WiMAX Forum® Test Procedures

WiMAX Forum® Radiated Performance Tests (RPT) for Subscriber and Mobile Stations

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WiMAX Forum Proprietary

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1 Overview

This document specifies the scope, setup, procedures and conditions for Radiated Performance Testing of WiMAX® Subscriber and Mobile Stations. It specifies tests for determining the radiated performance of both the transmitter and the receiver, including the effects of the radio, antenna(s), platform architecture, and near-field phantoms in a variety of usage scenarios. These tests primarily relate to physical layer performance, but the test procedures require some basic functionality from the medium access control layer.

In order to perform the tests listed in this document, specialized test equipment and testing capabilities are required. These are outlined in Section 6. These tests currently do not specify any pass/fail criteria and are currently classified as Category E in the CPRM [1]. Once representative data are acquired for a range of devices, pass/fail criteria will be developed and implemented in a future revision.

2 Scope

The tests included in this document cover the transmit and receive performance aspects of WiMAX® Subscriber and Mobile Stations in a radiated test configuration. These tests are used to evaluate the radiated performance of devices that utilize WiMAX air interface profile(s).

3 Purpose

These radiated performance testing methodologies and specifications will be used by the WiMAX Forum® designated certification laboratories to perform the testing necessary for evaluating the radiated performance of WiMAX certified devices.

4 References

The following documents contain provisions, which through reference in this text, constitute provisions of the present document. References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific. For a specific reference, subsequent revisions do not apply. For non-specific references, the latest versions apply.

[1] WiMAX Forum® Certification Program Reference Manual (CPRM), RM 101 001 V001 (2007-10), WiMAX, Certification Working Group

[2] WiMAX Forum® Mobile System Profile WMF-T23-001-R010v09, WiMAX Forum® Technical Working Group

[3] WiMAX Forum™ Mobile Radio Conformance Tests (MRCT) v2.0.0, WiMAX, Technical Working Group

[4] Guide to the Expression of Uncertainty in Measurement, ISO, Geneva, 1995

[5] NIST Technical Note 1297-1994, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results", Barry N. Taylor and Chris E. Kuyatt.

5 Definitions and abbreviations

5.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Effective Isotropic Radiated Power (EIRP) indicates the power that would have to be radiated by a theoretical isotropic radiator substituted in place of the DUT to produce the same field level at a given point in space. It is equivalent to the power measured at the test equipment receiver, corrected for the range calibration path loss between the DUT and test equipment receiver.

Effective Isotropic Sensitivity (EIS) represents the power level that would be received by a theoretical isotropic receiver illuminated by the same plane wave that resulted in the target error rate (sensitivity level) at the DUT receiver. It is equivalent to the power transmitted from the test equipment transmitter when the DUT is at the target error rate, corrected for the range calibration path loss between the DUT and test equipment transmitter.

Interaction Factors are components of a device's radiated performance that account for the difference between the passive radiation pattern contribution and the conducted performance of the DUT transmitter or receiver. They represent the effect of active interactions between the transmitter/receiver and device components once the antenna is introduced to the circuit, and include contributions such as platform desensitization and non-linear amplifier performance due to mismatch.

Near Horizon Partial Radiated Power (NHPRP(min,max)) is the power radiated by the DUT over the range of theta angles from min to max degrees and is determined by integrating the EIRP over the partial surface of the sphere containing the specified theta angle range. It represents the portion of the total radiated power that is radiated in the given range of angles, and is useful for evaluating the performance of a device in a range of elevation angles.

Near Horizon Total Radiated Power (NHTRP(min,max)) is the total power that would be radiated by a theoretical isotropic radiator that had the same NHPRP as the DUT. It is determined by scaling the NHPRP by the ratio of the surface area of a sphere to the surface area of the partial surface between the theta angles of min to max degrees. It represents the average directional transmit performance of the DUT in the specified range of angles and can be directly compared to the TRP to determine if a device performs better or worse in the given range of angles than it does on average in all directions.

Near Horizon Partial Isotropic Sensitivity (NHPIS(min,max)) is the sensitivity of the receiver for an antenna over the range of theta angles from min to max degrees. It is determined by integrating the EIS over the partial surface of the sphere containing the specified theta angle range. It represents the portion of the total isotropic sensitivity to signals in the given range of angles, and is useful for evaluating the performance of a device in a range of elevation angles.

Near Horizon Total Isotropic Sensitivity (NHTIS(min,max)) is the total isotropic sensitivity of a theoretical isotropic receiver that has the same NHPIS as the DUT. It is determined by scaling the NHPIS by the ratio of the surface area of a sphere to the surface area of the partial surface between the theta angles of from min to max degrees. It represents the average directional receive performance of the DUT in the specified range of angles and can be directly compared to the TIS to determine if a device performs better or worse in the given range of angles than it does on average in all directions.

RPT Category A: WiMAX End Products not specified as an RPT Category B device including:

- For BC3.A CONFIG 1 MS Devices, BC3.A CONFIG 2 MS Devices, and MS Devices of all other band classes:

1. Customer Premise Equipments (CPEs) and
2. Devices that do not contain embedded WiMAX Certified Module including but not limited to, USB dongles, PCMCIA cards and other mobile WiMAX End Products that are not powered by their own integral battery.

RPT Category B:

- For BC3.A CONFIG 1 MS Devices:

1. WiMAX handsets and handheld devices that are powered by their own integral battery and
2. Devices that contain an embedded WiMAX Certified Module including, but not limited to, laptops and tablets.

- For BC3.A CONFIG 2 MS Devices and MS Devices of all other band classes:

Portable/mobile WiMAX End Products that are devices that contain an embedded WiMAX Certified Module including, but not limited to, laptops and tablets.

NOTE: WiMAX handsets and handheld devices that are powered by their own integral battery are explicitly excluded from certification for all band classes except BC3.A CONFIG 1.

Total Radiated Power (TRP) is the total power radiated by the DUT in all directions and is determined by integrating the EIRP over the surface of a sphere surrounding the DUT. It represents the average directional transmit performance of the DUT, accounting for losses due to the efficiency of the antenna and other transmit interaction factors.

Total Isotropic Sensitivity (TIS) is the equivalent sensitivity level of the DUT if it had a theoretical isotropic receiver for an antenna. It is determined by integrating the EIS over the surface of a sphere surrounding the DUT. It represents the average directional receive performance of the DUT, accounting for losses due to the efficiency of the antenna and other receive interaction factors.

Single Point Measurement refers to measurements that are performed at only one position and/or polarization on the spherical pattern. Results of these measurements do not benefit from certain reductions in measurement uncertainty associated with the integration of the entire spherical pattern and/or repeated measurements of random errors.

5.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BCG	Band Class Group
BSE	Base Station Emulator
DL	Down Link
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
EIS	Effective Isotropic Sensitivity
ICMP	Internet Control Message Protocol
MA	Measurement Antenna
MAC	Media Access Control
MS	Mobile Station
NHPRP	Near Horizon Partial Radiated Power
NHTRP	Near Horizon Total Radiated Power
NHPIS	Near Horizon Partial Isotropic Sensitivity
NHTIS	Near Horizon Total Isotropic Sensitivity
PER	Packet Error Ratio
PUSC	Partially Usage of Sub channels
QZ	Quiet Zone
RCT	Radio Conformance Test (Plan)
RF	Radio frequency
RMS	Root Mean Squared
RPT	Radiated Performance Test (Plan)
RSSI	Received Signal Strength Indication
TIS	Total Isotropic Sensitivity
TRP	Total Radiated Power
UL	Up Link
VSA	Vector Signal Analyzer
VSWR	Voltage Standing Wave Ratio

6 Measurement system

6.1 General requirements

The general block diagram for an RPT system is shown in Figure 6.1. The block diagram describes the main system components and interfaces conceptually, without specifying the implementation. The test equipment block represents one or more piece(s) of test equipment corresponding to the base station emulator and other components used for the related tests in RCT. With the exception of modifications required to support the radiated test interface, including signal conditioning and routing requirements, the requirements for the test equipment are similar to those in the corresponding RCT test.

The RPT test chamber provides the necessary isolation and free-space propagation characteristics for the radiated test environment and contains the supporting hardware necessary to position the DUT relative to the measurement antenna(s) used to perform the respective tests. Details on the requirements for this system can be found in the following sub-sections.

The MS/SS serving as the DUT must consist of a finished hardware configuration including antenna(s) capable of radiated communication and should be capable of passing RCT tests corresponding to the required tests listed in this document. In order to accurately determine the radiated performance, the DUT must allow determination of the performance of a static radiation pattern. This may entail measuring the performance of each receiver separately, or measuring with the signal processing between each receiver fixed. This test plan also assumes that the DUT contains only a single transmit antenna. The DUT must be capable of completing the required tests in a stand-alone configuration, without any cabled (RF or data) connections. The exception to this would be power and/or data cables for DUTs whose usage cases entail these elements to always be present.

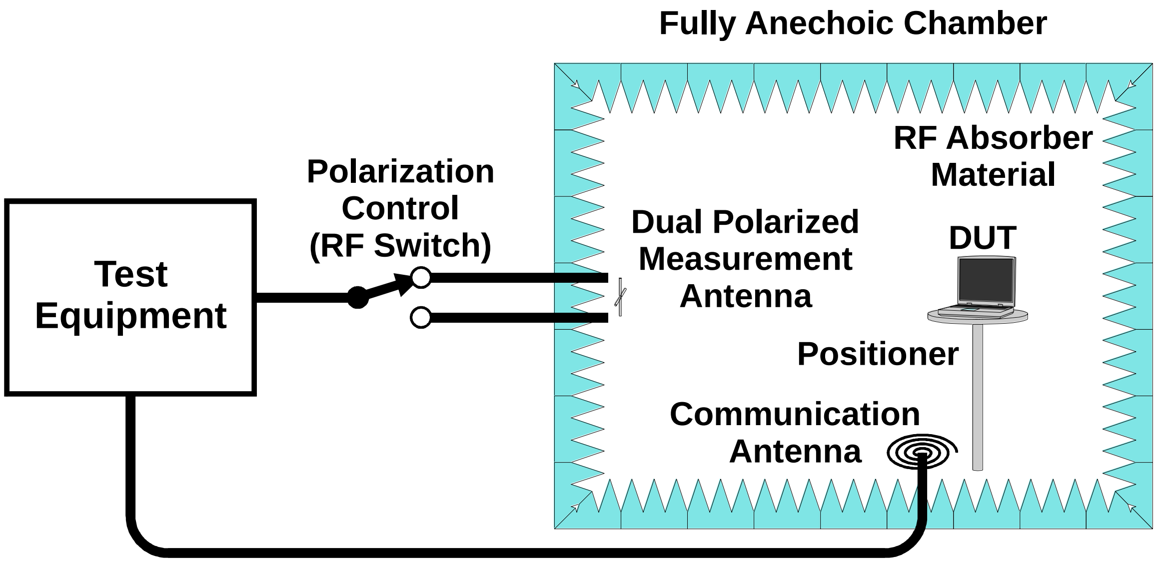


Figure 6.1. Basic RPT System Configuration including test equipment and anechoic test range.

6.2 Test condition declarations

All tests shall be carried out in normal environmental conditions. These are outlined in Table 6.1. It is recognized that all requirements given in the standard are relevant for all combinations of temperature and humidity of the chosen climatic class. However, some tests may be carried out only in environmental reference conditions for reasons of practicality and convenience.

Table 6.1. Condition Summary

Parameter	Test Condition Limits
Test Temperature	Between +15°C and +30°C
Test Relative Humidity	Between 25 % and 75 %

6.3 The Test environment

The radiated test environment used for RPT typically consists of the following components:

a) A fully anechoic chamber with sufficient shielding to isolate the DUT from outside interference and a quiet zone large enough to encompass the DUT and any associated near-field phantoms.
b) A positioning system with minimal RF impact capable of moving the DUT/Phantom and/or measurement antenna to cover the entire spherical radiation pattern of the DUT.
c) A dual polarized measurement/communication antenna suitable for acquiring two orthogonal components of the electric field vector at each point on the surface of a sphere.
d) An optional communication antenna used to provide an un-calibrated low loss communication path between the DUT and the test equipment.
e) Standardized phantom head, hands, table/lap tops for near field impact measurements.

The following sections describe these components and detail the impact of various contributions that would affect measurements made within this type of test environment. The resulting measurement uncertainty of tests performed within a given test environment will depend on how closely these guidelines are adhered to. In order to be considered acceptable for performing Certification Testing to the requirements of this test plan, the test system, including the test environment, will be required to meet maximum measurement uncertainty criteria as specified under the corresponding test methods.

6.4 The Fully Anechoic Chamber

The test environment required for RPT testing requires RF isolation from the outside environment to ensure that other RF signals including active WiMAX networks do not interfere with the measurements performed on the DUT. A shielded room is used to provide the necessary isolation. However, to measure the directional behavior of the DUT, reflections from the inner walls of the shielded room must be suppressed. This is accomplished by lining the walls with RF absorber material (RAM). When all walls, ceiling, and floor are completely covered with absorber material, the configuration is referred to as a fully anechoic chamber (FAC) or fully absorber-lined room (FAR). The performance of the FAC is a function of the overall size of the room, the level of absorber performance, and the quality of absorber coverage. For accurate representation of the peaks and nulls in a radiation pattern, an extremely high level of performance is required (on the order of 50 dB or more of attenuation at each surface). By comparison, absorber with only 20 dB of attenuation results in 1 dB or more of error at peaks in the pattern and limits the depth of the nulls that can be measured to 20 dB or less.

6.4.1 Range Length Considerations

Ideally, the range length (distance between the DUT and the measurement antenna) should be sufficient to ensure that the measurement antenna (MA) is in the far field of the DUT or DUT and phantom combination. The standard definition of the far field distance is anything greater than $2D^2/\lambda$, where D is the maximum dimension of the DUT or DUT and phantom and λ is the shortest wavelength (corresponding to the highest frequency) to be tested. Note that for small DUTs, where the measurement antenna may be larger than the DUT, it's necessary to ensure that the DUT is in the far field of the MA as well, using the same equation, where D now represents the maximum dimension of the MA. Table 6.2 shows typical range lengths for a variety of test volumes suitable for typical wireless DUTs with or without phantoms. Rather than being concerned with the size of all possible DUT combinations in a chamber, the above equation is typically used to define a maximum DUT size at each frequency for a given range length. This then defines the maximum far-field test volume available for any DUT tested using that range distance. Whatever range length is used, the chamber must be large enough to support the chosen range length, providing clearance on all sides of the DUT/phantom and the RF absorber.

This available test volume is commonly known as the “quiet zone” (QZ). This refers to the desired uniform field area needed for accurate measurements. In free space, when the QZ is far enough away from the measurement antenna, the RF wavefront propagating from the measurement antenna appears as a plane wave so that all points within the QZ have the same field level. Non-uniformity due to proximity to the MA appears as a falloff in signal magnitude from front (MA side) to back of the QZ, and from center to sides of the QZ. If the MA pattern is too narrow, it can also result in falloff from center to the sides of the QZ. This non-uniformity is referred to amplitude taper.

The amplitude taper due to range length can be predicted by simply converting the relative distances to dB. Thus, if the range length is L and the quiet zone is a sphere of radius r, the distance taper is given by $20 \log10((L \pm r) / L)$. For an amplitude taper of ±1 dB across the QZ (+1 dB at the front, -1 dB at the rear, for a total of 2 dB variation), the QZ must have a radius less than 11% of the path length to the center of the

QZ. To reduce that to ±0.25 dB, the QZ radius must be less than 3% of the path length. Table 6.3 shows the error due to the amplitude taper for the minimum range lengths based on the far field equation. From this it's obvious that using the far field equation only to determine a suitable range length is not sufficient to guarantee a low uncertainty. The wavefront at the DUT may be coherent, such that it appears to come from a point source, but it is still not sufficiently planar across the quiet zone at short distances. Longer range lengths also reduce the uncertainty due to placement of the DUT relative to the MA. Note that these effects primarily impact the measured radiation pattern in any given direction, while having a lesser effect on integrated surface quantities like total radiated power and total isotropic sensitivity, where the directional behavior is averaged out.

On a typical antenna test range, the imperfect performance of the absorber lining in the FAC also causes signal magnitude ripple within the quiet zone due to constructive and destructive interference of the different direct and reflected wavefronts reaching each point in the quiet zone. Effects from the environment outside the immediate vicinity of the DUT can have the same impact on integral results as it does on the individual pattern points, since the same energy may be measured more than once; once on the direct path, and again from a reflection in the test environment. Support structure for the DUT and associated positioning equipment can also impact the quality of the quiet zone. Therefore it is necessary to perform site validation measurements to determine the uncertainty associated with the use of a particular sized quiet zone with a given range length in any test system.

Table 6.2. Far-field distances for various test volumes for the defined Mobile WiMAX Band Classes.

WiMAX Band Class Index†	Highest Test Frequency f (GHz)	Shortest Test Wavelength λ (m)	Maximum Test Volume Dimension D (m)	Far Field Distance L (m)
1	2.4	0.125	0.1	0.16
			0.2	0.64
			0.3	1.44
			0.4	2.56
			0.5	4.00
2	2.36	0.127	0.1	0.16
			0.2	0.63
			0.3	1.42
			0.4	2.52
			0.5	3.93
3	2.69	0.112	0.1	0.18
			0.2	0.72
			0.3	1.61
			0.4	2.87
			0.5	4.48
4	3.4	0.088	0.1	0.23
			0.2	0.91
			0.3	2.04
			0.4	3.63
			0.5	5.67
5	3.8	0.079	0.1	0.25
			0.2	1.01
			0.3	2.28
			0.4	4.05
			0.5	6.33

†Based on current band class index definitions in [2].

Table 6.3. Indication of Amplitude Taper Error for Various Quiet Zone Diameters based on the Far Field Distance.

WiMAX BandClass Index†	Maximum Test Volume Dimension D (m)	Range Length based on Far Field Distance L (m)	EIRP/EIS Error at Front of QZ (dB)	EIRP/EIS Error at Back of QZ (dB)
1	0.10	0.16	3.3	-2.4
	0.20	0.64	1.5	-1.3
	0.30	1.44	1.0	-0.9
	0.40	2.56	0.7	-0.7
	0.50	4.00	0.6	-0.5
2	0.10	0.16	3.3	-2.4
	0.20	0.63	1.5	-1.3
	0.30	1.42	1.0	-0.9
	0.40	2.52	0.7	-0.7
	0.50	3.93	0.6	-0.5
3	0.10	0.18	2.8	-2.1
	0.20	0.72	1.3	-1.1
	0.30	1.61	0.8	-0.8
	0.40	2.87	0.6	-0.6
	0.50	4.48	0.5	-0.5
4	0.10	0.23	2.2	-1.7
	0.20	0.91	1.0	-0.9
	0.30	2.04	0.7	-0.6
	0.40	3.63	0.5	-0.5
	0.50	5.67	0.4	-0.4
5	0.10	0.25	1.9	-1.6
	0.20	1.01	0.9	-0.8
	0.30	2.28	0.6	-0.6
	0.40	4.05	0.4	-0.4
	0.50	6.33	0.3	-0.3

†Based on current band class index definitions in [2].

6.4.2 Minimum Range Length Requirements

While it is not practical to enforce far-field requirements for WiMAX RPT test systems, there are minimum criteria beyond which the quality of any measurements would be suspect. For example, it is critical that the measurement antenna be outside the reactive near field of the DUT and vice versa. In addition, if the overall size of the DUT is large relative to the volume encompassed by the range length, even the integral quantities like TRP and TIS become suspect. For the purposes of this test plan, the minimum distance between any point on the DUT and the measurement antenna must be at least three wavelengths (3λ) and at least twice the maximal dimension of the DUT ($2D$) in order to address these concerns. Assuming the

DUT is centered within the test volume, then the range length requirement from the center of the quiet zone is the greater of 3λ + *D*/2, or 2.5*D*. In the event that the measurement antenna is larger than the DUT, then the minimum separation distance shall be twice the maximal cross dimension of the measurement antenna or three wavelengths, whichever is larger. Figure 6.2 through Figure 6.4 illustrate the minimum allowed separation distance and range length for each of these situations.

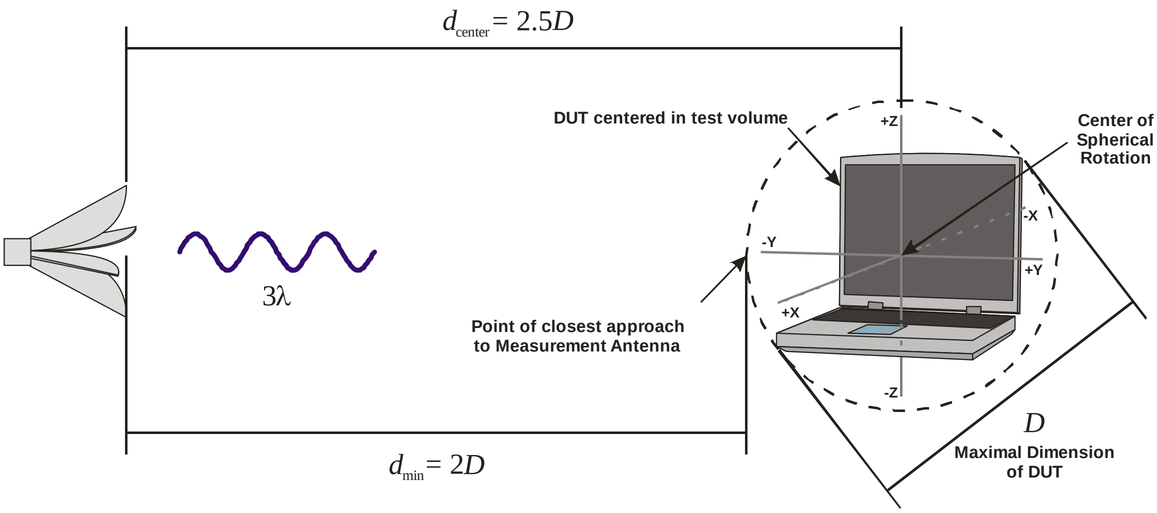


Figure 6.2. Illustration of minimum range length for a large device at short wavelengths.

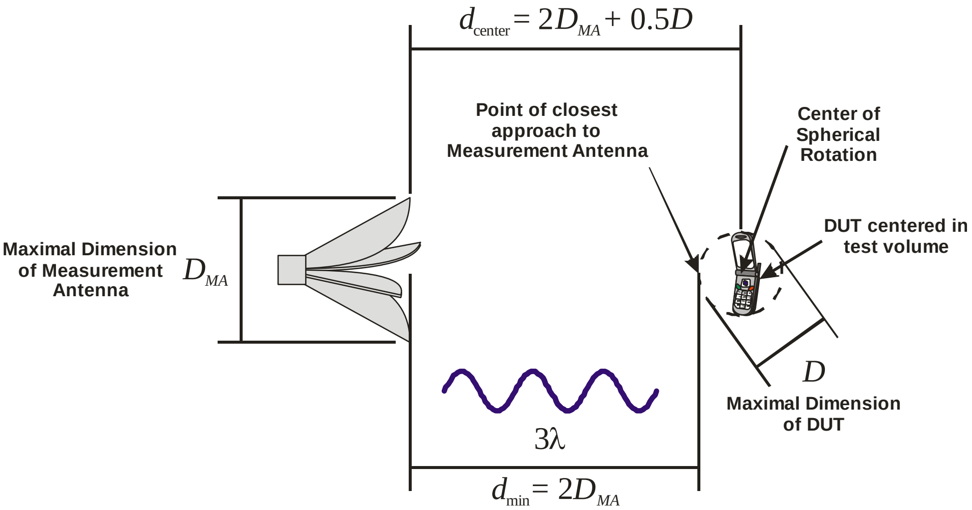


Figure 6.3. Illustration of minimum range length for a small device at short wavelengths.

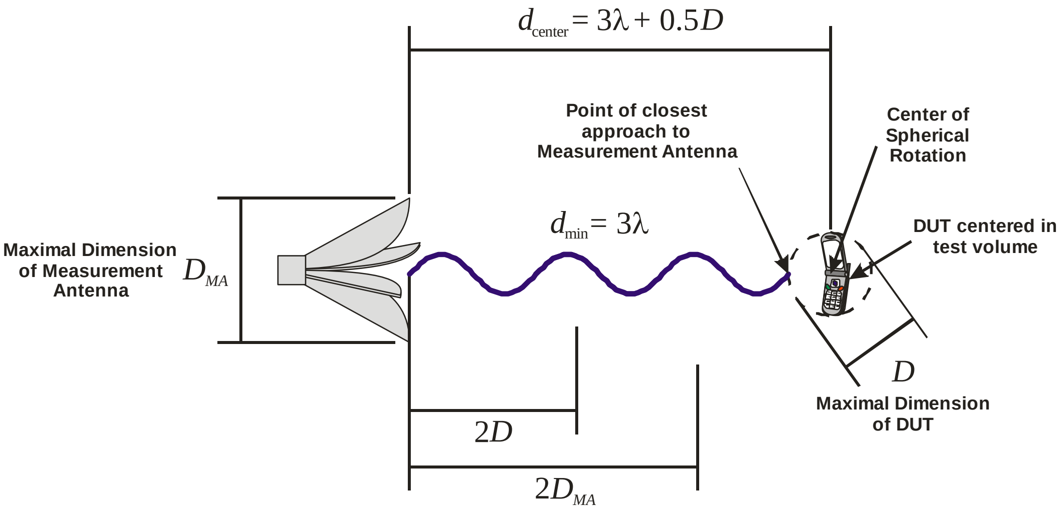


Figure 6.4. Illustration of minimum range length for an electrically small device at longer wavelengths.

6.5 The Measurement Antenna

The measurement antenna is used to sample the power density at each point on the surface of the test sphere. The antenna must be able to measure the total field vector at each point, no matter what the orientation of the DUT with respect to the MA. This is typically done by measuring two orthogonal polarizations at each point and combining the power in each component in order to determine the total power density at that point. This can be done using two separate orthogonal antenna elements and switching between them electrically, or by mechanically changing the polarization of a single antenna. Note that it is assumed that the behavior of the DUT is stable between each measurement of the two orthogonal components such that they truly represent components of the same field vector. For DUTs with multiple antennas, this may not be the case unless a special configuration of the DUT is used to test each antenna separately. For DUTs known to have linearly polarized radiation patterns, a circularly polarized measurement antenna may be used to eliminate the need to toggle between orthogonal polarizations during the measurement. However, any ellipticity in the MA or the DUT can cause errors in the measurement result.

Due to reciprocity, the same basic concepts apply whether the measurement antenna is used for measuring radiated power from the device, or for generating the downlink signal received at the device for sensitivity measurements. However, the relationship between the two field vector components for the signal received by the DUT follows an inverse power relationship as opposed to that typically used when calculating radiated power. When measuring sensitivity, just combining the two transmitted components from each polarization would result in a net signal level at the DUT that was above sensitivity, since each polarization resulted in a level that was at sensitivity. Instead, the desired quantity is the resultant total field level that would result in the receiver being at sensitivity. Refer to 8.2.2.4 for more information on calculating this value.

6.6 Near Field Phantoms

Since devices typically don't operate suspended in free space, it's often necessary to determine the effects of objects commonly found in the immediate vicinity of the DUT in order to represent an accurate picture of the DUT performance. The effect of user head, hands, and torso, as well as tabletops or walls on which the DUT would typically be mounted, must be evaluated. Objects placed in the near field of the DUT can have significant impact on resulting performance. Near field loading can detune the antenna, changing its impedance. The resulting mismatch can greatly reduce the efficiency of the antenna, and even cause non-linear effects due to overloading of the output stage of the radio. Objects near the DUT can absorb or reflect a significant amount of RF energy. These near field effects cannot be predicted by far field modeling techniques and must be evaluated using test objects (standardized phantoms) used to replicate the real behavior of the DUT in proximity to these objects.

Depending on the type of DUT, there are a variety of phantoms that may be used to determine the near field impact on the measured quantity. The IEEE Std 1528 defines one of a number of standardized phantom head and torso configurations for SAR (specific absorption rate) testing, including fluid formulas for simulating body tissue at various frequencies. CENELEC EN50361: 2001 defines a variant of the Standard Anthropomorphic Model (SAM) head phantom that has been adopted by the wireless industry for radiated performance tests of mobile phone devices. This SAM phantom defines additional neck and shoulder regions of the phantom. Since these tests are not concerned primarily with the actual absorption properties of the tissue, but rather the overall near field loading and blocking effects of the phantom, the exact conductivity and permittivity of the phantom is not critical. The basic sugar water and cellulose solution is typically used (45.3% water, 54.3% sugar, 0.3% hydroxyethylcellulosis (HEC), 0.1% Bactericide (Dowicil™ 75) by weight). Other solutions may be used as needed for different frequency ranges. The permittivity and conductivity of the solution should be verified against the specifications of the above references to confirm that the solution is mixed correctly.

Work is currently underway for standardization of hand phantoms and a number of such phantoms are available on the market. For the purpose of body or lap phantoms, a flat phantom with the appropriate width for the application may be used. Common flat phantom width is 40 cm.

For tabletop and wall mount phantom measurements, stable dielectric materials are recommended for testing purposes. Wood and other porous materials are not likely to produce repeatable results day to day or between test facilities. Recommended materials are polycarbonate or polyvinylchloride (PVC), both with relative dielectric constants on the order of 3, and FR4 fiberglass with dielectric constant on the order of 4.5. Metal phantoms of aluminum or zinc plated steel (i.e. sheet metals with good conductivity) may be used to simulate those environments. If necessary, phantoms of the specific target material may be used. In all cases, the exact type and parameters of the material should be listed. The surface phantom should be at least three wavelengths in diameter and should extend at least one wavelength beyond the maximum dimension of the DUT. Standard phantom sizes of 0.5, 0.75, and 1.0 m (± 1 mm) diameter or width in circular or square configurations with a dielectric thickness of 12.5 mm (±0.5 mm) are recommended. Sheet metal phantoms should have sufficient skin depth for the frequencies of interest. Thickness on the order of 1 mm is typically sufficient.

6.7 Spherical Positioning Systems

The final components of the test environment are the support structures and test positioners necessary to hold the DUT and manipulate it relative to the measurement antenna in order to cover the surface of a sphere. While this manipulation could be done manually for each data point to be measured, a desire for repeatability and test speed typically dictates the use of automated positioning equipment to provide the needed manipulation. All positioning systems typically start with a turntable capable of rotating the DUT 360° around a vertical axis. This allows measurement of single two-dimensional cuts through the desired three-dimensional surface. These cuts, made with the measurement antenna in the plane of the DUT, may also be referred to as “great circle” cuts, since the circle traversed by the measurement antenna relative to the DUT makes a cut through the center of a sphere surrounding the DUT. There are then two common alternatives to expand this system to measure the full spherical surface. The first option, referred to as a combined axis system, is to place a second positioner on top of the first, with its axis perpendicular to the first (i.e. horizontal), and rotate the DUT about two axes. This can also be accomplished semi-automatically, by manually rotating the DUT around a horizontal (roll) axis and using the turntable to take great circle cuts through the 3-D surface at each orientation of the DUT on the support. The second option involves moving the measurement antenna up and down around a rotational axis perpendicular to the turntable axis. Rotating the turntable causes the measurement antenna to transcribe conical section cuts around the DUT, where the radius of the cut is reduced by a factor of sin(θ), where θ is the angle of the measurement antenna relative to a point directly above the DUT. In this case, for full spherical coverage the DUT must be suspended in the middle of the chamber in order to allow the measurement antenna to move from directly over the top of the table to directly underneath. For the purposes of determining spherical integral quantities like total radiated power (TRP) and total isotropic sensitivity (TIS), the bottom-most point on the spherical surface can typically be ignored due to the sin(θ) weighting of the spherical integration. This allows the DUT to be supported on a dielectric post in the center of the turntable. Figure 6.5 illustrates examples of each of the two positioning systems.

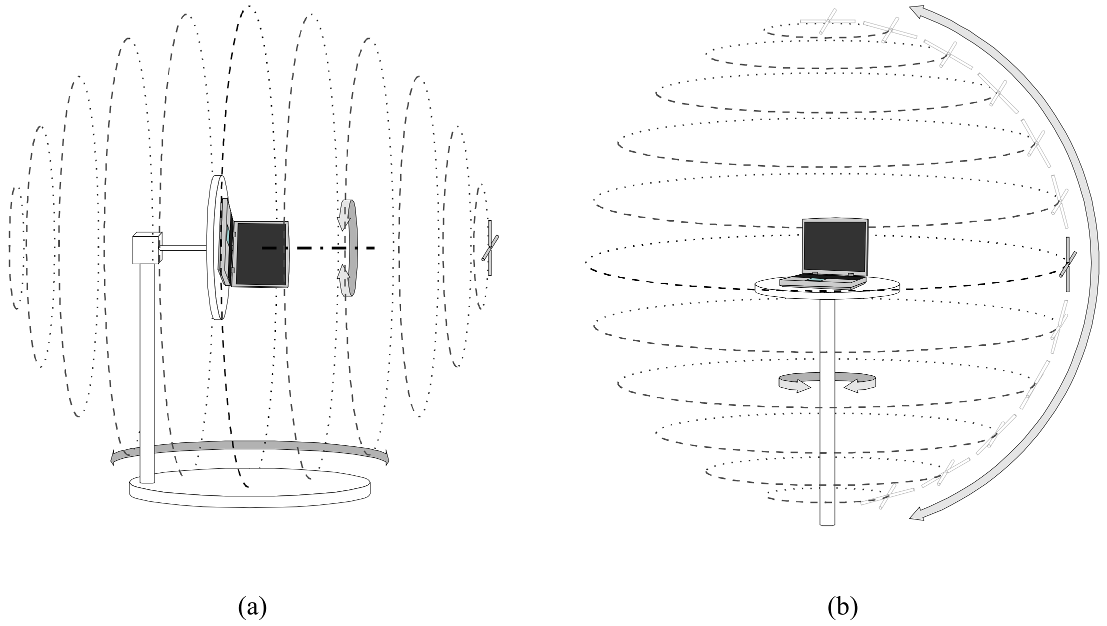

(a) (b)

Figure 6.5. Illustration of combined axis system (a) and distributed axis system (b), showing conical section cuts in each. Note the change in orientation of the DUT in each system in order to maintain the same coordinate system.

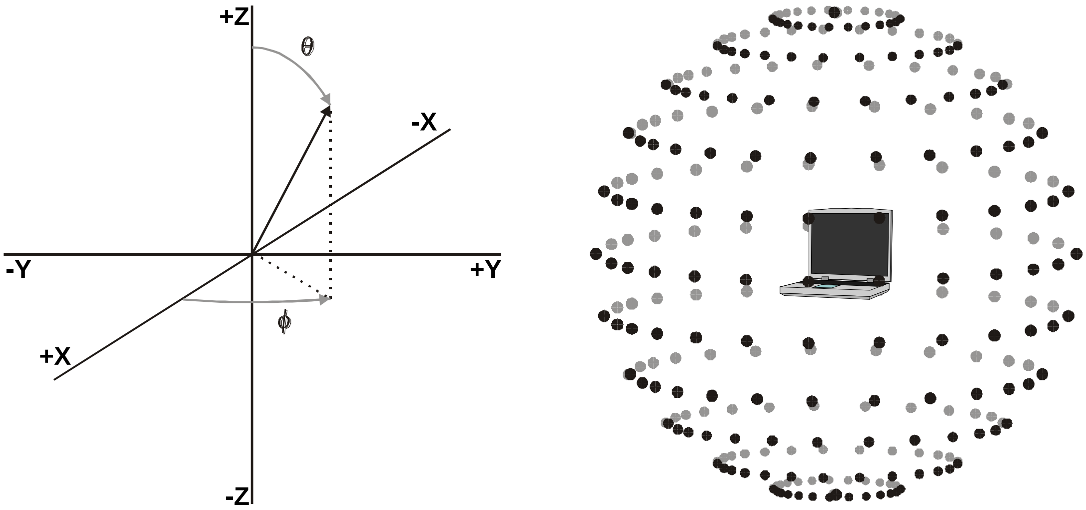
Each of these systems has its advantages and drawbacks. The combined axis system simplifies the positioning relative to the test chamber by being one unit. Since the measurement antenna remains fixed in the chamber, the chamber only needs to be large enough to support the test range distance along one axis, whereas the distributed axis system needs the chamber to be as wide as the required range length and over twice as tall. The excessive cost of a large test chamber means that this system is usually restricted to short range lengths, implying small devices or near field testing only. Conversely, DUT mounting is typically much simpler for the distributed axis system, where an expanded polystyrene column can usually be used to support even large DUTs. For the combined axis system, the DUT must be mounted to the positioner and be able to rotate end-over-end. The larger the DUT, the more significant the support structure must become to be able to support the additional weight. This can have an impact on the RF performance of the system. In either case, for testing the omnidirectional antennas typically seen in portable wireless devices, the support structure must be made of suitably low dielectric materials to minimize the overall impact to the measurement. The effect of the dielectric support should be accounted for when determining the quality of the quiet zone and the overall uncertainty associated with measurements made using the system.

There are numerous variants of these systems, including multi-sensor systems that replace one or both positioners with additional measurement antennas at fixed positions around the sphere, and a combined axis system that reverses the roles of the two positioners for an “azimuth over elevation” configuration. This document cannot possibly capture all possibilities, but these are worth noting. Multi-sensor systems can be designed 1) to measure only a few points on the surface, thus reducing test time but still requiring two positioning axes to cover all points on the sphere; 2) to perform a 0-180° cut at the desired resolution, requiring 360° rotation of the turntable positioner; 3) to perform a 360° cut, requiring only a 0-180° rotation of the turntable, or 4) a full spherical array of antennas at the desired spacing, which completely eliminates the need for any positioner. The “positioning” between measurement points on the multi-sensor array is performed by switching the RF connection between each antenna, similar to changing the polarization on a dual polarized measurement antenna. From the viewpoint of the DUT, the azimuth over elevation combined axis system is the equivalent of attaching the chamber to the MA and rotating the entire assembly ±90°. Instead, the turntable tilts ±90° so that the MA transits from pointing along the axis of the turntable in one direction to pointing along the axis in the other. Each of these variants combines the benefits and drawbacks of the systems described above, as well as adding some unique ones of their own.

6.8 Test Setup

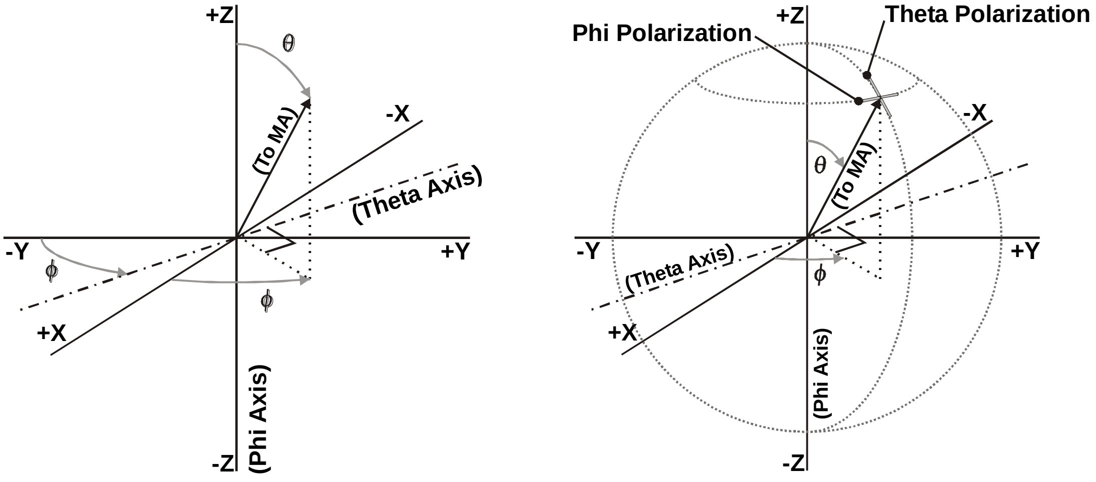
The basic setup of the RPT measurement system is shown in Figure 6.1. It includes a test environment as described above, consisting of a fully anechoic chamber, measurement antenna, and positioning system; an RF switch or other polarization control used to measure two orthogonal polarizations, and calibrated test equipment used to perform the actual measurements. The calibrated test equipment is similar to the equipment used for conducted power and sensitivity measurements, with the additional stipulation that the components of the test equipment must have the dynamic range necessary to maintain the connection and accurately measure the quantity of interest at each data point on the surface. On a typical system, the total path loss between the test equipment and DUT can be expected to be as much as 50 dB. An additional 20-30 dB of dynamic range is necessary to be able to measure nulls in the pattern and remain far enough above the noise floor to avoid large uncertainties in the power measurements at the peaks in the pattern.

Since the test system measures spherical pattern information, the data will be recorded using a spherical coordinate system. Figure 6.6 illustrates the angles associated with the spherical coordinate system and provides an example of measurement data points taken every 15° in that coordinate system. Figure 6.7 illustrates the definition of each rotation axis and the standard definition of the two orthogonal polarizations typically measured. The theta (θ) polarization is the polarization parallel to the direction of motion when rotating about the theta axis, and the phi (ϕ) polarization is the polarization parallel to the direction of motion when rotating about the phi axis. For the two positioning systems described above, the horizontal axis is the phi axis and the turntable is the theta axis for the combined axis system, while the turntable is the phi axis and the measurement antenna rotation is the theta axis for the distributed axis system. It’s important to remember that this defines the coordinate system of the DUT. The angles θ and ϕ define the location of the MA with respect to the DUT. Using this coordinate system, cuts made by rotating 360° about the phi axis while leaving theta fixed (phi cuts) produce conical section cuts in the pattern. Cuts made by rotating 360° in theta for a fixed phi value produce great circle cuts. It should be noted that these great circle cuts intersect at $\theta = 0°$ and again at $\theta = 180°$. Thus, it is typically preferable to measure conical cuts to avoid repeated measurements of these two data points. Alternately, the repeated points in great circle theta cuts can be skipped as long as the values are filled in from the first cut measured.



(a) (b)

Figure 6.6. Definition of angular components and axes for the spherical coordinate system (a) and illustration of data points taken every 15° in θ and ϕ (b).



(a) (b)

Figure 6.7. Definition of rotational axes (a) and polarization directions (b) corresponding to the spherical coordinate system.

6.9 Site Validation

There are a variety of methods for validating the quality of the quiet zone. The oldest method is the free space VSWR approach, where directional antennas are scanned across the quiet zone and the ripple magnitude is used to determine the reflectivity from the chamber wall(s) relative to the direct signal. Since the received signal is the vector sum (magnitude and phase) of the direct and reflected signals, deviations from a flat response are either due to reflections from the walls (ripple) or due to non-uniformity of the measurement antenna beam (amplitude taper). The ripple oscillations are separated from the amplitude taper and the reflectivity is determined by calculating the max (direct + reflected) to min (direct – reflected) for a range of orientations of the directional test antenna. A modern modification of this procedure uses a vector network analyzer to capture both magnitude and phase information and separate the direct signal from the reflected at each point using time domain gating. While these techniques are fine for determining the performance of individual regions of absorber on the walls of the chamber, and are popular for microwave antenna testing where the DUT commonly uses a directional antenna, they are not as useful for validating sites used for testing omnidirectional antennas such as those typically seen in portable wireless devices. Since an omnidirectional antenna illuminates most of the chamber simultaneously, the error in measurements will be due to the effect of all illuminated surfaces combined. There is currently no accepted simple way to combine the individual free space VSWR results to predict a total measurement uncertainty for an omnidirectional DUT.

An alternate method involves measuring the ripple using omnidirectional source antennas. Since the chamber is illuminated similar to the illumination that will occur from an omnidirectional DUT, the ripple behavior more accurately reflects the error that may be expected in a measurement of the DUT. Sleeve dipoles and resonant loop antennas are used to create omnidirectional illumination with orthogonal polarizations. By orienting the polarization direction of each antenna parallel to each of the two measurement polarizations, all surfaces of the chamber are tested with both normal and transverse polarizations. Moving the antenna throughout the quiet zone and measuring the ripple gives an indication of the expected magnitude uncertainty of each individual measurement point in the pattern. The surface standard deviation (SSD) method can be used to predict the error of surface integral quantities such as TRP and TIS based on the ripple test results. A version of this method has been adopted by another industry organization for qualifying test systems for this type of radiated performance testing. It assumes omnidirectional radiation and includes the positioning system in the measurement. If care is taken to orient the DUT such that support structure remains in the null of the antenna(s), or when phantoms are used that obscure the support structure behind them, the real uncertainty is typically much less than predicted by this worst-case approach. Note also that this method typically removes the effect of range length variation from the ripple test result, opting to account for the effect of short range lengths in another uncertainty contribution. The uncorrected ripple can be used to estimate the uncertainty on absolute power measurements of single position data points.

Appendix A specifies the method that has been adopted for RPT, which uses an isotropic field probe in place of the reference source antenna to determine the field uniformity in the quiet zone. By using an isotropic field probe offset to different positions in the quiet zone, and performing a pattern measurement at each position within the quiet zone, a good indication of the uncertainty of both individual points and integrated power quantities can be determined. It has similarities to the methods adopted by 3GPP, but overcomes some limitations in that methodology.

ANSI C63 and CISPR are currently considering several other site validation methodologies that may be applicable to this type of test system.

The site shall be validated at least annually starting before its first use and after any physical change that could affect the quiet zone performance (removal/replacement of absorber, movement of the test positioner, change of the antenna location relative to the quiet zone, etc.) The effect of ripple and amplitude taper due to the range length, the chamber, and the support structure shall be evaluated using the methods specified in Appendix A as well as any other applicable methods that may be necessary to determine the associated uncertainty component.

6.10 Range Calibration

Prior to use, the site must be validated (see previous section) and the range must be calibrated. The range calibration takes into account the path loss between the DUT and the measurement port of the test equipment, including all cables, switches, measurement antenna gain, range length, etc. The resulting calibration corrects the measured values so that they are referenced to a theoretical isotropic radiator. The theory behind this calibration process is documented elsewhere[1], so this document will only refer to the basic steps necessary for the calibration. A precision calibrated reference antenna and a network analyzer or signal generator/receiver combination with good linearity are required for this measurement.

Figure 6.8 illustrates a typical radiation pattern measurement system for active antenna measurements. The measurement signal paths to be calibrated are indicated in green. This includes the radiated propagation path through the chamber and the conducted path through any cables, switches, amplifiers, etc. all the way to the measurement port of the test equipment. For radiated power measurements, this is the input port to the signal/spectrum analyzer, or other calibrated receiver used to measure the radiated power of the DUT. For sensitivity measurements, this is the output of the signal generator in the base station emulator used to generate the communication traffic. Note that there are two paths inherent in the system, one for each polarization. A range calibration must be performed for each path, as well as for each path combination necessary to reach the test equipment. Thus, if there are two equipment configurations, one for power measurements and one for sensitivity, then a total of four different range calibrations must be performed.

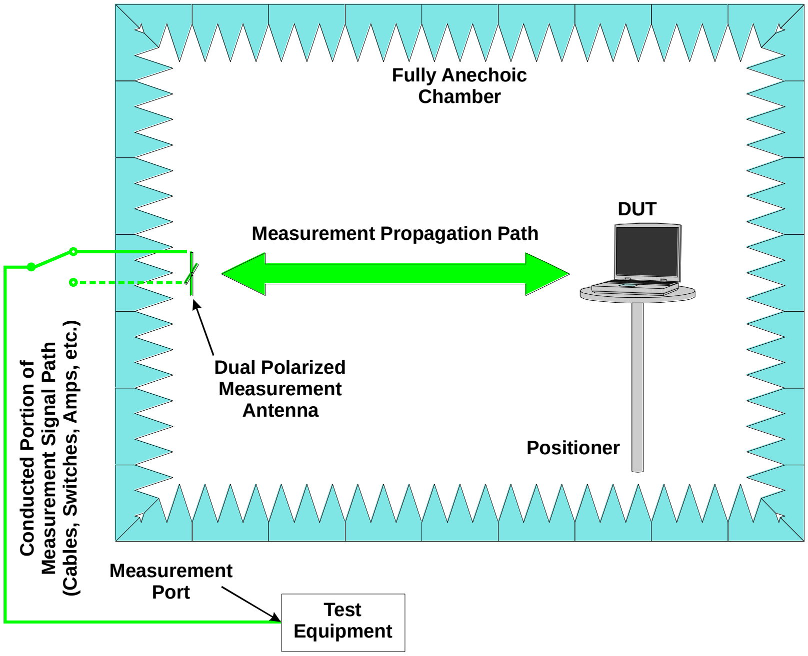


Figure 6.8. Typical Active Pattern Measurement System showing measurement path in green.

Figure 6.9 illustrates a typical range calibration configuration, highlighting the components that must be added to the system to perform the measurement. The reference antenna (yellow) is oriented in the center of the quiet zone parallel to the polarization of the measurement antenna to be calibrated. The cables needed to reach from the vector network analyzer (or other transmitter/receiver pair used to perform the

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[1] Foegelle, M.D., "Antenna Pattern Measurement: Theory and Equations", Compliance Engineering, 2002 Annual Reference Guide, Vol. XIX, No. 3, pp. 34-43.

range calibration) to the reference antenna (red cable), and from the end of the cable that would normally connect to the measurement port back to the VNA (purple cable) are not part of the range path to be calibrated (green) and must be removed. This is done by connecting the cables in a loop as shown in Figure 6.10 and measuring (or calibrating out) their path loss. The effects of the reference antenna gain are also not part of the measurement system and must be removed as part of the corrections applied to any measurements performed on the range. Note that the direction of propagation for the range calibration is configured for transmission from the reference antenna. While this is correct for the radiated power measurement path, it may be necessary to reverse the connections to the ports of the VNA (and thus the corresponding propagation direction) for calibrating the sensitivity path if there are any active components (i.e. amplifiers) in the signal path to be calibrated. If not, the same propagation direction may be used for both transmit and receive range calibrations due to reciprocity. If an optional communication antenna is used for EIRP measurements, a verification measurement is required to ensure that the communication antenna does not transmit the downlink signal from the test equipment, thereby impacting the DUT's estimate of the radiated propagation path through the chamber:

1) Prepare the chamber calibration routine for the downlink measurement path
2) Connect the communication antenna in the EIRP setup configuration, as shown in 8.2.1.3.
3) Perform the calibration measurements with the VNA, as described above
4) Ensure that the measured path loss over the radiated propagation path through the chamber is within acceptable uncertainty limits of the measurement obtained without the communication antenna.

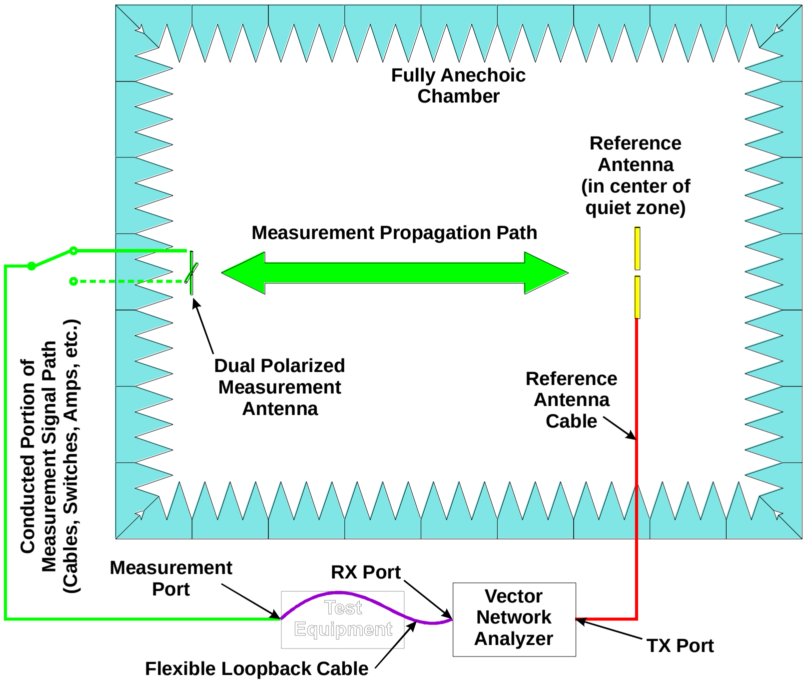


Figure 6.9. Typical Range Calibration Configuration showing additional components.

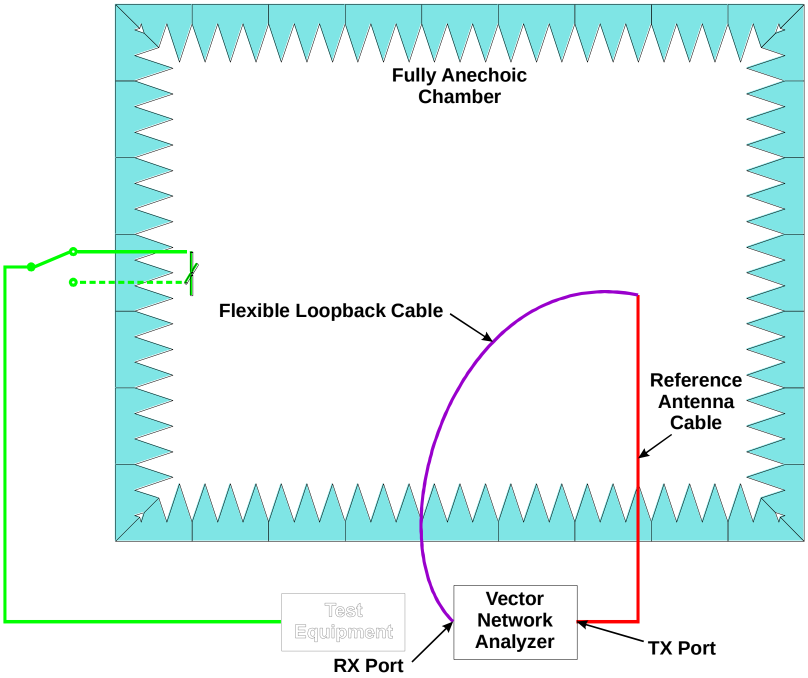


Figure 6.10. Example of Loop-back Configuration for Cable Calibration.

The following procedure provides detailed information for precise calibration of the test range, with special attention paid to possible sources of error to ensure that low uncertainty measurements can be made.

The equipment required for range calibration includes:

1. Anechoic chamber meeting desired quiet zone performance.
2. Reference antenna(s) with valid calibrations to cover the required range of test frequencies. To achieve suitable range calibration accuracy, precision calibrated reference antennas with uncertainties on the order of a few tenths of a dB are required. Sleeve dipoles are recommended as the reference antenna up to 2.5 GHz. Standard gain horns are recommended above 2.5 GHz. Other antennas may be used, however, the uncertainty contribution to the resulting measurements due to calibration and phase center issues may be significantly larger.
3. Low dielectric constant support structure (e.g. Styrofoam) for positioning the reference antennas.
4. Measurement antenna(s) (e.g. horn or dipole used to perform measurements of the mobile station). Note: If multiple antennas are used to cover the required frequency range, the range calibration measurement must be repeated each time the antennas are repositioned, unless a permanent mounting fixture is used to guarantee repeatable performance.
5. Network analyzer, spectrum analyzer with tracking generator, or stable signal generator and measurement receiver (spectrum analyzer, power meter, etc.) having a wide dynamic range and high linearity, all with current calibration(s).
6. All RF cabling, splitters, combiners, switches, attenuators, etc. required to connect the measurement antenna(s) to the test equipment required for measuring radiated power and sensitivity of the DUT. The connection to the receiver or base station emulator used to perform the DUT measurement shall be referred to as the "test port" in this section. These components will be characterized along with the range length and measurement antenna contributions.

7. Additional cabling to reach from the signal source to the reference antenna (the reference port), and from both the reference antenna location and the test port to the receiver input. The source cabling to the reference antenna should be treated with ferrite beads and routed to minimize its influence on the range calibration measurement. The effects of these cables will be removed from the range calibration results, however, cable lengths should be kept as short as possible to reduce the associated path loss.
8. Low loss cable adapters for performing various interconnects. These should be characterized to determine their influence on the measurements. That influence may be corrected for if measured, or applied to the measurement uncertainty if estimated.
9. Optional 3 to 10 dB fixed attenuators for reducing standing wave effects in cables.
10. Optional 50 Ω terminations.

The range calibration is performed in a two-step process whereby the effects of the cables and equipment external to the normal operation of the range are removed from the resulting range calibration values. By performing the measurement in this manner, the measurement uncertainty is reduced, since the result relies on the linearity of the receiver rather than its absolute value accuracy. Additionally, measuring all components of the signal path at once results in only one measurement uncertainty contribution to the total measurement uncertainty of the path loss measurement; as opposed to measuring the loss of each component and combining them for a total loss, which increases the uncertainty by the square root of the number of measurements required.

6.10.1 Measurement Step 1: Cable Calibration

The first step involves measuring the frequency response of all cabling, connectors, and equipment that is not a part of the test system. This step is normally only done once, provided all required test frequencies can be covered with one set of cables. If different cabling configurations are required for each polarization of the reference antenna, etc., this step must be repeated for each configuration. The two steps should be performed sequentially for each configuration to avoid additional uncertainty contributions due to changes in connections, etc.

For each configuration, perform the following steps:

1. Route the source cable(s) from the signal generator or output port of the network analyzer to the mounting location of the reference antenna. A minimum of 3 dB (preferably 10 dB) attenuator is recommended at the output (reference antenna side) of the cable to minimize standing waves. This output connection is defined as the reference port.
2. Connect the output of the source cable to the receiver or input port of the network analyzer, either directly (if the receiver can be moved to accommodate this connection) or through another cable. An additional attenuator is recommended at the input port of the receiver.
3. Ensure all equipment has been powered on long enough to have stabilized.
4. Perform a frequency scan or sweep to cover the required test frequencies and record the result. The power level of the signal source must remain fixed for all measurements. Ensure that the received signal is below the compression point of the receiver (linear region) and sufficiently far above the noise floor of the receiver to account for the expected range path loss. It is recommended that all receivers be set to narrow bandwidth to obtain the lowest possible noise floor. Depending on the equipment used, refer to the following procedure:
    a. For a vector network analyzer, first record the swept frequency response curve with no calibration applied. This will be used for verifying that the analyzer is in the appropriate linear region (not overloaded) and has enough dynamic range. Perform a calibration of the analyzer to normalize out the response of the cable

loop. This calibration will serve as the source reference test. While a full two-port calibration is desirable to provide the lowest measurement uncertainty and account for standing wave issues, etc., flexing of cables, movement of rotary joints, and other variations may make the calibration less accurate in practice. A through response normalization, while having a higher level of uncertainty specified by the manufacturer, may actually be more accurate in practice due to the cable variations involved. Refer to step 5 below for information on estimating these effects.

   b. For scalar swept frequency devices (scalar network analyzers, spectrum analyzers with tracking generators, etc.) record the swept frequency response curve of the cable loop. If the analyzer contains a scalar calibration or trace math function, it may be used to subtract this reference curve from subsequent measurements.
   c. For discrete signal generator and receiver combinations, tune the receiver and signal generator to each frequency and record the reading of the receiver.

5. Prior to proceeding to the next measurement step, move the cables around and monitor the received signal level. Any gross changes in the reading indicate bad cables or connections and should be rectified prior to continuing. Minor variations (fractions of a dB) are expected and should be accounted for in the measurement uncertainty of the range calibration measurement.

6.10.2 Measurement Step 2: Range Calibration

The second step measures the frequency response of the reference antenna, range, and all cabling, connectors, switches, etc. between the reference port and the test port, as well as the cabling and equipment included in measurement step 1. This step is required for each polarization of the receive antenna and for each separate signal path between the DUT and any different test ports connecting to test equipment used for the DUT measurement. Only the paths used to record data (i.e. the paths to the receiver used for TRP measurements, or the output path from the base station emulator for TIS measurements) need to be measured.

For each polarization and configuration, perform the following steps:

1. Connect the receiver or input port of the network analyzer to the test port connection to be characterized using the same cable configuration used to attach it to the reference port. Any cable adapters added or removed from the system to make the required connections must be accounted for as mentioned previously. Terminate any unused connections to the appropriate test equipment or by using 50 Ω loads.
2. Prior to connecting the source to the reference antenna, attach a 50 Ω termination to the reference port (or otherwise ensure no output from the signal generator) and record the noise floor of the analyzer or receiver at each frequency point. Use a frequency response sweep or discrete points as necessary based on the configuration. If available, use a max-hold function to obtain the maximum noise level for several sweeps.
3. Connect the reference antenna to the reference port and use a low dielectric support to hold the antenna in the middle of the quiet zone, boresight with the measurement antenna, and parallel to the polarization being characterized. For directional reference antennas, ensure that both the reference and measurement antennas are boresight to each other. Ensure that the support structure is out of the measurement path such that it has a minimal impact on the reference measurement.
4. Ensure that all equipment has been powered on long enough to have stabilized. The equipment should normally have been left on from the cable calibration step. All settings of the equipment should be identical to those for the cable calibration. The power level of the signal generator must be the same as that for the reference sweep (unless a vector

network analyzer is used to obtain relative power data) and must remain stable over time in order to obtain valid data.

5. Perform a frequency scan or sweep to cover the required test frequencies and record the result. Ensure that the received signal is below the compression point of the receiver (linear region) and high enough above the noise floor as measured in step 2 to ensure less than 1 dB measurement uncertainty due to the noise. This relationship will depend on the type of detector used in the test equipment (voltage detection without averaging requires ~20 dB difference, while for true RMS power detection, only ~6 dB is required, assuming Gaussian noise). Depending on the equipment used, refer to the following procedure:
    a. For a vector network analyzer, record a frequency response curve with the calibration applied. This curve is the desired range response measurement.
    b. For scalar swept frequency devices (scalar network analyzers, spectrum analyzers with tracking generators, etc.) record the swept frequency response curve of the cable loop. If the analyzer has been configured to automatically subtract the cable calibration reference curve, then the resulting curve is the desired range response measurement. If not, the resulting curve is the range response plus the cable contribution, which will be subtracted out later.
    c. For discrete signal generator and receiver combinations, tune the receiver and signal generator to each frequency and record the reading of the receiver. The resulting curve is the range response plus the cable contribution, which will be subtracted out later.

6.10.3 Calculating the Range Calibration Path Loss

Once the data has been acquired as described above, it’s necessary to convert it to a loss value and combine it with the reference antenna gain in dBi to obtain the total path loss to be used as the range calibration correction. Once this value has been determined, it can be added to the power readings of the DUT test equipment (in dBm) to represent the reading relative to an isotropic source.

6.11 Measurement Uncertainty Considerations

Appendix B provides detailed guidance on the uncertainty contributions associated with RPT measurements. It includes uncertainty budgets for integrated surface quantities like TRP and TIS, as well as relative quantities that are normalized to the spherical pattern data. For single point metrics used to determine relative values, the additional uncertainty is typically small, while absolute values can have significant errors depending on the quality of the quiet zone (see the site validation discussion above). Such effects could change the appearance of the measured pattern while having negligible effect on the integrated metrics.

While Appendix B is intended to list the most well known contributions to the overall measurement uncertainty that are required to be included in an uncertainty budget for the metrics of interest, some systems and configurations may have additional uncertainty contributions not listed there that must be included as well.

7 Radiated Performance Tests

The radiated performance tests are defined using a "building block" approach. Given that average performance metrics like TRP and TIS are derived from repeated measurements of the corresponding directional performance metrics of EIRP and EIS, it is useful to describe the process for measuring the directional quantities first and then add the steps for performing the spherical pattern measurement. This approach also allows for easy definition of normalization based test procedures, where only one directional performance metric is measured and then normalized by the radiation pattern determined for a related metric. Initialization steps required for measuring the baseline directional metrics are typically only required to be performed once at the start of a repetitive sequence of measurements for derivative measurements.

7.1 Device Classifications

For the purpose of RPT testing, there are a number of device classifications based on usage cases that determine the required test configurations. Devices may fall into one or more of these classifications depending the way they are expected to be used.:

Mobile Phone – includes all devices that are used in an against-the-head configuration while communication is active.

PDA/Hand-Held – includes all devices that are commonly used in a single-handed grip configuration, with or without the other hand in proximity to the device, while communication is active. This currently does not include the connection establish/release state prior to moving to one of the other configurations.

Body Worn – includes all devices that are commonly used in a body-worn configuration where the communication antenna(s) are in proximity to the human torso.

Compact Gaming – includes all devices that are commonly held in a two-handed grip, typically with the thumbs over control points on the device, while communication is active.

Notebook – includes larger format portable devices such as notebook and tablet PCs.

Plug-in Cards – includes PCMCIA, ExpressCard, USB, and other external form-factor devices. The expectation is that these devices will typically be connected to a notebook host for testing.

Fixed Location Devices – includes desktop PCs, CPEs, etc. with integral antennas that are typically mains powered and do not regularly change orientation or location.

7.2 Test Configurations

The required RPT tests must be repeated for each of the following range of test configurations based on the classification(s) that apply to a given device. Appendix D contains details on the various configurations for different device classifications.

7.2.1 Free-Space

All devices are required to be tested in a free-space configuration to determine the baseline performance of the device. The free-space condition is defined as being supported by the minimum practical amount of low dielectric support material (dielectric constant less than 5.0 and loss tangent less than 0.05) necessary to perform the required device positioning. The impact of the support structure must be accounted for in the measurement uncertainty budget.

7.2.2 Phantom Head and Hand

Mobile phone devices are required to be tested using a phantom head and hand combination as described below. Tests must be performed for both the left ear/hand and right ear/hand combination. The required hand grip(s) are dependent upon the form factor of the mobile device in its usage configuration. Where applicable, human factors studies may be used to determine alternate grips when the form factor or overall design of the device would challenge the use of a standard grip.

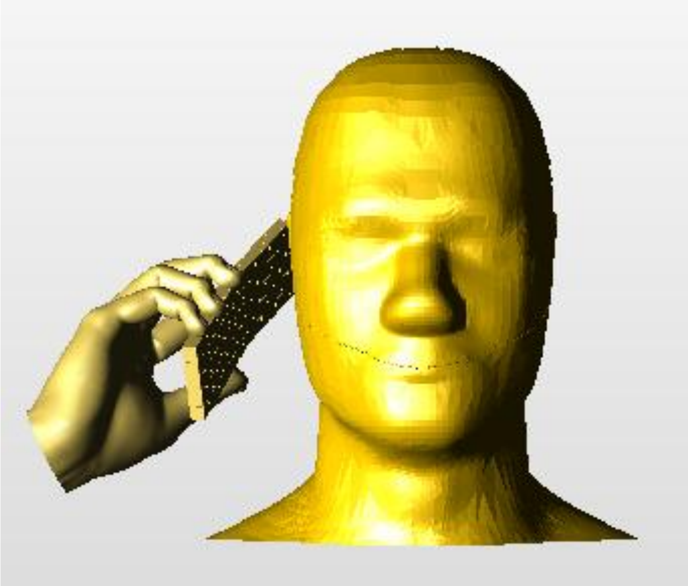


Figure 7.1 Illustration of the typical SAM phantom head and hand grip.

7.2.3 Hand-Held Grip

PDA or other hand-held devices are required to be tested using a hand-held grip matching the typical hold of the device when radio communications are active. There are two standard hand grips depending on the type of device and its capabilities. The first is the single-handed grip for web browsing, video viewing, etc. The second is the PDA grip, where one hand holds the device and the second is placed over the device to hold a stylus or other pointing device. Specifications on the required hand-held grip are TBD.

7.2.4 Two-Hand Gaming Grip

Gaming devices are required to be tested using a two-handed grip matching the typical hold of the device when in use. Specifications for the required phantom grip are TBD.

7.2.5 Tabletop

Notebooks and other devices that typically sit on a horizontal surface are required to be tested using a tabletop phantom to determine their typical performance. Requirements for the tabletop phantom are to be determined. This requirement is waived until such time as the phantom has been defined.

7.3 Test Frequencies

The device must be tested for TRP and TIS at the low, middle, and high frequencies in each supported band class and for each supported channel bandwidth as specified in Appendix 5 of [3], although for RF profile 2, the low and high sub-bands may be combined to reduce the overall testing. The intermediate frequencies shall be tested at a spacing of the corresponding channel bandwidth minus 250 kHz, centered on the middle channel and ending with the first frequency that overlaps the high and low channels of the band. The resulting band coverage will overlap by at least 250 kHz for each measured EIS value. Table 7.1 lists the required test frequencies for each RF profile, including the special test frequency spacing for Profile 2.

Table 7.1. Required test frequencies for each WiMAX Profile.

WiMAX RF Profile	TRP/TIS Test Frequencies (MHz)	Additional Frequencies for Intermediate Channel Test (MHz)
1A (M2300T-01)	2304.50, 2345.00, 2385.50	2311.00, 2319.50, 2328.00, 2336.50, 2353.50, 2362.00, 2370.50, 2379.00
1B-5(M2300T-02)	2302.50, 2350.00, 2397.50	2307.25, 2312.00, 2316.75, 2321.50, 2326.25, 2331.00, 2335.75, 2340.50, 2345.25, 2354.75, 2359.50, 2364.25, 2369.00, 2373.75, 2378.50, 2383.25, 2388.00, 2392.75
1B-10(M2300T-02)	2305.00, 2350.00, 2395.00	2311.00, 2320.75, 2330.50, 2340.25, 2359.75, 2369.50, 2379.25, 2389.00
2A(M2300T-03)	2306.75, 2358.25	2309.25, 2312.50, 2315.75, 2318.25, 2346.75, 2349.25, 2352.50, 2355.75
2B(M2300T-04)	2307.50, 2357.50	2310.75, 2314.25, 2317.50, 2347.50, 2350.75, 2354.25
2C(M2300T-05)	2310.00, 2355.00	2315.00, 2350.00
3A-5(M2500T-01)	2498.50, 2593.00, 2687.50	2502.75, 2507.50, 2512.25, 2517.00, 2521.75, 2526.50, 2531.25, 2536.00, 2540.75, 2545.50, 2550.25, 2555.00, 2559.75, 2564.50, 2569.25, 2574.00, 2578.75, 2583.50, 2588.25, 2597.75, 2602.50, 2607.25, 2612.00, 2616.75, 2621.50, 2626.25, 2631.00, 2635.75, 2640.50, 2645.25, 2650.00, 2654.75, 2659.50, 2664.25, 2669.00, 2673.75, 2678.50, 2683.25
3A-10(M2500T-01)	2501.00, 2593.00, 2685.00	2505.25, 2515.00, 2524.75, 2534.50, 2544.25, 2554.00, 2563.75, 2573.50, 2583.25, 2602.75, 2612.50, 2622.25, 2632.00, 2641.75, 2651.50, 2661.25, 2671.00, 2680.75

4A(M3300T-01)	3302.50, 3350.00, 3397.50	3307.25, 3312.00, 3316.75, 3321.50, 3326.25, 3331.00, 3335.75, 3340.50, 3345.25, 3354.75, 3359.50, 3364.25, 3369.00, 3373.75, 3378.50, 3383.25, 3388.00, 3392.75
4B(M3300T-02)	3303.50, 3350.00, 3396.50	3309.50, 3316.25, 3323.00, 3329.75, 3336.50, 3343.25, 3356.75, 3363.50, 3370.25, 3377.00, 3383.75, 3390.50
4C(M3300T-03)	3305.00, 3350.00, 3395.00	3311.00, 3320.75, 3330.50, 3340.25, 3359.75, 3369.50, 3379.25, 3389.00
5A(M3500T-01)	3402.50, 3600.00, 3797.50	3405.25, 3410.00, 3414.75, 3419.50, 3424.25, 3429.00, 3433.75, 3438.50, 3443.25, 3448.00, 3452.75, 3457.50, 3462.25, 3467.00, 3471.75, 3476.50, 3481.25, 3486.00, 3490.75, 3495.50, 3500.25, 3505.00, 3509.75, 3514.50, 3519.25, 3524.00, 3528.75, 3533.50, 3538.25, 3543.00, 3547.75, 3552.50, 3557.25, 3562.00, 3566.75, 3571.50, 3576.25, 3581.00, 3585.75, 3590.50, 3595.25, 3604.75, 3609.50, 3614.25, 3619.00, 3623.75, 3628.50, 3633.25, 3638.00, 3642.75, 3647.50, 3652.25, 3657.00, 3661.75, 3666.50, 3671.25, 3676.00, 3680.75, 3685.50, 3690.25, 3695.00, 3699.75, 3704.50, 3709.25, 3714.00, 3718.75, 3723.50, 3728.25, 3733.00, 3737.75, 3742.50, 3747.25, 3752.00, 3756.75, 3761.50, 3766.25, 3771.00, 3775.75, 3780.50, 3785.25, 3790.00, 3794.75
5.AH(M3700T-01)	3602.50, 3700.00, 3797.50	3605.00, 3609.75, 3614.50, 3619.25, 3624.00, 3628.75, 3633.50, 3638.25, 3643.00, 3647.75, 3652.50, 3657.25, 3662.00, 3666.75, 3671.50, 3676.25, 3681.00, 3685.75, 3690.50, 3695.25, 3704.75, 3709.50, 3714.25, 3719.00, 3723.75, 3728.50, 3733.25, 3738.00, 3742.75, 3747.50, 3752.25, 3757.00, 3761.75, 3766.50, 3771.25, 3776.00, 3780.75, 3785.50, 3790.25, 3795.00
5.AL(M3500T-02)	3402.50, 3500.00, 3597.50	3405.00, 3409.75, 3414.50, 3419.25, 3424.00, 3428.75, 3433.50, 3438.25, 3443.00, 3447.75, 3452.50, 3457.25, 3462.00, 3466.75, 3471.50, 3476.25, 3481.00, 3485.75, 3490.50, 3495.25, 3504.75, 3509.50, 3514.25, 3519.00, 3523.75, 3528.50, 3533.25, 3538.00, 3542.75, 3547.50, 3552.25, 3557.00, 3561.75, 3566.50, 3571.25, 3576.00, 3580.75, 3585.50, 3590.25, 3595.00
5B(M3700T-02)	3403.50, 3600.00, 3796.50	3404.25, 3411.00, 3417.75, 3424.50, 3431.25, 3438.00, 3444.75, 3451.50, 3458.25, 3465.00, 3471.75, 3478.50, 3485.25, 3492.00, 3498.75, 3505.50, 3512.25, 3519.00, 3525.75, 3532.50, 3539.25, 3546.00, 3552.75, 3559.50, 3566.25, 3573.00, 3579.75, 3586.50, 3593.25, 3606.75, 3613.50, 3620.25, 3627.00, 3633.75, 3640.50, 3647.25, 3654.00, 3660.75, 3667.50, 3674.25, 3681.00, 3687.75, 3694.50, 3701.25, 3708.00, 3714.75, 3721.50, 3728.25, 3735.00, 3741.75, 3748.50, 3755.25, 3762.00, 3768.75, 3775.50, 3782.25, 3789.00, 3795.75
5.BH(M3700T-03)	3603.50,3700.00, 3796.50	3605.50, 3612.25, 3619.00, 3625.75, 3632.50, 3639.25, 3646.00, 3652.75, 3659.50, 3666.25, 3673.00, 3679.75, 3686.50, 3693.25, 3706.75, 3713.50, 3720.25, 3727.00, 3733.75, 3740.50, 3747.25, 3754.00, 3760.75, 3767.50, 3774.25, 3781.00, 3787.75, 3794.50

5.BL(M3500T-03)	3403.50, 3500.00, 3596.50	3405.50, 3412.25, 3419.00, 3425.75, 3432.50, 3439.25, 3446.00, 3452.75, 3459.50, 3466.25, 3473.00, 3479.75, 3486.50, 3493.25, 3506.75, 3513.50, 3520.25, 3527.00, 3533.75, 3540.50, 3547.25, 3554.00, 3560.75, 3567.50, 3574.25, 3581.00, 3587.75, 3594.50
5C(M3500T-04)	3405.00, 3600.00, 3795.00	3414.75, 3424.50, 3434.25, 3444.00, 3453.75, 3463.50, 3473.25, 3483.00, 3492.75, 3502.50, 3512.25, 3522.00, 3531.75, 3541.50, 3551.25, 3561.00, 3570.75, 3580.50, 3590.25, 3609.75, 3619.50, 3629.25, 3639.00, 3648.75, 3658.50, 3668.25, 3678.00, 3687.75, 3697.50, 3707.25, 3717.00, 3726.75, 3736.50, 3746.25, 3756.00, 3765.75, 3775.50, 3785.25
5.CH(M3700T-04)	3605.00, 3700.00, 3795.00	3612.25, 3622.00, 3631.75, 3641.50, 3651.25, 3661.00, 3670.75, 3680.50, 3690.25, 3709.75, 3719.50, 3729.25, 3739.00, 3748.75, 3758.50, 3768.25, 3778.00, 3787.75
5.CL(M3500T-05)	3405.00, 3500.00, 3595.00	3412.25, 3422.00, 3431.75, 3441.50, 3451.25, 3461.00, 3470.75, 3480.50, 3490.25, 3509.75, 3519.50, 3529.25, 3539.00, 3548.75, 3558.50, 3568.25, 3578.00, 3587.75

7.4 Test Data Rate

For the purposes of baseline RPT measurements, the minimum supported modulation and coding scheme (MCS) of QPSK-1/2 shall be tested using a PUSC zone. While not currently a requirement for certification, the relative performance of different modulations, coding schemes, and zones can be measured to determine the corresponding total spherical performance metrics using the single point normalization technique.

7.5 Packet Error Rate Settings

For Wave 2 devices, PER measurements for sensitivity tests shall be performed using the ACK/NACK method as described in *MS-09.1: MS receiver sensitivity* found in [3]. The payload and PDU specification shall be set according to *Table 37, Parameters for Single-Antenna Receiver Sensitivity under AWGN*, in [3].

The relevant data from the RCT table is provided in Table 7.2. The allocation parameters ensure that all the subchannels are occupied. This, in turn, ensures that effects of noise on any of the subchannels are captured in the sensitivity test.

Table 7.2. Parameters for Single Antenna Receiver Sensitivity (CTC, PUSC, AWGN)

MCS	Payload (ACK/PING)	PDU Size (bytes)	Slots per PDU
QPSK-rate 1/2	532/502	540	90

For devices that do not support the HARQ based ACK/NACK method, the PING method specified in [3] may be used instead. As an alternative to the PING test, PER may also be determined using UDP packets sent to an invalid port by counting the invalid destination ICMP responses.

Given the repetitive nature of the PER measurements used in RPT sensitivity searches, the statistical values specified in MS-09.1 are impractical. Determining sensitivity using a PER measurement requiring 30,000 frames (2.5 minutes) would take an inordinate amount of time to complete. A typical sensitivity search requires performing dozens of PER measurements across a range of power levels. At the largest allowed step size of thirty degrees, a dual polarized TIS test requires at least 92 sensitivity search measurements (assuming theta dependent phi step size optimization, otherwise it would require 124 measurements). In order to keep each sensitivity search on the order of one minute in duration, the sensitivity shall be determined using a target PER of 10% using a maximum of 1000 frames per PER measurement. The sensitivity search may use statistical early pass/fail determination with a 95% confidence interval to increase the speed of the search algorithm, provided the required number of frames converges to 1000 frames as the measured PER approaches 10%. Use of other optimizations, such as using the RSSI to quickly determine the approximate power level associated with the sensitivity level is allowed, provided the resulting sensitivity determination is based on actual PER measurements.

For single point sensitivity measurements, including normalized sensitivity measurements and intermediate channel tests, the PER shall be determined using 1000 frames near the sensitivity level without applying statistical early pass/fail conditions. For single point PER measurements, the PER shall be determined using 1000 frames.

7.6 Power Control

For power and sensitivity measurements the DUT shall be directed to transmit at full power. It is required that the device be maintained at full transmit power during the measurement phase of each test procedure. Power saving options or any other feature that could potentially reduce transmit power during the measurement shall be disabled.

7.7 Transmit Data

Uplink padding control shall be used to cause the DUT to transmit uplink packets for each frame that fully occupy the available bandwidth.

7.8 Antenna Diversity and MIMO

The current test procedure is intended to determine baseline performance of the DUT on the network and is based on the assumption that the DUT has a static radiation pattern. This implies testing the receiver performance of each diversity antenna separately, or otherwise ensuring that the radiation pattern does not change as the measurement progresses. Research is ongoing for suitable methods for testing with diversity active, but current techniques will report erroneous results if diversity is not disabled. Likewise, MIMO performance is a function of the environment in which it is used and cannot be evaluated properly in a fully anechoic environment using the test system described here. For both MIMO and diversity, it is expected that there is a correlation between the TIS results for single/static antenna performance and the combined receiver performance found through conducted testing that should be sufficient to estimate the behavior in the combined antenna case. For devices with transmitter diversity algorithm capabilities, it is expected that the TRP test will provide results with these modes enabled Additional research into other desired MIMO related metrics may result in future test requirements. Such tests are likely to require considerably different test configurations than those for the baseline TRP and TIS tests described here.

7.9 Converged Devices

It is expected that many devices that implement a WiMAX radio will also include radios based on other technologies. While specific methodologies for converged device testing are not being specified in the test plan at this time, it is expected that any additional radios that are required to be in operation during normal use of the WiMAX radio (such as a Bluetooth radio for use with a wireless headset) will be in operation when the DUT sensitivity is measured.

7.10 Summary of Required Tests

The following table summarizes the required tests for RPT certification.

Table 7.3. RPT Certification Test Summary.

Test ID	Test Description	Required Measurements	Test Method
RPT1	Total Radiated Power (TRP) or Near Horizon Total Radiated Power (NHTRP)	Low, Mid, and Hi Channel of Each Supported Band	8.3.2
RPT2	Total Isotropic Sensitivity (TIS) or Near Horizon Total Isotropic Sensitivity (NHTIS)	Low, Mid, and Hi Channel of Each Supported Band	8.3.3
RPT3	Intermediate Channel Sensitivity (ICS)	Continuum of Channels across Each Supported Band	8.4.2

8 Test Procedures

8.1 General Statement for All Tests

1. Test procedures are provided below for all mandatory tests.
2. In any test the losses for all RF elements including measurement antennas and range path loss will be determined and compensated for. Range path loss will be referenced to a theoretical isotropic radiator. This procedure will be called range calibration.
3. The DUT will be attached to any required phantom and mounted in the center of the test system quiet zone in the orientation specified for the given DUT form factor and configuration.
4. The illustrated test setup for each test is an abstract representation of the system required to execute test procedures described in each section.

In order to perform these tests, the DUT (equipment vendor) has to provide the necessary configuration interface to the Test Facility in order to:

1. Configure the device to single/static antenna radiation pattern(s) for both transmit and receive.
2. Perform network entry and maintain a connection to a suitable base station emulator, allowing for uplink padding and downlink PER measurements.
3. Control uplink power level either manually or through the network interface.
4. Modify the modulation and coding rates
5. Modify UL MAP and DL MAP as needed for the corresponding tests
6. Modify any applicable HARQ parameter as needed by corresponding tests.
7. Modify and set ID_cell and Perm_Base.

The Base Station Emulator must be capable of performing the specified measurements (eg. PER/Sensitivity) to the level of quality expected by the associated RCT test [3].

8.2 Baseline Directional Performance Metrics

This subsection defines metrics that represent the performance of a DUT in one direction of propagation. The baseline procedures describe measurement of an individual polarization orientation and indicate how to determine the total field power density quantity by combining two orthogonal polarization measurements. While these metrics are of limited use by themselves, they provide the fundamental building blocks required for determining the overall radiated performance of the DUT.

8.2.1 Effective Isotropic Radiated Power Measurements

The purpose of this test is to determine the EIRP for a single polarization and orientation of the measurement antenna relative to the DUT.

8.2.1.1 Introduction

This test will determine the transmit performance of a device in a given propagation direction and polarization.

8.2.1.2 Testing requirements

This test requires a BSE and MS connection with the following capabilities. The MS must support the necessary network commands sent from the BSE via the radio interface to set its transmit power to the maximum supported transmit power meeting regulatory requirements and to transmit uplink padding packets at that power level.

The power shall be measured with a spectrum analyzer or I/Q analyzer as specified in Appendix C.

The test shall be performed in a radiated performance test system like those described in Section 6 that has been qualified as described in Appendix A.

8.2.1.3 Test setup

Figure 8.1 shows the test setup for the EIRP measurement. To perform traceable power measurements the analyzer receives the UL signal from the MS using the calibrated signal path(s) through the measurement antenna. The measurement and communication links share the same RF path through the measurement antenna to ensure uplink and downlink path loss reciprocity in the communication channel between the test equipment and the DUT. The uplink path may utilize an optional communication antenna to reduce packet loss at the test equipment, as shown below. In the event of a test setup using the communication antenna, additional calibration procedures are described in Section 6.10.

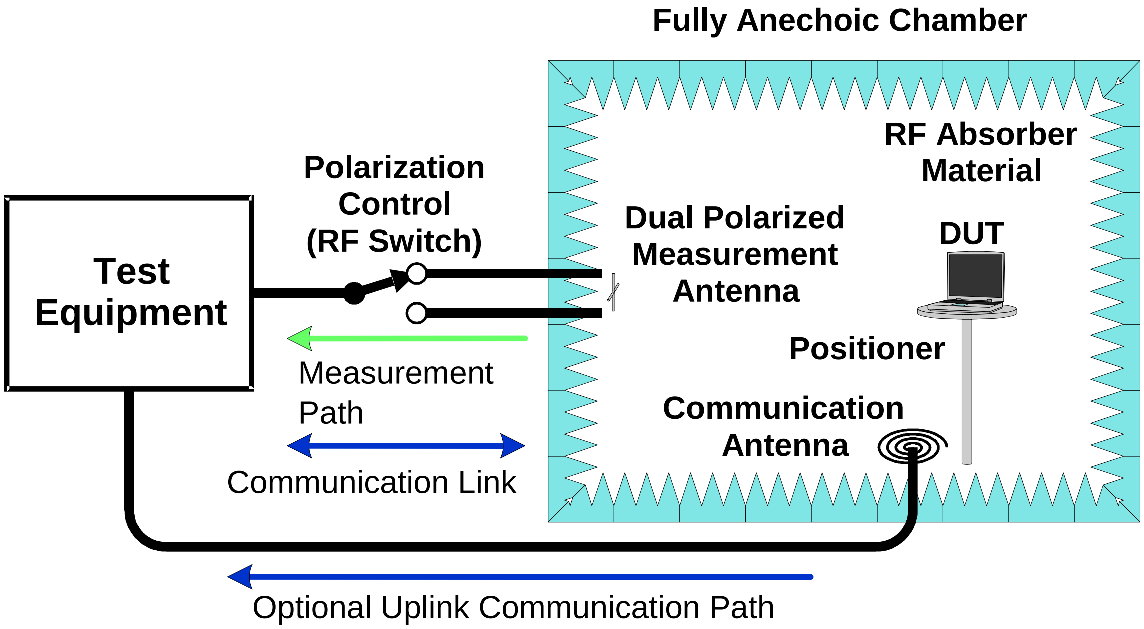


Figure 8.1. Typical test setup for EIRP measurement

8.2.1.4 Test procedure

The following initialization steps are typically followed once per test sequence when this test procedure is used as part of a larger test sequence.

1. Establish a wireless connection between the DUT and the BSE.
    a. Set the BSE to the target measurement frequency
    b. Select the required UL bandwidth for the profile to be tested.
    c. Set UL map to fully use all subchannels.
    d. Select the appropriate DL and UL modulation and coding scheme (MCS).
    e. Complete the network entry between the DUT and the BSE.
2. Instruct the DUT to transmit at full power.
3. Set the analyzer to measure power as described in Appendix C.

The following steps are followed to determine the EIRP.

4. Have BSE cause the DUT to generate the required uplink traffic at the target data rate by performing a single burst allocation with all subchannels and a control channel as in the default frame structure of Appendix 2 from reference [3].
5. Measure the average power of the specified number of uplink packets, where the duration is sufficient to allow the DUT's measurement of received signal strength to stabilize, using the method defined in Appendix C.
6. Correct the power measurement using the range loss for the chosen polarization of the measurement antenna to determine EIRP for this polarization and orientation.
7. If required, repeat the above steps 4-6 for the orthogonal polarization and then determine the total EIRP for this propagation direction by converting the measured power to linear units (dBm to mW) and adding the resulting quantities:

$$EIRP_{Total}(mW) = EIRP_{\theta}(mW) + EIRP_{\phi}(mW) \qquad \text{Eq. 8-1}$$

where

$$EIRP(dBm) = 10\log(EIRP(mW)) \qquad \text{Eq. 8-2}$$

and

$$EIRP(mW) = 10^{EIRP(dBm)/10}. \qquad \text{Eq. 8-3}$$

8.2.1.5 Compliance requirements

There are currently no compliance requirements for RPT testing.

8.2.1.6 Measurement Uncertainty

There are currently no individual requirements for single point metrics like EIRP, so it is not necessary to determine the measurement uncertainty of these quantities directly. Instead, Appendix B lists a variety of measurement uncertainty contributions related to total radiated performance metrics like TRP and TIS. While many of these same contributions apply directly to the EIRP, integral quantities like TRP tend to average out a number of additional random error contributions to the individual EIRP data points.

8.2.2 Effective Isotropic Sensitivity Measurements

The purpose of this test is to determine the EIS for a single polarization and orientation of the measurement antenna relative to the DUT.

8.2.2.1 Introduction

This test will determine the receive performance of a device in a given propagation direction and polarization.

8.2.2.2 Testing requirements

This test requires a BSE and MS connection with the following capabilities. The MS must support the necessary network commands sent from the BSE via the radio interface to set its transmit power to the maximum supported transmit power meeting regulatory requirements. The BSE must be able to create a static channel (no simulated fading). The test system must allow varying the downlink power level to determine the level where the PER at the MS reaches the target threshold level. The downlink channel shall be configured with a 2.5 dB pilot boost and 9 dB preamble boost relative to the data subcarrier. Sensitivity results shall be reported based on the average power level of all subcarriers across the data burst, minus the effect of any pilot boosting occurring during the data burst, as specified in the RCT sensitivity test in [3]. If the BSE output power level is referenced to some other level, such as the preamble power, the appropriate offset shall be applied to the measured data in order to report the data subcarrier average power.

The table below provides a summary of the power corrections to be applied when the BSE power level is referenced to the Preamble power level for sensitivity measurements. Table 8.1 provides the downlink power corrections for PUSC subcarrier allocation mode r. The correction values for various channel bandwidth and FFT sizes are the same.

Table 8.1. Power Correction from Preamble Power to Data + Pilot Power (with no Boosting) for DL PUSC

BW	5	10
FFT size	512	1024
Delta between Preamble power and un-boosted pilot + data power (dB)	4.29	4.29

[Note: In the future, it is expected that BSE units incorporate the capability to report this data power with correction for boosted pilots directly.]

The test shall be performed in a radiated performance test system like those described in Section 6 that has been qualified as described in Appendix A.

8.2.2.3 Test setup

Figure 8.2 shows the test setup for the EIS measurement. The downlink from the base station emulator uses the dual polarized measurement antenna in order to determine the DUT sensitivity for each polarization. The uplink may be through the measurement antenna or through a separate communication antenna to minimize the path loss on the uplink and help ensure that no packets are lost.

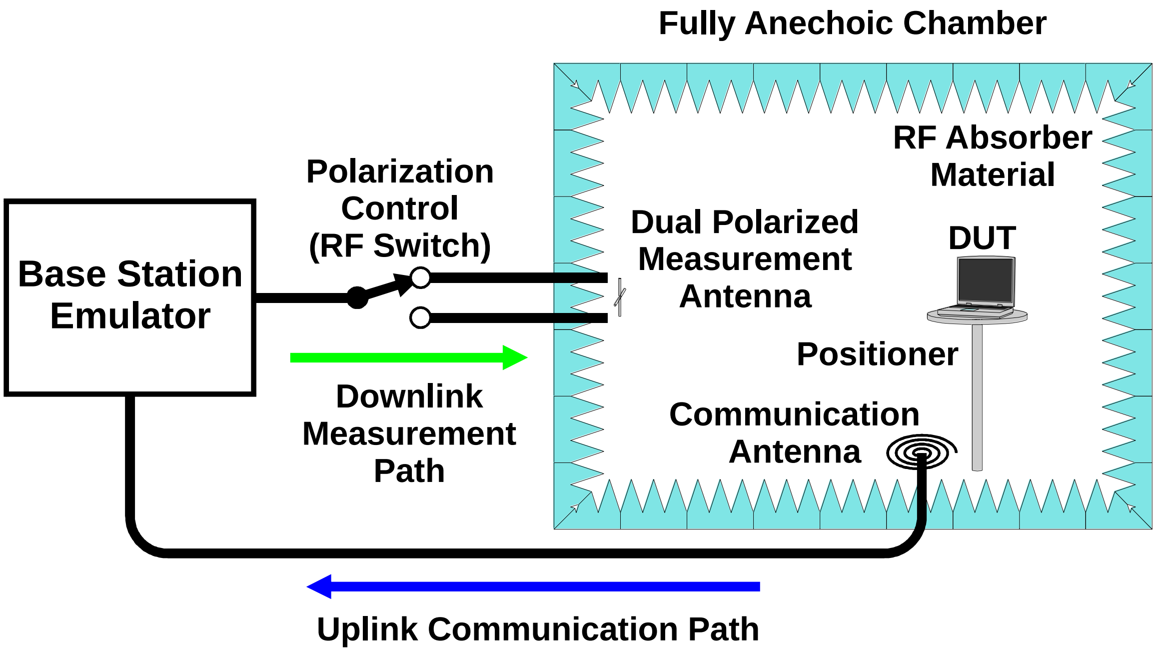


Figure 8.2. Typical test setup for EIS measurement

8.2.2.4 Test procedure

The following initialization steps are typically followed once per test sequence when this test procedure is used as part of a larger test sequence.

1. Establish a wireless connection between the DUT and the BSE.
   a. Set the BSE to the target measurement frequency
   b. Select the required DL and UL bandwidth for the profile to be tested.
   c. Select the appropriate DL and UL modulation and coding scheme (MCS).
   d. Set HARQ to zero retries (Wave 2 devices only).
   e. Complete the network entry between the DUT and the BSE.
2. Ensure that the uplink signal strength at the BSE is sufficient to avoid packet/ACK loss on the return path throughout the required measurement.

The following steps are followed to determine the EIS.

3. Configure the BSE to allow repeated PER measurements at the required data rate and packet size.
4. Determine the lowest downlink power level, to within 0.5 dB, that will produce a passing PER level using the specified number of packets with a 95% confidence interval (see 7.5). Searches may be optimized as required to reduce overall search time; including reducing the number of packets required and enlarging the step size during the initial portion of the search, and using statistical pass/fail determinations based on the confidence interval; provided that the final measurements done at the reported downlink power level are consistent with a 95% confidence at the required number of packets. While the search algorithm is left to the discretion of the implementer, some devices may not recover well when stepping from below the target sensitivity to a point above it. The test lab should ensure that the device reports a stable sensitivity level and if necessary switch to a single-ended search that only approaches sensitivity from power levels above the target point.

5. Correct the resulting power level from the sensitivity search using the range loss for the chosen polarization of the measurement antenna to determine EIS for this polarization and orientation. Note that the correction for EIS is opposite in sign to that for EIRP, since better EIS values are more negative in dB. If necessary, also correct for the difference between the reported power and the data subcarrier power.
6. If required, repeat the above steps 3-5 for the orthogonal polarization and then determine the total EIS for this propagation direction by converting the measured power to linear units (dBm to mW) and adding the resulting quantities:

$$EIS_{Total}(mW) = \frac{1}{\dfrac{1}{EIS_{\theta}(mW)} + \dfrac{1}{EIS_{\phi}(mW)}} \qquad \text{Eq. 8-4}$$

where

$$EIS(dBm) = 10\log\left(EIS(mW)\right) \qquad \text{Eq. 8-5}$$

and

$$EIS(mW) = 10^{EIS(dBm)/10}. \qquad \text{Eq. 8-6}$$

Note that the EIS sums as an inverse value since better performance is represented by smaller values. Thus, the total EIS is smaller than either orthogonal component of the EIS.

8.2.2.5 Compliance requirements

There are currently no compliance requirements for RPT testing.

8.2.2.6 Measurement Uncertainty

There are currently no individual requirements for single point metrics like EIS, so it is not necessary to determine the measurement uncertainty of these quantities directly. Instead, Appendix B lists a variety of measurement uncertainty contributions related to total radiated performance metrics like TRP and TIS. While many of these same contributions apply directly to the EIS, integral quantities like TIS tend to average out a number of additional random error contributions to the individual EIS data points.

8.3 Total Radiated Performance Tests

This subsection defines measurements that determine performance of a DUT in all directions of propagation and defines metrics that represent the average performance of the DUT in any orientation. The procedures describe measurement of spherical radiation patterns around a DUT using a generic test procedure, and then specify the variants required to use the baseline performance metrics to determine quantities like TRP, NHTRP, TIS, and NHTIS.

8.3.1 Spherical Radiation Pattern Measurements

The purpose of this test is to measure a spherical radiation pattern around the DUT and determine an integral total performance metric based on the resulting pattern data. The procedure is written in a generic fashion so that subsequent requirements can use this procedure by filling in the required fields.

8.3.1.1 Introduction

This test will determine the total radiated performance of a device for a given performance metric.

8.3.1.2 Testing requirements

In order to ensure that the pattern surface is sampled with sufficient resolution to resolve peaks and nulls in the pattern, use the following formula to determine the maximum angular step size around the DUT:

$$Max\ Step = \min(30°, 40°/(D_L/\lambda)) \qquad \text{Eq. 8-7}$$

where D_L is the maximal linear dimension (length, width, or height) of the DUT, and λ is the wavelength being measured. However, for portable and mobile devices with pseudo-omni patterns TIS will be performed with a 30° sampling grid in θ and φ. It is recommended that the step size be chosen such that there are an integral number of steps in 360°.

To improve test time by as much as 25-35% an optional optimization can be used for measurements performed using a conical cut acquisition process. In this case, the φ angle step size can be varied as a function of the θ position according to the formula:

$$N_\phi(\theta) = 1 + \mathrm{int}((N_\phi(90°) - 1)\sin(\theta)) \qquad \text{Eq. 8-8}$$

where $N_\phi(\theta)$ is the number of points at any given θ position, $N_\phi(90°)$ is defined as 360° divided by the chosen ϕ angle step size, and int() refers to taking the integer portion of the result within the parentheses. The ϕ angle step size for this θ angle is then given by 360°/ $N_\phi(\theta)$. The target positions may be rounded to the nearest whole degree if desired. For portable and mobile devices with pseudo-omni patterns, for TIS, $N_\varphi(90°) = 360/30=12$.

8.3.1.3 Test setup

Refer to the corresponding baseline performance metric for the required test setup for the spherical radiation pattern test.

8.3.1.4 Test procedure

To cover the surface of a sphere, one axis of the spherical positioning system will typically be stepped from 0-180°, while the other axis will be stepped from 0-360° at each position of the first axis. Provided the DUT is stable over time, this order can be varied without affecting the measurement result provided full and unique coverage of the surface is obtained. The following procedure describes an example of conical section data acquisition, however it is acceptable to use other stepped acquisition methods that measure the same data points such that the formulas in step 11 may be applied.

Perform the following steps to measure the spherical radiation pattern:

1. Choose a step size that evenly divides into 180° and adheres to the maximum step size requirements.
2. Move both positioners to 0°.
3. Initialize the DUT as described for the corresponding baseline performance metric. (Note: This step can be performed anywhere in the measurement sequence prior to initiation of the first measurement.)
4. Measure and record the total directional performance metric (both polarizations) for this data point.
5. Move the □ positioner to the next position (take a step). Note that there is only one data point at the □ = 0° and □ = 180° positions in the pattern, so there is no reason to measure for each □ angle at the top and bottom of the pattern.
6. Repeat step 4 for this data point.
7. While the current □ position is less than 360° minus the step size, move the □ positioner to the next position (take a step) and repeat step 4. Note that □ = 360° is the same point as □ = 0°, so there is no reason to measure it twice.

8. While the current □ position is less than 180° minus the step size, move the θ positioner to the next position (take a step) and go to step 6. (Note that the step direction can be reversed every other cut to reduce test time, stepping from the last ϕ position to ϕ = 0° for even cuts. Otherwise, the positioner must be moved back to ϕ = 0° before proceeding to step 6.)
9. Move the θ positioner to θ = 180° (take last step).
10. Repeat step 4 for this data point.
11. Calculate the required total spherical radiation performance quantity using one of the following equations. If the ϕ angle step size optimization was used, the total surface integral can be calculated from the following equation:

$$T = \frac{\pi}{2N} \sum_{n=1}^{N-1} \frac{1}{N_n} \sum_{m=0}^{N_n - 1} P(\theta_n, \phi_m) \cdot \sin(\theta_n)\,, \qquad \text{Eq. 8-9}$$

assuming N even steps between 0 and 180°, with $\theta_0 = 0°$, $\theta_N = 180°$, $\phi_0 = 0°$, and $\phi_{N_n} = 360°$, where N_n is the number of points for a given ϕ cut at θ_n angle.

Otherwise, assuming N even steps between 0 and 180°, with $\theta_0 = 0°$, $\theta_N = 180°$, $\phi_0 = 0°$, and $\phi_{2N} = 360°$ (conical cut data acquisition order), then the total surface integral can be calculated from the following equation:

$$T = \frac{\pi}{4N^2} \sum_{n=1}^{N-1} \sum_{m=0}^{2N-1} P(\theta_n, \phi_m) \cdot \sin(\theta_n)\,, \qquad \text{Eq. 8-10}$$

where P is the measured radiated performance value at each position, represented in linear units and inverted as necessary so that larger values indicate better performance; and T is the resulting total radiated performance, in the same units and inversion.

Note that in both equations, the $\theta_0 = 0°$, $\theta_N = 180°$ points don't actually appear in the sum. That is because the sin(θ) term at each of those points is zero.

For near-horizon calculations the sums in Eq. 8-9 or 8-10 are modified to integrate only near-horizon elevations. The nomenclature for the near-horizon sum will be $T_{NH}\left(\theta_{\min}, \theta_{\max}\right)$.

We can rewrite Equation 8-9 as:

$$T = \frac{\Delta\theta}{2}\sum_{n=0}^{N-1}\frac{1}{2}\left(\frac{\sin(\theta_n)}{N_n}\sum_{m=0}^{N_n-1}P(\theta_n,\phi_m) + \frac{\sin(\theta_{n+1})}{N_{n+1}}\sum_{m=0}^{N_{n+1}-1}P(\theta_{n+1},\phi_m)\right), \qquad \text{Eq. 8-11}$$

where we have made the trapezoidal integration formula explicit and substituted:

$$\Delta\theta = \frac{\pi}{N}, \qquad \text{Eq. 8-12}$$

To account for variable spacing between cuts, this becomes:

$$T = \frac{1}{2}\sum_{n=0}^{N-1}\frac{\Delta\theta_n}{2}\left(\frac{\sin(\theta_n)}{N_n}\sum_{m=0}^{N_n-1}P(\theta_n,\phi_m) + \frac{\sin(\theta_{n+1})}{N_{n+1}}\sum_{m=0}^{N_{n+1}-1}P(\theta_{n+1},\phi_m)\right), \qquad \text{Eq. 8-13}$$

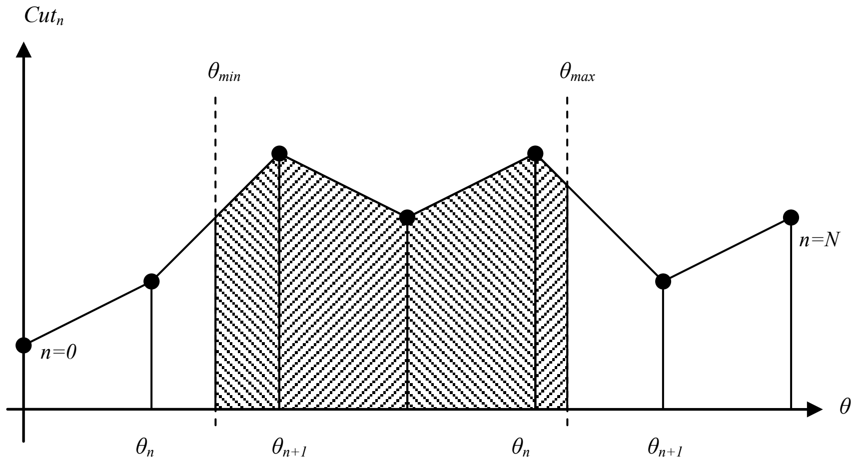
This can be simplified by defining:

$$Cut_n = \frac{1}{N_n}\sum_{m=0}^{N_n-1}P(\theta_n,\phi_m), \qquad \text{Eq. 8-14}$$

such that

$$T = \frac{1}{4}\sum_{n=0}^{N-1}\Delta\theta_n\left(Cut_n \cdot \sin(\theta_n) + Cut_{n+1}\cdot \sin(\theta_{n+1})\right), \qquad \text{Eq. 8-15}$$

When the minimum and maximum near-horizon elevations do not correspond to elevations of measured values, the first and last trapezoids of the integral will have different widths and the heights of two end-points must be interpolated as shown in the following diagram:



We define new variables, $\Delta\theta_n$, and $ICut_n$, that are computed differently for the first and last trapezoids:

$$\Delta\theta_n = \begin{cases} \theta_{n+1} - \theta_{\min} & \text{if} \quad \theta_n < \theta_{\min} < \theta_{n+1} \\ \theta_{\max} - \theta_n & \text{if} \quad \theta_n < \theta_{\max} < \theta_{n+1} \\ \theta_{n+1} - \theta_n & \text{otherwise} \end{cases}, \qquad \text{Eq. 8-16}$$

and

$$ICut_n = \begin{cases} Cut_{n+1} - R_n \Delta\theta_n & \text{if} \quad \theta_n < \theta_{\min} < \theta_{n+1} \\ Cut_{n-1} + R_{n-1}\Delta\theta_{n-1} & \text{if} \quad \theta_{n-1} < \theta_{\max} < \theta_n \\ Cut_n & \text{otherwise} \end{cases}, \qquad \text{Eq. 8-17}$$

where R_n is the slope of each segment:

$$R_n = \frac{Cut_{n+1} - Cut_n}{\theta_{n+1} - \theta_n}, \qquad \text{Eq. 8-18}$$

The near-horizon metric is defined as the partial integral of the interpolated cuts within the elevation angle range defined by $(\theta_{\min}, \theta_{\max})$ weighted by the ratio of the total surface area of the sphere to the surface area included in the sum. After simplifying the weighting, this can be written as:

$$T_{NH}\left(\theta_{\min},\theta_{\max}\right)=\frac{1}{2\left(\cos(\theta_{\min})-\cos(\theta_{\max})\right)}\sum_{n=0}^{N-1}\Delta\theta_n\left(ICut_n\cdot\sin(\theta_n)+ICut_{n+1}\cdot\sin(\theta_{n+1})\right) \quad \text{Eq. 8-19}$$

,

where:

$$N_{\min}=\text{floor}\left(\frac{\theta_{\min}}{\Delta\theta}\right)$$

and

$$N_{\max}=\text{floor}\left(\frac{\theta_{\max}}{\Delta\theta}\right)$$

8.3.1.5 Compliance requirements

There are currently no compliance requirements for RPT testing.

8.3.1.6 Measurement Uncertainty

Refer to Appendix B for a list of measurement uncertainty contributions related to total radiated performance metrics like TRP and TIS. The requirements for the measurement uncertainty budgets for each total radiated performance metric are listed in the associated sub-section.

8.3.2 Total Radiated Power Measurements

The purpose of this test is to measure the total radiated power produced by the DUT when transmitting full power. This metric represents the average directional transmitter performance of the DUT in the given usage case and can be used for estimating link budgets and comparing overall device performance

8.3.2.1 Introduction

This test will determine the total radiated power of a subscriber or mobile station. This test uses the spherical radiation pattern measurement in 8.3.1 and all requirements and procedures listed there apply. The procedures in 8.3.1 are used to repeatedly measure total EIRP numbers as described in 8.2.1 at each position on the surface of a sphere.

8.3.2.2 Testing requirements

The testing requirements include all requirements specified in 8.2.1.2 and 8.3.1.2.

8.3.2.3 Test setup

Refer to the EIRP test setup in 8.2.1.3 for the required test setup for TRP testing.

8.3.2.4 Test procedure

Follow the spherical radiation pattern test procedure in 8.3.1.4, measuring the total EIRP as described in 8.2.1.4 at each position in the pattern. Perform the TRP calculation specified in 8.3.1.4, using the measured EIRP values for P so that T is the resulting TRP value. Perform the NHTRP calculation specified in 8.3.1.4, using the measured EIRP values for P so that is the resulting NHTRP value.

8.3.2.5 Compliance requirements

Table 8.2 specifies compliance requirements for TRP. Requirements are applicable to Total Radiated Power (TRP) or Near Horizon Total Radiated Power (NHTRP).

For Power Class 2, Category B devices are specified by laptops (Notebook and Netbooks) with a remote antenna connection using antenna cable. Other devices are covered as Category A.

Table 8.2. Compliance Requirements for TRP (dBm)

BCG	Channel Bandwidth	Retail	
		RPT Cat A	RPT Cat B
1.B	5	20.0	18.1
	10	20.0	18.1
3.A CONFIG 1	5	18.1	18.1
	10	18.1	18.1
3.A CONFIG 2	5	20.0	19.0
	10	20.0	19.0
5L.A	5		
5L.B	7		
5L.C	10		

8.3.2.6 Measurement Uncertainty

Refer to Appendix B and section B.1 for requirements on determining the measurement uncertainty for TRP tests. For certification purposes, the resultant measurement uncertainty for TRP values must be 2 dB or less.

8.3.3 Total Isotropic Sensitivity Measurements

The purpose of this test is to measure the total isotropic sensitivity of the DUT while it is transmitting full power. This metric represents the average directional receiver performance of the DUT in the given usage case and can be used for estimating link budgets and comparing overall device performance

8.3.3.1 Introduction

This test will determine the total isotropic sensitivity of a subscriber or mobile station. This test uses the spherical radiation pattern measurement in 8.3.1 and all requirements and procedures listed there apply. The procedures in 8.3.1 are used to repeatedly measure total EIS numbers as described in 8.2.2 at each position on the surface of a sphere.

8.3.3.2 Testing requirements

The testing requirements include all requirements specified in 8.2.2.2 and 8.3.1.2.

For TIS testing, the maximum step size may be exceeded by no more than twice the indicated step size, provided the uncertainty budget is increased to account for the error introduced. In no case should the maximum step size of 30° be exceeded.

8.3.3.3 Test setup

Refer to the EIS test setup in 8.2.2.3 for the required test setup for TIS testing.

8.3.3.4 Test procedure

Follow the spherical radiation pattern test procedure in 8.3.1.4, measuring the total EIS as described in 8.2.2.4 at each position in the pattern. Perform the TIS calculation specified in 8.3.1.4, using the reciprocal of the measured EIS values represented in linear units so that P = 1/EIS (mW) and then the resulting TIS value is given by TIS (mW) = 1/T. Perform the NHTIS calculation specified in 8.3.1.4, using the reciprocal of the measured EIS values represented in linear units so that P = 1/EIS (mW) and then the resulting NHTIS value is given by $1/T_{NH}(60{,}100)$. Note again, that the reciprocal of the linear EIS terms must be summed according to the formula, and then the reciprocal of the resulting sum represents the final TIS value.

8.3.3.5 Compliance requirements

Table 8.3 specifies compliance requirements for TIS. Requirements are applicable to Total Isotropic Sensitivity (TIS) or Near Horizon Total Isotropic Sensitivity (NHTIS).

Table 8.3. Compliance Requirements for TIS (dBm)

BCG	Channel Bandwidth	Retail	
		RPT Cat A	RPT Cat B
1.B	5	-96.0	-91.5
	10	-93.0	-88.5
3.A CONFIG 1	5	-93.5	-91.5
	10	-90.5	-88.5
3.A CONFIG 2	5	-96.0	-93.5
	10	-93.0	-90.5
5L.A	5		
5L.B	7		
5L.C	10		

8.3.3.6 Measurement Uncertainty

Refer to Appendix B and section B.2 for requirements on determining the measurement uncertainty for TIS tests. For certification purposes, the resultant measurement uncertainty for TIS values must be 2.5 dB or less.

8.4 Normalized Radiated Performance Measurements

This subsection defines single orientation measurements that are then normalized to the corresponding total radiated performance metric (TRP or TIS) to determine an equivalent total radiated performance metric without having to re-measure the entire spherical pattern performance. The procedures describe the basic relative measurement and normalization process in a generic test procedure, and then specify the variants required to use the baseline performance metrics to determine quantities like Intermediate Channel Sensitivity.

8.4.1 Relative Radiation Performance Measurements

The purpose of this test is to determine the relative performance between two related quantities in a single direction and polarization orientation from the device. That relative data may then be used to normalize the total radiated performance metric corresponding to the reference value to represent the equivalent metric for the related quantity. The procedure is written in a generic fashion so that subsequent requirements can use this procedure by filling in the required fields.

8.4.1.1 Introduction

This test will determine the normalized total radiated performance of a device for a given performance metric, when a related metric is already known such that the radiation pattern of the device can be assumed to be the same.

8.4.1.2 Testing requirements and Test Setup

Relative normalization tests are required to be performed in the same test configuration as that used for determining the reference total radiated performance metric. Ideally, the normalization measurements would be made immediately after completion of the reference pattern measurement without altering the device setup. Additional uncertainty contributions may be required if it is necessary to interact with the device during the normalization process.

8.4.1.3 Test procedure

Perform the following steps to measure the relative performance of the DUT and normalize the corresponding total radiated performance metric to the resulting metric:

1. Measure the required reference total radiated performance metric, T_R, as described in the preceding sections.
2. Determine the position orientation of the best performance of the measured total radiated performance metric (e.g. total EIS pattern for Intermediate Channel Sensitivity measurements described in Section 8.4.2).
3. Determine the polarization orientation of the best performance of Step 2, and orient the test system to re-measure that data point.

4. Re-measure the single point reference quantity, P_R, (eg. EIRP or EIS) at this point.
5. Configure the BSE and/or DUT for the quantity of interest (eg. change frequency, modulation, etc.). It is critical to avoid interactions with the DUT that could change its orientation within the measurement system.
6. Measure the related single point quantity, P, with the new settings.
7. Determine the relative relationship between the two quantities in dB, $\Delta P = P - P_R$,
8. Determine the corresponding normalized total performance metric in dB, $T = T_R + \Delta P$.

8.4.1.4 Compliance requirements

There are currently no compliance requirements for RPT testing.

8.4.1.5 Measurement Uncertainty

Refer to Appendix B for a list of measurement uncertainty contributions related to normalized total radiated performance metrics. The requirements for the measurement uncertainty budgets for each metric are listed in the associated sub-section.

8.4.2 Intermediate Channel Sensitivity Measurements

The purpose of this test is to determine normalized TIS values across the entire band of a WiMAX radio to ensure that there are no desensitization issues or nulls within the frequency response of the device. These results are assumed to be valid provided the shape of the radiation pattern does not change significantly between the low, mid, and high channel TIS tests.

8.4.2.1 Introduction

This test will determine the difference between the Effective isotropic sensitivity of a subscriber or mobile station at the mid channel to that at each test frequency across the band. This test uses the results of the Total Isotropic Sensitivity measurements in 8.3.3 and all requirements and procedures listed there apply. Intermediate frequency EIS measurements shall be performed at the orientation and polarization of the best total EIS of the center frequency. The procedures in 8.4.1 are used to repeatedly measure total EIS numbers as described in 8.2.2 at each test frequency across the band.

8.4.2.2 Testing requirements

The testing requirements include all requirements specified in 8.2.2.2 and 8.4.2.2.

8.4.2.3 Test setup

Refer to the EIS test setup in 8.2.2.3 for the required test setup for ICS testing.

8.4.2.4 Test procedure

The intermediate channel measurement will be related to the TIS measurement of the closest frequency (low, mid, or high band). At each of these frequencies a TIS value has been derived from the corresponding EIS pattern. From this pattern, in one orientation and polarization the best sensitivity value has been obtained. Let this orientation for the minimum EIS be $(\theta_{ref},\varphi_{ref})$ and polarization be refpol. EIS for the given polarization is measured as described in 8.2.2.4 at each intermediate channel. Note that it is not necessary to determine the total EIS from both components of the dual polarized measurement antenna.

Step 1. *For relevant BCG, repeat Step 2 to Step 3 for all relevant channels listed in Table 7.1.*

Step 2. *The BSE Tx Power is related to the EIS value at the DUT by the calibration correction for a chosen polarization. Using this relation, set the BSE Tx Power to be 3 dB higher than that corresponding to the minimum EIS of the closest channel between L/M/H. Set the same orientation and polarization (refpol) corresponding to this EIS value. For example, when the closest channel is the middle channel, then BSE Tx Power = EIS_mid channel_refpol(θ,φ) + 3 dB + calibration correction for refpol. Then run one PER/FER test. If the error rate is ≤ 10 %, then that channel has a pass for this step, in which case step 3 will be skipped. If the error rate is > 10%, go to Step 3.*

Step 3. *Set the power of the BSE to be corresponding to the maximum between:*

- *5 dB higher than that of the minimum EIS of the closest reference channel (i.e. L/M/H)*
  and

- *TIS threshold + minimum_EIS - TIS (both TIS and EIS of the closest reference channel, i.e. L/M/H)*

and to that add calibration correction for refpol and run one PER /FER test. If the error rate is ≤ 10 %, then is has a pass for this step.

8.4.2.5 Compliance requirements

Compliance - If a device passes *Step 2* for at least 80% of channels (frequencies) and passes *Step 3* for all channels, then it passes ICS test, otherwise it fails.

8.4.2.6 Measurement Uncertainty

Refer to Appendix B and section B.3 for requirements on determining the measurement uncertainty for ICS tests. For certification purposes, the resultant measurement uncertainty for ICS values must be 2.6 dB or less.

9 Bibliography

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Appendix A. Quiet Zone Uncertainty Test Procedure (Normative)

This appendix describes the site validation procedure for determining the principal site contribution to the measurement uncertainty for TRP and TIS test results. This procedure provides a simple method for estimating the expected variation of integrated power surface quantities like TRP and TIS. It can also provide estimates of the average error in an individual EIRP or EIS data point due to ripple in the quiet zone. Like other ripple test methods, this test does not account for signal losses within the quiet zone (due to lossy support structures, etc.) or for increases in total measured signal due to large reflections within the environment. It is expected that proper design and installation of the measurement system will mitigate these conditions and that additional testing will be performed as necessary to validate the quality of the site as a whole.

A.1 Test Description

In order to determine the expected variation of an integral quantity like TRP or TIS for any device placed anywhere within the quiet zone, an isotropic field probe is used to measure the uniformity of fields generated within the quiet zone. Rather than comparing single field quantities at different locations, the isotropic pattern of the field probe is measured and then integrated to determine a single power quantity. The variance of these integral results produced by placing the probe at different locations within the quiet zone is then used to estimate the measurement uncertainty contribution to TRP/TIS measurements performed within that quiet zone.

There are several advantages to using a field probe based method over tuned dipoles and loops. Isotropic field probes are broadband devices covering a wide range of frequencies, so one probe can cover all of the frequencies of interest for this test plan, while a number of dipoles and loops would be required to accomplish the same task. Suitable isotropic field probes are available in small packages with fiber optic interfaces that minimize the RF impact on the measurement. The physical size of tuned dipole and loop antennas, and the RF cables required to connect to them, can have a significant impact on the resulting measurement and the flexibility of testing for a given quiet zone size and test system. In addition, the required angular resolution for the validation test is equivalent to that required for the corresponding device test, thus the system need not support an angular resolution finer than that needed for a given DUT. Another advantage of this method over similar field probe based methods described elsewhere is that the level of isotropy of the field probe is not as critical as it would be if only one orientation of the probe were used for each comparison or if the behavior in different directions around the probe were compared. Since field probes may not be perfectly isotropic, this method does not attempt to extract information using that assumption, but rather compares the results between different positions of the same field probe. The assumption is that the probe is repeatable, not that it is perfectly isotropic.

As an alternative, individual dipole elements connected to a more sensitive receiver can be measured in three orthogonal orientations to duplicate the result from an isotropic field probe in cases where a traditional field probe is not sensitive enough to perform the measurement with the required dynamic range.

A.2 Required Test Equipment

The goal of the test equipment is to generate a stable field within the quiet zone and use a broadband isotropic field probe that occupies the smallest possible volume to measure that field with a useable dynamic range of at least 20 dB. The specifications for the required field levels are based on typically available test equipment known to meet this criteria, but an alternate range of field levels may be used as long as the field probe can measure at least 20 dB below the maximum recorded value. This is critical to ensure that the three orthogonal antenna elements of the isotropic field probe have enough resolution to accurately represent the field in any orientation without introducing excessive measurement error.

The following table lists the test equipment required for this test.

1. Compact **Isotropic Field Probe** with independent orthogonal elements capable of operation down to 1 V/m across the required frequency bands.
2. Low dielectric **Support Structure(s)** for mounting the probe at various locations within the quiet zone.
3. Stable **Signal Generator** capable of generating CW signals at the required test frequencies.
4. Stable **Power Amplifier** capable of generating at least 10 V/m (assuming a probe with a minimum sensitivity of 1 V/m) throughout the quiet zone using the measurement antenna in its normal location.
5. Optional **Directional Coupler(s)** and **Power Meter** to allow monitoring the generated signal levels to ensure stability.
6. **Cables and connectors** as necessary.

As an alternative, the following list of test equipment may be used in cases where the above configuration is impractical for the site to be validated.

1. **Resonant Dipole(s)** centered near the frequency of interest (VSWR < 2.0:1). The dipole should be small relative to the wavelength.
2. Low dielectric **Support Structure(s)** for mounting the dipole(s) at various locations and orientations within the quiet zone.
3. Stable **Signal Generator** and **Receiver** or **Network Analyzer** capable of generating and measuring the CW test signals at the required test frequencies.
4. **Cables and connectors** as necessary.

A.3 Test Procedure

The following test procedure requires a minimum of six evenly spaced measurement locations covering the desired test volume. The number of required probe locations increases as the size of the quiet zone increases, and may be increased as desired to provide better statistical results. The test covers a cylindrical volume large enough to cover the maximum dimension of a DUT centered within the quiet zone. If it is necessary to test equipment that is not centered within the quiet zone, the required test volume must be increased to surround the DUT. The quiet zone measurement shall be repeated at each applicable frequency in Table A.1.

Table A.1. Required quiet zone test frequencies by band class.

Band Class Index	Required Test Frequency (GHz)
1 & 2	2.35
3	2.69
4	3.40
5	3.40 & 3.80

The basic configuration is shown in Figure A.1 where R is the radius of the test volume. For test volumes exceeding 300 mm in diameter (150 mm in radius), Figure A.2 illustrates the two additional probe locations that shall be measured for a total of eight locations. Test volumes exceeding 600 mm in diameter are required to measure a total of fifteen locations using the third order probe locations shown in Figure A.3.

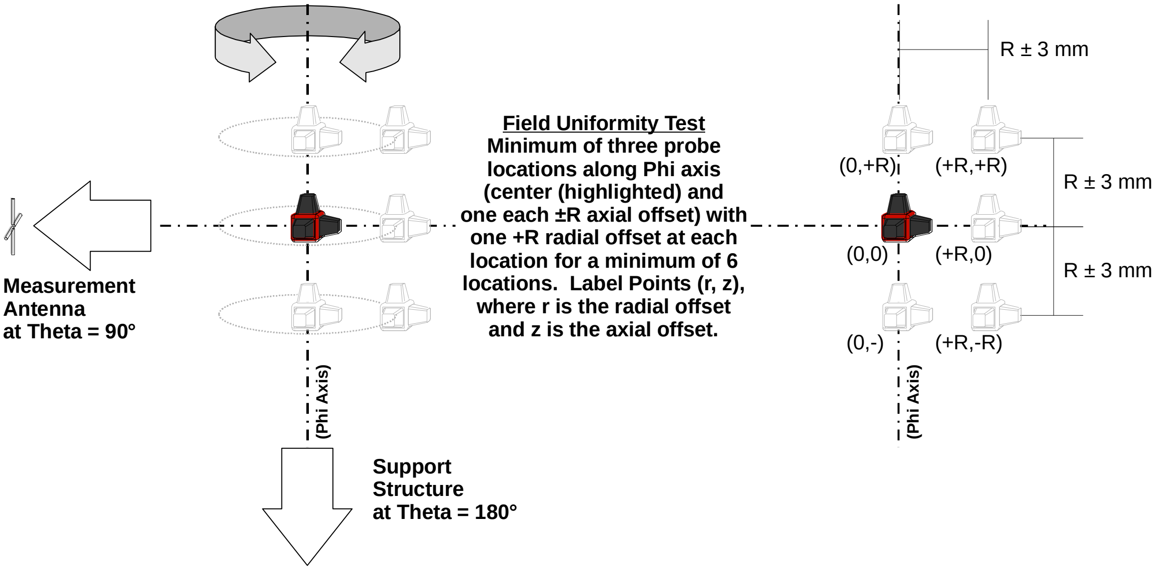


Figure A.1 Definition of minimum required field probe locations for quiet zone field uniformity tests.

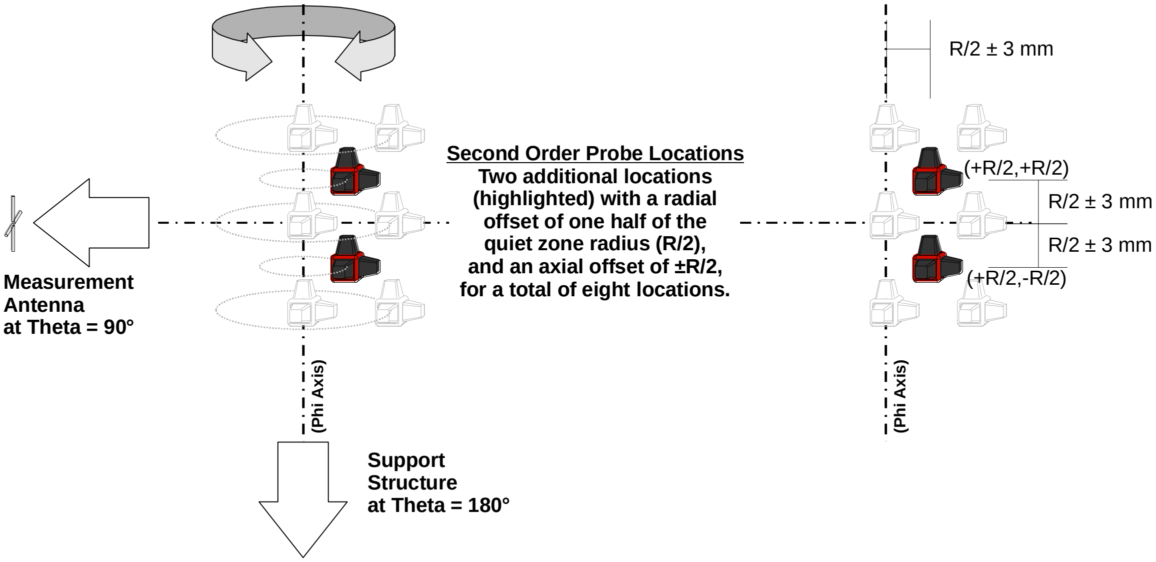


Figure A.2 Additional points required for quiet zones over 300 mm in diameter.

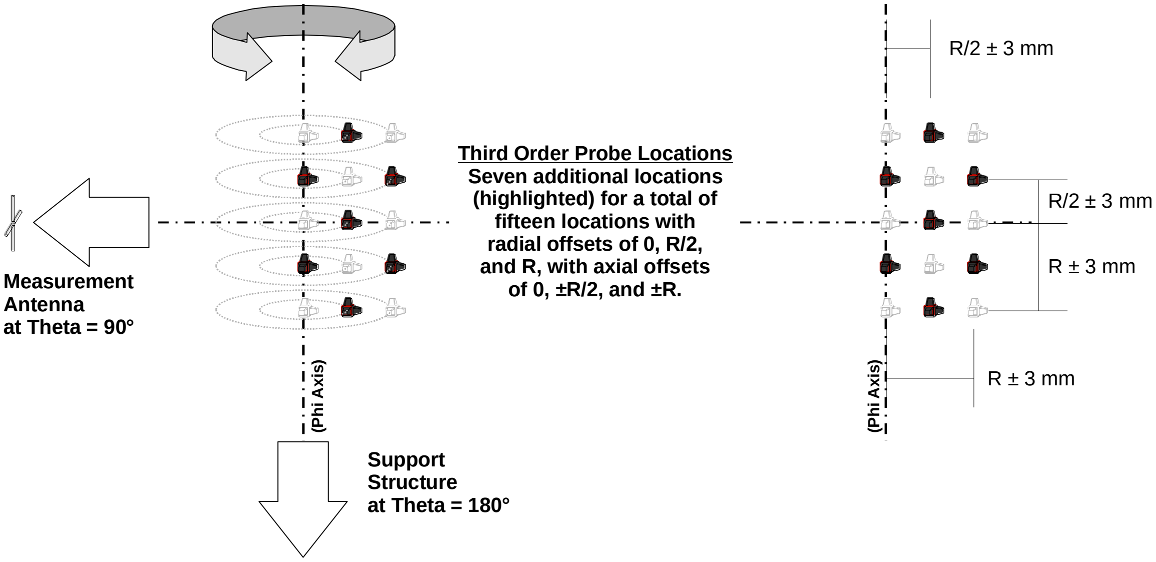
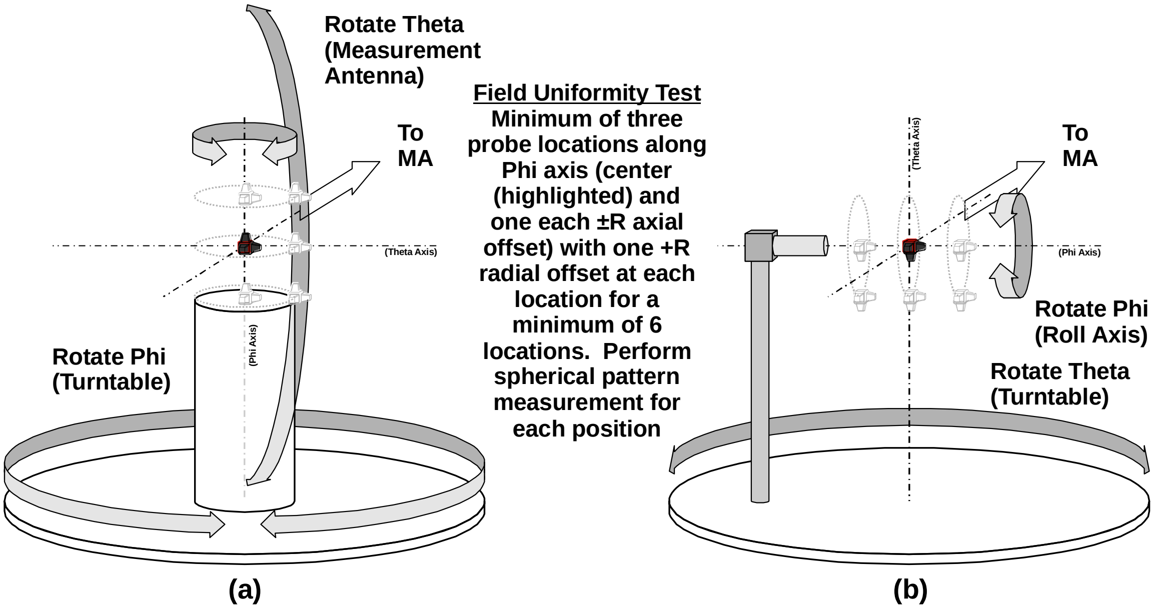


Figure A.3 Required probe locations for quiet zones over 600 mm in diameter.

Perform the following steps to measure the uniformity of the quiet zone at each required frequency. For the alternate procedure where passive dipole elements are used in place of a field probe, follow the same procedure repeating the measurement for each of three orthogonal element orientations in place of the field probe. In that case, the requirements on signal level and dynamic range only apply to the dynamic range of the test equipment and not the absolute levels used.

1. Place the probe on the DUT positioner at the middle of the quiet zone. See FigureA.4 for examples of the required configuration for different system types. Use a minimal amount of low dielectric material to support the probe in the desired location. Note the orientation of the probe relative to the test coordinate system.
2. Connect the amplifier and signal generator to one polarization of the measurement antenna and increase the field until the probe reads at least 10 V/m or enough to ensure that the field within the quiet zone is at least 20 dB over the minimum sensitivity of the probe. Note the required power settings and/or use a directional coupler and power meter to monitor and maintain a stable forward power into the measurement antenna.
3. Perform a complete spherical pattern measurement per the procedure in Section 8.3.1 (excluding the change in polarization), and record the total field value measured by the field probe at each angular position.
4. Switch the input signal from the power amplifier to the other polarization of the measurement antenna and repeat step 3, ensuring that the forward power level is maintained at the same level as in the previous step. It’s not absolutely necessary that the field probe have the same reading for this polarization, provided that the power into the chamber is maintained at a constant level.
5. Calculate a power quantity corresponding to the field probe readings for both polarizations at each point on the surface using the following formula: $P = E_\theta^2 + E_\phi^2$
6. Integrate the total power pattern using the formula in Step 11 of Section 8.3.1.
7. Convert the total power values to dB using the formula T (dBm) = 10 log (T).



FigureA.4 Example of minimum required probe locations for typical test systems.

8. Repeat steps 2-7 for each required probe location, placing the field probe in the same orientation relative to the positioner coordinate system.
9. Calculate the standard deviation of the set of results in dB obtained from step 7 for each probe location measured.
10. Convert the standard deviation result into an expanded uncertainty by multiplying by the appropriate coverage factor, k_p, based on the number of locations measured within the quiet zone. $U = k_p u_c$, where:

Table A.2. Coverage Factors vs. Number of Probe Positions Measured.

Number of Probe Positions	Required Coverage Factor
6	2.65
7	2.52
8	2.43
9	2.37
10	2.32
15	2.20
20	2.14
50	2.05
100	2.03
∞	2.00

The result is an estimate of the quiet zone contribution to the TRP/TIS measurement uncertainty.

In addition to the total power uncertainty estimate given by the procedure above, it is possible to estimate the average uncertainty of an individual pattern data point. To do this, calculate the standard deviation of the dB readings at the corresponding theta and phi position for each probe location within the quiet zone. Convert the resulting standard deviation pattern into an expanded uncertainty pattern using the equation above. The resulting pattern gives an indication of the ripple effects possible on a given pattern. To obtain an average error indication for any given pattern data point, leave the uncertainty values in dB and integrate the result across the sphere to obtain the weighted average of the uncertainty pattern.

Appendix B. Measurement Uncertainty Contributions (Normative)

This appendix describes a range of expected measurement uncertainty contributions that will impact the TRP and TIS test results. The lab shall generate detailed uncertainty budgets for each metric of record (TRP, TIS, and Intermediate Channel tests) that addresses each of these contributions as well as any other measurement uncertainty contributions that may be present in the measurement system.

The following sections either define a minimum required uncertainty budget for a given quantity in the form of a table, or provide details for determining a given contribution to the overall uncertainty budget. For each required uncertainty budget, the standard uncertainty values, u_i, in dB from each of the indicated contributions, as well as any additional contributions identified by the lab, shall be combined using root sum of squares (RSS) to determine the combined standard uncertainty, u_c, for the corresponding metric:

$$u_c = \sqrt{\sum_i u_i^2} \; . \qquad \text{Eq. B-1}$$

A coverage factor of $k = 2$ shall then be used to determine the expanded uncertainty with a 95% confidence:

$$U = k \cdot u_c \, . \qquad \text{Eq. B-2}$$

This expanded uncertainty shall be reported along with the measurement results of each associated metric. Refer to the ISO Guide to the Expression of Uncertainty in Measurement [4] or other references on the treatment of measurement uncertainty [5] for more information.

B.1 Total Radiated Power

The following table lists the required measurement uncertainty contributions that must be accounted for in TRP measurements.

Table B.1. Required TRP Uncertainty Budget Contributions

Uncertainty Contribution Description	Reference Section
Range Calibration Uncertainty	B.4
Quiet Zone Uncertainty Contribution	B.5
Receiver Total Measurement Uncertainty	B.6
Test System VSWR Uncertainty – Receiver Port	B.8
Test System Frequency Flatness Uncertainty	B.9
Linearity and Stability of Active System Components	B.12
DUT Positioning Repeatability	B.13
Coarse Surface Resolution	B.14

B.2 Total Isotropic Sensitivity

The following table lists the required measurement uncertainty contributions that must be accounted for in TIS measurements.

Table B.2. Required TIS Uncertainty Budget Contributions

Uncertainty Contribution Description	Reference Section
Range Calibration Uncertainty	B.4
Quiet Zone Uncertainty Contribution	B.5
BSE Total Output Power Level Uncertainty	B.7
Test System VSWR Uncertainty – BSE TX Port	B.8
Test System Frequency Flatness Uncertainty	B.9
Linearity and Stability of Active System Components	B.12
DUT Positioning Repeatability	B.13
Coarse Surface Resolution	B.14
Sensitivity Search Step Size	B.15

B.3 Intermediate Channel Sensitivity

The following table lists the required measurement uncertainty contributions that must be accounted for in intermediate channel sensitivity measurements.

Table B.3. Required ICS Uncertainty Budget Contributions

Uncertainty Contribution Description	Reference Section
TIS Measurement Uncertainty	B.2
BSE Output Power Linearity	B.16
Step Size Normalization Uncertainty	B.17

B.4 Range Calibration

The following table lists the required measurement uncertainty contributions that must be accounted for in range calibration measurements.

Table B.4. Required Range Calibration Uncertainty Budget Contributions

Uncertainty Contribution Description	Reference Section
Reference Antenna Gain	B.10
Test System VSWR Uncertainty – Loopback Cable	B.8
Test System VSWR Uncertainty – Reference Antenna	B.8
Test System VSWR Uncertainty – Measurement Cable	B.8
Reference Antenna Mounting and Quiet Zone Variation	B.11
Variation Due to Cable Movement	B.18
Linearity and Stability of Test Equipment	B.19

B.5 Quiet Zone Uncertainty Contribution

This contribution shall include the measurement uncertainty contribution determined through the Quiet Zone Uncertainty Test Procedure defined in Appendix A, as well as any other contributions determined by other site validation methods used to qualify the measurement site.

B.6 Receiver Total Measurement Uncertainty

This uncertainty contribution addresses the absolute accuracy of the receiver used for power measurements. It is intended to represent the ability of the test equipment to accurately measure the power levels received from the DUT. The manufacturer's specification shall be used to determine the required uncertainty contribution for a signal level at least 10 dB below the peak value received from the DUT during a TRP test. Ideally, the specification used will cover a range of 30-40 dB below the expected peak level to ensure that this uncertainty contribution is valid for a wide range of DUTs.

If the manufacturer specifies the total measurement uncertainty with a 95% confidence, then that value may be converted directly to a standard uncertainty by dividing by the coverage factor of $k = 2$ so that $u_i = U_i / 2$. Otherwise, the manufacturer's total accuracy specification, a_i, must be assumed to be a rectangular distribution such that the standard uncertainty is given by $u_i = a_i / \sqrt{3}$. If the manufacturer does not provide a total measurement uncertainty or accuracy specification, this uncertainty contribution must be determined by combining the various contributions of accuracy, linearity, stability, etc. that contribute to the total uncertainty of the measurement. The procedure for this analysis is beyond the scope of this document.

B.7 BSE Total Output Power Level Uncertainty

This uncertainty contribution addresses the absolute power accuracy of the transmitter in the base station emulator used for sensitivity measurements. It is intended to represent the ability of the test equipment to accurately represent the power levels generated for downlink to the DUT. The manufacturer's specification shall be used to determine the required uncertainty contribution for a signal level at least 10 dB below the minimum value transmitted to the DUT during a TIS test.

If the manufacturer specifies the total output power uncertainty with a 95% confidence, then that value may be converted directly to a standard uncertainty by dividing by the coverage factor of $k = 2$ so that $u_i = U_i / 2$. Otherwise, the manufacturer's total output power accuracy specification, a_i, must be assumed to be a rectangular distribution such that the standard uncertainty is given by $u_i = a_i / \sqrt{3}$. If the manufacturer does not provide a total output power uncertainty or accuracy specification, this uncertainty contribution must be determined by combining the various contributions of accuracy, linearity, stability, etc. that contribute to the total uncertainty of the output power level of the BSE. The procedure for this analysis is beyond the scope of this document.

B.8 Test System VSWR Uncertainty

This uncertainty contribution addresses variation in the test system VSWR that introduces measurement uncertainty. For modern automated test systems used for RPT, it is expected that there will be considerable impedance mismatch between the various RF cables and components used within the system. Standing waves result in cables between points of mismatch that can cause variations in the signal levels measured. At the frequencies of interest, longer cables tend to be self-attenuating, resulting in a reduction in the standing wave contribution. In other cases, attenuators may be added at connection ports to reduce standing wave effects. The assumption made here is that any standing wave contributions in the cable only serve to modify the resultant signal level, but do not introduce sufficient time delay to corrupt the digital communication being measured. In this case, the error in a measurement due to mismatches throughout the system is caused by the difference in the VSWR between the calibration step (where the path loss of cables and other components of the measurement system is determined) and the measurement step (where those cables and components are used in a power or sensitivity measurement). If only the magnitude of the mismatch at a given connection were to change, then the measurement uncertainty for that change could be estimated using the difference in VSWR magnitudes before and after the change. However, more often, the change in the system also entails a change in cable lengths between two mismatches. That change in cable length results in a change in the frequency dependence of the mismatch, which makes it impractical to try to consider the difference between VSWR values to determine the uncertainty. Instead, the VSWR uncertainty due to each mismatch where a cable connection is changed must be applied to determine the appropriate measurement uncertainty contributions.

The maximum error due to VSWR between two ports is given in general form by the following equation:

$$\varepsilon_{VSWR} = 20\log\left(|\Gamma_1| \times |\Gamma_2| \times |S_{21}| \times |S_{12}|\right), \qquad \text{Eq. B-3}$$

where Γ_1 and Γ_2 are the complex reflection coefficients of the two ports in question and S_{21} and S_{12} are the forward and reverse transmission coefficients between the two ports. From this it is evident that reducing the reflection coefficients (by reducing mismatches) or reducing the transmission coefficients (by adding attenuation) will reduce the resulting error contribution.

From this equation, a simpler two-port formulation can be derived to represent the VSWR error contribution due to the reflectivity of each side of a cable connection point. This allows estimating the required uncertainty contribution by simply measuring the reflection coefficients of each side of a cable connection that is changed between the calibration and measurement steps.

$$\begin{aligned}\varepsilon_{VSWR} &= 20\log\left(|\Gamma_1| \times \left(|\Gamma_2| \times |S_{21}| \times |S_{12}|\right)\right) \\ &= 20\log\left(|\Gamma_{source}| \times |\Gamma_{load}|\right)\end{aligned}, \qquad \text{Eq. B-4}$$

where Γ_{source} and Γ_{load} are the complex reflection coefficients of the cable/connector ends looking towards the source or load respectively.

For a typical RPT system, there are four principal cable junctions to evaluate: 1) the loop-back cable connection made to calibrate out cable losses and test equipment factors during the range calibration; 2) the connection between the “transmit” cable and the reference antenna placed within the quiet zone; 3) the connection between the measurement port cable of the test system (the cable normally connected to the RPT test equipment to route signals to or from the measurement antenna) and the loop-back cable; and 4) the connection of the measurement port cable to the RPT test equipment.

Since the error due to VSWR has a sinusoidal nature, it causes a deviation that clusters equally above and below the initial transmitted signal. This U-shaped distribution must be converted to an equivalent normal distribution probability by using the following equation to determine the standard uncertainty.

$$u_i = \frac{a_i}{\sqrt{2}} = \frac{\varepsilon_{VSWR}}{\sqrt{2}}, \qquad \text{Eq. B-5}$$

B.9 Test System Frequency Flatness Uncertainty

Since WiMAX uses communication channels that are relatively broadband, there is a likelihood that the test system used will not have a flat frequency response across the entire channel. While the range calibration corrects for any variation of frequency response as a function of the center frequency of the channel, the broadband power measured from a WiMAX signal will be a function of the entire channel bandwidth as opposed to just the center frequency. Thus, any deviation of the rest of the channel from the signal level at the center frequency will result in an error in the measured result. Therefore, the measurement uncertainty due to channel flatness must be accounted for.

To determine the appropriate measurement uncertainty for total channel power, use the range calibration curves measured with a 250 kHz or less frequency resolution, and, after applying the reference antenna gain, convert the path loss data to linear power units then perform a running average across the band, averaging the data points across the corresponding channel bandwidth. The following equation describes the expected error contribution that this uncertainty must address:

$$\varepsilon_j = 10\log\left(\frac{\sum_{k=j-N/2}^{j+N/2} PL_k}{(N+1)PL_j}\right), \qquad \text{Eq. B-6}$$

where ε_i is the expected relative error in the average power result for a given channel in dB, PL_i, is the linear path loss at the center frequency of the given channel, PL_k, is the linear path loss at each frequency point across the corresponding channel, and N is the number of 250 kHz frequency steps across a given channel bandwidth. Note that $N + 1$ points are actually averaged together from one edge of the channel to the other.

Table B.5. Required number of 250 kHz steps/points to be averaged for a given channel bandwidth.

Channel Bandwidth (MHz)	Frequency Steps *N*	Frequency Points *N*+1
5	20	21
7	28	29
8.75	36	37
10	40	41

The maximum deviation across all of the possible channels in a band shall be used to estimate the required uncertainty contribution using a rectangular distribution so that $u_i = a_i / \sqrt{3}$, where a_i is given by $a_i = \max\left(\left|\varepsilon_j\right|\right)$.

Note that while sensitivity results may be more directly affected by the frequency dependent behavior of variations in channel flatness, such that the sensitivity result would be biased to a higher power level (worse sensitivity result) this effect is deemed to be encompassed by the sensitivity search step size contribution in B.15.

B.10 Reference Antenna Gain

The uncertainty for the reference antenna gain shall be taken from the calibration certificate/test report of the reference antenna. Reference antennas shall be calibrated at a calibration lab accredited to ISO 17025 and the gain values vs. frequency must be reported along with the associated measurement uncertainty with a 95% confidence interval. The reported expanded uncertainty is converted directly to a standard uncertainty by dividing by the coverage factor of $k = 2$ so that $u_i = U_i / 2$.

B.11 Reference Antenna Mounting and Quiet Zone Variation

This uncertainty contribution affects the reference level measured in the range calibration. Unlike the quiet zone uncertainty contribution described above, this contribution directly impacts the result of a single measurement within the quiet zone. The principal contribution of interest is due to amplitude ripple or free-space VSWR within the quiet zone due to reflections from the chamber walls and other components present during the range calibration. For the purposes of range calibration, it is acceptable to remove portions of the support structure to eliminate their impact on the range calibration, since the effect on the resulting TRP and TIS quantities is addressed elsewhere. The ripple due to the remaining imperfections in the chamber results in a potential systematic error in the reference measurement used to correct for the range path loss. This range calibration result will then be applied as a correction to all subsequent EIRP and EIS measurements, so any error in the calibration applies directly to the TRP and TIS quantities. The magnitude of this contribution may be evaluated by moving the reference antenna to different locations within the quiet zone and comparing the resulting path loss variation to that expected due to the change in distance from the measurement antenna. A secondary contribution is that of the actual positioning of the reference antenna relative to the measurement antenna. Any variation in position, bore-sight orientation, or polarization relative to the center of the quiet zone and the target orientation and polarization of the measurement antenna can cause a variation in the range calibration. The maximum deviation in measured path loss shall be used to estimate the required uncertainty contribution using a rectangular distribution so that $u_i = a_i / 2\sqrt{3}$, where a_i is the peak-to-null ripple, corrected for distance variations, measured within the quiet zone.

B.12 Linearity and Stability of Active System Components

If there are any active components or other non-linear devices in the test system beyond the measurement equipment (receiver or BSE) used in the test, the linearity and stability of these components must be accounted for in the measurement uncertainty. This includes but is not limited to components such as amplifiers, electronic switches, up/down converters, and some types of couplers.

B.13 DUT Positioning Repeatability

This uncertainty contribution represents the primary user contribution to measurement repeatability, although it may be accounted for in conjunction with overall test system repeatability by comparing repeated measurements with complete setup and teardown between each test. This contribution is intended to encompass the general variation due to minor variations in DUT placement within the quiet zone, as well as the larger contributions that may occur due to factors such as DUT placement relative to a near-field phantom, orientation of antennas or other variable components of the DUT, and changes in relative position that may occur during a test due to battery replacement or other user interactions with the DUT.

B.14 Coarse Surface Resolution

Since there are occasions where it may be impractical to sample the radiation pattern surface with enough data points to accurately represent the TRP and/or TIS, this uncertainty contribution is intended to cover the error introduced when the required step size is exceeded. For devices with large, directive patterns, the uncertainty contribution due to coarse surface resolution will be adjusted upwards depending on directivity of the pattern.

B.15 Sensitivity Search Step Size

Rather than attempting to determine the sensitivity level exactly, the reported sensitivity at each measurement position is based on the power level required to produce the last passing PER measurement. Thus, excluding other uncertainty contributions, the actual sensitivity can be assumed to be somewhere between the reported value and one search step below the reported value. This can be represented as an asymmetric uncertainty contribution of +0/-step size, with a rectangular distribution. Given a statistical distribution of sensitivity search results, the actual sensitivity will, on average, be one-half step below the reported value for the sensitivity. Normally, an asymmetric uncertainty value would be converted to a symmetrical uncertainty by applying an offset to the corresponding measurement value and dividing the total range of the expanded uncertainty by two. However, since it is the intention of the TIS test to report a TIS value that has a high probability of being at or above the target sensitivity level, and since there may be other small contributions which would bias the search results in the positive (worse sensitivity) direction, this uncertainty contribution is assumed to be symmetrical about the TIS result with a fixed uncertainty contribution of ± one-half of the minimum step size, assuming a rectangular distribution.

To determine this contribution, treat the minimum step size as a rectangular distribution centered about the reported level such that a_i,= *minimum step size* / 2. The standard uncertainty is then given by $u_i = a_i / \sqrt{3}$.

B.16 BSE Output Power Linearity

This uncertainty contribution addresses any linearity error introduced in the BSE output signal level when performing relative sensitivity measurements. This contribution is likely to be small since the relative values themselves should be small, but the linearity of the BSE and associated downlink path should be evaluated and an uncertainty contribution should be applied as necessary.

B.17 Sensitivity Normalization Uncertainty

This contribution is intended to address the uncertainty caused by the sensitivity search step size granularity when taking the difference between two EIS search results. Each measured EIS value suffers from aliasing that introduces uncertainty at each end of the difference. Since each individual EIS value can be considered to have an uncertainty of ± one-half of the step size, then, assuming the same step size for both measurements, the normalization uncertainty is given by $a_i = step\ size / \sqrt{2}$. To determine the standard uncertainty, treat this as a rectangular distribution such that $u_i = a_i / \sqrt{3}$.

B.18 Variation Due to Cable Movement

When RF cables are flexed, their impedance and loss can change, resulting in signal level variations. Ideally, cables integral to the measurement system are not moved between the calibration and measurement steps (if this is not the case, an additional contribution must be applied for all other measurements performed using the system). However, during the calibration step, several flexible cables are used to route signals between the reference antenna, the measurement port of the cables used in the test system, and the test equipment used to calibrate the system. When these cables are moved, the resulting changes can introduce measurement errors.

To determine this uncertainty, follow the procedure in Section 6.10.1, step 5. The maximum deviation, ε_j, across the band shall be used to estimate the required uncertainty contribution using a rectangular distribution so that $u_i = a_i / \sqrt{3}$, where a_i is given by $a_i = \max\left(\left|\varepsilon_j\right|\right)$.

B.19 Linearity and Stability of Test Equipment

Since the range calibration primarily depends upon the linearity of the receiver and the stability of the signal source, these quantities need to be evaluated instead of the absolute accuracy of the test equipment used. The manufacturer's specification(s) shall be used to determine the required uncertainty contribution for linearity and stability based on the maximum path losses observed during a range calibration.

If the manufacturer specifies the linearity and stability values as an uncertainty with a 95% confidence, then that value may be converted directly to a standard uncertainty by dividing by the coverage factor of $k = 2$ so that $u_i = U_i / 2$. Otherwise, the manufacturer's linearity and stability specifications, a_i, must be assumed to be a rectangular distribution such that the standard uncertainty is given by $u_i = a_i / \sqrt{3}$.

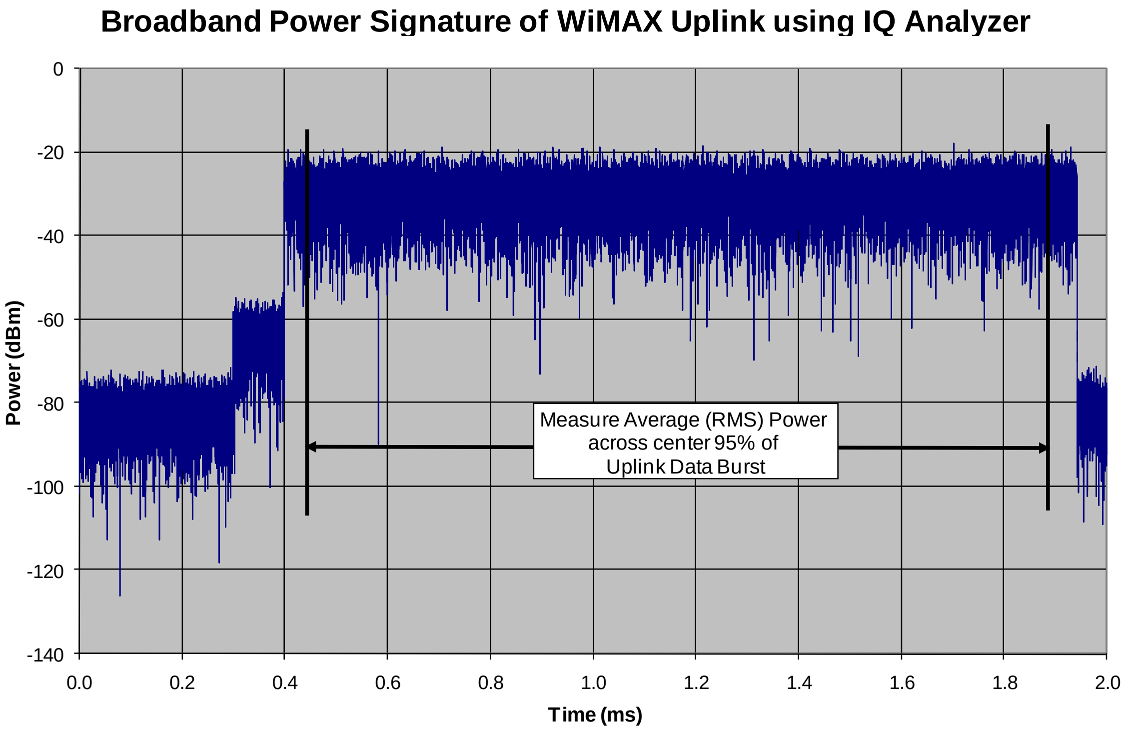
Appendix C. Broadband Power Measurements (Normative)

This appendix describes the acceptable methods for measuring the broadband power of the WiMAX® uplink signal for determining radiated performance. Due to the dynamic nature of the WiMAX signal being tested, the test equipment must be able to support measuring the entire bandwidth of the WiMAX channel instantaneously. For the power measurement, either a signal analyzer or a spectrum analyzer can be used. The instrument must support an instantaneous channel bandwidth at least as wide as the WiMAX channel bandwidth to be tested.

For the signal analyzer, it shall be set to an information bandwidth matching the channel bandwidth to be measured and configured for time domain (zero-span) measurements. The signal analyzer, if capable, shall correct for the shape of the filter.

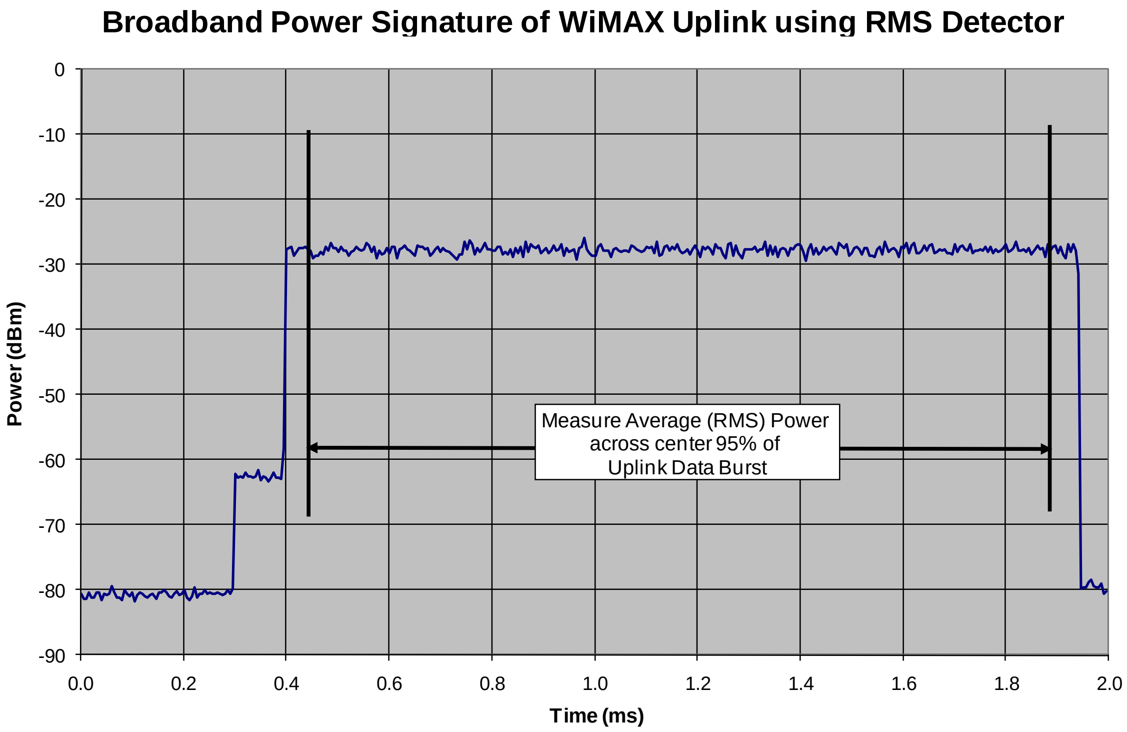
For a spectrum analyzer, the resolution bandwidth RBW setting must be set to at least five times the channel bandwidth if the normal 3 dB RBW filter is used. If the analyzer supports a channel filter, it may be used instead, and then the RBW must be set to a value larger than the channel bandwidth. The video bandwidth shall be disabled if possible or else set to maximum. The spectrum analyzer shall be configured for zero-span mode using an RMS detector.

The required power measurement is the average linear power of the center 95% ± 5% of the data burst in the uplink subframe. Triggering of the analyzer can be done internally or externally from the BSE in order to synchronize with the target data burst.



Measure Average (RMS) Power across center 95% of Uplink Data Burst

FigureC.1 Example of an uplink trace sampled using an IQ Analyzer.



FigureC.2 Example of an uplink data frame captured using an RMS detector.

Appendix D. Device Orientation and Setup Requirements (Normative)

This appendix describes the required physical orientation and setup of the DUT relative to the defined coordinate system. Repeatable setup is necessary to ensure traceable results. For devices for which the examples given here do not apply, or where the given orientation and configuration would deviate significantly from actual use, the device should be oriented and configured to represent actual use as closely as possible. Any deviations from the standard setup must be documented in detail to allow reproduction of the result.

D.1 Free-Space Configuration

The baseline physical setup for most devices consists of a free-space measurement of the DUT without other near field influences. The standard orientation of any DUT is with the “front” of the DUT facing along the +X ($\theta = 90°$, $\phi = 0°$) direction, and the “top” of the DUT facing along the +Z ($\theta = 0°$) direction. Except as otherwise noted below, the device should be positioned so that it is centered within the qualified quiet zone test volume. The entire device should fit within the test volume, and under no circumstances shall the radiating region of the device extend outside the qualified quiet zone.

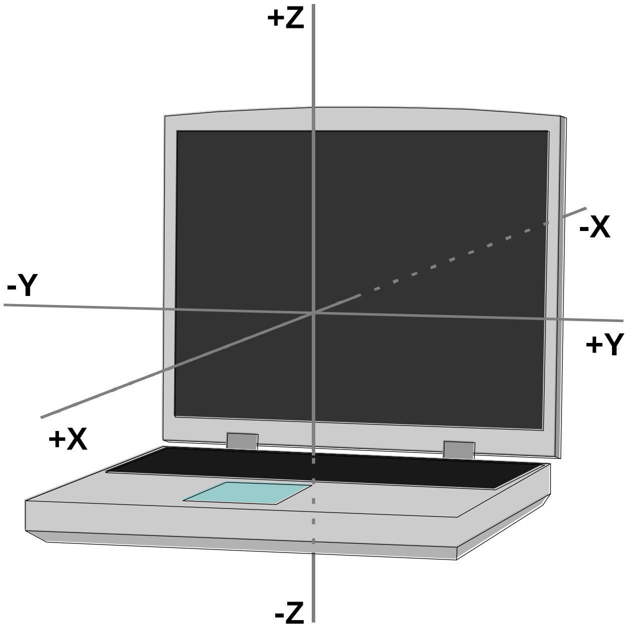
For DUTs with adjustable antenna(s), the standard orientation of the antenna(s) is linearly polarized along the +Z direction. The goal is to orient the antenna(s) to be omnidirectional in the X-Y ($\theta = 90°$) plane, so for adjustable elements that are not simple dipoles or monopoles, the orientation of the antenna element itself may differ from the desired pattern orientation direction and should be clearly documented. If the antennas cannot be oriented along the +Z direction, the secondary orientation is perpendicular to the surface of the DUT. Additional discrete orientations may be measured in cases where the specified orientation is sub-optimal. However, the reported figures of merit shall be based on the average of the results from all measured orientations including the specified defaults.

Except as noted below, the baseline configuration for battery-powered devices is to run under battery power with no extra cables. For line powered devices and devices requiring additional wired connections (network cables, etc.) the cables should be neatly dressed to extend away from the DUT and along the –Z direction. The cables should be dressed with ferrite clamps or RF chokes as needed to eliminate surface currents along the cables that can affect the measurement results. All cables should be restrained to ensure that they maintain consistent position and orientation as the DUT rotates. Cables that move relative to the DUT during the test can significantly alter the measurement results.

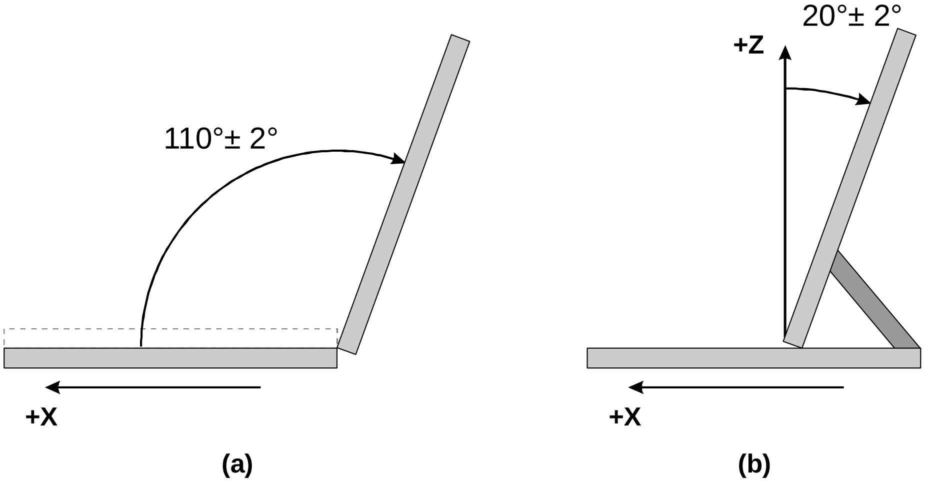
D.1.1 Notebook Computers

Notebook computers with an adjustable display shall be oriented with their base parallel to the X-Y plane, with the front of the computer facing in the +X direction as indicated in FigureD.1. The display shall be held open at an angle of 110° ± 2° from the closed position as illustrated in FigureD.2(a). In cases where the configuration of the DUT makes this measurement impractical or would otherwise result in an unintended display angle, the display shall be tilted away from the user or keyboard location such that the face of the display has an angle of 20° ± 2° from the +Z (“vertical”) direction as shown in FigureD.2(b).

Since notebooks 1) are regularly used in a powered configuration, 2) are physically large compared to the wavelengths in question, and 3) are not typically expected to have the antennas located near the power connector; they may be tested in a line powered configuration provided sufficient steps are taken to ensure that the power cable does not impact the measurement result. A coarse resolution TRP test with and without the power cable may be used to determine if the power cable is impacting the measurement result.



FigureD.1 Illustration of the orientation of a notebook within the coordinate system.



(a)

(b)

FigureD.2 Illustration of the required notebook display angle.

By default, the notebook shall be configured to operate in a normal user mode with all components of the operating system functioning normally. All other wireless radios in the platform should be disabled (except for desensitization tests). Screen savers and all power save modes shall be disabled, with all options for turning off the monitor or hard drive, system hibernation, and system standby set to “never”. The backlight shall be set to maximum intensity. The PC should be configured to run any utility necessary for establishing and maintaining the WiMAX connection.

D.1.2 Plug-in Cards

Plug-in cards such as Cardbus/PCMCIA, ExpressCard, and USB devices shall be tested using a reference notebook chosen by the vendor and/or test lab. The device may be tested in more than one notebook, but the average performance across all tested platforms shall be reported as the resultant metric.

Orientation and location of the notebook within the quiet zone, and orientation of any adjustable antennas or components shall be as described in D.1 and D.1.1.

Appendix E. Recommendation for Minimum and Maximum Elevation Angles for Near-Horizon Performance Measurements (Informative)

The elevation angle of arrival distribution depends on the propagation environment. The recommended minimum and maximum elevation angles are chosen to be representative of the values what would be seen for the most challenging cases, outdoor urban macrocells and outdoor-to-indoor propagation in urban microcells.

E.1 Outdoors

The double directional channel model in COST 259 [6] has developed a model for the distribution of the signal arrival elevations. The distribution is uniform across the elevation angle range from 0, the horizon, to a maximum elevation angle, θ_m:

$$p(\theta,\tau) \sim \text{uniform}\left[0,\theta_m(\tau)\right]. \qquad \text{Eq. E-1}$$

The maximum elevation angle is dependent on the delay spread, τ :

$$\theta_m(\tau) = \frac{1}{1+\dfrac{\tau-\tau_1}{\tau_a}} \arctan\left(2\frac{H_b}{w}\right), \qquad \text{Eq. E-2}$$

where:

H_b = average building height,

w = average street width,

τ = delay spread,

τ_1 = reference bulk (minimum) propagation delay, and

τ_θ = rate of decrease of the delay (~ 3 μs).

We use this model and assume the minimum delay $(\tau = \tau_1)$, which results in the highest elevation arrival angles (due to rooftop diffraction and reflections). Larger delays result from "street canyon" effects but have been found to result in lower elevation arrival angles. Under these assumptions the maximum elevation angle is approximately:

$$\theta_m(\tau) = \frac{1}{1 + \frac{\tau - \tau_1}{\tau_a}} \arctan\left(2\frac{H_b}{w}\right), \qquad \text{Eq. E-3}$$

COST 259 has given the following parameters for guidance:

- the average building height, $H_{b,}$ is 30 m for bad urban environments and 15 m for typical urban environments,.
- the building separation or the width of the road, w, is 50 m for bad urban environments and 30 m for typical urban environments,

which result in the following maximum elevation angles:

- bad urban, $\theta_m \approx \arctan\left(\frac{2 \times 30\,m}{50\,m}\right) = 50^\circ$
- typical urban, $\theta_m \approx \arctan\left(\frac{2 \times 15\,m}{30\,m}\right) = 45^\circ$

The above figures are for a receiver in a vehicle in the middle of the road $\left(\frac{H_b}{w/2}\right)$. If one assumes portable operation as would be typical for notebooks a location on the side of the street is more likely as shown in Figure E.1, the maximum angle is less:

- bad urban, $\theta_m \approx \arctan\left(\frac{30\,m}{50\,m}\right) = 31^\circ$
- typical urban, $\theta_m \approx \arctan\left(\frac{15\,m}{30\,m}\right) = 26.5^\circ$

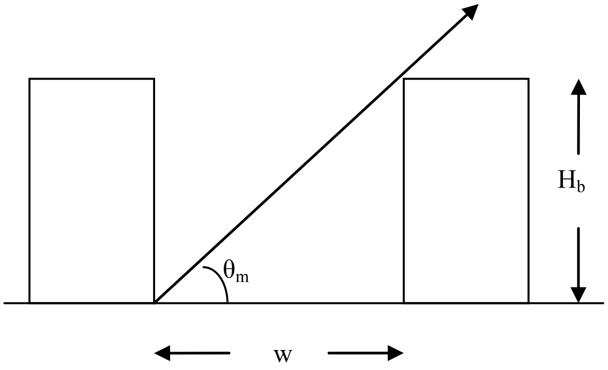


Figure E. 1 - Relationship between maximum elevation angle (θ_m), road width (*w*) and building height (H_b).

In addition to [1], more recent elevation angle of arrival measurements are reported in [3]. These measurements are the basis for the 802.16m [2] and 3GPP channel models [4]. Measurements of urban macro-cell elevation power distributions show peaks at 10 to 20 degrees above the horizon with standard deviations of 10 to 20 degrees. These measurements are consistent with those in [1].

E.2 Outdoor To Indoor

For outdoor to indoor microcell propagation, the results in reference [3] show a median elevation angle of -1 degrees and standard deviations of 8 and 14 degrees. The distribution of elevation angle is approximately Gaussian. To ensure capturing almost all of the power in outdoor-to-indoor scenarios the minimum integration range should be extended to approximately 10 degrees below the horizon.

E.3 Conclusion

The outdoor and indoor propagation measurement data indicate that radiated performance testing can be limited to the range from 10 degrees below the horizon to + 30 degrees above (e.g. NHTRP(60,100) and NHTIS(60,100)), since these elevation angles of arrival or departure contain almost all of the signal power.