



ATIS-0500040

ATIS Standard on -

Unified X/Y and Z Indoor Test Methodology



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Unified X/Y and Z Indoor Test Methodology

Alliance for Telecommunications Industry Solutions

Approved January 13, 2020

Abstract

This document provides guidelines for simultaneously measuring horizontal (X/Y-axis) and vertical (Z-axis) indoor position accuracy performance in a common testing framework. It also defines a technology-agnostic testing methodology to account for emerging vertical height determination technologies, including WiFi-based techniques. Additionally, this document incorporates an approach to increase test point positional diversity, which is required to improve test sample independence for newer indoor wireless location technologies.

Foreword

The Alliance for Telecommunications Industry Solutions (ATIS) serves the public through improved understanding between carriers, customers, and manufacturers. The Emergency Service Interconnection Forum (ESIF) provides a forum to facilitate the identification and resolution of technical and/or operational issues related to the interconnection of wireline, wireless, cable, satellites, Internet, and emergency services networks.

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes an optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, ESIF, 1200 G Street NW, Suite 500, Washington, DC 20005.

At the time of consensus on this document, ESIF, which was responsible for its development, had the following leadership:

- J. Green, ESIF Chair, ESIF ESM Co-Chair (Sprint)
- R. Muscat, ESIF 1st Vice Chair, (Bexar Metro 911)
- D. Morkunas, ESIF 2nd Vice Chair (Intrado)
- K. Springer, ESIF ESM Co-Chair (AT&T)

The ESM Subcommittee was responsible for the development of this document.

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ATIS Standard on –
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1 Scope, Purpose, & Application

1.1 Scope

This document provides guidelines for assessing the performance of wireless location technologies in various types of indoor conditions and environments. It defines an integrated test methodology for simultaneously measuring horizontal (X/Y-axis) and vertical (Z-axis) position accuracy performance, drawing from a number of existing ATIS standards [Ref 1]. Guidelines for this new, combined test methodology are specified in this document, with necessary background and reference information also provided. This document also extends the testing methodology to account for additional emerging vertical height determination technologies, including WiFi-based techniques, so that testing of such approaches in the production environment is technology agnostic.

Given the greater use of WiFi signals for both horizontal and vertical position determination, more independence between successive location fix samples is needed to correctly characterize the performance that actual 9-1-1 callers encounter. This greater independence between samples can be achieved through more diversity of test point positions. Such considerations have been taken into account when extending and merging existing X/Y and Z-axis testing methodologies into a unified test framework. Specifically, the testing approach defined in this document expands positional diversity through the use of static test points along fixed 'paths', as defined in 'Approach #1' in ATIS-0500038 [Ref 2]. Dynamic test routes (i.e., testing while moving, as defined in 'Approach #2' in ATIS-0500038 [Ref 2]) are not called for in this document, but are a possible approach in the future.

1.2 Purpose

The purpose of this document is to capture considerations for a unified testing approach for emerging and deployed 9-1-1 location technologies to accurately measure both horizontal and vertical performance in the indoor Test Bed, while being efficient and technology neutral, reflecting enhancements in handset-based technologies and handset behavior, and addressing emerging non-barometric-centric Z-axis technologies.

1.3 Application

This document is intended to be applied in future test campaigns undertaken by the 9-1-1 Indoor Location Technologies Test Bed, or independently by wireless carriers or location technology vendors. This applies particularly to campaigns measuring the X/Y and Z performance of production or near production systems.

2 References

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

2.1 Normative References

The following references are normative.

[Ref 1] ATIS-0500031.v002, Test Bed and Monitoring Regions Definition and Methodology¹

[Ref 2] ATIS-0500038, Recommendations for Extensions to Indoor Test Methodology¹

2.2 Informative References

The following references are informative.

[Ref 101] ATIS-0500013, Approaches to Wireless E911 Indoor Location Performance Testing¹

[Ref 102] ATIS-0500022, Test Plan Input for a Location Technology Test Bed¹

[Ref 103] ATIS-0500030, Guidelines for Testing Barometric Pressure-Based Z-Axis Solutions¹

¹ This document is available from the Alliance for Telecommunications Industry Solutions (ATIS) < <https://www.atis.org/> >.

3 Definitions, Acronyms, & Abbreviations

For a list of common communications terms and definitions, please visit the *ATIS Telecom Glossary*, which is located at < <http://www.atis.org/glossary> >.

3.1 Definitions

X/Y-axis: Refers to a horizontal position, or testing intended to measure horizontal accuracy performance.

Z-axis: Refers to a vertical position or height, or testing intended to measure vertical accuracy performance.

3.2 Acronyms & Abbreviations

A-GNSS	Assisted-Global Navigation Satellite System (a location technology type)
ATIS	Alliance for Telecommunications Industry Solutions
DBH	Device Based Hybrid
E9-1-1	Enhanced 911
ESIF	Emergency Services Interconnection Forum (a group within ATIS)
ESM	Emergency Services & Methodologies (an ESIF subcommittee)
GNSS	Global Navigation Satellite System
HAE	Height Above Ellipsoid
HVAC	Heating, Ventilation, and Air Conditioning
PSAP	Public Service Answering Point
RF	Radio Frequency
SIM	Subscriber Identity Module

4 Test Methodology Considerations

This section defines the considerations used to create test campaigns capable of measuring both horizontal and vertical position accuracy performance. These considerations are grouped into the following themes:

- **Test Regions, Morphologies, and Buildings** – lists the test regions, defines the morphologies, quantifies building/morphology distributions, and offers building selection criteria.
- **Use of Test Point ‘Paths’** – introduces the concept of forming test points into ‘paths’ for enhanced test execution efficiency while increasing the total number of test points used in each building.
- **Test Point and Path Counts** – defines the approximate number and distribution of test points and paths to be used.
- **Test Point Selection Criteria**– defines guidelines for test point selection.
- **Test Call Execution Timing, Sequencing, and Considerations** – defines how test calls are placed, duration of test calls, sequencing of test calls, and considerations for test execution.
- **Test Mobile Devices** – defines the sources of mobile test devices, model selection, and subscription provisioning.
- **Ground Truth** – defines how test point ground truth is determined, the geodetic reference system used to represent ground truth positions, and ground truth accuracy requirements.
- **Special Considerations for Barometric-pressure-based Systems** – describes special aspects of testing needed when the technology under test relies directly on barometric pressure measurements when determining height.

These considerations will be used as the framework for test campaign definition. When defining a test campaign, a great number of factors must be taken into account, and at times, these factors can be at cross-purposes. Thus, it is important to understand that a balance must be found that both accurately quantifies the performance real E9-1-1 users’ experience, while implementing an efficient and cost-effective testing regime. Logistical realities on the ground need to be taken in to account, for example site access constraints. Thus, these considerations constitute a framework for test exercise definition as a whole, rather than a set of individual rigid requirements.

4.1 Test Regions, Morphologies, and Buildings

This section lists the test regions, defines the morphologies, quantifies building/morphology distributions, and outlines building selection criteria.

4.1.1 Number of Regions

For simultaneous testing of X/Y and Z technologies, testing is to be performed in at least three diverse regions for nationwide wireless carriers. Presently, testing is performed by the Test Bed LLC in San Francisco, Atlanta, and Chicago, but other regions may be added in the future. Use of at least three regions is intended to provide the necessary test environment diversity, sample a sufficient variety of structures and building use patterns, provide an adequate spectrum of WiFi deployment and database strategies and maturities, as well as offer wide climate variety, especially if harsher weather (e.g., extreme cold and strong wind) may play a role in affecting Z-axis performance. Testing performed on a smaller scale independent of the Test Bed LLC is recommended to follow the guidelines in ATIS-0500031.v002 [Ref 1] along with the guidelines stated in this document.

4.1.2 Morphologies

Data collection is to occur in four morphology regions – ‘Dense Urban’, ‘Urban’, ‘Suburban’, and ‘Rural’ – as defined in ATIS-0500031.v002 [Ref 1]. ATIS-0500030 [Ref 103] provides additional context. Note that testing of all morphologies in all three regions may not be possible due to logistical or cost constraints. For example, the cost of testing in suburban and rural morphologies in Chicago may not be justified if it is believed that the information to be obtained is not sufficiently different than the performance anticipated in San Francisco and Atlanta for these same morphologies. Moreover, if a technology is not applicable to a certain morphology then it is understood that testing it in that morphology would not be meaningful or required in the context of its evaluation.

4.1.3 Buildings per Test Region

Testing a morphology in a given region requires the number of buildings outlined in Table 4-1 for each morphology shown.

Table 4-1 Number of Test Buildings per Region

Morphology	Number of Test Buildings per Region
Dense Urban	5 or 6
Urban	5 or 6
Suburban	5 or 6
Rural	2

4.1.4 Building Selection Considerations

The goal of building selection is to identify a set of structures representing the broad range of typical indoor environments from which 9-1-1 calls are placed. Desired is a broad range of building types and usage conditions. In order to provide the desired diversity, buildings should be selected to include:

- A broad range of both residential and commercial usage models.
- Various building styles and construction materials.
- Various building thicknesses.
- A diversity of building size, height, and number of floors.
- A diversity in horizontal footprint and internal structure.
- Different surrounding building environments.
- A good geographic distribution of test buildings within the morphology polygons. Note that this has the effect of providing a broader range of socioeconomic level, which can impact WiFi deployment characteristics.
- A diversity of radio frequency penetration loss characteristics.
- Both 'sealed' and 'unsealed' building types (to the extent that this distinction may affect Z-axis performance).

A diverse example set of building types is shown in Table 4-2.

Table 4-2 Example Set of Building Types

Building Type
Commercial high rise – concrete
Commercial high rise – glass
Hotel (Commercial) mid/high rise
Apartment/condo high rise
Commercial mid rise
Commercial low rise surrounded by High rises
Mixed use mid/high rise
Residential mid rise
Residential low rise (3-4 story)
Apt/condo complex 3-4 story, with a bigger footprint
Residential 2 story
Hotel/Motel standalone 2 story
Individual home in middle of single-family homes

Building Type
Individual home next to larger apartment complex
Stadium/arena
Museum/Exhibition hall
Mall/commercial center
Public or retail 2-story (or equivalent)

It should be noted that “Hotel” and “Residential” are two categories that typically behave quite differently for WiFi-based positioning. One is likely to have an enterprise or public Wi-Fi system and the other a collection of private and non-uniform installations in individual units. It is therefore not appropriate to substitute one for the other.

4.1.5 Efforts to Avoid Over-represented Buildings and Test Points

Effort should be made to avoid over-representing buildings which are particularly easy to access or acquire – such as hotels and malls. This is important because such buildings have unique characteristics (such as WiFi deployment strategies and density characters) which are not representative of other building types. While the use of some of these buildings is acceptable and appropriate, the use of private spaces – both commercial and residential – should be stressed, as such structures represent the greater proportion of real-world indoor emergency usage scenarios.

4.2 Use of Test Point ‘Paths’

Initially, ‘Approach #1’ defined in ATIS-0500038 [Ref 2] will be used to increase the number of test points, thus enhancing positional diversity, while enabling greater data collection efficiency. In ‘Approach #1’, test points are aligned along fixed routes or ‘paths’, such that the tester can quickly move from one test point to the next, enabling a greater number of test calls to be placed from more test points more quickly, thus reducing cost while increasing positional diversity. Note that all the points on a path are very likely to be on the same physical floor.

In ‘Approach #1’, test calls are still placed while ‘static’ – while not in motion. Once a cycle of calls is complete at the current point, the tester moves to a different point to perform the next cycle of calls. If a path contains a minimum of four points, the tester may complete all test call cycles for all the points of a path, not necessarily taken in sequence of proximity, before moving on to the next path. This substantially reduces the time consumed moving between floors, improving test efficiency. However, for paths with fewer test points, cycles of test calls should intersperse test points from different paths to provide for adequate randomization and independence of test call performance across the test points. Section 4.5.2 further explains motion between test call cycles.

In the future, ‘Approach #2’ defined in ATIS-0500038 [Ref 2] may be used, which involves walking the paths at a steady velocity, where fixes can occur anywhere along the path while in motion.

4.3 Test Point and Path Counts

Table 4-3 shows the approximate number of test points per building, what this means in terms of test points per morphology in each test region, the approximate average number of paths per building, and the approximate number of test points per path. Note that these numbers should be viewed as approximate guidelines to be used when planning a test exercise, subject to real-world logistical constraints, rather than firm requirements.

Table 4-3 Approximate Test Point and Path Counts

Morphology	Approximate No. of Test Points per Building	Approximate No. of Test Points per Region per Morphology	Approximate No. Paths per Building	Approximate No. of Test Points per Path
Dense Urban	40	240 (assuming 6 buildings)	8	5
Urban	35	210 (assuming 6 buildings)	7	5
Suburban	25	150 (assuming 6 buildings)	5	5
Rural	10-15	25 (assuming 2 buildings)	2-3	5

The number of test points varies greatly by building and morphology. Larger urban and dense urban buildings and multi-family residential structures will of course have a greater number of test points than single family residences and other smaller structures. In each test region, one or two of the larger buildings may also be selected to be tested with a greater number of test points, so that the test points can be more evenly distributed along floors to further assess barometric pressure and WiFi effects unique to tall structures. In such buildings, test points would be distributed approximately every five to seven floors, as discussed in Section 4.4.6.

4.4 Test Point Selection Criteria

This section defines guidelines for test point selection. The primary goal when selecting test points is to choose a set which represents the range of indoor environment conditions encountered by live E9-1-1 callers. Additional criteria are also needed to facilitate the testing process. In this section, the following criteria are addressed:

- The need for adequate RF coverage.
- Broad selection of use cases.
- An approximately equal ratio of interior and near-exterior (interior building perimeter) test points.
- Distance from windows.
- Distance from entry ways.
- Distribution of test points across floors.
- Test points near atriums.
- Use of parking structures.
- Use of vacant office spaces and residences.
- Barometric pressure considerations for test point selection (when testing a technology known to directly rely on barometric pressure measurements when determining height.)

Note that the criteria outlined in this section represent a starting point when gathering a set of test points. Logistical realities on the ground must be taken into account, and it is not always possible to achieve with equal success all these criteria in real-world situations. They are intended as best practices guidelines.

4.4.1 RF Coverage

Test points must be chosen so that adequate cellular RF coverage exists for all mobile devices under test, so that test calls can be placed and are likely to be served by the intended wireless network.

4.4.2 Broad Selection of Use Cases

Test points should be chosen to achieve as wide a variety of use cases as possible, including offices, residential spaces, public spaces, etc. The selection of use cases should represent the type of building, and should represent a broad cross-section of the environments typical of that type of building. Note however that public spaces should not be over-represented, as discussed in Section 4.1.5.

4.4.3 Interior / Near-Exterior Test Point Ratio

An approximately equal ratio of interior and near-exterior test points is recommended.

A ‘near-exterior’ test point is a location within a structure that is close to exterior windows. Such a test point would typically have a clear view out one or more windows, some GNSS signals would not be unexpected, and WiFi Access Points located outside the structure in other buildings could easily be within range. An ‘interior’ test point is a location deeper within the structure, more towards the center. Such a test point would not typically have a view out a window (or only a very limited view), and there may be interior walls between it and the exterior of the structure. GNSS coverage is less likely, and WiFi Access Points located outside the structure in other buildings are less likely to be observed. In general, points within five meters of an exterior window, with a clear, unobstructed view to the window and not around a corner or through a doorway, are likely to be ‘near-exterior’, while deeper points are likely to be interior, though every circumstance is unique and no absolute rule in terms of distance can be applied.

4.4.4 Minimum Distance from Windows

For ‘near-exterior’ test points, a variety of distances from windows should be used to reflect normal 9-1-1 usage patterns in the chosen surroundings – e.g., in an office, apartment, hall, lobby, etc. Care should be taken to not over-emphasize test points very close to windows simply because they may be more convenient due to RF coverage or logistical considerations.

4.4.5 Distance from Entry Ways

The requirement to be a specific minimum distance from entry ways has been removed. However, test points should be selected so as not to impede or be a nuisance to building occupants.

4.4.6 Distribution of Test Points Across Floors

When testing in multistory structures, points should be chosen so that there is a diversity of floors where testing occurs. Additionally, there should be a reasonably uniform distribution across building height, and high floors should not be excluded. Table 4-4 describes how many floors should have test points (at least one path), as a function of the total number of floors in the building, where possible and practical given real-world access constraints.

Table 4-4 Approximate Minimum Number of Floors with Test Points as a Function of Total Floors

Building Number of Floors	Approximate Minimum Number of Floors with Test Points
one	one floor tested minimum
two	two floors tested minimum
three to five	three floors tested minimum
six to ten	four floors tested minimum
more than ten	at least five floors tested and no more than five to seven floors apart

4.4.7 Test Points Near Atriums

The requirement to not test near or under atriums has been removed. Test points near atriums are valid and may be used when available, but should not be over-represented. Such test points present an interesting case where WiFi signals from multiple floors can be seen, and where interesting air stack pressure effects may occur.

4.4.8 Use of Parking Structures

Attached or stand-alone parking structures may be used for placement of test points, with no prescribed restrictions on distance from the exterior, as real 9-1-1 users in an emergency could be anywhere inside a parking structure. Such test points should not be over-represented, however. Note that any test point chosen must have sufficient RF coverage for the wireless network used in the testing, as discussed in Section 4.4.1. Note also that

the top floor of a parking garage, with open sky conditions, is not considered indoor and therefore would not be a suitable location for testing.

4.4.9 Use of Vacant Space for Test Points

Vacant offices or residences may be used as test points, and they represent a legitimate emergency use case. Such environments have possible implications for WiFi-based location systems. Consequently, such test points, which may be easier to acquire than in occupied spaces, should not be overrepresented, nor should they be completely avoided. As a rule of thumb, no more than 15% of the test points in a multiunit building should be in vacant spaces.

4.4.10 Test Point Barometric Pressure Considerations

When the technology under test relies directly on barometric pressure measurements when determining height, additional criteria for test point selection may apply. Specifically, test points in separate, distinct air zones, and test points in atrium areas should be specifically chosen. Test points should also be selected in areas where obvious air flows, draftiness, or observable pressure deltas are observed, though such points should not be over-represented.

4.5 Test Call Execution Timing, Sequencing, and Considerations

This section defines how test calls are placed, the duration of test calls, sequencing of test calls, and considerations for test execution.

4.5.1 Test Calls Used to Create Location Fixes

When testing is performed for a location technology deployed in a wireless carrier network, special digits are dialed from the test mobile devices using specially configured subscriptions (see Section 4.6.3) to place a test call and in so doing invoke a location fix. Each of these test calls triggers the standard 9-1-1 location determination process to occur on the operator's network exactly as would occur during an actual 9-1-1 call, but calls are routed to a test Public Service Answering Point (PSAP) instead of a live PSAP. When a location technology not fully integrated into a wireless carrier's network is tested, it is possible that an application on the test mobile devices may be used to mimic the behavior of location transactions occurring during wireless 9-1-1 calls. Without loss of generality, "test calls" will be used in the remainder of this section.

4.5.2 Test Call Cycles and Number of Test Calls per Cycle

Test calls are broken up into smaller groups, known as cycles, in order to better simulate actual 9-1-1 call performance. Between cycles, testing occurs at other test points, such that no two cycles for the same test point would occur in sequence. This action helps to provide more independent test samples.

A study examining the correlation of performance leveraging data from earlier test campaigns found that 15 independent test calls placed per test device, per test point, broken in to three cycles of five test calls each, would perform well – given the number of test points used in previous campaigns. However, with the much larger number of test points called for in this methodology, fewer test calls per test point would be sufficient.

Given that a smaller number of test calls per test point is a primary objective of this new test methodology, assuming the number of test points called for in Table 4-3 can be achieved, a smaller number of test calls per test point would be sufficient – on the order of six test calls, placed in **three cycles of two calls each**. This is consistent with the objective of this test methodology of achieving more independent test samples. However, should practical logistical considerations preclude achieving the number of test points called for in Table 4-3, the number of test calls per test point should be increased proportionally.

4.5.3 Power Reset Following Each Cycle No Longer Needed

Mobile test devices no longer need to be powered off between test points at the end of each cycle.

4.5.4 Call/Wait Duration

The duration each test call is allowed to continue after the call is established, and the duration each mobile device is directed to pause before beginning the next call, shall be determined in consultation with the wireless operators involved in the testing, based on network constraints within the operators' networks. Minimum call duration shall be 30 seconds. The shortest call duration and pause duration that allow reliable generation of location fixes should be used. The same considerations apply whether actual test calls are used, or location determination is triggered using location transactions that emulate 9-1-1 test call operation.

4.5.5 Minimum Valid Duration

Test calls are considered valid if the duration between when the call is established, as determined at the mobile, and when the call drops (either intentionally or unintentionally) is at least 30 seconds. This minimum duration is needed to accommodate location technology types that require more time, including A-GNSS.

4.5.6 Mid-cycle Cart Rotation

Where possible, for each test point, the cart holding the mobile test devices should use different orientations at the beginning of each subsequent cycle.

4.5.7 Environmental Considerations at Time of Data Collection

The conditions that are typically present at a test point – including factors such as open or closed doors, open or closed windows, the presence of passersby, etc. – should be present during test execution when possible. For example, if a hotel room door is normally closed, then that door should be closed during testing. Or if in an office people occasionally come and go through an interior door, then people should be allowed to come and go as normal.

4.5.8 After-hours Data Collection

To assess conditions that may only occur at non-work hours, some test points should occasionally be collected during non-working hours. Non-working hours are between 6pm and 7am, as well as on weekends.

4.6 Test Mobile Devices

This section defines the sources of mobile test devices, model selection, and subscription provisioning.

4.6.1 Source of Devices

Mobile test devices may be procured by the test vendor, provided by an operator, or provided by a technology vendor, depending on the nature and purpose of the test campaign.

4.6.2 Model Selection

The selection of mobile device models depends on the type of test participant and the purpose of the testing. When testing the current capabilities of a wireless network, the participating operator decides on the models used. In this case, the models chosen should represent a cross-section of models in wide use in that wireless network, and should not all be the latest models. When testing a specific technology, the types of devices are driven by the capabilities of the location technology vendor. In this case, as wide a selection of devices as possible should be used.

Typically, production device hardware should not be modified, or should only be modified if there is no other viable approach to achieve the specific goals of the test campaign. Use of special software representative of what can be implemented in production mobile devices can be acceptable, but is subject to review. In general, test device configuration should be as close as possible to production device configuration.

If non-barometric-pressure-centric technologies are under test, the set of test devices chosen should include one or more devices not containing a barometer in each test region.

4.6.3 Test Subscriptions

Special test subscriptions (and SIMs) are used to enable location fixes to be generated exactly as would occur during an actual 9-1-1 call, while routing the test call to a test PSAP recording instead of a live PSAP. These subscriptions are generally provided by and managed by participating wireless operators.

4.7 Ground Truth

This section defines how test point ground truth is determined, the geodetic reference system used to represent ground truth positions, and ground truth accuracy requirements.

4.7.1 Ground Truth Source

A mix of professionally surveyed and propagated ground truth points will be used, as described in ATIS-0500038 [Ref 2]. Note that propagated test points will be selected to be near surveyed test points (typically 5 to 15 meters depending on environment and logistical considerations), and will generally be on the same floor so that any delta in height can be easily and accurately measured. In certain circumstances some limited variation in floor level is permitted when easily measurable (for example, if testing along an indoor ramp is unavoidable), although extreme care would need to be taken to avoid ground truth error in the Z direction.

4.7.2 Ground Truth Geodetic Reference System

Ground truth positions shall be captured and maintained in the WGS-84 Datum, geodetic latitude/longitude and height above the WGS-84 ellipsoid. The height above ellipsoid (HAE) will also be translated into a Geoid-based 'Mean Sea Level' orthometric height, typically using the GEOID12b database or a more recent broadly accepted version thereof. This orthometric height is for informational purposes only, and is not intended for use in the evaluation of fix results.

4.7.3 Required Vertical Ground Truth Accuracy

Vertical ground truth shall be accurate to within 10 centimeters.

4.7.4 Required Horizontal Ground Truth Accuracy

Horizontal ground truth shall be accurate to within five centimeters for surveyed points, and accurate to within two meters for propagated test points per ATIS-0500038 [Ref 2].

4.8 Special Considerations for Barometric-pressure-based Systems

This section lists special measures needed when the technology under test relies directly on barometric pressure measurements to determine height. When testing technologies that do not use barometric pressure directly, or do not produce vertical height, some of these measures may not be needed, depending on the technology under test.

4.8.1 Broaden and Randomize Weather Conditions Present During Test Calls

Inclusion of the Chicago test region is intended to broaden the diversity of environmental and test conditions, both of barometric pressure, as well as factors affecting building-interior RF signal distribution and population of the related databases. However, inclusion of a wide range of seasonal weather conditions (for example, Chicago in mid-winter) is not as relevant if barometric pressure measurements are not used directly in determining Z in the technologies under test.

Data collection scheduling will be fairly random, so that a variety of atmospheric weather conditions are encountered by the test devices over the test duration.

Daily atmospheric conditions will be recorded for each test building from two nearby but not collocated weather stations using National Weather Service standard data.

4.8.2 Study In-building Vertical Pressure Effects

In taller buildings, it is useful to spread test points evenly across the floors, as discussed in Section 4.4.6, to ensure consistent performance in the presence of in-building vertical pressure effects.

4.8.3 Long Duration Collects

Long duration 24-hour data collects are useful in assessing and quantifying the sidereal effects of Heating, Ventilation, and Air Conditioning (HVAC) systems, and can also shed light on possible effects of after-business-hours operation of building-interior RF signals. Consequently, the use of long duration 24-hour data collects should be assessed on a case-by-case basis, based on the location technology under test.

4.8.4 Reference Barometer Measurements

Reference barometric pressure measurements taken from a scientific-grade pressure sensor mounted adjacent to the test mobile devices should be collected when logistically feasible, even if direct barometric-pressure-based technologies are not under test. Such measurements are useful in cross-checking test point floor levels and performing consistency checks.

5 Location Technology Metrics

Location technology system performance is typically assessed in terms of accuracy, yield, and latency, and several common metrics are used to quantify these areas of performance. Additional metrics can be used to quantify the size of the test and to provide insight into the success of the testing process. A typical set of metrics used to characterize the results of a location technology test campaign are defined in Table 5-1.

Table 5-1 Typical Location Technology Performance Metrics Definitions

Metric	Description
Test Calls Placed	Total number of test calls placed in the set.
Completed Test Calls	The number of test calls where the call stayed up a required minimum duration to be considered valid (see Section 4.5.5).
Correlated Test Calls	The number of completed test calls where a result exists and where mobile-side logging was successfully correlated to results logs (typically coming from a network element).
Correlation Efficiency	The percentage of calls that correlated, thus 'Correlated Test Calls' divided by 'Completed Test Calls'.
Valid X/Y Location	The number of test calls which produced an X/Y horizontal location fix.
Horizontal Location Yield (%)	The percentage of calls that produced an X/Y location fix, thus 'Valid X/Y Location' divided by 'Completed Test Calls'.
Average Time to Fix	The average time from when the call was placed (as measured at the mobile) to when the fix was produced, in seconds.
Horizontal Accuracy – Within 50 and Within 150 meters	The total number of fixes where the true horizontal error was equal to or less than 50 meters or 150 meters, respectively. Also calculated are the percentages of these quantities relative to the number of calls producing a location ('Valid X/Y Location').
Horizontal Accuracy 67th, 80th, and 90th Percentiles	The horizontal error in meters encompassing 67% of the samples in the set, 80% of the samples in the set, and 90% of the samples in the set, respectively.
Valid Height	The number of test calls which produced a height result.
Height Yield	The percentage of calls that produced a height result, thus 'Valid Height' divided by 'Completed Test Calls'.
Average Height Error	The average Height error, in meters, where Height error is the signed difference between the reported Height and true Height.
Std. Dev. Height Error	The standard deviation of the Height error values.
Average Height Distance Error	The average height distance error, in meters, where height distance error is the unsigned difference (absolute value) between the reported Height and true Height.
Height Distance 67th, 80th, and 90th Percentiles	The distance in meters, measured from the true Height to the reported Heights in the vertical plane, encompassing 67% of the samples in the set, 80% of the samples in the set, and 90% of the samples in the set, respectively.
Height Within 3 meters count and percentage	The total number of fixes where the true height error was equal to or less than 3 meters. Also calculated as the percentage of the number of test calls which produced a height result ('Valid Height').

Note that although these metrics can be applied to any arbitrary set of test calls – for example all test calls in the entire test campaign, all calls from a given morphology, or all calls from a single building – the critical statistics are those obtained for each morphology, aggregated across the various test regions. These per-morphology metrics are subsequently entered into the live call weighting process, as defined in ATIS-0500031.v002 [Ref 1], Clause 8, for regulatory compliance purposes.

Note also that the metrics definitions provided above can be generalized or adjusted (e.g., threshold levels or percentiles modified) as technology evolves, to meet specific regulatory needs, or simply to meet the specific needs of any given test campaign.