

Testing WiMAX™ receiver performance in a faded environment using Agilent's E6651A with an Azimuth ACE MX radio channel emulator

Application Note



Agilent Technologies

Summary

As a part of the certification regime the Mobile WiMAX™ Radio Conformance Test specification (mRCT) requires designs undergo a number of RF tests, including some which require the use of a channel emulator. This application note describes how to perform receiver testing in a faded environment with the E6651A Mobile WiMAX test set, the N6422C Wireless Test Manager software and a channel emulator - the Azimuth ACE MX radio channel emulator in this case. The article concludes by showing results for two different mobile devices, highlighting the importance of testing in a faded environment.

Introduction

Mobile WiMAX is a new wireless technology which has the capability of providing the high data rates required for the next generation of mobile broadband services. The WiMAX Forum™ is an industry body which is seeking to promote the commercialization of the technology. As a part of their role the WiMAX Forum define test requirements which both mobiles and base stations must pass if they are to achieve certified status. One key component of this testing is the Mobile WiMAX Radio Conformance Test (mRCT)[1]. For certification testing there is a requirement that the testing be completed at a WFDCL (WiMAX Forum Designated Certification Lab) using validated RCT equipment. Engineers who are preparing for RCT testing, but do not have access to a full RCT tester, can use Agilent's N6422C Wireless Test Manager software in conjunction with the E6651A, WiMAX Test Set, to complete some preparatory testing ahead of visiting the test lab. This can help to trouble shoot potential errors as well as highlight areas where the device may fail. This paper describes how the E6615A can be used in conjunction with an Azimuth ACE MX radio channel emulator in order to carry out measurements using fading profiles defined by the ITU.

Agilent E6651A WiMAX Tester

The E6651A is a fully featured WiMAX base station emulator whose scope of test is unrivalled in the industry. The E6651A supports the following types of testing:-

1. Functional test of WiMAX protocol features
 - a. Test the DUT with a fully featured base station, complete with logging tool for de-bugging
2. RF measurements to test a WiMAX devices parametric performance
 - a. The standalone box includes RF measurement capability
 - b. Add WTM to run automated tests in preparation for RCT testing
3. Fully validated PCT testing for BS and MS test
 - a. Agilent offer a validated solution for PCT certification testing
4. E2E application testing
 - a. Add Connectivity Service Network (CSN) emulation in order to support testing with a real application, for example ftp server or video streaming server

This breadth of test allows customers to make a single purchase and be confident that they have the test coverage required for their WiMAX needs.

Agilent N6422C Software

The Agilent N6422C Wireless Test Manager software provides the user with the ability to run automated test cases which approximate to the tests required in the mRCT specification. This is not a substitute for full RCT testing, which is a requirement of the WiMAX Forum certification process, however it does give designers the opportunity to use the multi-purpose E6651A test equipment for preparatory testing ahead of visiting a certification lab. This can be valuable in that it may highlight issues with the design which can be addressed prior to full doing RCT testing.

The mRCT specification includes a number of tests which require the use of a channel emulator to represent the multipath fading environment. The E6651A can be configured to work with either a baseband IQ or RF based channel emulators. This application note describes how the E6651A can be used in conjunction with a Azimuth ACE MX channel emulator in order to test receiver performance under fading conditions. For more information on the Azimuth channel emulators consult www.azimuthsystems.com.

Measurement Set-up

Figure 1 shows the measurement set-up which was used. The output of the E6651A was fed into the Azimuth ACE MX which is setup in UNI+ mode, providing a fading forward path and a non fading reverse path integrated into the unit. The Azimuth ACE MX was then used to fade the down link signal before being fed into the DUT. The UL signal, passes through the ACE MX but does not undergo any fading. The ACE MX achieves this using an integrated return path with all the RF circulators, attenuators that are required for the setup internal inside the box. **Note:** Attenuators may be needed in the paths between the channel emulator and the DUT to insure the input powers levels into the channel emulator are not exceeded. See ACE MX User's Guide.

This set-up allows for testing the receiver in the DUT by fading the downlink signal, but not fading the UL and hence ensuring that the UL ACK and NACK packets are correctly received by the base station emulator. This set-up supports the requirements for receiver sensitivity testing in the WiMAX Forum mRCT specification. This specification calls out the need for fading on the DL only.

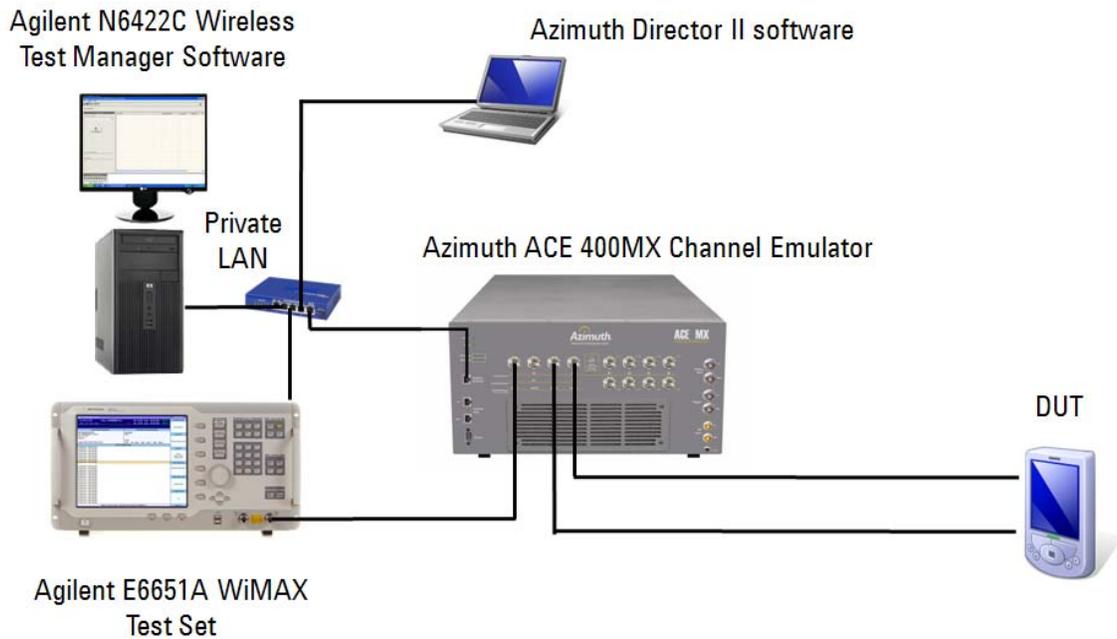


Figure 1. Measurement set-up.

Connecting the Radio Channel Emulator

The Azimuth Director II PC application provides a means of configuring and controlling the ACE MX channel emulator. The Director II application connects to the ACE MX via a LAN interface. The Director II then provides a GUI application which allows the user to define their measurement set up and set both the power levels and channel models required. Figure 2 shows the graphical interface for the Director II software highlighting both the measurement set-up and the selected channel models. Note that the “UNI +” setup is used and the reverse model is shown as “High Gain Bypass.”

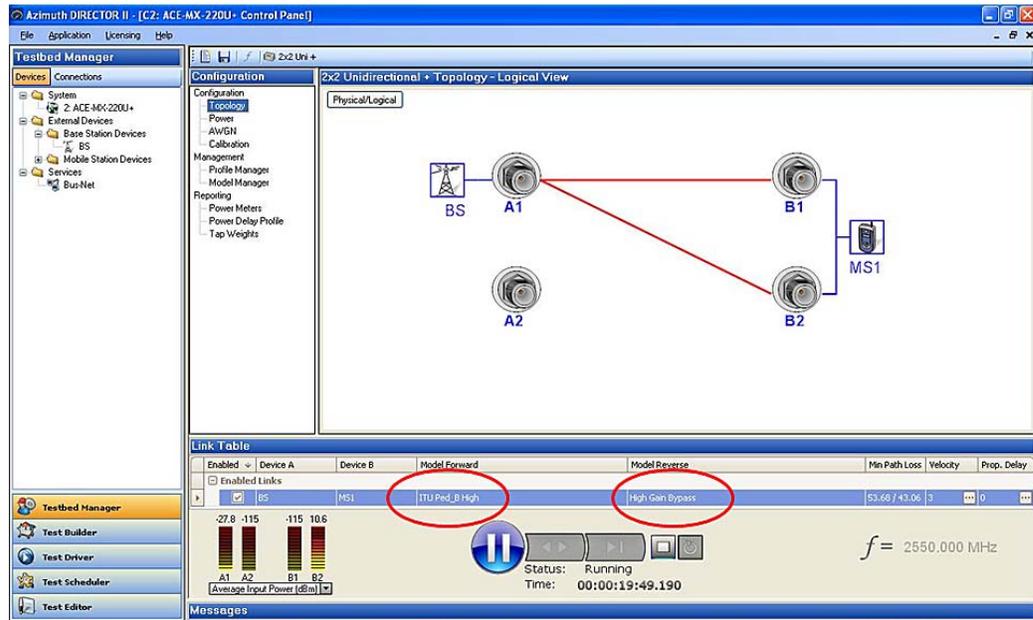


Figure 2. Director II graphical interface for controlling the ACE MX.

The Azimuth Director II software includes a library of tools to support the user in programming the ACE MX. This includes a programming interface which uses a TCL (Tool Command Language) based DLL (dynamic link library). The N6422C Wireless Test Manager software uses a .NET programming environment. In order to program the ACE MX the programmer needs to embed the TCL DLL within the .NET environment as well as embed a TCL interpreter. This allows the user to access TCL commands from within the .NET programming environment. The Azimuth Director II software includes a full listing of the TCL commands available.

Checking the Powers

In order to achieve optimal dynamic range performance from the channel emulator it is important to provide a signal that is sufficiently high power to exploit the dynamic range for the input analogue to digital conversion but not so high that the signal could be clipped or distorted. The input range of the ACE MX is from +15 to -40dBm with a maximum crest factor of 15dB. For this testing the E6651A was set to a preamble power level of -22dBm which is the maximum figure in the datasheet.

Figure 3 shows the user interface for the Azimuth ACE MX including the expected input power and the minimum path losses.

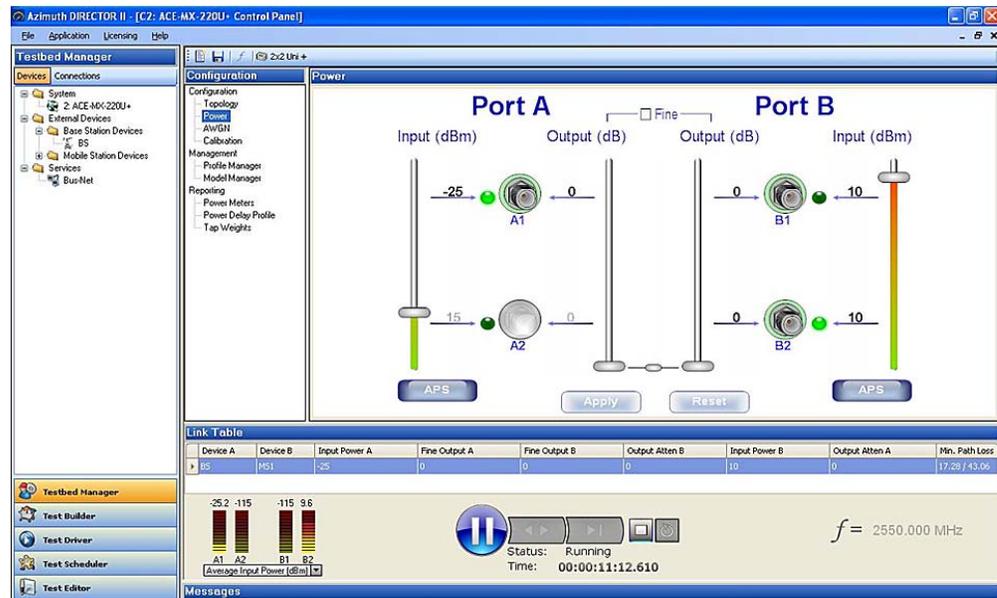


Figure 3. Azimuth Director II user interface showing UL and DL input powers.

Standard Channel Models

In order to do testing in accordance with the requirements in the WiMAX Forum mRCT specification the following channel models are required:

1. ITU pedestrian profile B with a mobile speed of 3km/h
2. ITU vehicular profile A with a mobile speed of 60km/h

The testing presented in this application note was limited to the ITU pedestrian profile B channel. Table 1 details the path delays and relative mean powers for this channel model. However the E6651A and the Azimuth ACE MX fading emulator can also be used for testing MIMO (multiple input, multiple output) channels, see figure 4. Table 2 provides details a number of matrices which can be used to represent different levels of antenna correlation.

For each of the ITU channel models the Doppler spectra is Classical and amplitude distributions on each of the paths is Rayleigh.

Path	ITU Pedestrian B, 3 km/h				ITU Vehicular A, 60 km/h			
	Relative Delay [ns]	Relative Mean Power [dB]	Mean AoA	Mean AoD	Relative Delay [ns]	Relative Mean Power [dB]	Mean AoA	Mean AoD
1	0	0	147.34	18.11	0	0	142.22	165.11
2	200	-0.9	50.84	24.48	310	-1.0	13.92	170.43
3	800	-4.9	139.08	21.11	710	-9.0	110.94	182.2
4	1200	-8.0	49.50	6.47	1090	-10.0	42.25	162.44
5	2300	-7.8	260.03	23.85	1730	-15.0	93.38	170.6
6	3700	-23.9	128.93	24.24	2510	-20.0	50.41	155.68
Total AS			67.91	4.99			69.9	4.99

Table 1. RF paths for ITU Pedestrian B and ITU Vehicular A channel models.

$$R_{MIMO} = \begin{bmatrix} 1 & \beta & \alpha & \alpha\beta \\ \beta^* & 1 & \alpha\beta^* & \alpha \\ \alpha^* & \alpha^*\beta & 1 & \beta \\ \alpha^*\beta^* & \alpha^* & \beta^* & 1 \end{bmatrix} \quad R_{MIMO} = \begin{bmatrix} 1 & 0 & \gamma & 0 \\ 0 & 1 & 0 & -\gamma \\ \gamma & 0 & 1 & 0 \\ 0 & -\gamma & 0 & 1 \end{bmatrix} \quad R_{MIMO} = \begin{bmatrix} 1 & 0 & \gamma\alpha & 0 \\ 0 & 1 & 0 & -\gamma\alpha \\ \gamma\alpha^* & 0 & 1 & 0 \\ 0 & -\gamma\alpha^* & 0 & 1 \end{bmatrix}$$

High Correlation
Medium Correlation
Low Correlation

Tap	Pedestrian B			Vehicular A		
	β	α	γ	β	α	γ
1	-0.1468 + 0.4156i	0.0303 + 0.7064i	0.7264	-0.2366 + 0.4312i	0.6883 + 0.1211i	0.7264
2	-0.4467 + 0.4227i	-0.4007 - 0.6073i		0.1388 + 0.2343i	-0.3508 - 0.5926i	
3	-0.2906 + 0.4347i	-0.6664 + 0.2620i		-0.6443 + 0.3650i	0.3884 - 0.5604i	
4	-0.4273 + 0.4259i	-0.6522 + 0.2088i		-0.3620 + 0.4431i	0.1899 + 0.6795i	
5	-0.7026 - 0.3395i	-0.5378 - 0.4866i		-0.7074 + 0.3372i	-0.3933 - 0.5650i	
6	-0.4500 + 0.4222i	-0.4564 - 0.5655i		-0.4405 + 0.4238i	-0.4383 - 0.5800i	

Table 2. MIMO correlation matrices for multiple antenna variants of ITU Pedestrian B and Vehicular A channel models.

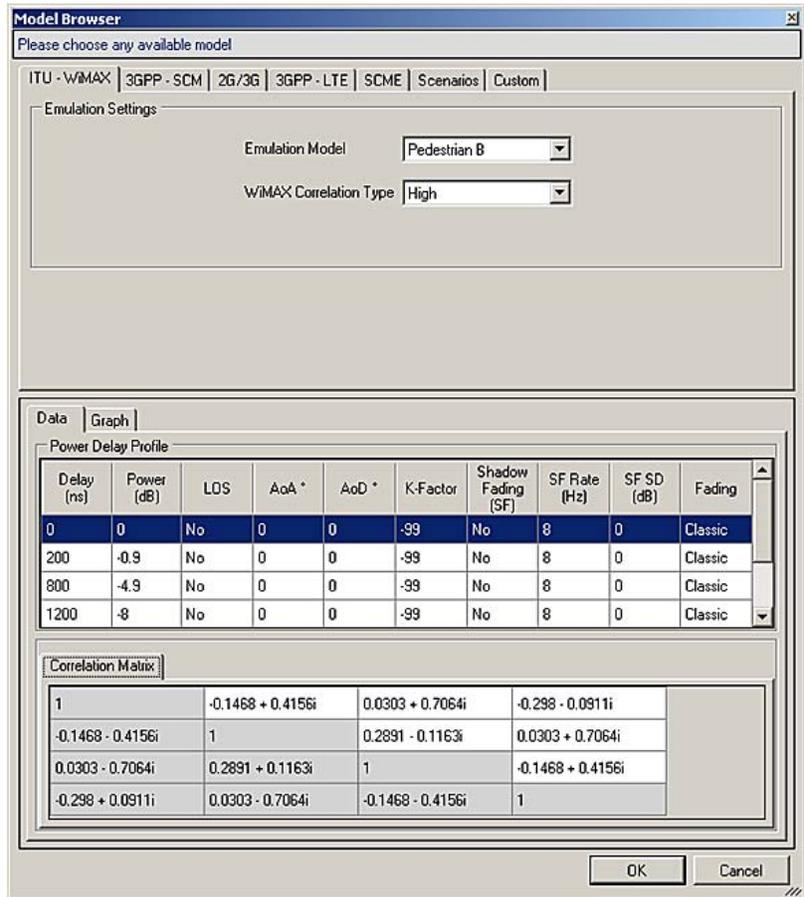


Figure 4. Screenshot of Azimuth Model Manager showing the Ped B High Correlation MIMO model as shown in Tables 1 and 2.

Test Automation

Figure 5 shows simple block diagram representing the schematic for SISO fading block. This model was used to represent the variables used for the fading tests in MS-09.1, the MS Receiver Sensitivity test.

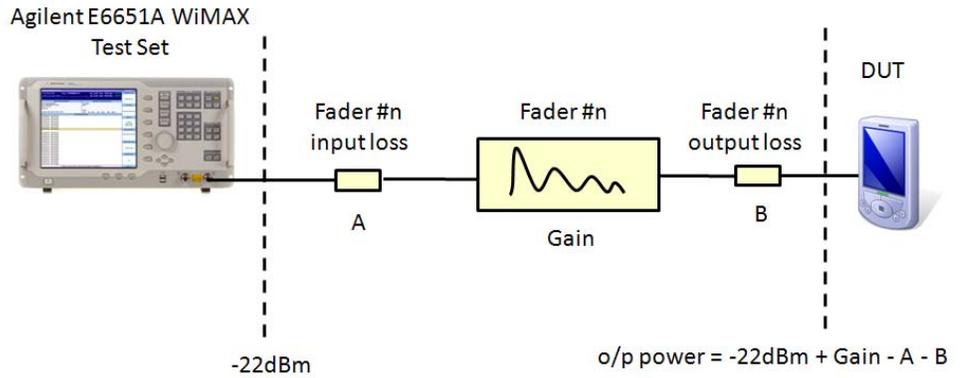


Figure 5. Schematic for SISO fading block, used for MS test 09.1.

The N6422C WTM software provides test cases which have been based upon the mRCT test specification. Users of this software are able to take these test cases and then make changes to suit their particular needs. In this example we took the test for receiver sensitivity (MS-09.1) and adapted it for use with the channel emulator.

As described earlier the Azimuth ACE MX channel emulator can be remotely controlled by using WTM to send TCL based control commands to the Director II software via a TCL based API. This allows the user to embed fading control in the existing WTM code, for example the MS-09.1 receiver sensitivity test. The Azimuth documentation provides a full listing and details of all supported commands.

Results

Figure 6 and 7 show the RF output spectrum for a case with no fading (fader in bypass mode) and a case with the fader using the ITU pedestrian profile B. For the faded case the speed of the mobile was significantly reduced in order that the VSA could perform averaging over a static channel. The pedestrian B profile clearly demonstrates the impact of the multiple paths combining to produce a number of significant notches in the RF spectrum.

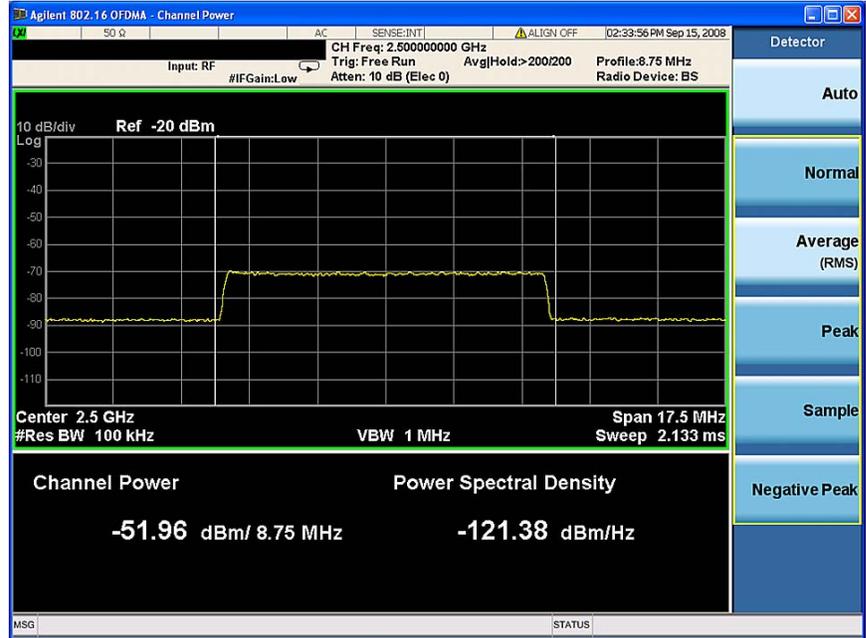


Figure 6. RF spectrum with no fading.



Figure 7. RF spectrum for Pedestrian B fading.

Sensitivity measurements were then taken for two different Mobile WiMAX DUTs (see table 3 below). The results are interesting in that they show the gain that diversity can offer in a faded environment. The results in a faded environment were taken using both a single faded path with a splitter and then using two independently (although correlated) faded paths. For the two faded paths the sensitivity performance is significantly improved over the results achieved with the splitter. This can be accounted for by the diversity gain in the receiver. Note that without the benefit of diversity both receivers suffered from irreducible error rates when tested with the pedestrian B channel fading profile.

	Modulation Scheme	Sensitivity in noise (2 RF paths)	Sensitivity under ped B fading	
			2 RF paths (High correlation)	One RF path & splitter
Device I	½ rate CTC QPSK	-93 dBm	-92dBm	-85 dBm
	5/6 rate CTC 64QAM	-76 dBm	-75 dBm	Irreducible error floor
Device II	½ rate CTC QPSK	-94 dBm	-90 dBm	-89dBm
	5/6 rate CTC 64QAM	-74 dBm	-71 dBm	Irreducible error floor

Table 3. Sensitivity performance for two different Mobile WiMAX receivers.

Conclusion

This paper has shown how the Agilent E6651A WiMAX Test Set can be used in conjunction with the Azimuth ACE MX fader in order to perform receiver testing using a channel emulator. The E6651A is a fully functional base station emulator which can be used to establish a link with a device under test. The WiMAX Forum has defined a number of link based RF tests in the mRCT test specification. Some of these require the use of a radio channel emulator. Following this application note will help customers to integrate the Azimuth ACE MX with Agilent’s N6422C Wireless Test Manager product. This allows the customer to extend their test coverage to include testing with fading. As an example this paper describes receiver sensitivity testing using a faded channel.

Acknowledgements

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References

[1] WiMAX Forum™ Mobile Radio Conformance Tests mRCT Release 1.0 Approved Specification Revision 2.2.1



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