AWS-3 TO AWS-1 INTERFERENCE LABORATORY TEST REPORT

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Table of Contents

1 Executive Summary 3
1.1 Interference Problem 3
1.2 Laboratory Tests Performed by T-Mobile 4
1.3 Test Results and Conclusions 4
2 Introduction 6
2.1 Intersystem Interference Mechanisms 6
2.2 T-Mobile's Hypotheses 9
3 Test Objectives and Assumptions 10
3.1 Scope of Tests 11
3.2 Out-of-Band Emission (OOBE) Tests 11
3.3 Combined OOBE and Adjacent Channel Interference Tests 11
4 Assessment of Typical Serving and Interfering Signal Powers 13
5 Test Setup and Calibration 17
5.1 Test Setup 17
5.2 Serving and Interfering Signal Configurations 18
5.3 Calibration 19
6 Test Procedures and Results 20
6.1 Out-of-Band Emissions (OOBE) Tests 20
6.2 Combined OOBE and Adjacent Channel Interference Tests 22
7 Conclusions 29
7.1 Further Work 29
Appendix A Test Equipment List 30
Appendix B Acronyms and Abbreviations 31

1 EXECUTIVE SUMMARY

The Federal Communications Commission (FCC), through a Notice of Proposed Rule Making (NPRM) and a Further Notice of Proposed Rule Making (FNPRM)[1], proposes service rules allowing time division duplex (TDD) broadband wireless service in the new AWS-3 band (2155 – 2180 MHz), which is adjacent to the downlink of the previously auctioned AWS-1 band (2110 – 2155 MHz). Comments filed by T-Mobile USA ("T-Mobile") and several other parties raised concerns about this TDD proposal because of the potential risk of mobile-to-mobile interference from the AWS-3 terminal devices into the receive band of AWS-1 mobiles.[2] In those comments, T-Mobile and others stated that to avoid significant interference, stringent service rules on maximum allowed mobile transmit power and Out-of-Band Emissions (OOBE) would have to be enforced on the AWS-3 terminals, if TDD is allowed to operate immediately adjacent to the existing AWS-1 frequency division duplex (FDD) band. The primary goals of the laboratory testing described here were to measure the severity of the interference and precisely quantify the service rules necessary for AWS-3 to avoid severe interference to AWS-1.

1.1 Interference Problem

Interference due to the coexistence of TDD and FDD systems operating in adjacent frequency bands can be especially acute because frequency separation cannot be used to isolate the uplinks and downlinks, meaning that sensitive receivers can be operating in close spectral, geographical and temporal proximity to transmitters. As the WiMAX Forum points out, "This scenario [FDD-TDD coexistence] includes the same interference paths found in the FDD-FDD scenario plus potentially crippling BS-to-BS [base station] and SS-to-SS [subscriber station] interference paths between the systems."[3] There are radio engineering practices to reduce or eliminate base-station-to-base-station interference[4] because it is static; however, mobile-to-mobile interference is another story altogether due to its dynamic nature. As the WiMAX Forum observes, "if the SSs [subscriber stations] are operated close enough to one another there is *nothing that can be done to mitigate this [interference] problem*."[5] When the TDD system is operating in a band adjacent to the FDD downlink, as is the case with AWS-3 TDD adjacent to AWS-1 FDD, this most problematic mobile-to-mobile interference scenario occurs from AWS-3 transmissions into AWS-1 mobile receivers. As the WiMAX Forum clarifies the interference is asymmetrical: "...[I]f the TDD system operates in a channel adjacent to the FDD DL [downlink], the FDD SS suffers

[1] See *Service Rules for Advanced Wireless Services, WT Docket Nos. 07-195 and 05-356*, Further Notice of Proposed Rulemaking, FCC 08-158 (rel. June 20, 2008).
[2] See previous comments to NPRM by T-Mobile USA, Verizon Wireless, CTIA and AT&T.
[3] See WiMAX Forum, *Service Recommendations to Support Technology Neutral Allocations FDD/TDD Coexistence*, April 10, 2007, p. 21.
[4] See for example Neil J. Boucher, *The Cellular Radio Handbook: A Reference Guide for Cellular System Operation*, Fourth Edition, John Wiley & Sons, 2001, pp. 87-97.
[5] WiMAX Forum, op. cit. (emphasis added)

interference from the TDD SS, but not necessarily vice versa."[6] Ofcom reports that for TDD macrocells (which would clearly be the case for an AWS-3 deployment where a nationwide service achieving 95% coverage footprint could likely only be economically achieved with macrocells, not picocells) and even at extremely good FDD received powers (at or above -80 dBm), "TDD terminal stations operating in the 1st adjacent block with respect to a FDD terminal station can cause a significant (albeit graceful) degradation in throughput."[7]

1.2 Laboratory Tests Performed by T-Mobile

To assess the real-world potential for interference from terminal devices transmitting in AWS-3 to mobiles receiving in AWS-1, T-Mobile conducted extensive testing at an independent, third-party laboratory facility. The purposes of the testing at the third-party lab facility were as follows: to determine if the FCC's proposed service rules[8] for AWS-3 would result in harmful interference to AWS-1 mobiles; to quantify the OOBE and mobile transmit power limits necessary for AWS-3 to avoid severe interference to AWS-1; and to provide an open test bed for the FCC and other interested parties to observe or participate in the testing. The test plan was designed to measure the AWS-3 interference power levels at which serious degradations (*i.e.* the inability to establish a connection, excessive block error rates or dropped calls) occurred in the AWS-1 mobiles operating under typical serving signal conditions. Particular care was taken to select the AWS-1 serving signal levels and AWS-3 transmit powers to match typical operating conditions, rather than worst cases. Specific tests were performed to determine if better filtering on the AWS-1 devices could eliminate or reduce the interference. A number of different AWS-1 commercial and pre-commercial mobile handsets were tested to compare performance across various manufacturers and models.

1.3 Test Results and Conclusions

The measured results from the laboratory tests demonstrated that there can be serious interference problems should AWS-3 mobiles operating under the currently proposed rules be permitted adjacent to the AWS-1 band. Disturbingly, the tests showed that with the FCC's currently proposed OOBE and transmit power limits, AWS-1 customers could be unable to communicate within an extremely large radius around an AWS-3 device that is transmitting at full power, as would often be the case for broadband data services.

The tests in the laboratory showed that OOBE from the AWS-3 transmitters directly into the AWS-1 receive band is a major component of the interference, a problem for which the AWS-1 mobiles can have no defense. Because OOBE interference is radiated by the AWS-3 mobiles directly into the AWS-1 receive band, it manifests

[6] Ibid.
[7] See Ofcom, On *the impact of interference from TDD terminal stations to FDD terminal stations in the 2.6 GHz band*, April 21, 2008, p. 14.
[8] OOBE of 60+10log(P) (P in W/MHz) and maximum mobile transmit power of 23 dBm/MHz.

as in-band, co-channel interference that cannot be filtered out by the AWS-1 receiver. The tests demonstrated that better receive filtering on the AWS-1 mobile handsets would not alleviate the dominant interference source. To avoid harmful OOBE emissions at one meter separation distance, the AWS-3 filters should provide an attenuation of 96+10log(P) (P in W/MHz), instead of the FCC's proposed 60+10log(P). It is presumed that with OOBE of 60+10log(P), the dominant source of interference is OOBE, whereas at 96+10log(P) the dominant mechanism is receiver blocking in the AWS-1 mobile.

The tests using WCDMA as a interfering signal source further demonstrated that with the FCC NPRM's proposed OOBE of 60+10log(P), the AWS-3 mobile transmit power level had to be limited to between -11 dBm/MHz (adjacent channel with no guard band) and -4 dBm/MHz (with 15 MHz guard band). Based on our wireless systems engineering experience, T-Mobile recognizes that such low transmit power levels would likely be impractical for a commercial AWS-3 mobile system to be viable. Additional WCDMA tests were performed using transmit filtering with OOBE extremely close to the 96+10log(P) derived from earlier tests, with the measurements indicating that maximum AWS-3 transmit power levels of 2 dBm/MHz with no guard band and 10 dBm/MHz with 15 MHz guard band could be tolerated.

Tests using a WiMAX signal source at OOBE of 60+10log(P) indicated that if AWS-3 used WiMAX the transmitter powers would have to be limited to -9 dBm/MHz for 20 MHz WiMAX channel bandwidth with no guard band.

The laboratory tests conclusively demonstrated that the FCC's proposed service rules are wholly inadequate to protect AWS-1 mobiles from debilitating interference when operating under typical usage conditions. The measurements further showed that improved receiver filtering on the AWS-1 devices would not mitigate the primary interference source. T-Mobile plans to perform additional tests to further characterize the interference for other test cases.

2 INTRODUCTION

The Federal Communications Commission (FCC), through a Notice of Proposed Rule Making (NPRM) and a Further Notice of Proposed Rule Making (FNPRM)[9], proposes service rules allowing time division duplex (TDD) broadband wireless access services in the new AWS-3 band (2155 – 2180 MHz), which is adjacent to the downlink of the previously auctioned AWS-1 band (2110 – 2155 MHz). Comments filed by T-Mobile and several other parties raised concerns about this TDD proposal because of the potential risk of mobile-to-mobile interference from the AWS-3 terminal devices into the receive band of AWS-1 mobiles[10]. In those comments, T-Mobile and others stated that to avoid significant interference, stringent service rules on maximum allowed mobile transmit power and Out-of-Band Emissions (OOBE) would have to be enforced on the AWS-3 terminals, if TDD is allowed to operate immediately adjacent to the existing AWS-1 frequency division duplex (FDD) band. Two of the primary goals of the laboratory testing described here were to measure the severity of the interference and precisely quantify the service rules necessary for AWS-3 to avoid severe interference to AWS-1.

2.1 Intersystem Interference Mechanisms

The coexistence of two different mobile technologies operating in adjacent frequency bands can lead to interference problems due to practical limitations of the transmitter and receiver equipment. The interference problem can be particularly acute when the adjacent bands are the receiving band for one system and the transmitting band for the other system, which would be the case if the FCC allowed TDD operations in AWS-3 adjacent to the existing FDD operations in AWS-1.

In such adjacent band coexistence cases, the intersystem interference problem manifests through various mechanisms[11], as depicted in Figure 1. The interference mechanisms can be categorized as follows:

1. **Out-of-Band Emissions (OOBE)** are unwanted emissions outside the nominal channel resulting from the modulation processes and non-linearities in the transmitter, but excluding spurious emissions[12]. These emissions from the interfering transmitter create co-channel interference to the victim receiver which cannot be eliminated by the victim receiver (meaning that no amount of receiver filtering can remove the interference because it is in-band). The detrimental effects of OOBE can be reduced by increasing the suppression of the transmitter filter or by reducing the transmitted power levels for the interfering system.

[9] See *Service Rules for Advanced Wireless Services, WT Docket Nos. 07-195 and 05-356*, Further Notice of Proposed Rulemaking, FCC 08-158 (rel. June 20, 2008).
[10] See previous comments to NPRM by T-Mobile USA, Verizon Wireless, CTIA and AT&T.
[11] See J. Laiho, A. Wacker, T. Novosad, *Radio Network Planning and Optimization for UMTS*, John Wiley & Sons, 2002, pp. 234-237.
[12] See 3GPP Technical Specification 25.101, section 6.6.2.

2. **Adjacent channel interference** is due to the imperfect filtering on the victim receiver, which captures energy from frequencies that are outside its own nominal channel. If the interference levels are of sufficiently high power levels, then receiver overload (saturation) or blocking can occur. The adjacent channel interference can be reduced by increasing the suppression of the receiver filters or by limiting the power levels of the interfering system. The ability of a receiver to combat adjacent channel interference is usually quoted in terms of Adjacent Channel Selectivity (ACS) and Blocking specifications.[13]

3. **Spurious emissions** are emissions other than the desired transmit signal which are caused by undesired transmitter effects such as harmonics, parasitics, intermodulation products or frequency conversion products, but exclude out of band emissions.[14] Harmonic emissions occur at multiples of the transmitter's fundamental carrier frequency due to nonlinearities in the processing; hence they will be far removed from the AWS-1 receive band. Parasitic emissions are undesired oscillations that can occur within the transmitter at frequencies typically far removed from the carrier frequency, so would also be expected to be far removed from the AWS-1 receive band. Intermodulation or frequency conversion products come from nonlinear mixing of various signals in the transmitter processing. In well designed transmitters, these products would typically be at levels below those of OOBE.

In the particular case of AWS-3 interference to AWS-1 it is anticipated that spurious emissions will have negligible effects for the reasons noted above; therefore the analysis concentrates on the other two effects.

[13] See 3GPP Technical Specification 25.101, Sections 7.5 and 7.6.

[14] See 3GPP Technical Specification 25.101, Section 6.6.3.

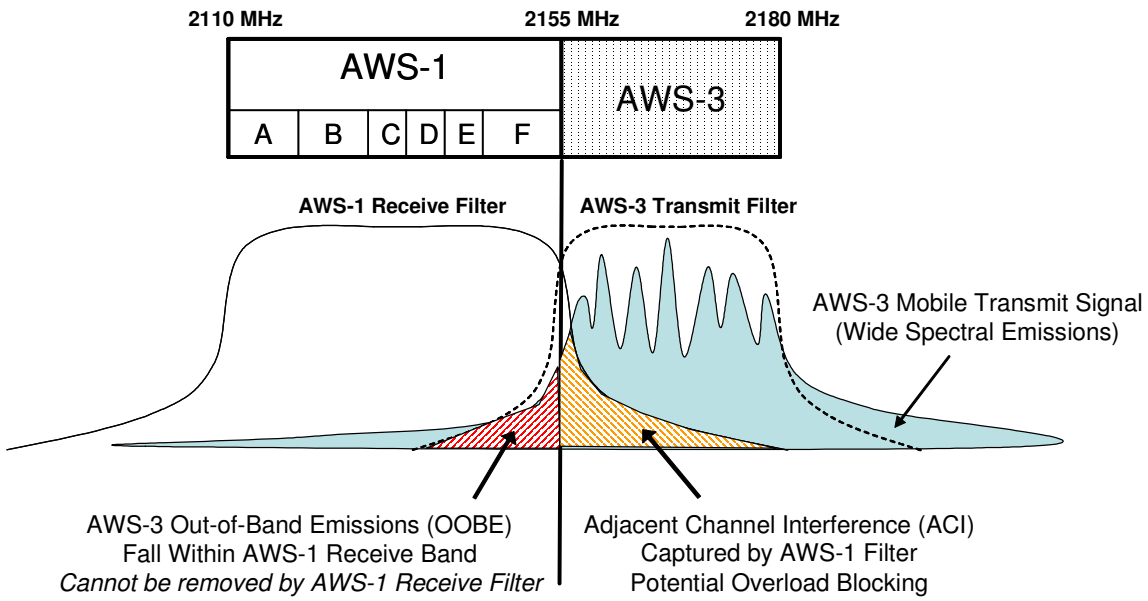

Figure 1. Illustration of Interference Mechanisms from AWS-3 into AWS-1.

Figure 1 illustrates the various interference mechanisms and paths in the context of the AWS-3 to AWS-1 interference scenario. OOBE interference leaks through the AWS-3 transmit filter, for example from the AWS-3 terminal devices transmitting in the 2157.5 MHz channel adjacent to the AWS-1 F-band channel centered at 2152.5 MHz. The result is radiation from the AWS-3 terminal device inside of the AWS-1 downlink mobile receive band, causing co-channel interference. Even a perfect brick wall filter on the AWS-1 receiver would not reject the OOBE interference because it arrives directly in the nominal receive channel. This OOBE interference mechanism must be controlled by the OOBE specifications defining the transmit filter performance of the AWS-3 transmitter and by transmit power limitations for the AWS-3 terminal device.

Adjacent channel interference is received by the AWS-1 mobile due to the roll-off skirts of the receive filter, as shown in Figure 1. Some energy from adjacent channels, such as those from the AWS-3 channel centered at 2157.5 MHz, leak into the AWS-1 receiver tuned to the 2152.5 MHz channel. The adjacent channel energy acts as interference, reducing the carrier-to-interference ratio of the desired AWS-1 serving signal. If the adjacent channel interference is strong enough, then it can cause saturation overload or blocking of the AWS-1 receiver. Receiver saturation overload occurs when the interfering signal is so strong that it drives the receiver into the nonlinear operating region causing potentially severe degradation of the desired signal performance. The adjacent channel

interference can be reduced through better filter or receiver specifications in the AWS-1 receiver, or by transmit power limitations for the AWS-3 terminal device.

It is obvious that the two primary interference mechanisms are distinct and as such require uniquely different mitigation approaches. OOBE is caused by leakage from the AWS-3 transmitter radiating directly into the AWS-1 receiver band causing co-channel interference; therefore it can only be controlled at the AWS-3 terminal device by appropriate OOBE specifications and transmit power limits. Adjacent channel interference results from leakage in the AWS-1 receive filter; therefore it can be controlled by the AWS-1 mobile receiver specifications or by transmit power limits on the AWS-3 terminal device.

2.2 T-Mobile's Hypotheses

Based on T-Mobile's previous analyses and laboratory tests, we believe that TDD systems operating in the AWS-3 band with the current power and OOBE limits proposed by the FCC will create debilitating interference into AWS-1 mobiles operating under typical usage conditions. Radio engineering principles suggest that this interference will stem from OOBE and adjacent channel interference.

T-Mobile further believes that the use of better AWS-1 receive filters would not alleviate the interference problem because (a) the OOBE from AWS-3 transmitters falls inside the AWS-1 channel as co-channel interference; and (b) AWS-1 receiver filters designed for the 2110-2155 MHz pass band instead of the current 2110-2170 MHz pass band would only attenuate the interfering adjacent band AWS-3 signals by a few decibels[15], which would still not eliminate the adjacent channel interference from AWS-3.

The laboratory measurements described here were designed to rigorously test these hypotheses.

[15] See Verizon Wireless Comments to NPRM, Dec 14 2007, Attachment B.

3 TEST OBJECTIVES AND ASSUMPTIONS

The purposes of the testing at the independent, third-party laboratory facility were as follows: to determine if the FCC's proposed service rules for AWS-3 would result in harmful interference to AWS-1 mobiles; to quantify the OOBE and transmit power limitations necessary for AWS-3 to avoid severe interference to AWS-1; and to provide an open test bed for the FCC and other interested parties to observe or participate in the testing.

The tests were performed at the Boeing EMC Laboratory in Seattle, Washington, an independent, third-party facility. To assess the potential interference, T-Mobile conducted laboratory tests using the following assumptions to create realistic scenarios:

- The provision of broadband wireless access services in AWS-3 requires considerable bandwidth to achieve high data rates; therefore the test cases utilized an AWS-3 interfering signal of 5 MHz or wider. Interference sources employing Universal Mobile Telecommunications System (UMTS) Wideband Code Division Multiple Access (WCDMA) as well as IEEE 802.16e Mobile WiMAX were tested.
- Interference measurements were performed using AWS-1 serving sector received power levels and AWS-3 interference transmit power levels that are typical of real-world customer usage scenarios, not worst cases. Detailed descriptions and supporting data for the real-world scenarios of serving signal levels and interference transmit power levels are presented in Section 4.
- Interference situations could commonly occur if AWS-1 mobiles are within one meter of an AWS-3 terminal device transmitter. This can easily occur if the user simultaneously makes use of an AWS-1 mobile phone and an AWS-3 data card, for example, or in typical day-to-day situations such as a group of people in a conference room, in a car, train, subway, home, etc. A coupling loss of 40 dB (38 dB of free-space loss plus an additional 2 dB of body loss) was assumed, which is in accordance with typical industry standards[16].

To analyze the effect of an improved AWS-1 receive filter that would receive in the 2110-2155 MHz pass band instead of the current 2110-2170 MHz pass band implementation, additional tests were performed on the lower side of the AWS-1 band, *i.e.* at interfering frequencies below 2110 MHz. These tests assumed that the filter suppression below 2110 MHz would be equivalent to the suppression above 2155 MHz. This was done to mimic the scenario where the AWS-1 mobiles had a 2110-2155 MHz receive filter in place, since no such filters exist in commercial devices. In other words, 'mirror image' tests were conducted with the interference source first above and then later below the AWS-1 band of 2110-2155 MHz. Since current AWS-1 mobiles have 2110-2170 MHz

[16] See 3GPP Technical Specification 25.942, table 4.2A.

receive filters, the test on the upper side reflects the current interference situation, while the test on the lower side reflects improved filtering with the edge of the receive filter pass band coincident with the edge of the AWS-1 band.

3.1 Scope of Tests

The scope of tests included (a) OOBE and (b) combined OOBE and adjacent channel interference tests. During the tests, the AWS-1 mobile phones were subjected to interference from a source transmitting in the bands adjacent to the AWS-1 receive channel. The AWS-1 mobiles were first set up with serving signals at received power levels of -90 dBm, -100 dBm and -105 dBm, which were deemed to be typical levels observed in actual networks (see Section 4 for details). The source interference was then introduced to measure the interference power at which debilitating interference occurred. The power level of the interfering signal source was increased in steps until debilitating interference occurred (typically this was call setup failures).

Two air interfaces were used as interference sources: 3GPP UMTS WCDMA and IEEE 802.16 WiMAX. Several interfering frequency channels were tested, including channels interfering with AWS-1 in the lower part of the band (*i.e.* below 2110 MHz) and in the upper part (*i.e.* above 2155 MHz), to analyze the performance differences introduced by the duplex filters that commercial AWS-1 equipment have in place (covering from 2110 to 2170 MHz).

3.2 Out-of-Band Emission (OOBE) Tests

The OOBE tests were designed to determine the in-band interference levels which would cause debilitating interference to AWS-1 mobiles in one or more of the following forms:

- Call setup failures,
- Excessive Block Error Rates (BLER) > 3% or
- Dropped calls.

These tests were designed to measure the associated interference levels, excluding the effects of receiver overload.

3.3 Combined OOBE and Adjacent Channel Interference Tests

These tests were designed to determine the AWS-3 transmit power levels at which debilitating interference occurred (*i.e.* call setup failures, excessive BLER > 3% or dropped calls). The causes of the failures could be a combination of in-band interference (*i.e.* OOBE) and out-of-band interference (*i.e.* adjacent channel interference). To assess the range of likely conditions, the frequency separations between the serving and interference signals

were set at 5, 10, 15 and 20 MHz; these also served to assess the impact of guard bands of various bandwidths between AWS-1 and AWS-3 TDD.

4 ASSESSMENT OF TYPICAL SERVING AND INTERFERING SIGNAL POWERS

To properly conduct the laboratory experiments and sensibly interpret the results, it was important to understand the serving and interfering signal power ranges that are representative of real-world conditions for networks currently deployed in the AWS-1 band and those to be potentially deployed in AWS-3. The goal was to evaluate power levels appropriate for typical operating conditions, rather than worst case scenarios such as at the edge of a cell. In the laboratory experiments, the levels of AWS-1 serving sector signal powers were set to represent typical operating conditions. The interfering AWS-3 transmit power level at which debilitating interference occurred was then measured for various test cases. Interpreting the results requires assessing whether the AWS-3 transmit power levels causing the interference are likely to occur in typical operating conditions, not just rare or extreme situations.

To accomplish the goal of understanding typical serving and interfering signal powers, drive test measurements were collected in several different markets with mixed urban and suburban environments, which are samples from typical T-Mobile network deployments in the AWS-1 band. These drive test measurements allowed statistics of the serving sector received powers and mobile transmit powers to be characterized in operating networks. It is important to note that these drive tests results do not include any indoor test cases where received power statistics typically would be considerably lower and transmit power levels would be higher; obviously, indoor wireless usage is extremely prevalent and a growing trend due to wireline replacement.

Figure 2 and Figure 3 show the probability density functions (PDF) and cumulative distribution functions (CDF) for mobile received signal code power (RSCP) for the pilot channel (broadcast control channel used by mobiles for various functions including carrier recovery for coherent demodulation of the downlink) from two of T-Mobile's Universal Mobile Telecommunications System (UMTS) Wideband Code Division Multiple Access (WCDMA) networks in different market cities. According to the measurements from Market A in Figure 2, approximately 28% of the cases in the area received the serving cell signal with a RSCP power level of -90 dBm or lower, 7% of the users at -100 dBm or lower, and 3% of cases at -105 dBm or lower. Similar results were measured for Market B in Figure 3, with approximately 26% of the cases in the area received the serving cell signal with a RSCP power level of -90 dBm or lower, 9% of the cases at -100 dBm or lower, and 5% of cases at -105 dBm or lower. The laboratory tests described here used these three received signal power levels (-90 dBm, -100 dBm and -105 dBm) as representative of real-world operations and usage scenarios most likely to experience harmful interference; clearly from the market measurements these signal levels do not represent extreme or edge-of-cell conditions.

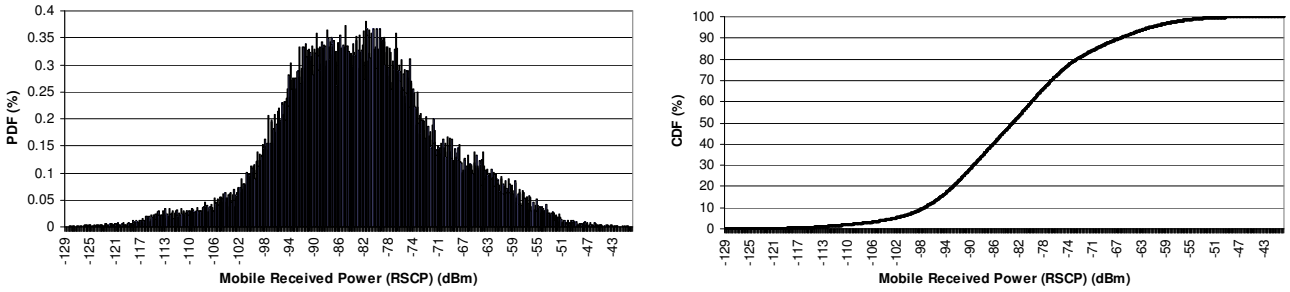

Figure 2. Mobile Received Signal Code Power (RSCP) Probability Density Function (PDF) (left) and Cumulative Distribution Function (CDF) (right) for an AWS UMTS Network from Drive Test Measurements from Market A.

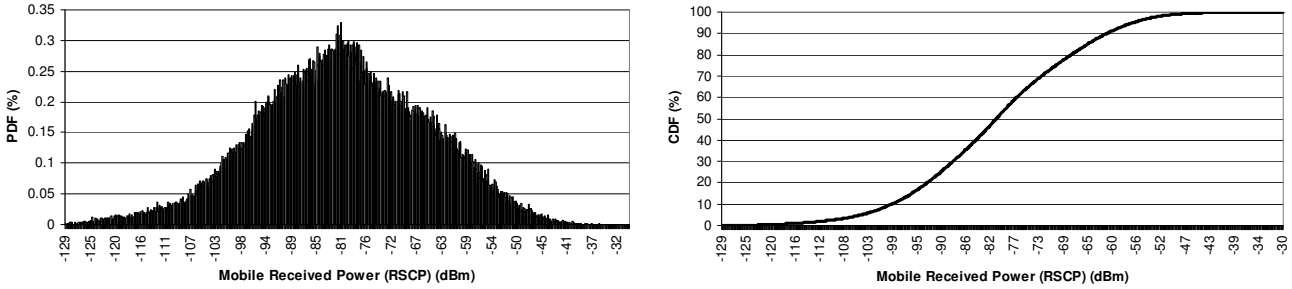

Figure 3. Mobile Received Signal Code Power (RSCP) Probability Density Function (PDF) (left) and Cumulative Distribution Function (CDF) (right) for an AWS UMTS Network from Drive Test Measurements from Market B.

With regard to typical interfering AWS-3 terminal device transmit power levels, it is quite probable that broadband data devices will be transmitting at high power when sending data, even in relatively good radio conditions. To accommodate transmission of high data rates, it is common for wireless air interfaces to adopt mechanisms which can directly or indirectly result in the need for higher transmit powers (e.g. lowering the spectral spreading ratio, reducing processing gain, use of multiple spreading codes, lessening the forward error correction, switching to higher order modulations). For example in Orthogonal Frequency Division Multiple Access (OFDMA) systems such as IEEE 802.16 WiMAX, transmitting at high data rates often necessitates high order modulations, such as 16-QAM or 64-QAM (16 or 64 level Quadrature Amplitude Modulation).[17] Communications theory posits that moving to a higher order modulation, it is possible to send more bits per symbol; however, because the levels representing the information states are closer together with higher order modulations, they are more susceptible to noise and interference.[18] Management of mobile transmit power for broadband and multimedia wireless applications is a challenging research topic due to the transmit power

[17] See D. Poulin, *How to meet the design challenges of WiMAX power amplifiers*, Wireless Net Design Line, June 10, 2008.
[18] See for example J. Proakis, *Digital Communications*, Second Edition, McGraw-Hill, 1989, pp. 278-289.

demands.[19] The result is that transmitting higher data rates, for given bandwidth and signal conditions, often necessitates higher transmit powers to achieve acceptable bit error rates. A broadband, high data rate service will thus most often require relatively high transmit powers from the terminal devices.

Broader analysis arriving at a similar conclusion can be drawn from a more fundamental assessment based on information theory using Shannon's channel capacity theorem. Shannon's theorem provides a bound on the maximum amount of digital data that can be transmitted over a communications link within a specified bandwidth in the presence of noise and hence is independent of the particular air interface (e.g. WiMAX, UMTS WCDMA, CDMA2000). Shannon's equation is

$$C = B \log_2(1 + S/N)$$

where C is the channel capacity in bits/sec, B is the channel bandwidth in Hz and S/N is the signal-to-noise ratio power ratio at the input to the receiver.[20] For a fixed channel bandwidth, B, such as that for an AWS-3 channel, the signal-to-noise ratio, S/N, must be raised to increase the channel capacity, C, to support high data rates. With a fixed noise level (in practice this would be noise plus interference), to increase the S/N requires that the received signal level increase, which is accomplished by increasing the transmit power. Note also that the channel capacity grows only logarithmically with increases in signal-to-noise ratio, which means that relatively larger increases in signal level, and hence transmit power, are required to facilitate even modest channel capacity enlargement. The unavoidable consequence is, in fixed channel bandwidth and signal conditions, transmitting higher data rates incurs the penalty cost of higher transmit powers.

The requirement for high terminal device transmit powers to support broadband data services in the uplink is highlighted by the presence in the market of PC wireless data modem cards (e.g. Sierra Wireless Aircard 595U USB card) with integrated, rechargeable batteries to support the additional transmit power requirements associated with transferring high data rates in the uplink.

As a practical illustration of the actual uplink transmit powers observed for UMTS, drive tests were performed with mobiles uploading data to the network, as would be the case for broadband data services. The drive tests on T-Mobile's network used the UMTS High Speed Uplink Packet Access (HSUPA) capability, which supports wireless broadband data services for the uplink. It is important to again note that these drive tests results do not include any indoor test cases where received power statistics typically would be considerably lower and transmit powers higher. Figure 4 shows a scatter plot of User Equipment (UE) handset transmit powers versus the RSCP received power, along with the average uplink transmit versus downlink received power. As has been explained above, with high rate data services it is often necessary to have high uplink transmit powers even when

[19] See K. M. Koumadi, K. Sohaib, W. Chirwa, and Y. Han, *Uplink Rate and Power Allocation at Mobile Stations for Multimedia Services,* IEEE 66th Vehicular Technology Conference, Sept. 30 to Oct. 3, 2007, p. 1757.
[20] See for example L. W. Couch II, *Digital and Analog Communications Systems*, Third Edition, McMillan, 1990, pp. 18-19.

users are in relatively good radio conditions. This can easily be observed from Figure 4 where even in excellent RSCP received power conditions of up to -80 dBm the required UE mobile transmit powers are often 'pegged' at the maximum value (the clusters of crosses lined along the upper part of the scatter plot with UE transmit power at 23 dBm or more). In radio conditions that were not ideal, with RSCP received powers at or below -100 dBm, the UE transmit power was nearly always 'pegged' at or near the maximum due to the effects of power control, as can be observed in the upper right part of Figure 4 (the line of crosses and horizontal flat part of the average line).

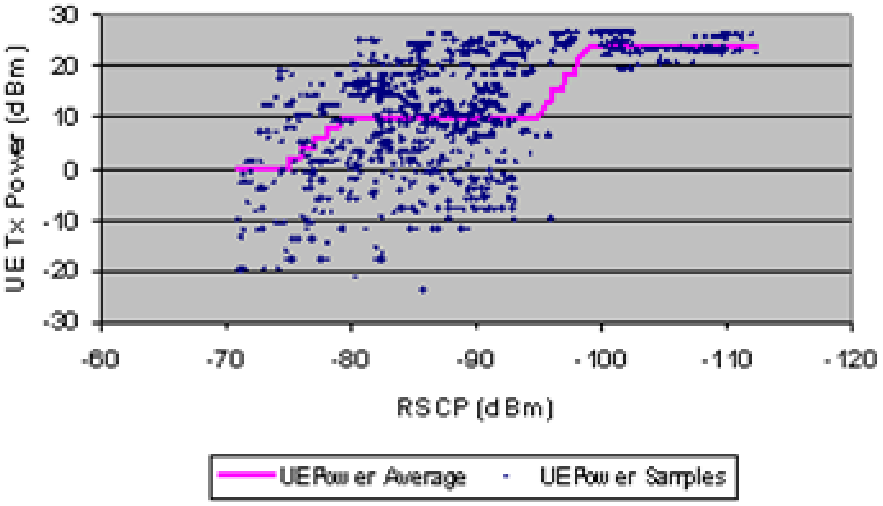

Figure 4. User Equipment (UE) Handset Transmit Power versus Received Signal Code Power (RSCP) for High Speed Uplink Packet Access (HSUPA) Mobile Drive Test.

Another factor to consider is the potential correlation between low desired signal receive powers and high interference transmit powers. It is typical for wireless service providers to have their base stations co-located with other wireless operators, because of the limited tower and antenna site real estate options available (*e.g.* through a limited number of tower lease companies). For example, it is common to visually observe cell towers or building mounts with antennas from three to five different wireless carriers. New wireless service provider market entrants, such as those who might provide services in the AWS-3 band, would likely be leasing tower space from these same tower companies. This makes it likely that both the serving and the interfering base stations would be in the same geographical vicinity. Therefore it is quite probable that interfering AWS-3 terminal devices will be transmitting at high or full transmit power in the same areas as AWS-1 mobiles are simultaneously receiving low serving signal powers. In these collocated or similarly located base station scenarios, it might be surmised that the AWS-3 transmit powers and AWS-1 receive powers would tend to be inversely correlated, meaning that it is likely the AWS-1 receive powers will tend to be low precisely where the AWS-3 transmit powers tend to be high.

5 TEST SETUP AND CALIBRATION

5.1 Test Setup

A diagram of the laboratory test setup is shown in Figure 5. Three different models of T-Mobile UMTS WCDMA[21] phones were tested in conducted mode (cabled test environment). Two of the mobile phones under test are part of T-Mobile's current commercial WCDMA offering (*i.e.* currently available at T-Mobile retail stores), and the third one is a pre-commercial mobile. The mobile phones under test were designed according to the WCDMA 3GPP specifications and the commercial models are FCC certified.

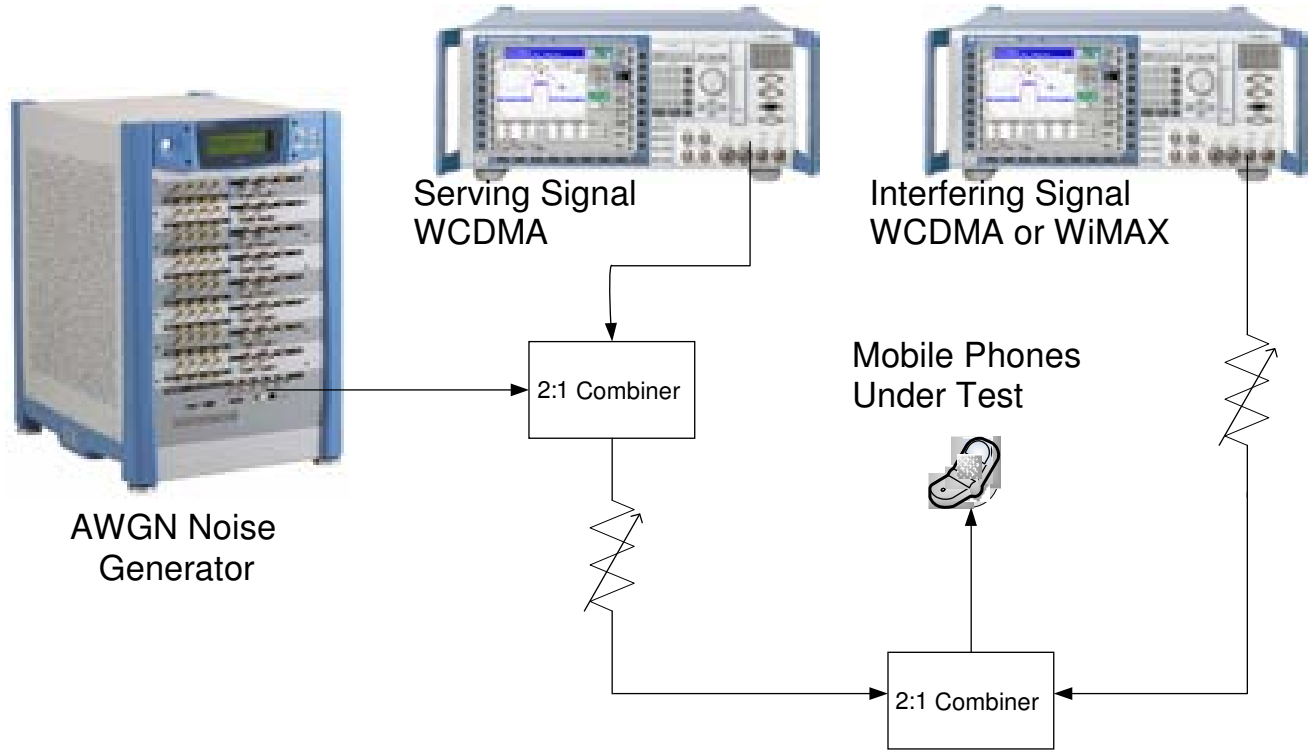

Figure 5. Diagram of Laboratory Experimental Setup.

[21] Wideband Code Division Multiple Access (WCDMA) is the air interface technology defined for the Universal Mobile Telecommunications System (UMTS) within the 3GPP.

5.2 Serving and Interfering Signal Configurations

A base station transceiver system (BTS) emulator was used to generate the WCDMA serving signal, additional BTS emulators were used to generate the interfering WCDMA and WiMAX signals, and a fading channel simulator was used to create the AWGN noise. Details about the test equipment models and serial numbers are presented in Appendix A.

The configuration of the WCDMA serving signal in the AWS-1 band was as follows: the pilot channel was configured as 10% of the maximum transmit power, with other common channels accounting for another 8% of the maximum power. The serving BTS signal included 50% traffic load generated with an Orthogonal Channel Noise Source (OCNS) embedded in the BTS equipment.[22] To create realistic channel conditions, the serving signal was mixed with AWGN until the signal-to-noise ratio reached T-Mobile's network design criteria (pilot channel energy-per-chip to noise spectral density ratio Ec/No = -12 dB) for pilot power coverage (received signal code power RSCP = -105 dBm). The Ec/No value of -12 dB represented a 3 dB increase in the noise plus interference level, which was consistent with typical industry test conditions for intersystem interference.[23]

The WCDMA interfering source was a 5 MHz single carrier modulated signal. The WiMAX interfering signal was configured for different channel bandwidths, OFDMA sub-channel configurations and activity factors.

Figure 6 a screen shot of the power spectral density of a WCDMA waveform with 5 MHz channel bandwidth. This configuration was used for the test cases with WCDMA as the interfering signal source.

Figure 7 shows a screen shot of the power spectral density of a WiMAX OFDM waveform with 10 MHz channel bandwidth. This particular WiMAX configuration represents a raw uplink data rate of about 230 kbps. Several other different configurations of WiMAX parameters were also tested, including different channel bandwidths, sub-channel setups and activity factors. The various WiMAX signals tested were deemed to be representative of what might be utilized by WiMAX terminal devices operating in a broadband wireless network.

[22] The OCNS setting of 50% traffic load (or 3 dB noise plus interference increase) is common practice in CDMA design and corresponds to T-Mobile's network design guidelines.
[23] See 3GPP Technical Specification 25.942, Section 4.2.1.

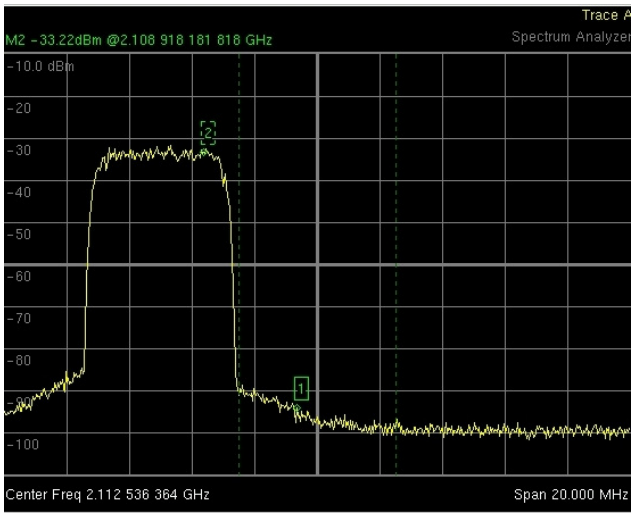

Figure 6. WCDMA Power Spectral Density with 5 MHz channel bandwidth.

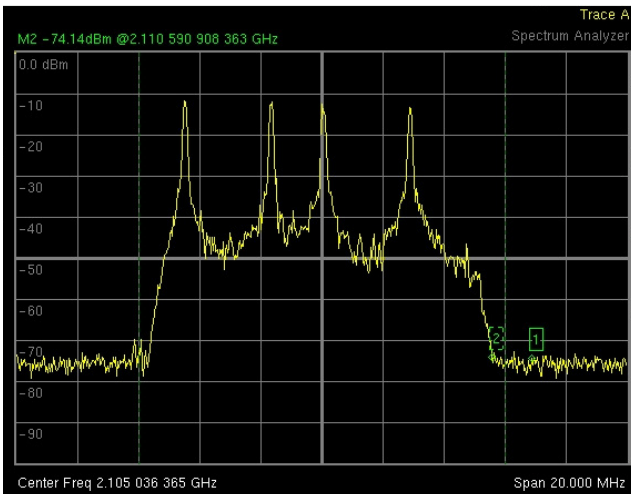

Figure 7. WiMAX Power Spectral Density with 10 MHz channel bandwidth.

5.3 Calibration

The path loss for all equipment was measured and recorded independently for each mobile device under test. The power measurements were performed using a spectrum analyzer, as well as with received power reported by the mobile through the WCDMA measurement reports. The measurement reports, which included pilot channel Received Signal Code Power (RSCP), Block Error Rate (BLER) and pilot channel energy-per-chip to noise spectral density ratio (Ec/No), were monitored in real-time.

6 TEST PROCEDURES AND RESULTS

6.1 Out-of-Band Emissions (OOBE) Tests

6.1.1 Test Procedure

The test procedure was as follows:

1. Connect and calibrate the mobile to the interfering, serving and AWGN signal sources through cables (conducted mode)
2. Set the serving BTS frequency channel to 2152.5 MHz
3. Set the BTS power so that the mobile reports a serving level RSCP= -105 dBm.
4. Adjust the AWGN noise power until the reported Ec/No= -12 dB.
5. Set the interfering signal to the 2152.5 MHz frequency channel[24], with a transmit power of -80 dBm (-120 dBm seen at the AWS-1 mobile).
6. Attempt to establish a WCDMA call. If the connection is successful, record the Ec/No and BLER. Note if the connection drops. Disconnect the call after 10 seconds.
7. Increase the interference level by 1 dB and repeat steps 5 to 7 until serious degradation occurs.
8. Set RSCP= -100 dBm and repeat steps 5 to 7.
9. Set RSCP= -90 dBm and repeat steps 5 to 7.
10. Repeat steps 1 to 9 with the different AWS-1 mobile devices under test.

The outcome of these tests yielded the maximum tolerable interference power by the different mobile devices under test, at different levels of the serving signal power. The interference power was reported as the power (in dBm/MHz) at the antenna port of the AWS-1 mobile. The maximum transmit power of the mobile operation in AWS-3 was derived as the equivalent transmit power (in dBm/MHz) assuming a coupling loss of 40 dB at one meter separation distance, shown in the third column of Table 1.

6.1.2 Test Results with WCDMA as Interfering Signal

Table 1 lists the in-band interference levels at which serious degradation (typically connection failure) occurred on the AWS-1 test mobiles in the presence of the interfering signal. The equivalent OOBE formulas

[24] Tests were performed with the interference tuned to the same channel as the received signal. The interference power injected represents the part of the AWS-3 transmit power that effectively leaks into the AWS-1 received channel. The results of the tests helped determine the attenuation that the AWS-3 transmit filter should have on the adjacent band (*i.e.* leakage power = TX Power – OOBE attenuation).

were derived from the transmitter attenuation required to achieve the measured maximum interference level. The following illustrates the example for mobile A at RSCP = -105 dBm:

- Maximum interference level = -66 dBm/MHz
- Maximum UE[25] Transmit Power = 23 dBm/MHz → Required attenuation = 23 – (-66) = 89 dB
- OOBE attenuation = X + 10log(P) (P in W/MHz) = 89
- X + 10log(P) (P in W/MHz) = 89 + 30 = 119 → X + 23 = 119 → X= 119 – 23 = *96*

Table 1 shows what OOBE limits should be imposed on the AWS-3 mobile in order to avoid severe degradation on a victim AWS-1 mobile at one meter separation distance, assuming the maximum mobile transmit power indicated in the NPRM (23 dBm/MHz) was used.

Table 1. Maximum Interference Levels and Derived OOBE Formulas.

	Serving signal power RSCP (dBm)	Derived Interference level in dBm/MHz When Call Setup Failed at Equivalent Attenuation to one meter Separation	Equivalent OOBE (P in W/MHz)
Mobile A	-105	-66	96 + 10log(P)
	-100	-56	86 + 10log(P)
	-90	-44	74 + 10log(P)
Mobile B	-105	-61	91 + 10log(P)
	-100	-52	82 + 10log(P)
	-90	-41	71 + 10log(P)
Mobile C	-105	-60	90 + 10log(P)
	-100	-51	81 + 10log(P)
	-90	-42	72 + 10log(P)

While all tested handsets comply with the 3GPP specifications for WCDMA, they failed at different interference power levels, within about a 6 dB range. This would be expected from typical manufacturer and model variations.

The test results demonstrated that the FCC FNPRM's proposed OOBE failed to protect the AWS-1 devices from harmful interference (36 dB shortfall on isolation) for one meter separation distance. With the proposed limits, AWS-1 customers would be unable to communicate within an extremely large radius (greater than 60 meters) around an AWS-3 device transmitting at full power.[26]

[25] User Equipment (UE) is a defined term for mobile terminal devices within 3GPP.

[26] The extra 36 dB of required isolation would correspond to a radius greater than 60 m assuming free-space propagation and line of sight. The equivalent distance can be calculated as 36=20log(Δd) → Δd = 10^(36/20)=63 m (total distance = 1m + Δd = 64m)

6.2 Combined OOBE and Adjacent Channel Interference Tests

6.2.1 Test Procedure

The test procedure was as follows:

1. Connect the mobile to the interfering, serving and AWGN signal sources through cables (conducted mode). Calibrate the path loss from each of the sources.
2. Set the serving BTS frequency channel to 2152.5 MHz.
3. Set the interfering signal to the 2157.5 MHz frequency channel (5 MHz separation).
4. Set the BTS power so that the mobile reports a serving level RSCP= -105 dBm.
5. Adjust the AWGN noise power until the reported Ec/No equals -12 dB.
6. Fix the AWS-3 interference power at -30 dBm/5 MHz. (approximating a WCDMA signal).
7. Adjust the variable attenuator value to set the required interference level.
8. Attempt to establish a WCDMA call. If the connection is successful, record the Ec/No and BLER. Note if the connection drops. Disconnect the call after 10 seconds.
9. Increase the interference level by 1 dB and repeat step 8 until serious degradation is found.
10. Set RSCP= -100 dBm and repeat steps 7 to 8.
11. Set RSCP= -90 dBm and repeat steps 7 to 8.
12. Set the interfering signal to different frequency separations: 10, 15 and 20 MHz and repeat steps 7 through 11.
13. Tune the serving BTS signal to 2112.5 MHz, and set the interfering at 2107.5 MHz (5 MHz separation). Repeat steps 4 to 11.
14. Repeat steps 1 to 13 with the different AWS-1 mobiles under test.

The outcome of these tests yielded the maximum allowed transmit power levels for the different mobiles under test, at different values of the serving signal strength. The transmit power level was reported in dBm/MHz for one meter separation distance (equivalent to a coupling loss of approximately 40 dB).

6.2.2 Test Results with WCDMA as Interfering Signal

The test equipment exhibited a suppression of OOBE by 50 dB for the adjacent channel at 5 MHz and 57 dB at 10 MHz or more; these suppressions are equivalent to an OOBE of 57+10 log(P) and 64+10 log(P), respectively. These levels of OOBE suppression are believed to be consistent with or better than what commercially available mobile duplex filters typically achieve (*e.g.* 30-50 dB).

The results of the tests demonstrated that the proposed AWS-3 service rules in the FNPRM can result in a significant degradation to WCDMA service in AWS-1. Table 2 lists the interference AWS-3 transmit power levels which caused call setup failure at one meter separation with different guard bands.

Table 2. Maximum AWS-3 Transmit Power Allowed to Avoid Debilitating Interference at one meter Separation Based on Measured Test Results.

Serving Signal Center Frequency 2112.5 MHz	Serving Signal Received Power RSCP (dBm)	AWS-3 Mobile Transmit Power Level (dBm/MHz) When Call Setup Failed at one meter Separation			
		0 MHz Guard Band	5 MHz Guard Band	10 MHz Guard Band	15 MHz Guard Band
Mobile A	-105 dBm	-10	-6	-5	-7
	-100 dBm	-3	1	3	3
	-90 dBm	8	16	16	17
Mobile B	-105 dBm	-11	-5	-2	-3
	-100 dBm	-4	5	6	5
	-90 dBm	4	11	12	14
Mobile C	-105 dBm	-11	-6	-6	-4
	-100 dBm	-2	6	7	7
	-90 dBm	6	13	15	16

As it can be observed from Table 2, even at strong receive signal powers (*i.e.* RSCP = -90 dBm) the AWS-1 mobiles cannot communicate when physically near an AWS-3 mobile device transmitting at the maximum transmit power levels proposed by the FCC FNPRM (23 dBm/MHz).

6.2.3 Test Results with WCDMA Using Additional AWS-3 Transmit Filtering

Using a custom-made AWS-3 transmit filter ordered by T-Mobile specifically for this laboratory study, additional tests were conducted to quantify the absolute limits on AWS-3 mobile transmit power levels. With this external filter placed in the modified experimental test setup, the effects of OOBE could be significantly reduced to aide in measuring the AWS-3 interference power levels at which AWS-1 receiver overload occurs. The interference source used for these tests was a WCDMA signal.

Figure 8 shows the measured frequency response of the filter, which provides an overall attenuation of approximately 30 dB throughout the 2150-2155 MHz AWS-1 F-block channel.

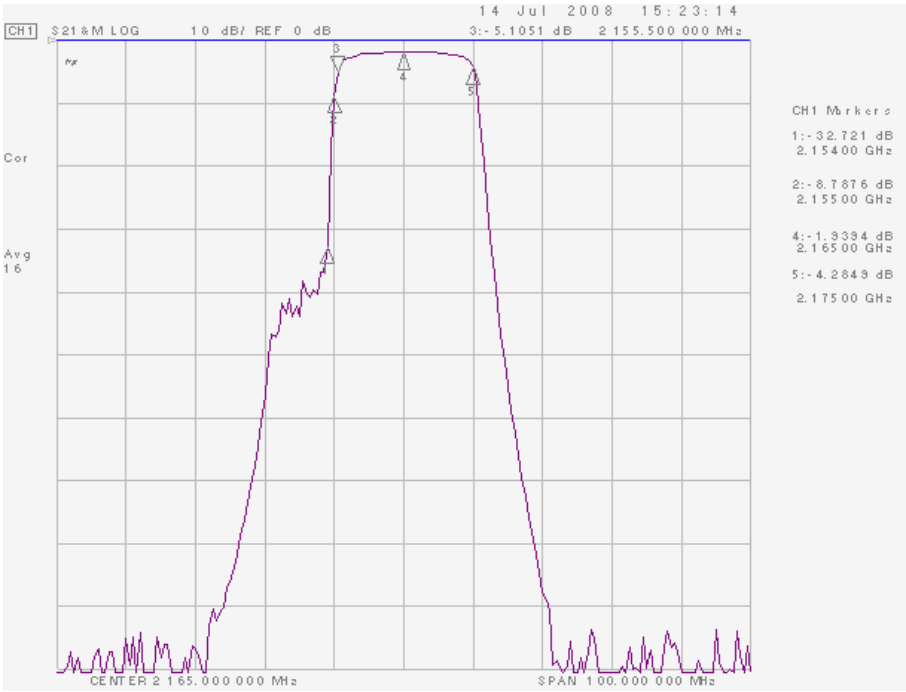

Figure 8. Custom AWS-3 Transmit Filter Response Frequency Response.

The attenuation response of the filter at specific AWS frequencies of interest is listed in Table 3.

Table 3. Measured Attenuation Response of Custom Filter at Selected Frequencies.

Frequency (MHz)	2154	2155	2155.5	2165	2175
Attenuation Measurement (dB)	-32.7	-8.8	-5.1	-1.9	-4.2

In the modified experimental test set up, the custom filter was placed after the AWS-3 interference signal source to attenuate the OOBE falling inside the AWS-1 channel, as shown in Figure 9. The overall rejection of emissions in the AWS-1 band corresponds to the combined attenuation from the filter inside the interference source equipment, plus this custom external filter. In this case, the OOBE rejection ranged between 87+10log(P)

for the adjacent channel, and 94+10log(P)[27] for channel separations greater than 10 MHz. These values are quite close to the previously indicated 96+10log(P) for OOBE requirements (see Section 6.1.2 for details).

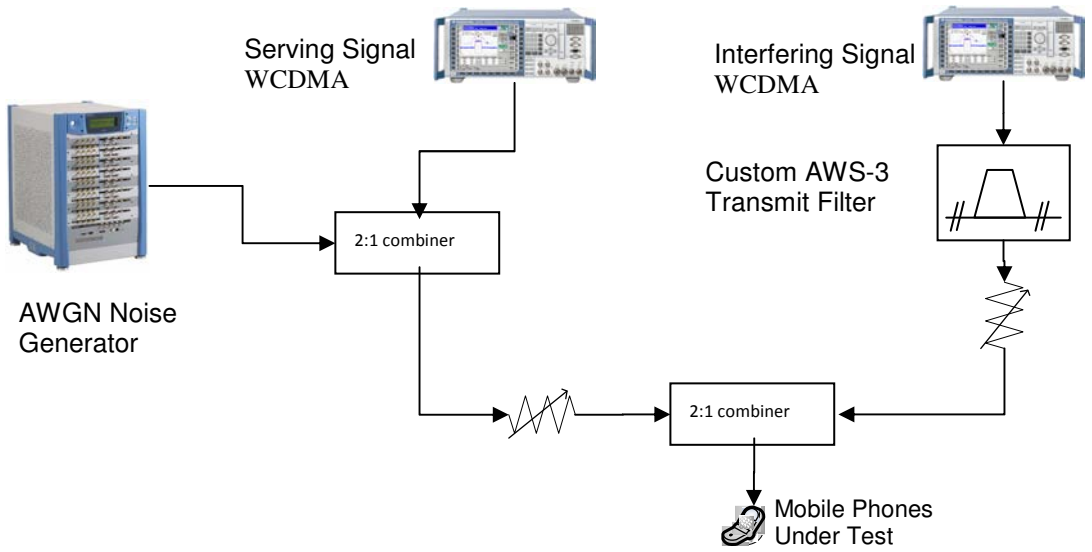

Figure 9. Diagram of Modified Experimental Test Setup with Additional Custom AWS-3 Transmit Filter Inserted After the Interfering Signal Source.

It was believed that with the OOBE rejection values afforded by the addition of the custom filter, the mobiles under test would be limited by the adjacent channel interference captured by the AWS-1 receiving filter, thus causing receiver overload or blocking to become the dominant interference mechanism.

Table 4 presents the AWS-3 transmit power levels at which debilitating interference occurred in the AWS-1 mobiles under test at path loss attenuations equivalent to one meter separation distance. Note that with no guard band 2 dBM/MHz could be tolerated, and for 15 MHz guard band 10 dBm/MHz could be tolerated by the AWS-1 mobile before debilitating interference occurred.

[27] The revised OOBE with external filter is calculated as follows: revised OOBE = previous OOBE + 30 dB. The previous filter response was 57+10log(P) for 5 MHz, and 64+10log(P) for 10 MHz. The combined response was therefore 57+30+10log(P) = 87+10log(P) for 5 MHz, and 64+30+10log(P) = 94+10log(P) for 10 MHz.

Table 4. Measured AWS-3 Transmit Power that Caused Debilitating Interference.

	Maximum AWS-3 Transmit Power with Different OOBE Limits (dBm/MHz)							
	0 MHz Guard Band		5 MHz Guard Band		10 MHz Guard Band		15 MHz Guard Band	
OOBE	57 +10log(P) [without custom filter]	87 +10log(P) [with custom filter]	64 +10log(P) [without custom filter]	94 +10log(P) [with custom filter]	64 +10log(P) [without custom filter]	94 +10log(P) [with custom filter]	64 +10log(P) [without custom filter]	94 +10log(P) [with custom filter]
Mobile A	-13	3	-8	8	-7	8	-9	10
Mobile C	-13	2	-10	9	-7	13	-6	12

6.2.4 Test Results with WiMAX as Interfering Signal

Due to the time constraints associated with the comment period for the FCC's FNPRM, even after an extension was granted, only a limited amount of testing could be performed with WiMAX as the interfering signal source. The results of these tests emulating WiMAX as the air interface used by the AWS-3 terminal device are presented in this section.

At the present time, test results consistently suggest that WiMAX creates worse interference than WCDMA as the interfering source. T Mobile is continuing to perform additional tests with WiMAX. We would welcome the participation of parties interested in deploying WiMAX in the AWS-3 band to participate in these ongoing tests.

Table 5 shows the interference powers where debilitating interference occurred to the AWS-1 mobile using WiMAX as the interference source. Separate columns present the interfering transmit power levels where call setup failed and where excessive BLER > 3% was observed. Path loss attenuation values were set up to emulate a one meter separation between AWS-1 mobile and AWS-3 interfering terminal device. Because of the limited time available for the FCC FNPRM comment period, only test mobile A was used for this testing. As with prior tests, different adjacent channel configurations were tested, reflecting the absence of guard band (first adjacent channel) as well as 5 MHz (second adjacent channel) and 10 MHz (third adjacent channel) guard bands.

In Table 5 results are presented for a number of different WiMAX configurations of channel bandwidths, sub-carrier allocations and activity factors. Two configurations of WiMAX at 10 MHz channel width are shown

along with two configurations at 20 MHz. The configurations represent different sub-carrier allocation schemes and uplink activity factors ranging from 25% to 100% (since WiMAX is a TDD system with the terminal device transmitting for only 50% of the time, these uplink activity factors equate to between 12.5% and 50% total activity). These WiMAX configurations equate to raw data rates ranging from 230 kbps to 5.4 Mbps; these were selected to represent the range of data rates that might be expected in a wireless broadband access network operating in AWS-3. Several other different configurations of WiMAX parameters were also tested, including different channel bandwidths, sub-channel setups and activity factors. The range of WiMAX configurations tested was believed to be representative of what might be utilized by WiMAX terminal devices operating in a broadband wireless access network.

The WiMAX test results presented in Table 5 clearly demonstrate that WiMAX terminal devices operating in AWS-3 using the FCC FNPRM's proposed service rules would cause harmful interference to AWS-1 WCDMA mobiles. The FCC proposed AWS-3 service rules in the FNPRM can result in a significant degradation to WCDMA service in AWS-1.

Table 5. Maximum AWS-3 Transmit Power Allowed to Avoid Debilitating Interference at one meter Separation Based on Measured Test Results for a Range of WiMAX Configurations.

Serving Frequency 2112.5 MHz	Interference Type (Channel Width, Air Interface)	Interference Power Where Call Setup Failed at Equivalent to One meter Separation (dBm/MHz)			Interference Power Where BLER > 3% at Equivalent to One meter Separation (dBm/MHz)		
		0 MHz Guard Band	5 MHz Guard Band	10 MHz Guard Band	0 MHz Guard Band	5 MHz Guard Band	10 MHz Guard Band
Mobile A	10 MHz WiMAX [Note 1]	-8	-2	0	-1	4	8
	10 MHz WiMAX [Note 2]	-5	1	4	-3	5	9
	20 MHz WiMAX [Note 3]	-7	N/A	N/A	-3	N/A	N/A
	20 MHz WiMAX [Note 4]	-9	N/A	N/A	-4	N/A	N/A

Serving Signal Received Power RSCP = -105dBm

Note 1: WiMAX Interfering Signal was configured with 8 of 16 sub-channels active, 10 MHz channel bandwidth, raw data rate ~2.3 Mbps
Note 2: WiMAX Interfering Signal was configured with 1 of 16 sub-channels active, 48% activity factor, 10 MHz channel bandwidth, raw data rate ~230 kbps
Note 3: WiMAX Interfering Signal was configured with all sub-channels on, 25% activity factor, 20 MHz channel width, raw data rate ~1.4 MBps
Note 4: WiMAX Interfering Signal was configured with 100% activity factor, 20 MHz channel width, raw data rate ~5.4 Mbps

The laboratory test results with WiMAX as an interfering source emulating the AWS-3 terminal device thus far have demonstrated that AWS-3 WiMAX will cause harmful interference to AWS-1 WCDMA mobiles. T-Mobile is continuing to perform additional laboratory test cases with WiMAX as an interfering source.

7 CONCLUSIONS

The results from these tests demonstrate that there are likely to be serious interference problems to AWS-1 mobiles if the rules currently proposed in the AWS-3 FNPRM are adopted. These problems are likely to be predominantly due to OOBE from the AWS-3 transmitters into the AWS-1 receive band, a problem against which AWS-1 mobiles are wholly defenseless (meaning that no amount of AWS-1 duplex receive filtering can remove it). In order to avoid harmful OOBE emissions at one meter separation distance, the AWS-3 filters should be designed to implement an attenuation of 96+10 log (P) (P in W/MHz).

The tests using WCDMA as a interfering signal source further demonstrated that with the FCC NPRM's proposed OOBE of 60+10log(P), the AWS-3 mobile transmit power level had to be limited to between -11 dBm/MHz (adjacent channel with no guard band) and -4 dBm/MHz (with 15 MHz guard band). Additional tests were performed using transmit filtering with OOBE extremely close to the 96+10log(P) derived from earlier tests, with these measurements indicating that maximum AWS-3 transmit power levels of 2 dBm/MHz with no guard band and 10 dBm/MHz with 15 MHz guard band could be tolerated.

Tests using a WiMAX signal source at OOBE of 60+10log(P) indicated that if AWS-3 used WiMAX the transmitter powers would have to be limited to -9 dBm/MHz for 20 MHz WiMAX channel bandwidth with no guard band.

7.1 Further Work

T-Mobile is continuing to perform additional tests cases to investigate the interference scenarios with Mobile WiMAX (IEEE 802.16e) as an interference source. WiMAX is a TDD system and therefore the results should be representative of the likely real-world scenario in a future AWS-3 TDD broadband wireless network, as would be permitted under the FCC's currently proposed rules.

APPENDIX A TEST EQUIPMENT LIST

Table 6 lists the details of the test equipment used in the laboratory test setups.

Table 6. List of Test Equipment Used in Laboratory Experiments.

Model	Description	Manufacturer	Part Number	Serial Number
CMU-200 (Serving Signal)	Universal Radio Communication Tester	Rohde & Schwarz	11000008K02	111777
CMU-200 (Interference source)	Universal Radio Communication Tester	Rohde & Schwarz	11000008K02	111775
SMJ-100A[28] (Interference source)	Vector Signal Generator	Rohde & Schwarz	14034507K02	101110
Prop Sim C-8 (AWGN noise generator)	Wideband Channel Emulator	Elektrobit	C-8	215009
374BNM	50ohm Load	Narda	374BNM	2X000332
MT8222A	BTS Master	Anritsu		0745103
700	Variable Attenuator	Narda	0-11db/1db increments	10372942
8495A	Variable Attenuator	HP	0-70db/10db increments	1X436780
AC119A-99.43	Variable Attenuator	AeroFlex Weinschel	0-90db/10db 0-9db/1db increments	21955
WPD-50/2	Combiners (2)	Trilithic	N/A	N/A
152-043-002	Combiner	Broadwave	N/A	N/A

[28] Rhode and Schwarz SMJ-100A Vector Signal Generator complies with IEEE 802.16 WiMAX specifications.

APPENDIX B ACRONYMS AND ABBREVIATIONS

Table 7 defines the acronyms and abbreviations used in the test report.

Table 7. Table of Acronyms and Abbreviations used in the Test Report.

Acronym	Definition
ACI	Adjacent Channel Interference. Refers to the amount of interference captured by a victim receiver from a transmitter that is operating in a frequency other than the receiver's frequency.
ACS	Adjacent Channel Selectivity. Indicates the ability of the receiver to operate without significant degradation in the presence of an interference source transmitting in a frequency channel adjacent to the receiver. The Adjacent Channel Selectivity is defined for the adjacent channel (5 MHz), while the Blocking Requirements are specified for more than 10 MHz of frequency separation.
BLER	Block Error Rate
OFDMA	Orthogonal Frequency Division Multiple Access
OOBE	Out-Of-Band Emission. Refers to the amount of interference leaking from a transmitter into the victim's receiving band. It is manifested at the receiver as co-channel interference.
RSCP	Received Signal Code Power. Refers to the pilot channel received power in UMTS WCDMA mobiles.
TDD	Time Division Duplex
QAM	Quadrature Amplitude Modulation
WCDMA	Wideband Code Division Multiple Access
UE	User Equipment. Refers to the mobile, handset or terminal device in UMTS.
UMTS	Universal Mobile Telecommunications System