Testing WiMAX™ receiver performance in a multipath propagation environment using Agilent's E6651A with an EB Propsim C8 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 Elektrobit Propsim C8 radio channel emulator in this case.   The article concludes by showing results for two different mobile devices, highlighting the importance of testing in a multipath propagation 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 commercialisation 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 EB Propsim C8 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 unrivaled 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 offers 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 doing full 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 an Elektrobit Propsim C8 channel emulator in order to test receiver performance under fading conditions. For more information on the Elektrobit channel emulators consult www.elektrobit.com.

Measurement Set-up

Figure 1 shows the measurement set-up which was used. The output of the E6651A was fed, via a circulator, into the EB Propsim C8. The EB Propsim C8 was then used to emulate multipath propagation in the down link signal before being fed to the DUT, via another circulator (see red line). The UL signal, depicted with a green line, passes through both circulators but does not undergo any fading.

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.
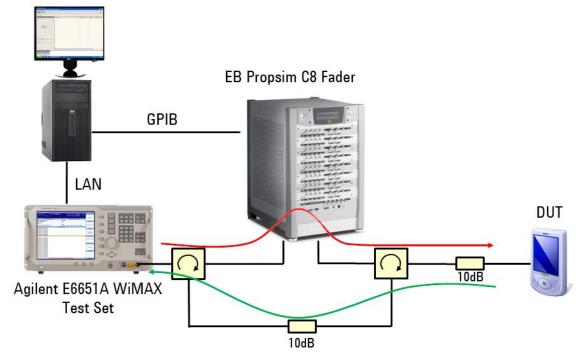

Figure 1. Measurement set-up.

Connecting the Radio Channel Emulator

Connecting with the EB Propsim C8 is easy using the Agilent IO libraries Suite 15.0. All you need to do is:

1. Install the Agilent IO Libraries suite software on your PC
2. Connect the instrument to the PC via GPIB or LAN
3. Detect the instrument and then configure the interface using the Agilent Connection Expert

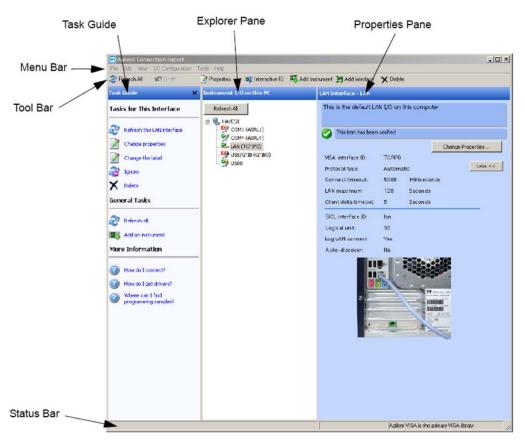The figure below shows the connection expert screen indicating the properties for a specific interface.

Figure 2. Agilent Connection Expert.

It is possible to control the EB Propsim C8 via either the GPIB or LAN interfaces. In our case we sent scpi (Standard Commands for Programmable Instrumentation) over GPIB (General Purpose Interface Bus).

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 use all the available "bits" for the input analogue to digital conversion but not so high that the signal could be clipped or distorted. WiMAX is an OFDM (Orthogonal Frequency Division Multiplexed) based signal which has quite a high peak to average ratio. During this testing the E6651A was set to the maximum preamble power output 0f -22dBm. Adjusting for the effects of the cabling and the circulator this gave us a preamble power of -25dBm at the input to the channel emulator. This power level was sufficient to provide a high dynamic range without causing any clipping or distortion.

Measurements were then made to verify the cabling losses and ensure that actual output powers matched the expected output power predicted by the channel emulator when placed in bypass mode. The channel emulator then adjusts the path gains for each of the channel models in order that the average output power is kept constant for a given gain setting. Figure 3 shows the user interface for the EB Propsim C8 including the expected average output power level.
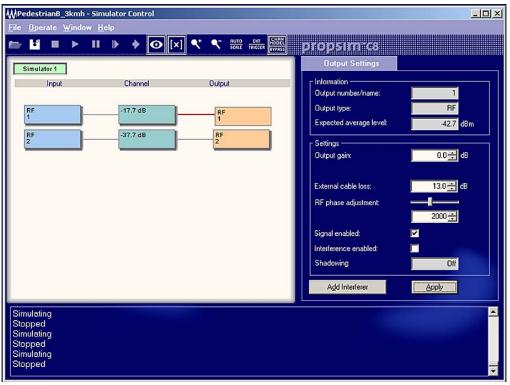

Figure 3. Propsim C8 user interface showing expected output powers.

The final step during set-up was to add attenuation such that the equipment set-up had appropriate levels of attenuation for the intended measurement. In this case we were doing sensitivity measurements and we added an additional 10dB attenuator prior to the input to the WiMAX receiver and also 10dB attenuation between the two circulators separating the UL and DL channels . This was required to optimise the power levels in the set up and to prevent the power finding a path from the base station to the DUT through the non faded connection. This path is the reverse of the path shown by the green arrow in figure

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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

For the testing presented in this application note we limited ourselves with a single antenna pair and tested with 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 EB Propsim C8 radio channel emulator can also be used for testing MIMO (multiple input, multiple output) channels. 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.

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

High Correlation   Low Correlation   Medium Correlation

	Pedestrian B			Vehicular A		
Tap	β	α	γ	β	α	γ
1	-0.1468 + 0.4156i	0.0303 + 0.7064i		-0.2366 + 0.4312i	0.6883 + 0.1211i	
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	0.7264	-0.6443 + 0.3650i	0.3884 − 0.5604i	0.7264
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.
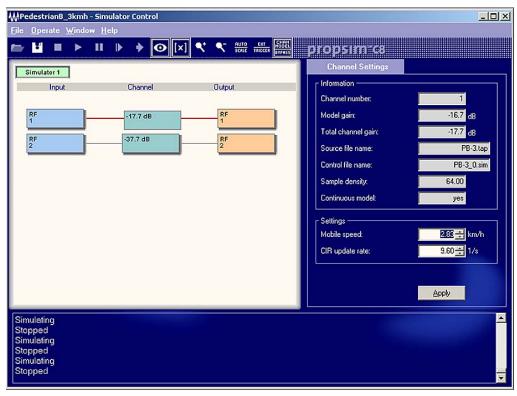
Figure 4. EB Propsim C8 set to use Pedestrian profile B @ 3km/h.

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.
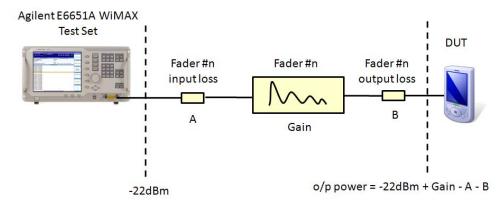

Figure 5. Schematic for SISO fading block, used for MS test 09.1.

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. We programmed the EB Propsim C8 channel emulator by using WTM to send direct IO scpi (Standard Commands for Programmable Instrumentation) commands over a GPIB (General Purpose Interface Bus) interface connected to the channel emulator. The Elektrobit 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 (EB Propsim C8 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.
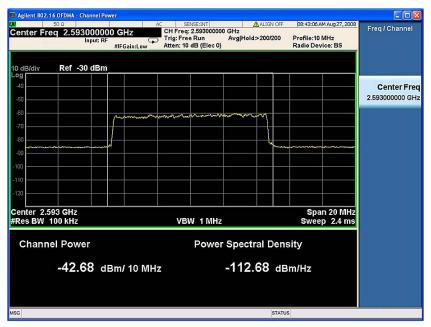
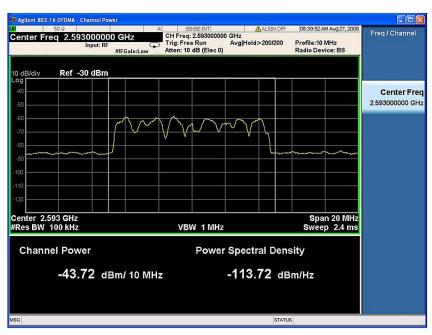

Figure 6. RF spectrum with no fading.

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 showed that, for noise only, one device performed 5dB better than the other. However when the testing was done with a fading channel the device which had worked well in noise was not able to cope with a faded channel and showed errors regardless of the input power.

This result serves to highlight the importance of including faded measurements when characterising the performance of receivers. As seen from the measurements testing under fading conditions might end up to surprising results. The problems with device A might have been avoided if there was a radio channel emulator available during development phase.

½ rate CTC QPSK	Sensitivity in noise	Sensitivity under Ped B fading
Device A	-80 dBm	Irreducible errors
Device B	-75 dBm	-69 dBm

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

The two devices used were both wave 1 8.75MHz DUTs of an early vintage, with performance that did not meet the MS-09.1 test limits.

Conclusion

This paper has shown how the Agilent E6651A WiMAX Test Set can be used in conjunction with the EB Propsim C8 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 EB Propsim C8 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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