA is connected to the Rx antenna at the antenna port, and to the BTS at the BTS port.

#### Single duplex configuration (D)

This configuration is used in antenna systems that have a common Rx/Tx antenna, and separate Rx and Tx feed lines to the BTS. A single duplexer isolates the receiver and transmitter path from the Rx/Tx antenna. The TMA is connected to the Rx/Tx antenna at the antenna port, and to the BTS at the BTS port.

#### Dual duplex configuration (DD)

This configuration is used in antenna systems that have a common Rx/Tx antenna, as well as, a common Rx/Tx feed line as shown in Figure 1. The duplexers isolate the receiver and transmitter paths from the Rx/Tx antenna and the Rx/Tx feed line, reducing the amount of antennas and feed lines in the system. The TMA is connected to the Rx/Tx antenna at the antenna port, and to the BTS at the BTS port.

All three configurations have a Low Noise Amplifier (LNA) in the uplink path. A bias-tee injects DC voltage, from the power distribution unit (PDU), through the center conductor of the feed line. A second bias-tee,



► Figure 2. Typical internal TMA configurations.

within the TMA, separates the DC voltage, and the RF signal. The TMA might also have circuitry to bypass the LNA when no DC power is detected. This is used in case of TMA malfunctioning or as an emergency bypass. The provision of the bypass circuitry is essential when sweeping the Rx band of the antenna and to measure the (relative) gain on mounted amplifiers.

Configurations of TMAs are sometimes illustrated using Rx and Tx filters instead of duplexers. The overall operation is the same. Duplexers and filters are frequency selected devices. They pass signals with very little loss inside its frequency bands, while attenuating all signals outside its bands. A duplexer isolates the receiver and transmitter signal paths.

Application Note



▶ Figure 3. RF Signal path with and without bypass.

## Importance of the Bypass Circuitry When Testing Antenna Systems

Figure 3 illustrates the RF signal path of a dual duplex TMA with bypass circuitry, and its interaction with the YBA250 when testing an antenna system.

On the Rx side, the RF signal path between the YBA250 and the antenna depends on the condition of the bypass circuitry. When the bypass relay is closed, the LNA is bypassed and the YBA250 "sees" the antenna through the filter and the bypass connection. When the bypass relay is open, the YBA250 does not "see" the antenna but the output of the LNA. Under this condition the uplink (Rx) side of the antenna cannot be tested. Typically, the DC voltage, applied through the center conductor of the feed line, is used to control the bypass circuitry.

# How Filters and Amplifiers Affect the Measurement

In order to demonstrate the effect of filters and amplifiers on the return loss, we are going to measure a real antenna system. Figure 4a shows a return loss measurement screen of an antenna system that includes a 42-foot feed line, a jumper cable and a Yagi antenna (824 MHz - 896 MHz). It has a reasonable return loss with values greater than 18 dB.





► Figure 4b. Blue: LNA bypassed, Yellow: No TMA.

You then connect a TMA-DD between the feed line and the Yagi antenna. The Rx and Tx frequency bands for this TMA are [835.0 - 849.0] MHz and [880.0 - 896.0] respectively. It also includes a bypass circuitry.

If you now measure again with no DC power applied to the TMA, so that the bypass relay is closed, you will find a result similar to the one shown in Figure 4b. It shows both traces together and inside the Rx and Tx frequency bands, you can see that the return loss is still greater than 18 dB. The performance inside the Rx and Tx bands was not affected. Outside these bands, the return loss is much lower. It is caused by the very low return loss of the duplexer at those frequencies, which dominates the overall antenna system performance.

Application Note



▶ Figure 4c. LNA bypassed. Blue: failure, Yellow: Antenna.

Keeping the LNA OFF and the bypass relay closed, you can then simulate a severe failure by disconnecting the Yagi antenna and measure again. Figure 4c illustrates how much lower the return loss within the Rx and Tx bands is (blue line). On the Rx band, the resulting return loss is slightly better because it is also affected by the LNA output and the bypass characteristics.

You can now reconnect the antenna, turn the LNA on, and measure once more. Figure 4d shows both antenna systems: the blue line measures when the LNA is ON, and the yellow line when the LNA is bypassed. Even though the performance of the antenna system in the Rx side changes in shape, it is still greater than 18 dB. Changes are more noticeable on the edges outside the Rx band which is due to the different transient properties of the LNA and the duplexer.

Keeping the LNA ON, you can simulate a severe failure by disconnecting the antenna. Figure 4e shows that the degradation on the Rx side is not nearly as severe as the degradation in the Tx side. This confirms that when the LNA is ON, the YBA250 does not "see" the antenna, but rather, sees the output impedance of the LNA.



Figure 4d. Blue: LNA ON, Yellow: LNA bypassed.



▶ Figure 4e. LNA ON. Blue: failure, Yellow: antenna.

# Procedure to Sweep Antennas with TMA Using the YBA250

When making return loss (VSWR) sweep measurements the key is to bypass the LNA so that the test equipment can "see" the antenna on the Rx band. The general procedure on the YBA250 is as follows:

- Select Return Loss measurement.
- If greater accuracy is desired, perform a (one-port) User Calibration at the end of the precision test jumper.
- Connect precision test jumper to the RF port of the bias-tee (blue test point in Figure 1).
- Make sure the amplifier is bypassed. If a bypass circuitry is not available in your TMA, only the Tx band of the antenna will be swept.

Application Note

- Select frequency parameters to cover Rx and Tx frequency bands.
- Perform measurement. Press Auto Scale (you might obtained similar results to the blue trace in Figure 4b).

When the Return Loss (VSWR) in frequency mode shows a problem with the system, a Distance To Fault (DTF) measurement is performed to find where the fault might be. To improve distance resolution, DTF requires sweeping with a wide frequency range. The wider the frequency range the smaller (better) the distance resolution is.

When no frequency selective components, such as antennas, bias tees, or TMAs are present, and a 50 Ohm load is on the far end of the antenna feed, DTF technology can work at its best and most accurate. When antennas, bias tees and TMAs are present, two options exist.

- First, the DTF sweep can still be made over a wide frequency, as in the ideal case mentioned above. In this case, frequencies outside the pass band of the components will be swept. The return loss of the components will be artificially high, but the distance resolution of the measurement will be preserved.
- Second, the DTF sweep can be made over a reduced frequency range. This will allow the measurement to be made with greater return loss accuracy, but with less distance resolution.

As an example of frequency selective equipment, the Bias-tees normally used for TMA installations may be frequency selective and may contain a 1/4 wave shorting stub for lightning. The narrower bandwidth bias-tees may limit the distance resolution of the DTF.

To perform a DTF measurement under ideal conditions and obtain the most accurate results:

- Remove all frequency selective components and terminate the end of transmission line system (feed line, jumpers and connectors) with a 50 Ohm load. This will allow the best and most accurate measurements to be made.
- ► Select Distance To Fault measurement.
- Perform a (one-port) User Calibration at the end of the precision test jumper.

- Connect precision test jumper to the feed line (or the jumper in your system before the feed line).
- Setup DTF measurements using the Distance Options setup page (Edit->Distance Option). Select "Cover Distance" and set the distance to somewhat longer than the feed line.
- ▶ Perform measurement. Press Auto Scale.

If, under these conditions, the DTF measures a healthy system (high return loss for connectors, jumpers, and feed line) any problems may be due to the TMA.

To perform measurements with frequency selective components in place, the procedure is similar but instead of selecting "Cover Distance" in the procedure above, select "Limit Bandwidth" and set the bandwidth as wide as possible given the components installed. In the case that a TMA is present, you likely will need to cover only the uplink or downlink frequency band. (Also, make sure that the TMA is in bypass mode.) Limiting the frequency of the sweep will reduce the distance and return loss accuracy, but can give a useful indication of the health of your antenna system, particularly when compared to other, similar, antenna systems.

## **Testing Tower Mounted Amplifier** before Installation

In previous sections we described the use and advantages of antennas with Tower Mounted Amplifier. You learned what to consider when testing such antenna systems, the effects of filters and amplifiers on your measurement as well as the procedures to sweep antennas with TMA. This section now will move away from the Antenna system and uniquely focus on testing the TMA itself.

The YBA250 is capable of performing two-port measurements (Insertion Gain and Loss) when used in conjunction with the NetTek<sup>®</sup> YBT250. A normalization kit, such as the YBAC2 (or equivalent) is required to make more accurate insertion measurements. Other accessories used for these tests are:

 DC power supply (Tektronix Part Number 119-7017-00 or equivalent).

Application Note

rile View Setup	Tools 🛛 🔛		12/6/200	04 12:47:20 F	M 💽
CDMA US Cellular 💌	$\mathfrak{J}_{\bullet\bullet}^{\mathrm{H}}  \hat{\mathfrak{U}}_{\bullet\bullet}^{\mathrm{H}}  \hat{\mathfrak{U}}_{\bullet\bullet}^{\mathrm{H}}  \hat{\mathfrak{U}}_{\bullet\bullet}^{\mathrm{H}} $	🕄 Chan   820.0	0 🔢 to 91	0.00 #	MHz
Measurement:	Method:		Lines Normoli	Totion	$\nabla$
Insertion Gain 💌	Normal	-		280011	₹→
Auto Scale		Trace	1: Normal	▼	V Hendred
9.00	· · · ·				
8.00 7.00					± 64
6.00					
5.00					$\Lambda \Lambda^{f} \rightarrow \Lambda$
9.00					
2.00					
1.00					Stop (MHz)
0.00	<b>♦</b>	V			00000 (0 11 12)
-1.00				F	10.00
▶ 820.00		🔺 865.00 MHz		910.00 🖌 🎽	10.00 111
Avg. Insertion	Gain:	-0.01 dB	Dutput Power Le 20 dBm		
◆ 850.000 □ 87 M1 -0.008 M2	73.800 <b>◇↔□</b> -0.005 M1-M2	-23.800 V 866 -0.003 Max -0	.000 🔨 820.4 .003 Min -0.0	00 MHz 20 dB	
ኛ Start 🛛 🌾 Virtual CE	🔍 YBA25	ЭК 🚺 – ҮВА.	250 - 🛛 🔍	¥\$ 8∰	12:47 PM 🧭

Figure 5a. IG measurement after User Normalization.

- Bias-tee (Tektronix Part Number 015-0718-00 or equivalent).
- BNC to DC adapter (Tektronix Part Number 012-1686-00 or equivalent).

#### **Test procedure**

- Prepare the YBA250/YBT250 to perform two-port measurements for a TMA.
  - Set up the cabling as shown in the Normalization section of Figure 5b.
- Select Insertion Gain/Loss button, and Insertion Gain measurement type. The default output power level is -20 dBm.

Check the manufacturer's gain specification to make sure the power at the RF INPUT (YBT250) will not exceed its maximum value. If it might exceed the maximum, you can change (lower) the output power level.

- ► Select frequency range (appropriate to the TMA).
- Perform a User Normalization following the wizard's instruction. Make sure not to apply DC power to the bias-tee during normalization.
- Measurements immediately after normalization will display reference trace at 0 dB as shown in Figure 5a.
- Disconnect the through connector and connect the TMA as shown in Figure 5b.
- ► Apply DC power to the DC port of the bias tee.
- Perform Insertion Gain measurement and press Auto Scale.



▶ Figure 5b. Normalization and Measurement Setups.



► Figure 5c. Insertion Gain for a TMA-DD.

Figure 5c shows the insertion gain of a TMA-DD for both, the Rx and Tx frequency bands ([835.0 - 849.0] MHz and [880.0 - 896.0] respectively). It has a 13 dB gain over the Rx band, which complies with the manufacturer's specification.

For all TMA configurations (single, single duplex and dual duplex) the measurement setup is the same: connect the BTS port of the TMA to the bias-tee (YBT250 side), and the ANT port of the TMA to the attenuator at TEST PORT (YBA250 side). This test setup might be difficult to realize when the TMA is already mounted on the tower.

Application Note

# **Testing Tower Mounted Amplifier** after Installation

*Caution: Please check your country's laws regarding transmitters before using the NetTek<sup>®</sup> analyzer to transmit a test signal.* 

When the Tower Mounted Amplifier is already mounted to the tower, you can only measure its relative gain (as opposed to the absolute gain value as described in previous section).

The purpose of this test is to verify that the TMA is working properly. The relative gain is obtained by comparing the signal change at the BTS when the amplifier is ON and when it is bypassed. For this test, you may use the bias-tee and the DC power supply (from the PDU) already in your system.

The key point for this test setup is to transmit the test RF signal up to the TMA within the Rx frequency band. There are several options to accomplish this and some of them are:

- Use a directional antenna as the Tx antenna at ground level pointing the Tx/Rx antenna where the TMA under test is mounted.
- Use an available Tx antenna mounted in the tower.

# Test procedure

- ► Setup YBA250 two-port measurement.
  - Select to Insertion Gain measurement type.
    Setup frequency parameters according to the Rx frequency range of the TMA.
  - Verify the output power level is in compliance with transmission regulations. Adjust the level if necessary.



Figure 6a. TMA testing when using a directional antenna.

- Using a YBAC2 or equivalent normalization kit, perform a User Normalization following the wizard's setup and instructions.
- If using a directional antenna, you may use a setup as illustrated in Figure 6a. Connect the 10 dB attenuator at TEST PORT (YBT250) to the directional (Tx) antenna. Secure the antenna to make the signal path as constant as possible during the test.

Application Note

- If using a transmit antenna on the tower, set up as illustrated in Figure 7. When using a Tx antenna that is mounted at the tower you might need to increase the output power level to counteract the isolation between antennas. Make the antenna a YAGI, pointing at the tower.
- Connect the 10 dB attenuator at RF INPUT (YBT250) to the coax from antenna.
- Bypass the LNA, by removing DC power, and make the insertion gain measurement. Save trace (File->Save->"Filename").
- Turn ON LNA, by connecting DC power, and make insertion gain measurement. You may make several sweeps to ensure that the TMA is being powered on.
- Using the dual trace capability of the NetTek<sup>®</sup> analyzer, display both traces on the same screen (Edit->Insertion Tab->Gain->View Trace 2-> "Filename").
- You can view marker M1 on trace 1 (View->Marker 1->Trace1) and market M2 on trace 2. (View-> Marker 2->Trace 2). Then you can use the M1-M2 indicator to obtain the relative gain.

For more details on how to work with traces, refer to the YBA250 User Manual.

Figure 6b shows the relative gain result for a similar setup as of Figure 6a. Each trace represents the total gain (or loss) which includes loss of cables and path.



Figure 6b. Relative gain measurement result.

The yellow trace is the total gain (loss) when the LNA is bypassed, and the blue trace is the total gain (loss) when the LNA is ON.

Since both measurements are performed using the same signal path, except at the LNA, the difference between trace 1 and trace 2 (at Rx frequencies) gives approximately the gain of the LNA minus the loss of bypass circuitry. This result is approximately 14.5 dB in our setup.

It's interesting to know that the measurement when the LNA is bypassed actually is the antenna isolation measurement. There are more details on this in the next section.

Application Note

# Measuring Antenna-to-Antenna Isolation

*Caution: Please check your country's laws regarding transmitters before using the NetTek<sup>®</sup> analyzer to transmit a test signal.* 

Antenna-to-antenna isolation becomes more important as more antennas are located on a common tower. The easiest method of improving isolation, by increasing the distance from each other, is limited. Even though antennas in different sectors are pointing to different directions, signals that are transmitted from one sector can also be received at another sector. This is also known as co-channel or co-band interference. The lower the isolation between antennas, the greater the potential of interference signals at the receiver.

The basic setup to measure antenna isolation is similar to the one illustrated in Figure 8.

## Test procedure

- ► Setup YBA250 two-port measurement.
  - Select to Insertion Loss measurement type and setup frequency parameters to cover Rx and Tx frequencies.
- Perform a two-port normalization following the wizard instructions.



Figure 7. Installed TMA testing when using a transmit antenna.

Application Note

- Connect the 10 dB attenuator at TEST PORT (YBT250) to the Tx antenna's coax.
- Connect the 10 dB attenuator at RF INPUT (YBT250) to the Rx antenna's coax.
- ► Make insertion loss measurement. Press Auto Scale.

The insertion loss measured at the Rx band is the amount, in dB, that a signal sent by the transmitter (at Tx antenna side) is reduced by before interfering in the receiver (at Rx antenna side).

## Conclusion

Tower Mounted Amplifiers (TMA) and Masthead Amplifiers (MHA) are playing a key role In order to maximize the sensitivity of the receiver link. This enables antennas to receive even weak signals, extends the coverage area, and helps to reduce the number of dropped calls. To ensure the proper functionality there is the clear need to test such systems as well as the TMAs themselves. The Tektronix YBA250 and YBT250 with is Insertion Gain/Insertion Loss measurement capabilities are perfectly equipped to meet these needs.

To find out more about other measurement functionalities, application notes or technical briefs, please visit www.tektronix.com/wireless.



Figure 8. Antenna isolation measurement.

Contact Tektronix: ASEAN / Australasia / Pakistan (65) 6356 3900 Austria +41 52 675 3777 Balkan, Israel, South Africa and other ISE Countries +41 52 675 3777 Belgium 07 81 60166 Brazil & South America 55 (11) 3741-8360 Canada 1 (800) 661-5625 Central Europe & Greece +41 52 675 3777 Central East Europe, Ukraine and Baltics +41 52 675 3777 Denmark 80 88 1401 Finland +41 52 675 3777 France & North Africa +33 (0) 1 69 81 81 Germany +49 (221) 94 77 400 Hong Kong (852) 2585-6688 India (91) 80-22275577 Italy +39 (02) 25086 1 Japan 81 (3) 6714-3010 Luxembourg +44 (0) 1344 392400 Mexico, Central America & Caribbean 52 (55) 56666-333 Middle East, Asia and North Africa +41 52 675 3777 The Netherlands 090 02 021797 Norway 800 16098 People's Republic of China 86 (10) 6235 1230 Poland +41 52 675 3777 Portugal 80 08 12370 Republic of Korea 82 (2) 528-5299 Russia, CIS & The Baltics 7 095 775 1064 South Africa +27 11 254 8360 Spain (+34) 901 988 054 Sweden 020 08 80371 Switzerland +41 52 675 3777 Taiwan 886 (2) 2722-9622 United Kingdom & Eire +44 (0) 1344 392400 USA 1 (800) 426-2200 USA (Export Sales) 1 (503) 627-1916 For other areas contact Tektronix, Inc. at: 1 (503) 627-7111 Updated November 3, 2004

#### For Further Information

Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit www.tektronix.com

#### - E

Copyright © 2005, Tektronix, Inc. All rights reserved. Tektronix products are covered by U.S. and foreign patents, issued and pending. Information in this publication supersedes that in all previously published material. Specification and price change privileges reserved. TEKTRONIX and TEK are registered trademarks of Tektronix, Inc. All other trade names referenced are the service marks, trademarks or registered trademarks of their respective companies.

1/05 FLG/WOW

2EW-18514-0

