Advanced Wireless Service Interference Tests Results and Analysis

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I. Introduction:

The Commission has initiated a proceeding to consider provisions for Advanced Wireless Service (AWS) in the 2155–2175 MHz band, referred to as AWS-3.[1] Concerns have been raised that, if the Commission were to allow time-division-duplex (TDD) operations in this spectrum under the proposed technical conditions, there is a significant risk of harmful interference from mobile devices operating in the AWS-3 band to mobile devices that receive signals in the adjacent 2110–2155 MHz band, referred to as AWS-1. The Commission also invited comment as to whether the proposed band might be expanded to 2155-2180 MHz to provide greater flexibility to mitigate harmful interference.

T-Mobile submitted into the record test results which it claims shows that under the proposed rules, harmful mobile-to-mobile interference is likely to occur.[2] To further inform the record, the Commission staff, together with interested parties, performed laboratory bench tests to investigate this interference potential on September 3-5 at a test facility in Seattle, Washington.[3] These laboratory bench tests were designed to increase understanding of T-Mobile's previously conducted tests including test setup, underlying assumptions, suitability of the equipment used and the extent to which they may be relied upon to assess the effect AWS-3 handset operations could have on AWS-1 handsets. We previously published the raw data from these tests on September 12, 2008.[4]

It is important to note that the laboratory bench tests were performed with both the desired and interfering signals coupled directly into the antenna connection of the AWS-1 mobile device. The tests were conducted at various AWS-1 receive signal levels and various frequency separations from the AWS-3 signals. Tests were also performed to investigate whether improved filtering of the AWS-1 receiver might reduce potential interference. While these tests produced important information, they are only one element in assessing the potential for harmful interference. Other elements must be considered such as what signal levels are appropriate to protect, what assumptions should be made about the typical separations between the mobile devices, and various factors that affect the coupling of signals between the devices under actual operating conditions.

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[1] *See* Service Rules for Advanced Wireless Services, WT Docket Nos. 07-195 and 05-356, *Further Notice of Proposed Rulemaking*, 23 FCC Rcd 35995 (2008).

[2] *See* http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520035719. T-Mobile submitted a report titled "AWS-3 to AWS-1 Interference Laboratory Test Report" (T-Mobile Test Report) on July 28, 2008.

[3] The joint tests were open to the public and conducted at Boeing's test facility in Seattle Washington.

[4] *See*: http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520067726.

In this report, we present the test results from the joint testing, provide an analysis of the potential for harmful interference, and make tentative conclusions as to the standards necessary to control the potential for harmful interference.[5] This report tentatively concludes that for the static case that is examined AWS-3 devices could operate at a power level of up to 23 dBm/MHz equivalent isotropic radiated power (EIRP) and with out-of-band emissions (OOBE) attenuated by 60 + 10*log(P) dB without a significant risk of harmful interference. However, this report also notes that the Commission has in the past adopted less stringent OOBE standards under flexible service rules whereby the licensees and industry work together cooperatively to manage potential interference.

II. Laboratory testing:

A. Test Setup:

The joint tests consisted of a test setup identical to that described in the T-Mobile Test Report. This is shown in Figure 1.

As shown in Figure 1, the link between the AWS-1 mobile station (MS), depicted here as a UMTS mobile station, and its associated base station (BS) was established using two signal generators (*i.e.*, a serving BS (CMU 200) and an AWGN noise generator) connected to the MS through a set of combiners and step attenuators. The function of the AWGN noise generator is to simulate the inherent noise typical within mobile systems due to factors such as loading.[6] A second signal generator is also connected to the MS through a custom filter to simulate the interfering signal (*i.e.*, the AWS-3 transmitter).

The specific tests were conducted by first establishing a link between the BS and the MS at various MS desired receive signal levels. Then, an interfering signal was injected into the system and its level was adjusted to determine the signal strength at which either a Call-Setup-Failure (CFS) or Call-Drop (CD) occurred. This interfering signal level was recorded for each combination of desired receive level and frequency separation between the BS transmitter and MS receiver. We note that parties have generally stated that UMTS or WiMAX based systems are likely to be used in the AWS-3 band. Thus, the joint tests simulated these signals as the interference sources.

[5] This report focuses only on the potential for mobile-to-mobile interference. Other interference scenarios, such as mobile-to-base, base-to-base and base-to-mobile are well understood and mitigation techniques are well established and are routinely employed by network designers.
[6] This noise is known in the standards as In-Cell and Out-of-Cell Interference.

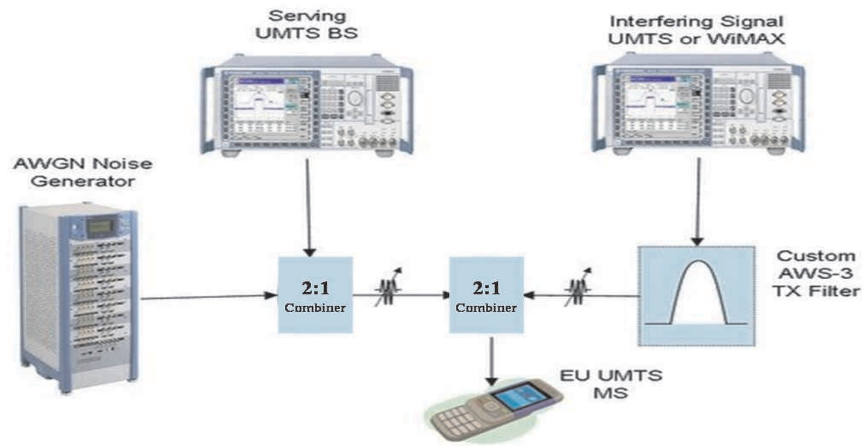

Figure 1: Test setup

B. Interference Mechanisms:

The joint tests examined two interference mechanisms - in-band interference and out-of-band (*i.e.*, adjacent band) interference – to determine the level at which an AWS-3 mobile transmitter causes interference to AWS-1 handsets. More specifically, AWS-1 in-band interference is caused by out-of-band emissions from an AWS-3 mobile transmitter that, due to practical limitations affecting how quickly the transmitter filter can roll-off or suppress emissions in the adjacent band, are located in the receive band of the AWS-1 mobile receiver. Correspondingly, AWS-1 out-of-band interference is caused by AWS-3 emissions within the AWS-3 mobile receive band that, due to the roll-off of the AWS-1 receiver filter, enter the front-end of AWS-1 receiver and causes it to saturate. This is more commonly referred to as overload interference. The specific interference scenarios of an AWS-3 mobile transmitter and an AWS-1 mobile receiver are shown in Figure 2.

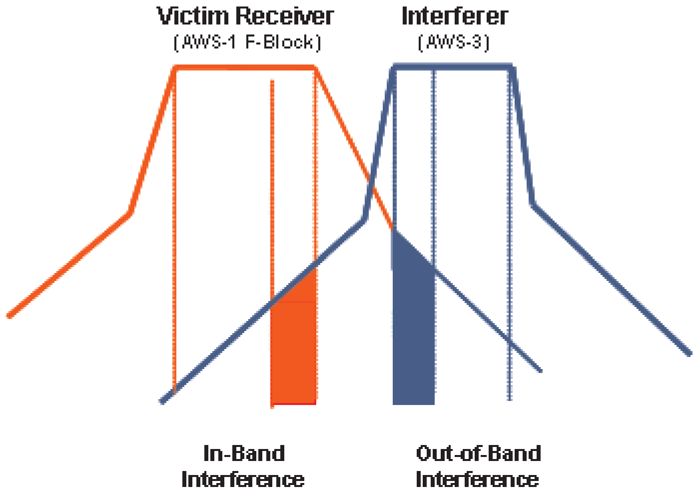

Figure 2: Representation of in-band and out-of-band interference mechanisms

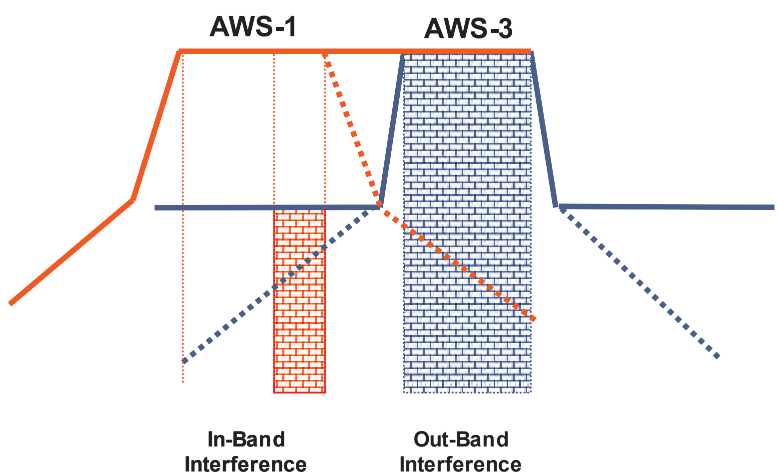

Figure 3: Representation of test equipment vs. actual performance.[7]

Transmit Masks of UMTS/WiMAX used to emulate an AWS-3 interferer in the tests.
Actual AWS-3 transmit mask follows this pattern.
Actual AWS-1 receiver extending across the entire AWS-3 spectrum.
A hypothetical AWS-1 front end filter (for illustration) pattern.

[7] If the difference is significant, as is the case here, between the predictable performance of an actual device and test equipment (emulator) the results of the test are faulty, unless the difference is accounted for somehow.

C. Characterization of mobile handsets:

The ability of a mobile handset to either cause interference to or tolerate a signal from a nearby handset is directly related to the transmit power of the interfering handset and the filter characteristics of the interferer and the victim handset. Interference potential is reduced with lower power. Similarly, steeper roll-off of the receiver and transmit filters reduces interference potential. Figure 2 shows that interference can be significantly reduced by the combined effect of the two devices' front end filters.[8]

Figure 3 shows the situation of interest in this proceeding, where the front end filter of the victim AWS-1 receiver is designed to operate across the entire AWS-3 spectrum. In such a situation conventional spectrum management practice suggests that interference can be avoided or minimized by either setting a strict power limit on the AWS-3 transmitter, or improving the filtering of the AWS-1 device to better reject signals outside the AWS-1 band.

For our testing, we did not have an actual AWS-3 handset and instead used a signal generator to simulate the interfering signals. In this regard, it is important to note that test equipment often does not function exactly like an actual handset. This appears to be the situation encountered during these tests. In practice, a transmitted RF signal concentrates most of its energy within its desired channel; outside of this channel the signal levels will fall as a function of frequency separation from the desired channel. In contrast to the way an actual handset would be expected to behave, we determined that the signal generator used in these tests simulated the interfering transmitter (*i.e.*, the AWS-3 transmitter) signals with a signal level that remained essentially constant outside of the desired channel regardless of frequency separation. This results in higher out-of-band energy levels than would typically be produced using an actual handset. The practical effect is that using the signal generator will tend to overestimate the interference potential of an AWS-3 handset. To further illustrate this point, Figure 4 shows the transmit spectrum of the AWS-1 mobile handset used in the joint testing and Figure 5 shows the spectrum for five transmitters measured by OFCOM which were used as the basis for their proposed rules in the 2.6 GHz band.[9] These are distinctly different from those generated by the UMTS/WiMAX signal generator as shown in Figures 6 and 7.

[8] This is most pronounced under static conditions such as those under which these tests were conducted. These effects also affect interference potential in a mobile environment. However, in a mobile environment we note that the occurrence of mobile-to-mobile interference is also subject to a large number of variables. Thus, such interference is affected by the statistical nature of these variables and often will only occur under the unlikely condition that several low probability events occur simultaneously. *See* Section V., *infra*.

[9] *See* OFCOM technical reports available at: http://www.ofcom.org.uk/consult/condocs/2ghzawards/2ghzawards.pdf and http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/tech.pdf.

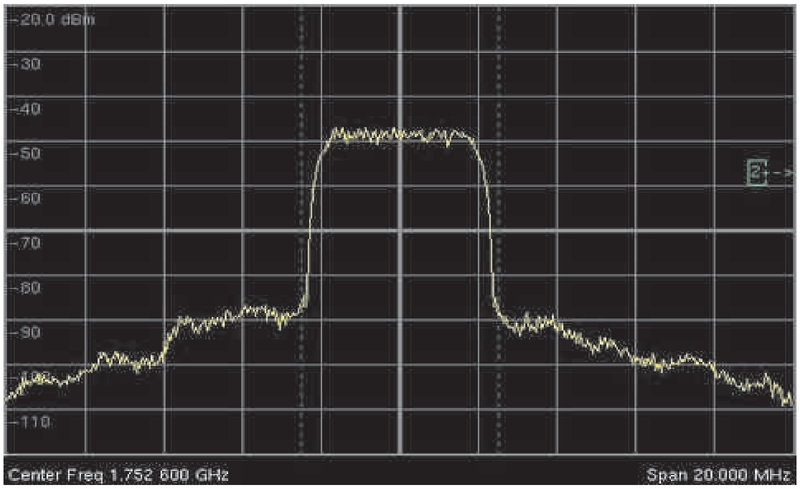

Figure 4: UMTS EU Transmit Spectrum

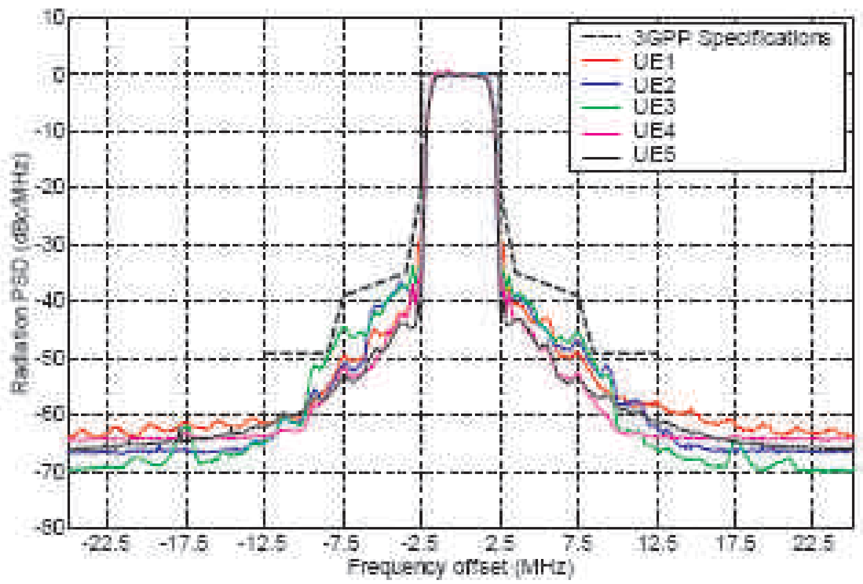

Figure 5: 3GPP Transmit Mask and OFCOM Measured Transmit Spectrum @ 2112.5 MHz[10]

[10] *See* OFCOM report, figure 17 page 41 at:http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/tech.pdf.

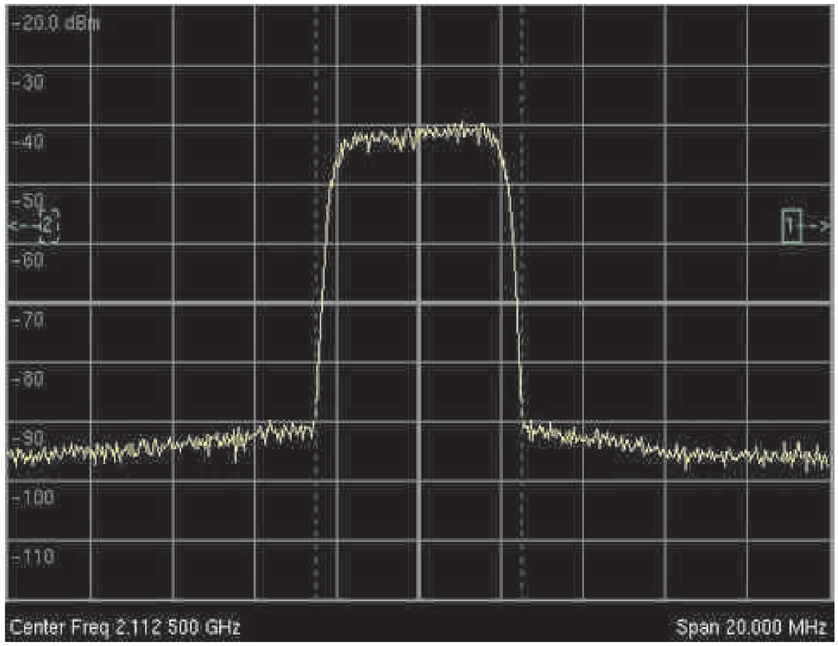

Figure 6. Signal Generator UMTS Transmitter Spectrum (Interferer)

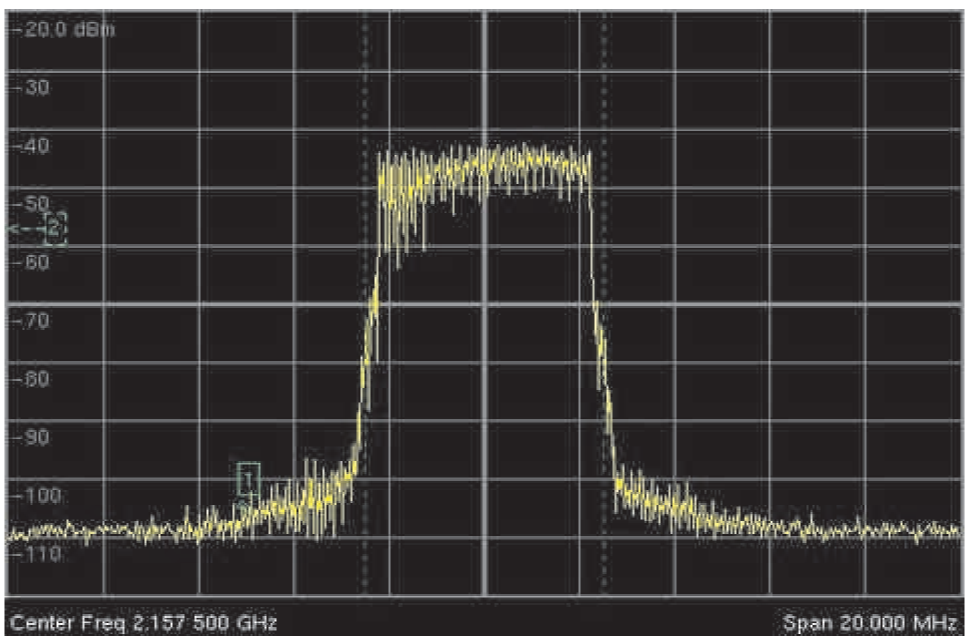

Figure 7: Signal Generator WiMAX Transmitter Spectrum (Interferer)

III. Analysis:

A. **Measurement Results**:

a. AWS-1 In-Band Interference:

As described above, this interference scenario is characterized by the AWS-3 out-of-band emissions (OOBE) that are directly in the pass band of the AWS-1 receiver.

For these tests, identical signals (*i.e.*, same frequency and bandwidth) were used for the desired and undesired signals. The test was conducted by setting the desired signal to a particular value (*e.g.*, -90 dBm) and adjusting the signal level of the interferer until an interference event – call set-up failure or call drop - was observed. The tests results are summarized in Table 1.

Desired Signal: UMTS 2152.5 MHz (dBm/5MHz)	**Interference Signal: UMTS 2152.5 MHz (dBm/5MHz)**
-105	-96.2
-100	-89.2
-95[11]	**-83.2**
-90	-77.2
-85	-72.2

Table 1: OOBE Test Results with a UMTS Interferer

We note that, though planned, OOBE measurement data with a WiMAX interfering signal were not collected. We present results for the tests we did conduct with a WiMAX interferer in Table 4 below. These tests generally show that a WiMAX signal has less potential for causing interference than a UMTS signal. Based on these observations, we can reasonably expect that WiMAX in the AWS-3 band would have less impact on an AWS-1 receiver than UMTS.

b. Receiver Overload measurement:

This interference scenario is characterized by the amount of energy within the AWS-3 channel that enters the AWS-1 receiver. In measuring overload interference, it is important to ensure that all effects of AWS-3 out-of-band interference are removed from the test. This is accomplished by using an external filter with a steep roll-off as shown in Figure 8.

The test results corresponding to overload from both UMTS and WiMAX interferer signals are summarized in Tables 2-4.

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[11] Measurements were not taken for a desired received signal level of -95 dBm. The interference signal levels shown here and below are interpolated from the results of the measurements taken.

Figure 8: Filter Response for External AWS-3 Transmit Filter for the Upper Band Edge

Desired Signal: UMTS 2152.5 MHz (dBm/5MHz)	Interference Signal: UMTS 2157.5 MHz (dBm/5MHz)	
	Combined effect of OOBE and overload interference (WITHOUT FILTER)	Overload interference only (WITH EXTERNAL FILTER)
-105	-44.2	-34.2
-100	-37.2	-30.2
-95	**-33.2**	**-28.2**
-90	-29.2	-26.2
-85	-27.2	-25.2
-75	-11.2	N/A

Table 2: Results of overload tests (with filter) versus the combined OOBE and overload interference (without filter) using a serving UMTS signal at 2152.5 MHz and a UMTS interfering signal at 2157.5 MHz.

Desired Signal: UMTS 2142.5 MHz (dBm/5MHz)	Interference Signal: UMTS 2157.5 MHz (dBm/5MHz)	
	Combined effect of OOBE and overload interference (WITHOUT FILTER)	Overload interference only (WITH EXTERNAL FILTER)
-105	-43.2	-27.2
-100	-35.2	-23.2
-95	**-29.2**	**-19.7**
-90	-23.2	-16.2

Table 3: Results of overload tests (with filter) versus the combined OOBE and overload interference (without filter) using a serving UMTS signal at 2142.5 MHz and a UMTS interfering signal at 2157.5 MHz.

Desired Signal: UMTS 2142.5 MHz (dBm/5MHz)	Interference Signal: WiMAX 2160 MHz (dBm/5MHz)	
	Combined effect of OOBE and overload interference (WITHOUT FILTER)	Overload interference only (ESTIMATED)*
-105	-30.2	-19.7
-100	-25.2	-17.2
-95	**-22.2**	**-16.2**
-90	-21.2	-15.2
-85	-19.2	-14.2

* As noted above, the tests only recorded data for a WiMAX interferer without a filter. Based on comparisons of the UMTS and WiMAX measurements for the combined effect of OOBE and overload interference, which show about a 5 to 10 dB difference between the UMTS measurements with and without the filter, we estimate the effect of overload interference from a WiMAX interferer would be about 6 dB less.

Table 4: Results of overload tests (with filter) versus the combined OOBE and overload interference (without filter) using a serving UMTS signal at 2142.5 MHz and a WiMAX interfering signal at 2160 MHz.

These tests result in the following observations:

1. Tables 2 and 3 show that overload interference improves with increased frequency separation.
2. Tables 2 and 3 show that OOBE improves with increased desired signal level.
3. Table 4 shows that the WiMAX signal provides more protection against overload interference than UMTS.

IV. Interference analyses and link budget calculations:

In this section we use a classical link budget calculation to analyze potential interference between an AWS-1 receiver and an AWS-3 transmitter. Figure 9 shows the scenario used for this analysis. An AWS-1 mobile receiver establishes a link with a serving base station (desired signal) and a nearby AWS-3 mobile transmitter is also operating (interferer). The signal level that reaches the AWS-1 device from the AWS-3 transmitter must not exceed the interference threshold level that would cause harmful interference.

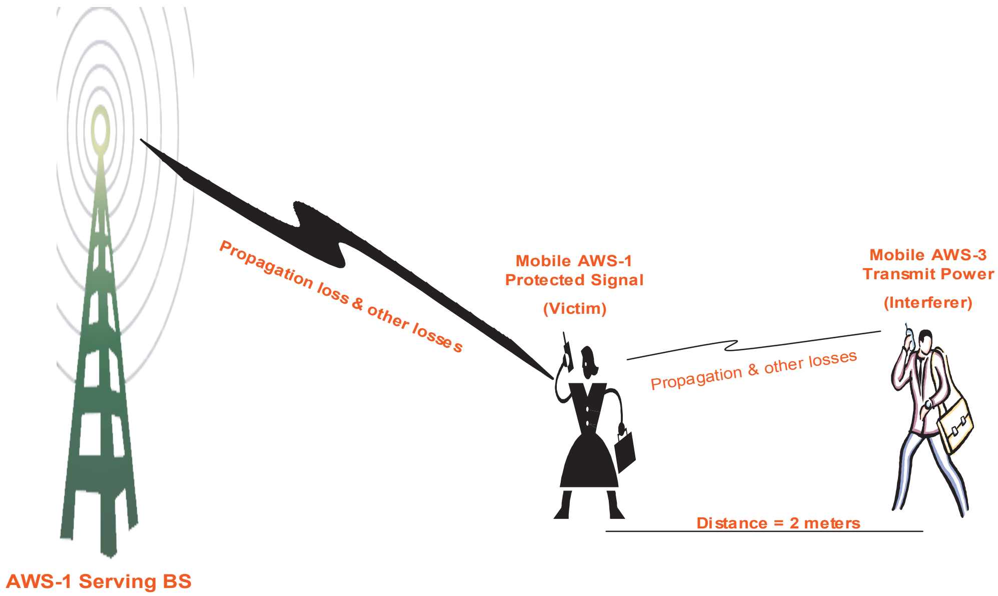

Figure 9: Interference Scenario for Link Budget Analysis

The following assumptions are used for the analysis:

- Desired AWS-1 serving signal to be protected is -95 dBm.[12, 13]

[12] The received signal code power (RSCP) measured by the user equipment (UE) receiver on the primary common pilot channel (CPICH) must be greater than -95 dBm. This is known as the high quality criterion (*i.e.*, CPICH RSCP > -95 dBm). For more information, see: Kruger and Heinz Mellein (2004). *UMTS Introduction and Measurement*. Germany: Rohde & Schwarz. 131 and Jukka Lempiäinen, Matti Manninen (2004). *UMTS Radio Network Planning, Optimization and QOSUMTS Radio Network Planning, Optimization and QOS Management: For Practical Engineering Tasks*. Michigan: Kluwer Academic Publishers. 141.

[13] The choice to protect a desired receive signal level of -95 dBm or greater is a reasonable assumption. In its Test Report, T-Mobile provides statistics relating to drive tests it conducted in two markets to assess the received signal strength that users may experience. The statistics presented in their Test Report show that for both markets, approximately 85 percent of the locations measured experience received signal levels of -95 dBm or greater. *See* T-Mobile Test Report at 13-16. We note that this data was collected from drive tests where users may use their mobile phones and not data based on actual calling patterns or locations. Nevertheless, given that most locations receive signal levels greater than -95 dBm coupled with the conservative static case analysis conducted herein, we believe that basing protection criteria on this received signal level is sufficient to protect the vast majority of AWS-1

- Interference criterion is call setup failure[14]
- Separation distance = 2 meters[15]
- Free Space Propagation Model[16]
- Head-body loss of 6 dB[17]
- Loss due to antenna mismatch of 2 dB[18]
- No loss was considered due to antenna efficiency[19]
- AWS-1 OOBE slope of 3 dB[20]
- Multipath/Shadowing loss of 3.5 dB[21]
- Signal Bandwidth = 5 megahertz
- Technologies: UMTS and WiMAX

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users from interference. With respect to the -95 dBm signal level, we note that our calculations assume a reference bandwidth of 5 megahertz. However, in standards documents, protected signal levels are generally referenced to a bandwidth of 3.84 MHz. For example, the standards 3GPP TS 25.133 & 304 (pg.15) indicate: 1. for an FDD cell, the measured primary CPICH RSCP value shall be greater than or equal to -95 dBm/3.84 MHz and 2. for a TDD cell, the measured P-CCPCH RSCP shall be greater than or equal to -84 dBm/3.84 MHz. For a signal bandwidth of 3.84 megahertz, the bandwidth correction factor would be 1.15 dB (*i.e.*, 10*log(5/3.84)).

[14] The choice of a particular interference criterion is important as it is a major determinant of the signal levels that lead to an interference event. We used the more conservative criterion of call setup failure rather than a call drop criterion. The difference between the two is about 4 dB – that is, an active call has about 4 dB of margin before it is severed completely either because of interference or some other phenomenon.

[15] A 2 meter separation distance is consistent with prior studies and proceedings, including UWB and H-Block, among others. We recognize that situations will exist where users may be attempting to communicate at separation distances less than 2 meters. However, in many locations where there are expected to be a high concentration of users, additional cell sites are used to ensure good coverage by relatively strong signals which will reduce the potential for harmful interference between the users.

[16] We note that free space propagation yields conservative results as it is a worst case model. In practice the mobile operating environment will result in losses that exceed those predicted by free space propagation. For example, the proximity of the handset to the human body/head, irrespective of angle of incident wave, introduces multipath components – that is because of the inherent ability of the human body/head to reflect energy at certain frequencies. We note that any increase in propagation loss results in reducing the required separation distance between the devices under study. Free Space Propagation loss (FSL) can be calculated using the following formula: FSL = 20*log(4*PI*d(m)*Freq(MHz)/300). Thus, FSL at 2152.5 MHz with a 2 meter separation distance is 45.12 dB.

[17] According to 3GPP TS 25.942, the body losses due to the close proximity of the user's head and also due to blockage of the hand on the UE may be as high as 12 dB. Other studies found the body losses can reach 9 to 15 dB. *See* H.-R Chuang, "Human operator coupling effects on radiation characteristics of a portable communication dipole antenna." IEEE Trans. Antennas Propagation, vol. 42 pp. 556-560, April 1994. In another study by Sprint/Telecordia Technologies, head loss is found to be between 12 to 15 dB. For details *see*: http://gullfoss2.fcc.gov/cgibin/websql/prod/ecfs/comsrch_v2.hts?ws_mode=retrieve_list&id_proceeding=98-153&applicant_name=sprint&start=31&end=32&first_time=N. In addition, we note that the conservative 6 dB figure we use here accounts for two mobile devices – the AWS-1 handset and the AWS-3 handset.

[18] In general, users do not hold their handsets perfectly upright when in use. Thus, some antenna mismatch due to changes in polarization occurs (roughly 1.5 to 2.5 dB). *See Id*. at Attachment 2, page 3).

[19] Though important, antenna efficiency losses are difficult to characterize and thus not considered in this static analysis.

[20] This accounts for the fact that OOBE levels are not flat, but instead drop as frequency separation increases. We used a conservative 3 dB to offset this error in the measurement data, which is induced by the UMTS/WiMAX signal generators. This was shown in Figures 3-5.

[21] This is generally consistent with the values specified in the (IEEE 802.11-03/940r2)" High Throughput Task Group, IEEE P802.11, 15 2004. We also note that this is the value OFCOM used for its analysis of FDD/TDD coexistence for the 2.6 GHz band. *See* the OFCOM report at page 35 available at: http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/tech.pdf.

The following acronyms will be used in the equations to follow:

EIRP	-- Equivalent isotropic radiated power (dBm)
I_{OOBE}	-- AWS-3 in-band interference (dBm)
HBL	-- Head and body loss (dB)
FR	-- Front end receiver filter rejection (dB)
FSL	-- Free space loss (dB)
AM	-- Antenna polarization and impedance mismatch (dB).
MF	-- Multipath fading and shadowing (dB)
L_{slope}	-- AWS-1 OOBE slope (dB)
CSF	-- Call setup failure (dB)
CD	-- Call drop (dB)
BCF	-- Bandwidth correction factor[22] (dB)

A. Required OOBE:

The following formula is used to determine the out-of-band emission levels of an AWS-3 handset that correspond to an interference event in an AWS-1 handset. All of the calculations shown in this section are based on the minimum desired received signal level of -95 dBm.

$$OOBE = I_{OOBE} + \sum losses - BCF, \text{ where}$$
$$\sum losses = FSL_{@2M} + HBL + AM + MF + L_{slope}$$

- UMTS Interferer:

From Table 1, for the desired received signal level of -95 dBm, interference occurs when the interferer reaches a level of -83.2 dBm/5 MHz. Substituting this into the formula results in:

$$OOBE_{AWS\text{-}3} = -83.2_{dBm/5\ MHz} + 45.12 + 6 + 2 + 3.5 + 3 - 10*\log(5) = -30.56_{\ dBm/MHz}$$

This level of OOBE translates to a requirement for an AWS-3 handset to reduce its OOBE by about (60 + 10*log(P) dB) or more to avoid causing interference to AWS-1 handsets.

The following observations can be made:

1. A UMTS AWS-3 handset can safely operate with an OOBE limit of about –30 dBm/MHz (or attenuation of 60 + 10*log(P) dB) without causing disruption of service to nearby AWS-1 handsets.

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[22] In all of our calculations, a bandwidth correction factor (BCF) is applied in order to normalize our results to 1 megahertz. The formula for the BCF = 10*log(BW_{ref}/1MHz). For a 5 megahertz reference bandwidth, the BCF is approximately 7 dB.

2. As noted, we do not have OOBE measurement data for a WiMAX interferer. However, based on the WiMAX tests we conducted and our observations from those tests, we expect that a WiMAX AWS-3 handset would provide a margin of improvement over that observed for a UMTS handset.

B. Maximum Power of AWS-3 to prevent interference:

To calculate overload interference, we consider that the maximum overload interference (I_{OL}) is related to the AWS-3 handset EIRP as follows:

$$EIRP_{AWS\text{-}3} = I_{OL} + \sum losses - BCF, \text{ where } \sum losses = FSL_{2M} + HBL + AM + MF + FR$$ [23]

a) **UMTS desired vs. UMTS Interferer:** Serving UMTS @ 2152.5 MHz and interferer UMTS at 2157 MHz

From table 2(a), desired signal level of -95 dBm corresponds to an I_{OL}= -28.2dBm. Substituting this into the formula results in:

$$EIRP_{AWS\text{-}3} = -28.2 + 45.12 + 6 + 2 + 3.5 - 10*\log(5) \approx 21.4_{\ dBm/MHz}$$

b) **UMTS desired vs. UMTS Interferer:** Serving UMTS @ 2142.5 MHz and interferer UMTS at 2157 MHz

From table 2(b), desired signal level of -95 dBm corresponds to I_{OL} = -19.7 dBm. Substituting this into the formula results in:

$$EIRP_{AWS\text{-}3} = -19.7 + 45.12 + 6 + 2 + 3.5 - 10*\log(5) \approx 30_{\ dBm/MHz}$$

c) **UMTS desired vs. WiMAX Interferer:** Serving UMTS @ 2152.5 MHz and interferer WiMAX at 2160 MHz

For the WiMAX interferer case, the only measured data available is that for the combined effect of OOBE and Overload interference. Data for the overload interference can therefore only be inferred from the UMTS interferer measurements case, summarized in Tables 2 and 3. From table 4, the desired signal level of -95 dBm corresponds to I_{OL} of -22.2 dBm. With OOBE removed, we estimate I_{OL} to be about -16.2 dBm. Substituting this into the formula results in:

$$EIRP_{AWS\text{-}3} = -16.2 + 45.1 + 6 + 2 + 3.5 - 10*\log(5) \approx 33.4_{\ dBm/MHz}$$

The following observations can be made:[24]

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[23] FR is a measure of the victim receiver's filter rejection. Under normal circumstances, this term should be set appropriately high as a protection from OOBE. There is a case where a victim receiver is designed to operate in a band where it has no jurisdiction (*i.e.*, FR = 0 dB). A properly designed UMTS duplex filter will provide at least a couple of dB of attenuation. We do not consider any filter rejection in this analysis.

[24] We again point out that the standards specify that the RSCP value be referenced to a bandwidth of 3.84 megahertz and that our analysis is based on a 5 megahertz bandwidth. *See* note 13, *supra*. Analysis based on the smaller

1. For a desired signal level of -95 dBm or greater, a UMTS AWS-3 handset, under static conditions, can safely operate with maximum EIRP of about 23 dBm/MHz without causing disruption of service to nearby AWS-1 handsets.
2. A WiMAX AWS-3 handset, under static conditions, can safely operate with an EIRP of about 33 dBm/MHz without causing disruption of service to nearby AWS-1 handsets.

V. Probability of Interference and Impact on AWS-1 System Performance

The interference analyses presented above are based on a static case where all of the elements are assumed to be fixed. Most importantly, even under these conditions, the analysis shows that an AWS-1 and AWS-3 device operating in close proximity does not necessarily result in interference. And when factoring in actual operation under non-static conditions, the situation only improves.

For example, as detailed above, in most cases an AWS-1 device will receive a stronger signal than -95 dBm, which results in a vastly reduced interference risk. Similarly, our analysis assumes an AWS-3 handset transmitting at its maximum power, which will occur only a small portion of the time;[25] a reasonable assumption especially if AWS-3 signal patterns are similar to those cited by T-Mobile in their Test Report.[26] This too would reduce the interference potential predicted here. In addition, we note that modern wireless phones operate across multiple frequency bands and channels. Our static analysis only considers the case where the AWS-1 and AWS-3 handsets are operating on directly adjacent channels and in close proximity. Under likely scenarios where this is not the case, the potential for interference would be reduced from that predicted in this report.

Thus, the static case as tested here provides insight as an upper bound on interference. The statistical nature of calling patterns, frequency selection, transmitter and receiver location, and signal levels only serves to improve the predicted performance and results in fewer instances of interference than would be predicted by this static case. We do not here analyze the various arguments in the record regarding the probability of interference and its impact on overall AWS-1 reliability or performance, but do note that this must be considered in a comprehensive analysis.

VI. Comparison with other Analyses and OOBE standards

We note that commenters in the record have cited analyses conducted by the United Kingdom's Office of Communications (OFCOM) assessing potential interference between TDD and FDD

3.84 megahertz bandwidth would provide additional margin allowing for higher AWS-3 power levels and/or less stringent OOBE levels than those calculated herein.

[25] We appreciate that there is a debate in the record as to whether they AWS-3 device would operate at maximum power most of the time, but also recognize that variable power control is a feature of virtually all current wireless technologies.

[26] *See* T-Mobile Test Report at 13-16.

mobile handsets in adjacent bands operating in the 2.5 GHz region of the spectrum.[27] The situation analyzed by OFCOM is very similar to the situation we are considering here, although there are some differences. OFCOM determined that TDD and FDD mobile handsets can operate in adjacent bands with appropriate technical constraints. Notably, OFCOM restricted base station power in the first adjacent 5 megahertz TDD channel as a means to ensure that operations would be restricted to small cells where the TDD handset power would tend to be reduced. OFCOM established an OOBE limit equivalent to 49 + 10*log(P) dB**.** We note that OFCOM's analysis found there was virtually no risk of interference beyond the first adjacent 5 megahertz channel.

The Commission has previously adopted standards for OOBE based on flexible rules that permit TDD or FDD operation. For example, in the upper 700 MHz band, the Commission permitted TDD operation in the commercial spectrum subject to an OOBE attenuation standard of 43 + 10*log(P) dB.[28] Indeed the Commission specifically amended its rules to provide for TDD operation, recognized the possibility of mobile-to-mobile interference, and adopted and maintained an OOBE limit of 43 + 10*log(P) dB. In considering rules for the lower 700 MHz band, the Commission specifically rejected a proposal to adopt a stricter OOBE standard for TDD operations and affirmed the 43 + 10*log(P) dB standard.[29] While many participants in the Commission's proceeding argue that such operation was not realistically contemplated, presumably because the Commission decided to continue to auction paired spectrum, the fact remains that the rules specifically contemplated the possibility of mobile-to-mobile interference using an OOBE standard of 43 + 10*log(P) dB and continue to provide for implementation of such technology in these bands if licensees were to choose to do so. In establishing rules for flexible operation in the 2.5 GHz band, the Commission adopted an OOBE attenuation standard for mobile digital stations of 43 + 10*log(P) dB and 55 + 10*log(P) dB at 5.5 megahertz from the channel edges.[30]

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[27] *See* United Kingdom's Office of Communications (OFCOM) *Award of Available Spectrum 2500–2690 MHz; 2010–2025 MHz* published on April 4, 2008 and available at: http://www.ofcom.org.uk/consult/condocs/2ghzrules/statementim/statement/statement.pdf. *See* also *On the Impact of Interference from TDD terminal stations to FDD terminal stations in the 2.6 GHz band* published on April 21, 2008 and available at http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/tech.pdf.

[28] See *Memorandum Opinion and Order and Further Notice of Proposed Rule Making* in WT Docket No. 99-168, CS Docket No. 98-120, and MM Docket No 00-83 available at: http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6511359021.

[29] See *Report and Order* in GN Docket No. 01-74 at para 122, where the Commission declined to adopt a stricter OOBE attenuation standard than 43 + 10*log(P) dB and stated "…. in the absence of data and other support from the many parties to this proceeding, we should not increase OOBE limits given the potential adverse effects that may result on the commercial usefulness of the spectrum. If developments in the industry change significantly by 2006 or later we can reconsider our OOBE limits at that time. We note, however, that Section 27.53(f) currently states that in the event of harmful interference the Commission may, at its discretion, require greater attenuation than specified in the rules." available at: http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6513075423.

[30] See *Report and Order and Further Notice of Proposed Rule Making* in WT Docket No. 03-66, WT Docket No 03-67, MM Docket No. 97-217; WT Docket No. 02-68, WT Docket No. 00-230, at para. 124–130 adopting an out-of-band emissions mask for digital; mobile stations of 43 + 10*log(P) dB at the channel edge and 55 + 10*log(P) dB at 5.5 megahertz from the band edge. The Commission noted that a tighter emissions mask may be needed to control adjacent channel interference between incompatible systems and provided for licensees to agree on a tighter mask upon a demonstration of harmful interference.

Notably, when establishing OOBE limits for frequency bands where flexible use is permitted the Commission has generally indicated that it expected the licensees to work together to mitigate any potential for harmful interference. Indeed the wireless industry often has established its own standards that are stricter than the FCC regulations. This cooperation has been a cornerstone in enabling a shift from command and control regulation whereby separate interference protection limits must be tailored to each technology and situation to one where industry has the flexibility to adopt the technologies and services of its choosing along with standards to practices to control harmful interference. We note also that the Commission has generally reserved the right to apply more stringent OOBE standards in the event that harmful interference may occur and cannot be resolved among the parties.

VII. **Remarks and conclusions:**

The appropriate power limits and OOBE limits are a function of the underlying assumptions of any analysis. The Commission has generally adopted standards that balance the risk of potential interference against a variety of other factors, including the impact those standards may have on the potential uses of spectrum. The analysis above is based on reasonable assumptions that support allowing power levels of up to 23 dBm/MHz and an OOBE limit of 60 + 10*log(P) dB. Alternatively, a standard of 43 + 10*log(P) dB would be consistent with past practice and would encourage the parties to work together to adopt whatever further measures may be necessary to control interference.[31]

[31] It must be kept in mind that the technology the ultimate licensee of the AWS-3 chooses to use and corresponding system architecture are undetermined.

Annex

The following are the underlining assumptions behind our study:

- Desired AWS-1 serving signal to be protected is -95 dBm
- Interference criterion is call setup failure
- Separation distance = 2 meters
- Free Space Propagation Model
- Head-body loss of 6 dB
- Loss due to antenna mismatch of 2 dB
- No loss was considered due to antenna efficiency
- AWS-1 OOBE slope of 3 dB
- Multipath/Shadowing loss of 3.5 dB
- Signal Bandwidth = 5 megahertz
- Technologies considered are UMTS and WiMAX

1. **AWS-3 EIRP**:

Table 1: EIRP Results for UMTS Interferer

Parameters	Values					Units
Desired Signal	-105.0	-100.0	-95.0	-90.0	-85.0	dBm/5 MHz
Frequency	2152.5	2152.5	2152.5	2152.5	2152.5	MHz
UMTS Interferer Signal	-34.2	-30.2	-28.2	-26.2	-25.2	dBm/5 MHz
Obstructions						dB
Multipath/Shadowing loss	3.5	3.5	3.5	3.5	3.5	dB
Mobile Antenna Gain						dBi
AWS-1 Rx Filter Rejection						dB
Head/body loss	6.0	6.0	6.0	6.0	6.0	dB
AWS-1/AWS-3 Antenna Impedance & Polarization Mismatch	2.0	2.0	2.0	2.0	2.0	dB
Separation Distance	2.0	2.0	2.0	2.0	2.0	Meters
EIRP	22.4	26.4	28.4	30.4	31.4	dBm/5 MHz
	15.4	19.4	21.4	23.4	24.4	dBm/MHz

Table 2: EIRP Results for WiMAX Interferer

Parameters	Values					Units
Desired Signal	-105.0	-100.0	-95.0	-90.0	-85.0	dBm/5 MHz
Frequency	2152.5	2152.5	2152.5	2152.5	2152.5	MHz
WiMAX Interferer Signal	-19.7	-17.2	-16.2	-15.2	-14.2	dBm/5 MHz
Obstructions						dB
Multipath/Shadowing loss	3.5	3.5	3.5	3.5	3.5	dB
Mobile Antenna Gain						dBi
AWS-1 Rx Filter Rejection						dB
Head/body loss	6.0	6.0	6.0	6.0	6.0	dB
AWS-1/AWS-3 Antenna Impedance & Polarization Mismatch	2.0	2.0	2.0	2.0	2.0	dB
Separation Distance	2.0	2.0	2.0	2.0	2.0	Meters
EIRP	36.9	39.4	40.4	41.4	42.4	dBm/5 MHz
	29.9	32.4	33.4	34.4	35.4	dBm/MHz

2. Out of Band Emission limit:

Table 3: OOBE Results for UMTS Interferer

Parameters	Values					Units
Desired Signal	-105.0	-100.0	-95.0	-90.0	-85.0	dBm/5 MHz
Frequency	2152.5	2152.5	2152.5	2152.5	2152.5	MHz
UMTS Interferer Signal	-96.2	-89.2	-83.2	-77.2	-72.2	dBm/5 MHz
Obstructions						dB
Multipath/Shadowing loss	3.5	3.5	3.5	3.5	3.5	dB
AWS-3 Antenna Gain						dBi
AWS-1 OOBE Slope	3.0	3.0	3.0	3.0	3.0	dB
Head/Body loss	6.0	6.0	6.0	6.0	6.0	dB
AWS-1/AWS-3 Antenna impedance & polarization mismatch loss	2	2	2	2	2	dB
Separation Distance	2.0	2.0	2.0	2.0	2.0	Meters
OOBE	-36.6	-29.6	-23.6	-17.6	-12.6	dBm/5 MHz
	-43.6	-36.6	-30.6	-24.6	-19.6	dBm/MHz
	73.6	66.6	60.6	54.6	49.6	+ 10*log (P) dB