Intelligibility
of
Fire Alarm
and
Emergency Communication Systems

Final Report

Prepared by:

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Fire Protection Research Foundation

THE
FIRE PROTECTION
RESEARCH FOUNDATION
Research in support of the NFPA mission

FIRE RESEARCH

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FOREWORD

Intelligibility is a measureable aspect of electronic voice transmission systems that indicates the degree that human listeners will be able to understand the voice messages transmitted through them. This study addresses the efficacy of testing the intelligibility of a fire alarm or emergency communications system, by testing available design guidance and recommending methods for the performance testing of voice communication intelligibility.

The content, opinions and conclusions contained in this report are solely those of the author.

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PROJECT SPONSORS

Cooper Wheelock

Honeywell Life Safety

NFPA

Siemens

SimplexGrinnell

INTELLIGIBILITY OF FIRE ALARM & EMERGENCY COMMUNICATION SYSTEMS

A Report for the

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THE FIRE PROTECTION RESEARCH FOUNDATION

EXECUTIVE SUMMARY

This study addresses the efficacy of testing the intelligibility of a fire alarm or emergency communications system. Intelligibility is a measureable aspect of electronic voice transmission systems that indicates the degree that human listeners will be able to understand the voice messages transmitted through them.

The goal of this project has been to "test" available design guidance and recommend methods for the performance testing of voice communication intelligibility. The project has achieved this goal by collecting data and observations from three separate field tests, and by developing a practical, repeatable and reliable test protocol. This has been a relatively fast-track project (on the order of three months) and the development effort has involved an appreciable contribution of expertise from approximately four dozen project field test participants.

The results of this project include the development of a repeatable Test Protocol that provides a practical and useful methodology to measure system intelligibility performance. This Test Protocol and the three field tests demonstrate that intelligibility can be readily predicted in a practical manner. The fire alarm community has traditionally had a different design focus than acoustic systems designers (i.e. public address or music systems), and the advent of a test protocol may require a transformation of the industry to a higher quality in terms of how these systems are designed.

The Test Protocol for intelligibility is effectively the same approach as now done for audibility but with additional clarifying detail, and with additional criteria addressing: (a) calibration/set-up; and (b) the question of where and when intelligibility testing should be performed. Audibility (dBA) and intelligibility (STIPA) are separate and distinctly different characteristics and both are important. However, it may not be required to measure intelligibility in all areas, while it is more important that the system is audible in most or all areas.

The question of "where and when" to implement intelligibility testing has evolved to be the single most fundamental outstanding issue on this subject. Additional work is needed on the "where and when" question to determine the required levels of intelligibility in a spatial (i.e. "where") and temporal (i.e. "when") sense. Several other specific areas worthy of further work include: development of field guidance to assist with judging the ability of an area to require and handle intelligible voice communication; conducting additional field tests to provide broader intelligibility test data for other occupancies; generating a detailed study of the two basic Talkbox set-up methods; and demonstrating the interoperability of different test measuring equipment.

The content, opinions and conclusions contained in this report are solely those of the author.

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1) INTRODUCTION

The use of voice communications as an emergency management tool has greatly expanded. In the past, systems that relied on simple, repeating, prerecorded messages allowed less intelligible communication systems to still be effective. However, changing threats and the use voice communication systems for a variety of emergencies in a dynamic fashion requires that the systems have an end-to-end communication path that does not hamper intelligible communication between those in command and the target audience.

The measurement (modeling) of speech intelligibility has been extensively studied, developed and standardized outside of the fire alarm industry. The Technical Committees of the National Fire Alarm Code® (NFPA 72) have required that voice communication systems be intelligible but, to date, have offered only limited guidance on system performance testing requirements and no guidance on how to plan, design and install systems to meet intelligibility requirements.

The Technical Committees of NFPA 72 have begun to address the issue of performance and testing. There is an immediate need for an assessment of intelligibility testing protocols and intelligible system design guidance.

The goal of this project is to "test" available design guidance and recommended methods for the performance testing of voice communication intelligibility. Specifically, the project will focus on:

a) clarifying the required system intelligibility threshold requirements;
b) defining when and where intelligibility testing is required; and
c) developing a practical, repeatable and reliable test protocol.

This research program has been conducted under the auspices of the FPRF, and the report and the recommended methodology are directly applicable to NFPA 72, *National Fire Alarm Code®*. On this basis, the project deliverables are being provided for consideration by the NFPA 72 Technical Committees responsible for Chapters 7 on Notification Appliances and Chapter 10 on Testing & Maintenance, specifically at their Report on Comments meeting in Birmingham Alabama during October 2008. This report also impacts the work of the new NFPA 72 Technical Committee on Emergency Communications Systems.

It is noted that this project involves three separate test facilities, the use of multiple types of measurement meters, and several specific fire alarm system installations. This project is NOT evaluating the merits of one facility over another or the attributes of specific equipment from any particular manufacturer. On this basis, all such information is being treated in a generic fashion throughout this report.

2) BACKGROUND

2.1) Problem Summary.

Automatic detection of fire within a building and notification of the building occupants has a long history in the modern era, as evidenced by the creation of the NFPA committee responsible for NFPA 72, National Fire Alarm Code® in 1898, and the issuance of the first edition in 1905. Traditionally the method to alert the building occupants to an emergency condition is through the use of a special signal or tone that will be distinctly understood by the building occupants.

Today, a feature common in modern fire alarm and emergency communications systems is the ability to broadcast voice commands directly to all building occupants using voice instructions. This could be done using pre-recorded messages or through the use of a hand-held microphone for use by the incident commander at an emergency. This voice communication feature is intended to supplement the audible fire alarm tone or signal that is used to alert occupants to evacuate the building.

Following the events of 11 September 2001, a heightened awareness has evolved on the use of a building communication system for emergencies other than a fire event. Although this has a strong relationship to building security concerns, other events are also being considered such as exterior man-made incidents (e.g. chemical leak), large-scale natural disasters (e.g. tornadoes, floods, wildfire, etc), or other events possibly requiring detailed instructions for the building occupants.

Some building owners and operators are expressing a need to enable the voice communication feature of their building fire alarm systems to do more than simply generate an alert signal to fully evacuate the building. Facilities that have a properly designed public address system can possibly directly address this need through the use of such a secondary system, but others are looking to traditional fire alarm systems to accomplish this task. Since these fire alarm systems are commonly installed throughout our infrastructure in the developed world, a need is evolving for acceptable performance quality for the voice command feature of a modern fire alarm system.

In general, a fire alarm system is designed differently than a public address or background music system, and is intended to be extremely reliable and only function on rare occasions. They have traditionally focused on the ability to provide an audible alert signal, and historically less attention has been given to providing communications via intelligible voice transmission ability. The advent of utilizing voice communication features of fire alarm systems on a more regular basis is generating a need to address the concepts of speech intelligibility.

The measurement (modeling) of speech intelligibility has been extensively studied, developed and standardized outside of the fire alarm community. NFPA 72 currently requires that voice communication systems be intelligible but, to date, offers only limited guidance on system performance testing requirements and no guidance on how to plan, design and install systems to meet intelligibility requirements. The Technical Committees responsible for NFPA 72 have begun to address the issue of performance and testing by considering the adoption of all or part of ISO Standard 7240-19, *Design, installation, commissioning and service of sound systems for emergency purposes*. However, the technical committees desired a more robust and detailed testing protocol. Further, a design guidance document is currently being finalized in the standards writing process of the National Electrical Manufacturers Association (NEMA). There is an immediate need for assessing the intelligibility testing protocols and intelligible system design guidance.

The goal of this project is to "test" available design guidance and recommended methods for the performance testing of voice communication intelligibility. Specifically, the project focuses on (1) clarifying the required system intelligibility threshold requirements, (2) defining when and where intelligibility testing is required, and (3) developing a practical, repeatable and reliable test protocol.

This project attempts to address when, where and how to test for speech intelligibility. It does not provide any significant or specific advice on how to design and install an emergency communications system to achieve speech intelligibility. Further, it is also not the intent of this study is to describe how to interpret results or how to correct systems or environments that contribute to poor speech intelligibility.

2.2) Technical Background.

2.2.1) General. Intelligibility is a measureable aspect of electronic voice transmission systems that indicates the degree that human listeners will be able to understand the voice messages transmitted through them. If a voice alarm system is going to be effective, it will also need to be audible and intelligible.

The performance of voice alarm system relating to its "intelligibility" characteristics is a relatively complex phenomenon and depends on multiple factors. Some of these factors are inherent within the electronics of the voice communications system, and others relate to the acoustical challenges of the environment being protected.

The factors that relate to the talker/listener transmission path can generally be grouped into three general areas: signal--to-noise ratio; decay; and distortion. The signal-to-noise ratio is the effect of masking or obscuring the voice signal due to noise. Humans can tolerate significant background noise, unlike artificial systems, but once intelligibility begins to diminish it does so rapidly. Decay includes sound reflections, such as echoes or reverberations, which blur or smear speech making it less clear and thus more difficult to understand. Finally, distortion is a form of noise that masks the original speech signal resulting from electrical or electro-acoustical components in the transmission system (Ref: Jacob, Understanding Speech Intelligibility and the Fire Alarm Code, and Watkins, A difference Between the Effects of Echo and Reverberation on Speech Identification). These are illustrated in Figure 1.

Where the communications system introduces little or no distortion to the voice signal, areas within buildings such as traditional office environments, hotel guestrooms, dwelling units, and spaces with carpeting and furnishings appear to generally meet intelligibility levels if the audibility levels are consistent with the requirements of NFPA 72, National Fire Alarm Code. This is because there is a good signal to noise ratio and very little reverberation caused by the acoustics of the space (see Figure 1). Performing intelligibility testing might not be necessary in these areas. Building areas that may be acoustically challenging appear to have hard and reflective floors and wall surfaces, tall ceilings with high reverberation, or high ambient noise. In some cases, intelligibility in some areas may be difficult or impossible to achieve throughout the entire space. Specialized sound system design procedures, principles and equipment may be necessary to achieve speech intelligibility in high noise areas or areas with challenging acoustics. For example, in a space with high reverberation, a system with a high signal to noise ratio may actually cause more loss of intelligibility because of the higher reverberant energy in the space.

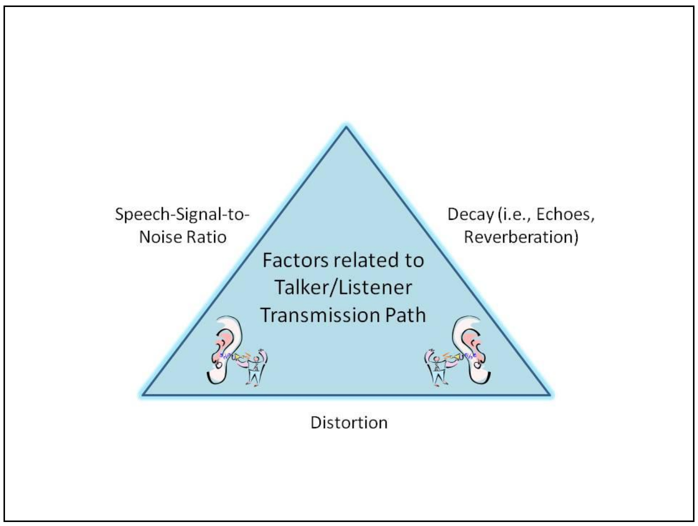

Figure 1: Factors Related to Talker/Listener Transmission Path

2.2.2) Intelligibility Measurement Methods. Speech intelligibility is not a physical quantity like feet, meters, Volts, Amperes, or decibels. It is a benchmark of the degree to which we understand spoken language. As such it is a complex phenomenon affected by many variables (Ref: Jacob, K. & Tyson, T., “Computer-Based Prediction of Speech Intelligibility for Mass Notification Systems”, SUPDET 2008, Fire Protection Research Foundation, Mar 2008).

There are two basic categories of intelligibility testing as follows:

1) <u>Quantitative based testing</u> that correlates measurements of physical quantities varied under experimental conditions to speech intelligibility scores obtained using human subjects; and
2) <u>Subject (human) based testing</u> that use human subjects, which are statistical predictions of how well speech might be understood at any other time for any other group of listeners.

Several subject based test methods have been extensively researched, tested for reliability and standardized. Examples include the Phonetically Balanced (PB) word scores (256 words or 1000 words) and Modified Rhyme Test (MRT). (Ref: ANSI S3.2-1989, "Method for Measuring the Intelligibility of Speech over Communication Systems". Ref: ISO/TR 4870, "Acoustics – The Construction and Calibration of Speech Intelligibility Tests"). However, quantitative based methods are arguably less subjective, more repeatable, and easier to implement. This project is focused on quantitative based testing methods using measurement instruments.

The results of speech intelligibility testing are usually described as predictions, not measurements. This has its roots in subject based test methods, which gauge how much of the spoken information is correctly understood by a person or group of persons for a particular test. When properly done, that resulting value is a prediction of how much of the spoken word will be correctly understood by others at some other time. Most of today's instrumentation refers to their results as measurements, not as predictions. Thus, the terms "prediction" and measurement will sometimes be interchanged in common usage, but in the scientific literature, the values are generally referred to as predictions.

Several quantitative based speech intelligibility methods using instruments have been standardized based on characteristics such as accuracy and repeatability. These are addressed in ANSI/ASA S3.5, "American National Standard Methods for Calculation of the Speech Intelligibility Index" and IEC 60268-16, "Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index". (Ref: IEC 60268-16, "Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index", 2003. Ref: ANSI/ASA S3.5, "American National Standard Methods for Calculation of the Speech Intelligibility Index", 1997). Perhaps most recognized are the following quantitative based methods:

Articulation Index (AI), now referred to as Speech Intelligibility Index (SII);
Speech Transmission Index (STI), and
Speech Transmission Index for Public Address (STIPA), a modified method of STI

Each of the recognized speech intelligibility methods has a finite measurement scale. To equate the values from each scale, the Common Intelligibility Scale (CIS) was developed to show the relationship between the different methods. The purpose in developing CIS was to allow codes and standards to require a certain level of performance while permitting any of the accepted measurement methods to be utilized (Ref: Barnett, P.W. & Knight, A.D., "The Common Intelligibility Scale", Proceedings of the Institute of Acoustics, Vol. 17, Part 7, 1995).

The measurement method used in this project was the STI, specifically, STIPA. The STIPA measurement equipment used in this project during the three field tests reported results using either the STI or CIS scale, and thus both sets of values are included in the data tables later in this report. The relationship between the CIS and STI is: CIS = 1-log10 (STI) (Ref: IEC 60849, Annex B, Sound Systems for Emerg Purposes, Feb 1998). This is shown graphically in Figure 2.

2.2.3) Audibility Versus Intelligibility. Both audibility and intelligibility are important characteristics of a fire alarm or emergency communications system, and are necessary to provide proper instructions to the occupants of a building. Audibility, which is generally measured in decibels (dBA), is defined as the state or quality of being perceptible by the human ear. Intelligibility is the state or quality of being understood by a human, and more specifically, as the percentage of speech units understood by a listener in a communications system. (Ref: http://www.answers.com, cited 10/Oct/08) Intelligibility is predicted based on STIPA, among several other possible scales.

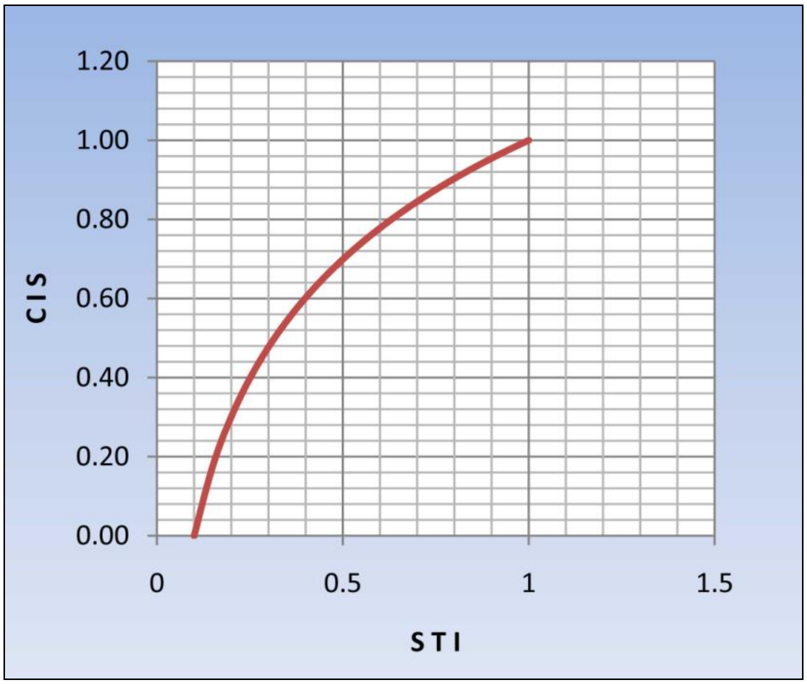

Figure 2: Relationship between STI and CIS

Achieving acceptable intelligibility levels in all areas is not always possible, such as in locations that have appreciably high ambient sound pressure levels (i.e. high audibility readings). For example, in areas where the ambient sound pressure level exceeds 90 dBA, speech intelligibility could be difficult to achieve with conventional communications equipment and designs. Alternate communications methods may need to be considered, such as visual occupant notification in these areas.

There may be applications where not all spaces will require intelligible voice signaling (Ref: NFPA 72, National Fire Alarm Code, 2007, Section A.7.1.4). For example, in a residential apartment building, audibility may be required in each separate room in an apartment, but not intelligibility. In another example, systems that use tone signaling in some areas and voice signaling in other areas would not require voice intelligibility in those areas only covered by the tone.

2.3) Test Method.

Prior to using equipment to measure the actual speech intelligibility predictions, a noteworthy amount of pre-planning and preparations are required. Most important among these pre-testing preparations are:

1) Calibration of the test equipment;
2) Assignment of the acoustically distinguishable spaces; and
3) Talkbox set-up.

Among these three pre-planning tasks, perhaps the best understood and least controversial task is the first task involving calibration of the test equipment. Contrary to this, the second pre-planning task of designating the acoustically distinguishable spaces is arguably the least resolved and most controversial. This is based on the ultimate question of where and when intelligibility is required. Some portions of a facility will require audibility but not intelligibility, while some will require audibility and intelligibility. Further, some facilities will require testing during building commissioning, and/or testing at some later designated time interval.

The third pre-planning task involving Talkbox set-up is similar to task 2 in its controversial nature, but it has a narrower technical focus. The Microphone Input Method for Talkbox setup is the preferred approach (assuming there is a command center microphone). If the Microphone Input Method for Talkbox setup is used, there are two possible approaches for set-up: (a) Method 1 sets the volume of the input test signal to match that of speech level under normal conditions; and (b) Method 2 sets the volume of the input test signal so that the dBA output in the area under test is the same as that for a pre-recorded message. Agreement on the virtues of each of these two set-up methods, and consequently the preference between them, has not been fully resolved.

The actual test procedure itself is relatively straight-forward, and aside from the aforementioned pre-planning details, the Test Protocol used for intelligibility is conceptually similar to the testing approach used to determine audibility. Testing when the area is occupied and when the ambient sound level is at or near its expected maximum is preferred because it is easier. This would utilize Test Form A that is included in Annex A. However, this approach does involve playing of a STIPA test signal through the emergency communications system for the duration of the test. This may be disruptive in certain occupancies.

When testing using the STIPA signal, the signal is a continuous noise (in field-speak this has been referred to as the “humpback-whale-noise”). If the test is considered too disruptive for a particular occupancy under test, an alternative approach is available that utilizes Test Form B in Annex A. This alternate procedure is to: (1) test and save the STI data and sound pressure levels (in dBA) during unoccupied times with the STIPA test signal, (2) measure and save the unoccupied sound pressure levels (in dBA) without the STIPA test signal, and (3) test and save the sound pressure levels (in dBA) during occupied times without the STIPA test signal. The three data sets are combined by software to calculate the corrected STI for the particular area.

Testing using this method requires three measurements at each measurement location, but conveniently, does not subject occupants to constant test signals.

The choice of testing occupied versus un-occupied for intelligibility is the same as for audibility testing of tone signaling systems and is based on convenience versus disruption of normal use of the space. However, unlike audibility testing, intelligibility testing is less likely to contribute to the “cry wolf syndrome” because the STIPA test signal is not the same as the evacuation tone, which would be sounded throughout testing of a tone signaling system. (REF: Schifiliti, Robert P., “Fire Alarm Testing Strategies Can Improve Occupant Response and Reduce the "Cry Wolf" Syndrome,” NEMA Supplement in Fire Protection Engineering, Society of Fire Protection Engineers, Bethesda, MD 20814, Fall 2003. and REF: Breznitz, S., “Cry Wolf: The Psychology of False Alarms”, Lawrence Erlbaum Associates, Hillsdale, NJ, February 1984.)

2.4) Project Tasks.

This project addresses voice intelligibility testing of a fire alarm or emergency communications system.

The goal has been to “test” available design guidance and recommend methods for the performance testing of voice communication intelligibility. Three separate field tests have been used to collect data and observations, to provide the basis for developing a practical, repeatable and reliable Test Protocol. This has been a relatively fast-track project (on the order of three months) and the development effort has involved an appreciable contribution of expertise from approximately four dozen project field test participants.

The Test Protocol contained in this report is intended for consideration by the Technical Committees responsible for NFPA 72, National Fire Alarm Code. Specifically, this information is being forwarded to the Technical Committees responsible for Emergency Communications Systems, Notification Appliances, and Inspection, Testing and Maintenance of NFPA 72, as well as the Technical Correlating Committee for the National Fire Alarm Code. This information was made available in time for consideration at their upcoming Report on Comments meetings for the 2010 edition of NFPA 72.

The scope of this project includes field tests to demonstrate the intelligibility of installed and operational voice communication systems. This utilizes several existing facilities that have volunteered their use for trial implementation of a prototype testing protocol. These facilities provide several occupancy use-groups and are designed to use with both simple and complex voice communication scenarios using commercial fire alarm equipment.

The results of this study are intended to be made publicly available. This project develops information to: (a) clarify required system intelligibility threshold requirements, (b) better define when and where intelligibility testing is required, and (c) develop a practical, repeatable and reliable test protocol. The primary tasks of the project were:

1) Task 1: Form the Project Technical Panel (PTP), and send an invitation to attend the field tests to NFPA 72 TCC, applicable TCs, and interested parties.

2) Task 2: Establish field test dates and clarify other related logistical details for field tests.

3) Task 3: Develop and refine certain key project preliminary documents, including: (a) Work/Test Plan; (b) Timetable; (c) Test Protocol. Review applicable literature relating to design and testing of voice communication sound systems.

4) Task 4: Convene a PTP conference call meeting to discuss relevant issues, including the refinement of the preliminary test protocol.

5) Task 5: Convene a meeting of interested participants, and conduct Field Tests #1 and #2 to collect data relevant to the proposed protocol and design issues.

6) Task 6: Convene a PTP conference call meeting to discuss relevant issues, including the further refinement of the test protocol and project deliverables.

7) Task 7: Convene a meeting of interested participants and conduct Field Test #3 to collect data relevant to the proposed protocol and design issues, followed by further refinement of the project deliverables.

8) Task 8: Convene a PTP conference call meeting to discuss relevant issues, including the further refinement of the test protocol and project deliverables.

9) Task 9: Prepare a final draft of the report and circulate it to the NFPA 72 project for consideration at their ROC Meeting in Birmingham AL.

10) Task 10: Finalize and issue the project report.

2.5) Project Task Groups.

At the meeting held in conjunction with Field Test #1 and #2, extensive discussion focused on how best to approach the overarching technical needs for addressing intelligibility testing. This discussion resulted in the generation of a flow chart depicting the fundamental technical questions being encountered. This flow chart is illustrated in Figure 3.

As a result of this discussion, and using the Figure 3 illustration as guidance, the fundamental technical issues were identified. Further, to address these fundamental technical issues, four task groups were appointed. These are likewise indicated in Figure 3. The primary charter of each task group was to work on draft text for the draft Test Protocol and report back. Each task group continued working on their technical issue throughout the remainder of the project.

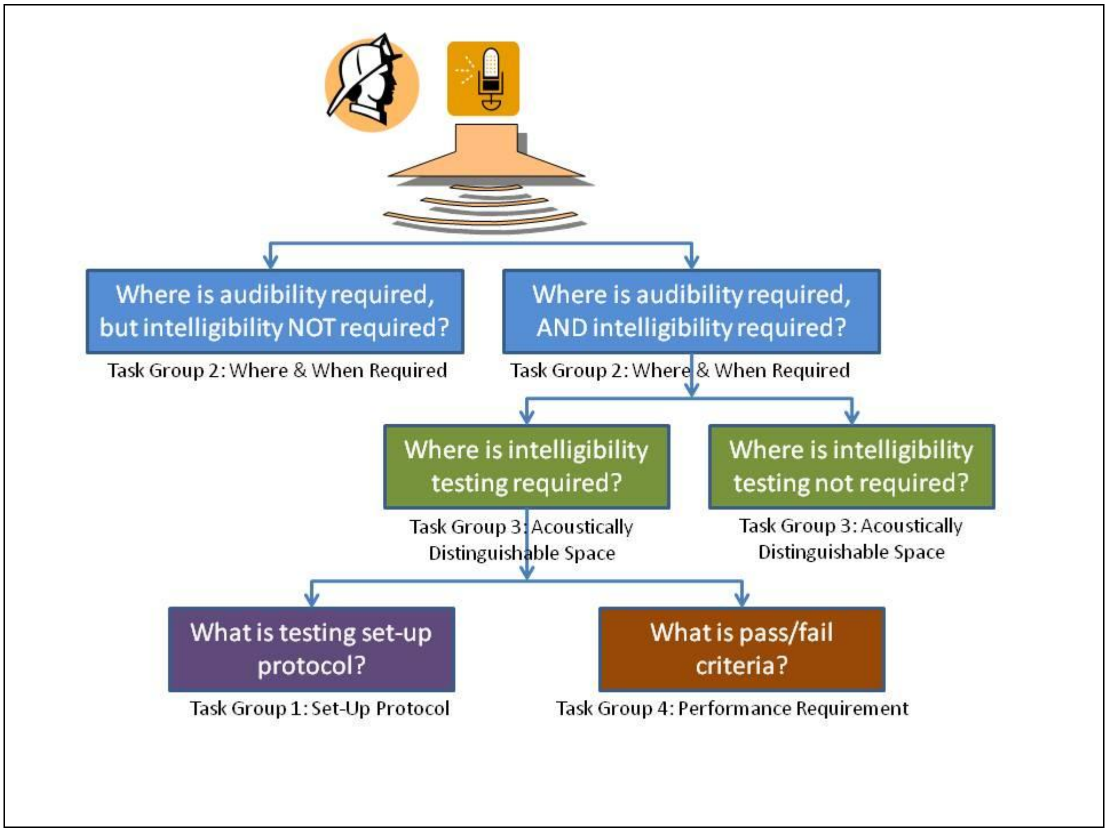

Figure 3: Logic Diagram for Establishment of Project Task Groups

The four task groups and the subjects they addressed were:

a) Set-Up Protocol Task Group. Address test set-up where a test is required, and establish test parameters. Clarify the proper Talkbox setup for testing of a system that uses pre-recorded content or manual announcements or both. Establish a repeatable baseline for the Talkbox setup based on sound pressure level (dBA) and distance between the Talkbox and microphone.
b) Where-and-When Required Task Group. Address where intelligibility measurements are required, with specific attention to where audibility is required but intelligibility is not required. Address when testing is required in relation testing a new facility based on partial occupancy before the building is occupied, and testing in its final acoustic configuration.
c) Acoustically Distinguishable Spaces Task Group. Define characteristics to establish test areas. Clarify the definition and description of acoustically distinguishable spaces, recognizing that sound pressure level measurements (in dBA) do not necessarily equate to STIPA measurements.
d) Performance Requirement Task Group. Clarify pass/fail criteria, and distinguish the level of precision required for the STI measurements.

3) REVIEW OF FIELD TEST #1

3.1) Background.

This project includes three specific field tests to evaluate the characteristics of voice intelligibility involving the notification appliances of fire alarm and emergency communication systems.

The first of three field tests involved a five story office building. This test was conducted on 20-21 August 2008 during normal occupied daytime hours, and during evening hours when the building was primarily unoccupied. Most of the testing was done without normal ambient noise on 20 August 2008 from 6:00 pm to 10:00 pm. Additional testing was done in the building's cafeteria on 21 August 2008 between 12:00 noon and 1:00 pm, when it was at its peak occupant capacity.

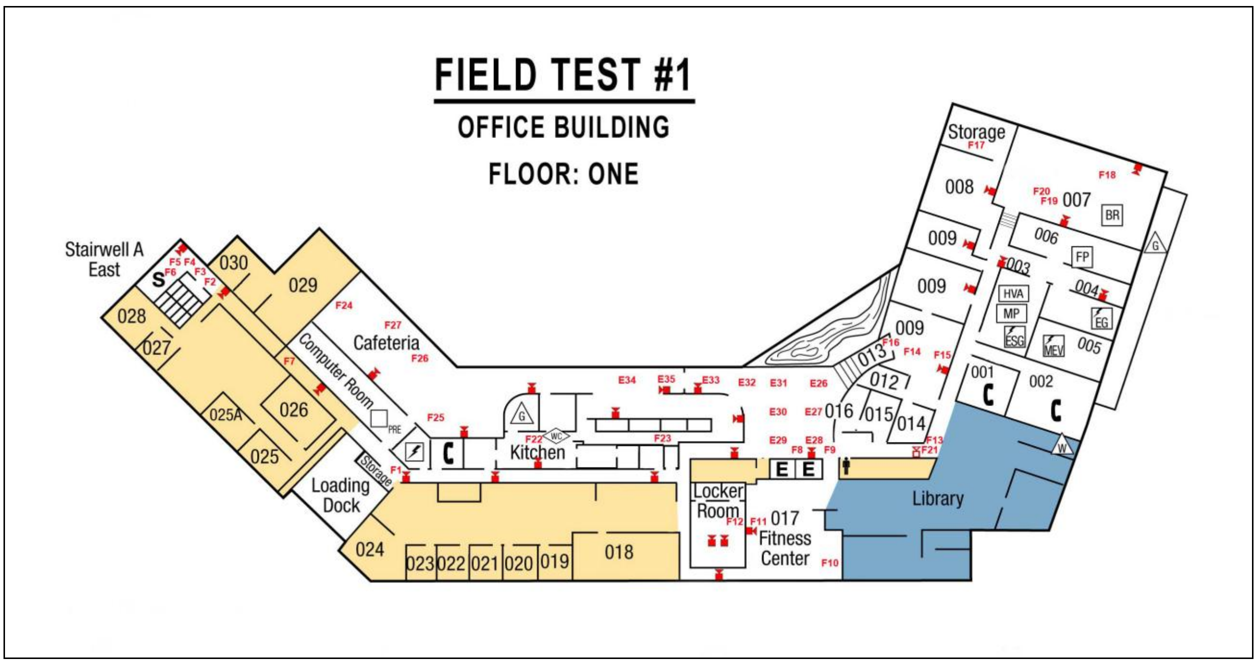

Figure 4, Field Test 1, Office Building, Floor One

Field Test #1 and Field Test #2 occurred in the same two-day time period and were in the same geographical vicinity, and a meeting was held in conjunction with these two field tests. The overall purpose was to refine a proposed test protocol in preparation for the upcoming NFPA 72 ROC meetings. The primary focus during this early project phase was to establish the conceptual basis for the test protocol and to identify outstanding technical concerns requiring more attention. Subsequent work would address these technical concerns and focus on refining the details of the test protocol.

Multiple technical topics were discussed in detail at the meeting. One topic that received considerable attention was the test protocol setup including the arrangement of the talkbox. It was agreed the preferred approach is to use a talkbox-microphone arrangement and not a direct electronic tie-in, since this more realistically simulates the actual use of the voice system microphone.

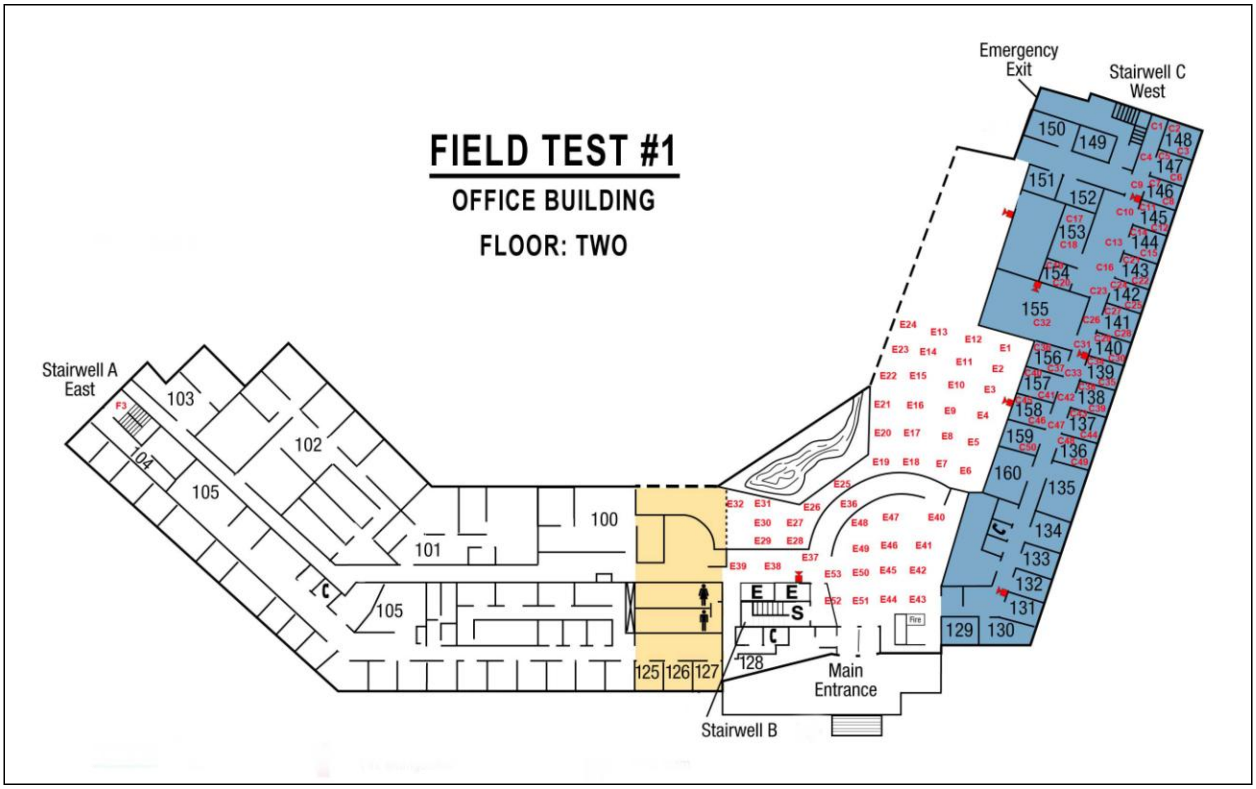

Figure 5, Field Test 1, Office Building, Floor Two

As a result of the preliminary test #1 (and also test #2) results, and based on extensive discussion, it was agreed that four specific subject areas required additional attention. On this basis four task groups were appointed with the following charters, and to report back prior to Field Test #3 with revised language for the draft test protocol:

a) Set-Up Protocol Task Group. Address test set-up where a test is required, and establish test parameters. Clarify the proper talkbox setup for testing of a system that uses pre-recorded content or manual announcements or both. Establish a repeatable baseline for the talkbox setup based on sound pressure level (dBA) and distance between the talkbox and microphone.

b) Where-and-When Required Task Group. Address where intelligibility measurements are required, with specific attention to where audibility is required but intelligibility is not required. Address when testing is required in relation testing a new facility based on partial occupancy before the building is occupied, and testing in its final acoustic configuration.

c) Acoustically Distinguishable Spaces Task Group. Define characteristics to establish test areas. Clarify the definition and description of acoustically distinguishable spaces, recognizing that sound pressure level measurements (in dBA) do not necessarily equate to STIPA measurements.

d) Performance Requirement Task Group. Clarify pass/fail criteria, and distinguish the level of precision required for the STI measurements.

3.2) Facility and Equipment.

The facility used in field test #1 had five operational floors and was fully occupied and operational at the time of the test. The overall occupancy classification, according to NFPA 101, Life Safety Code, is “Business Occupancy”; with certain portions of the facility also having additional occupancy requirements (e.g. cafeteria as an assembly), depending on their incidental use.

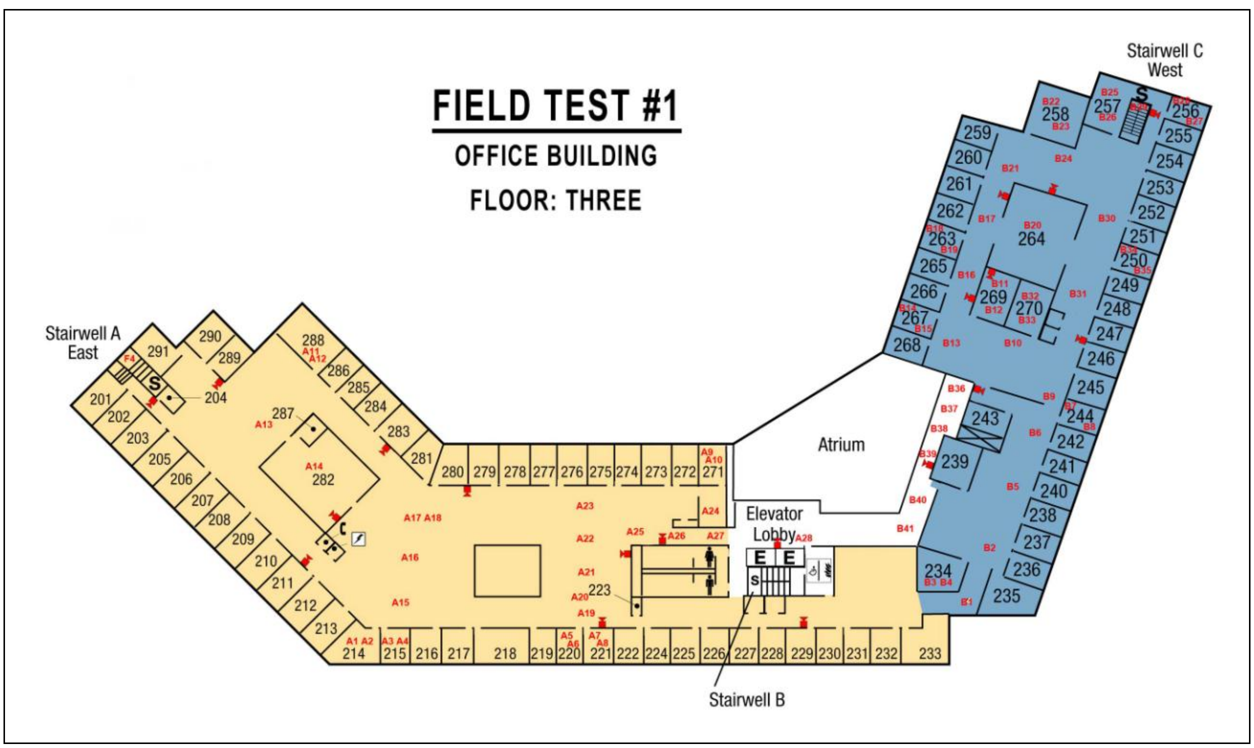

Figure 6, Field Test 1, Office Building, Floor Three

The field test #1 facility had various features that are commonly found in a typical office building. This includes numerous identical individual offices, large open common areas, and other areas that serve a variety of uses and functions. Some of the large open common areas were additional office areas with segregated low partition cubicles, while other areas were fully open spaces where portable tables and chairs can be added for functions. Additional miscellaneous areas throughout the facility included: kitchen, cafeteria, copy center, computer room, meeting rooms, library, health club, machinery spaces, and utility rooms. Also included was a main atrium through four floors in the central portion of the building that included a small waterfall.

The general acoustical characteristics of the building activities varied during normal operational hours. It was observed that some areas had generally lower ambient noise levels, such as the Library, while other areas had higher ambient noise such as machinery spaces. Certain areas appeared to have characteristics which were anticipated to be more acoustically challenging. An example was the four story atrium which, in addition to its significant height, included appreciable glass surfaces and terrazzo floors that would likely be more reflective of sound and thus be a challenge to the voice intelligibility.

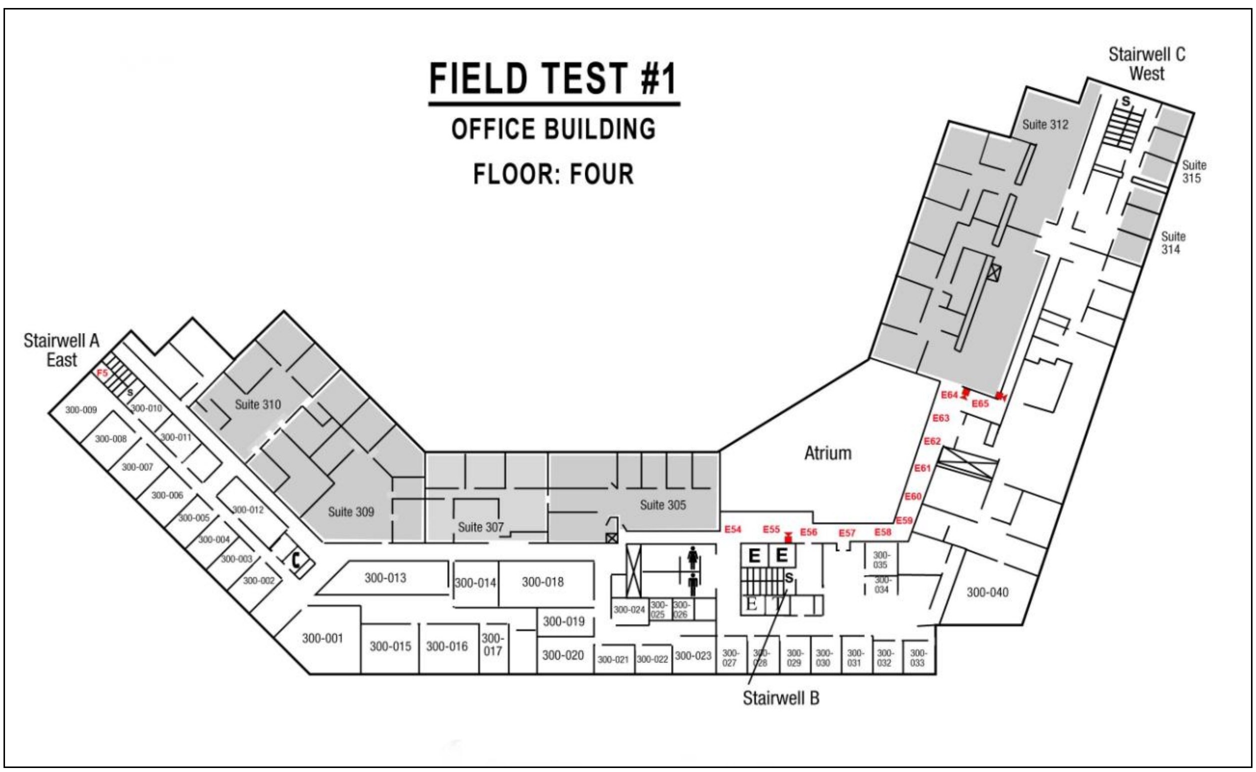

Figure 7, Field Test 1, Office Building, Floor Four

The test facility was equipped with an NFPA 72, National Fire Alarm Code compliant fire alarm system. This included a voice announcement feature to allow the incident commander of an emergency situation to broadcast "live" over the fire alarm system. The test building was almost three decades old, though a full building renovation had occurred approximately eight years prior and the fire alarm system was upgraded at that time. Notification appliances throughout the facility were strobe/speaker combinations, all of similar design from a single manufacturer.

The measurement equipment used during the tests was comprised of six separate test meters and one talkbox, all from a single manufacturer. The test meters were used to measure the system intelligibility at different locations, and the talkbox was used to transmit the STIPA test signal through the voice communication system.

3.3) Test Description.

Prior to beginning the test, six test teams were established based on six available test meters, and the approximate two dozen test participants were randomly assigned to a team. Each team was then given a designated portion of the building where they would implement the test protocol. The data collected is compiled in Tables 1 through 4 and the measurement locations illustrated in Figures 4 through 8.

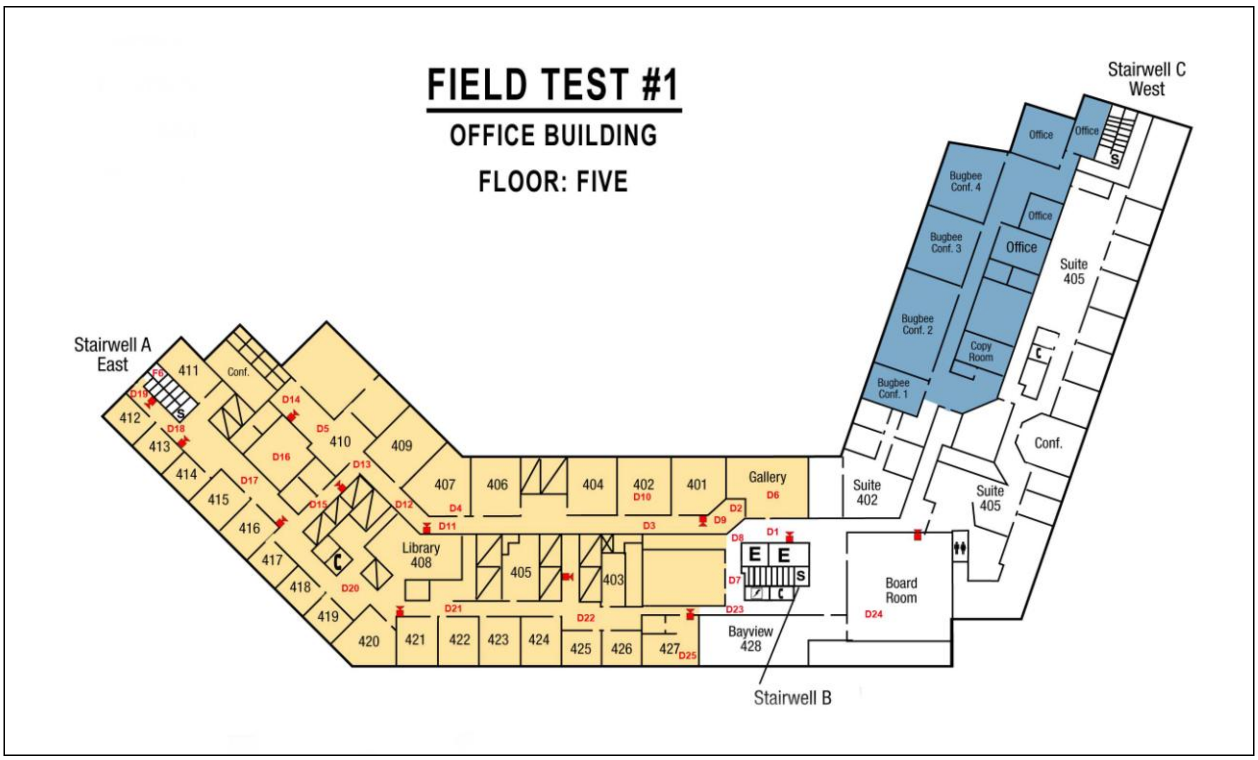

Figure 8, Field Test 1, Office Building, Floor Five

Due to the need to minimize the disruption to the building occupants, the primary test work was initiated after normal business hours during the time frame from 6:00 pm to 10:00 pm on

20 August 2008. Prototype forms were used to record the sound pressure levels and STIPA measurements throughout their assigned area. This data was compiled into Tables 1 through 4. The shaded entries in these tables represent the STIPA measurements that exceeded the threshold value of 0.45 STI or 0.65 CIS.

Table 1: Field Test 1, Office Building, Measurement Points from Teams A and B

Test Facility: Field Test #1, Office Building Date: 20 August 2008 Time: 6:00 PM

Meas Point	Description	SPL dBa	STI	CIS
A1	3rd Flr, Rm 214, door open	37	.42	.62
A2	3rd Flr, Rm 214, door closed	35	.14	.15
A3	3rd Flr, Rm 215, door open	40	.44	.64
A4	3rd Flr, Rm 215, door closed	36	.11	.04
A5	3rd Flr, Rm 220, door open	47	.64	.81
A6	3rd Flr, Rm 220, door closed	37	.45	.65
A7	3rd Flr, Rm 221, door open	49	.65	.81
A8	3rd Flr, Rm 221, door closed	41	.45	.65
A9	3rd Flr, Rm 271, door open	42	.22	.34
A10	3rd Flr, Rm 271, door closed	37	.11	.04
A11	3rd Flr, Rm 288, door open	37	.38	.58
A12	3rd Flr, Rm 288, door closed	34	.15	.18
A13	3rd Flr, Rm 287	48	.62	.79
A14	3rd Flr, Rm 282	55	.69	.84
A15	3rd Flr, Rm 223, between Rm 280 & 215	42	.61	.79
A16	3rd Flr, Rm 223, between Rm 280 & 215	41	.52	.72
A17	3rd Flr, Rm 223, between Rm 280 & 215	52	.67	.83
A18	3rd Flr, Rm 223, point A17 facing Rm 283	52	.75	.88
A19	3rd Flr, Rm 223, between Rm 276 & 220	53	.74	.87
A20	3rd Flr, Rm 223, between Rm 276 & 220	54	.75	.88
A21	3rd Flr, Rm 223, between Rm 276 & 220	55	.78	.89
A22	3rd Flr, Rm 223, between Rm 276 & 220	50	.69	.84
A23	3rd Flr, Rm 223, between Rm 276 & 220	50	.69	.84
A24	3rd Flr, Rm 223, outside Rm 271	44	.44	.64
A25	3rd Flr, Rm 223, Corridor	56	.63	.80
A26	3rd Flr, Rm 223, Corridor	62	.79	.90
A27	3rd Flr, Rm 223, Corridor	58	.68	.83
A28	3rd Flr, Elevator Lobby by elevator		.46	.66

Meas Point	Description	SPL dBa	STI	CIS
B1	3rd Flr, Corridor by Rm235	45	.42	.62
B2	3rd Flr, Open Area by Rm236	46	.40	.60
B3	3rd Flr, Rm 234, door open	38	.29	.46
B4	3rd Flr, Rm 234, door closed	32	.17	.23
B5	3rd Flr, Open Area by Rm 240	45	.56	.75
B6	3rd Flr, Open Area by Rm 242	53	.69	.84
B7	3rd Flr, Rm 244, door open	54	.70	.85
B8	3rd Flr, Rm 244, door closed	37	.48	.68
B9	3rd Flr, Open Area by Rm244	61	.79	.90
B10	3rd Flr, Open Area by Rm270	55	.75	.88
B11	3rd Flr, Rm 269, door open	63	.71	.85
B12	3rd Flr, Rm 269, door closed	63	.77	.89
B13	3rd Flr, Open Area by Rm267	54	.71	.85
B14	3rd Flr, Rm 267, door open	49	.68	.83
B15	3rd Flr, Rm 267, door closed	34	.21	.32
B16	3rd Flr, Open Area by Rm 265	50	.68	.83
B17	3rd Flr, Open Area by Rm 262	53	.73	.86
B18	3rd Flr, Rm 263, door open	46	.64	.81
B19	3rd Flr, Rm 263, door closed	36	.43	.63
B20	3rd Flr, Rm 264	43	.57	.76
B21	3rd Flr, Open Area by Rm 260	61	.78	.89
B22	3rd Flr, Rm 258, door open	46	.60	.78
B23	3rd Flr, Rm 258, door closed	39	.47	.67
B24	3rd Flr, Open Area by Rm258	55	.76	.88
B25	3rd Flr, Rm 257, door open	38	.59	.77
B26	3rd Flr, Rm 257, door closed	33	.43	.63
B27	3rd Flr, Rm 256, door open	55	.71	.85
B28	3rd Flr, Rm 256, door closed	47	.59	.77
B29	3rd Flr, Stairwell C	46	.43	.63
B30	3rd Flr, Open Area by Rm 251	52	.64	.81
B31	3rd Flr, Open Area by Rm 248	49	.64	.81
B32	3rd Flr, Rm 270, door open	47	.55	.74
B33	3rd Flr, Rm 270, door closed	43	.34	.53
B34	3rd Flr, Rm 250, door open	40	.41	.61
B35	3rd Flr, Rm 250, door closed	35	.33	.52
B36	3rd Flr, Atrium walkway by Rm 243	65	.27	.43
B37	3rd Flr, Atrium walkway by Rm 243	66	.29	.46
B38	3rd Flr, Atrium walkway between Rm 243 & 239	72	.56	.75
B39	3rd Flr, Atrium walkway by Rm 239	67	.35	.54
B40	3rd Flr, Atrium walkway between Rm 239 & 234	66	.28	.45
B41	3rd Flr, Atrium walkway by Rm 234	65	.26	.41

The first step of the test was to setup the talkbox to transmit the STIPA test signal through the voice communication system. All normal procedures were followed to take the fire alarm system off-line and to arrange the transmission of the STIPA signal through the system. Signification discussion and debate among the attendees focused on the setup of the talkbox. Ultimately, the talkbox was set at 85 dBA at a distance of 5" from the microphone. This corresponds to a talking level of approximately 67 dBA at 1 meter, which is greater than the 60 dBA recommended by IEC 60268-16, "*Sound system equipment*". It was agreed not to use direct tie-in of the test signal, but to play it into the microphone in the same manner as an actual human voice.

The draft test protocol was implemented and each team proceeded to record as many measurement points as possible during the available time. This was accomplished by measuring the intelligibility (STIPA) and audibility (dBA). It is noted that these measurements were made without normal ambient background sound pressure levels (noise) when most of the buildings occupants were not in the building (i.e., off-hours), and ideally these data results should be adjusted to account for normal ambient background noise. However, this series of tests was designed to test the test method, not necessarily to measure the level of speech intelligibility during the normal use of the building.

During Field Test #1 the definition of Acoustically Distinguishable Spaces, and precisely where intelligibility should be measured, was still not well established. Thus, each team took measurements with the intent of trying to collect data that would be most useful for identifying outstanding technical concerns and revising the draft test protocol. Areas that received additional focus included: identical offices, open areas segregated with low partition cubicles, the atrium, a large open meeting area, kitchen, cafeteria, copy center, computer room, meeting rooms, library, health club, machinery spaces, and utility rooms.

Additional testing was done the following day on 21 August 2008 and focused on taking measurements of ambient background noise during peak occupied conditions in the cafeteria. These measurements were used to calculate the corrected STIPA since all other measurements had been taken during off-hours without normal ambient background noise.

3.4) Observations.

The following are the general observations that were noted in Field Test #1:

a) Initial talkbox set-up is critical, and this needs to be standardized for repeatability of the test protocol. The general concept embraced was that the test signal should accurately replicate someone speaking into the microphone.

b) Audibility (dBA) and intelligibility (STIPA) are separate and distinctly different characteristics, and both are important. However, it may not be required to measure intelligibility in all areas, while it is more important that the system is audible in most or all areas.

c) The degradation of intelligibility predictions can be the result of multiple factors, but for convenience these can be summarized in the following three groups: 1) signal to noise (S/N) ratio; 2) distortion; and 3) decay (e.g., echoes, reverberation, etc).

d) Revise the test form to better document the test measurements, and include CIS since some test meters display only CIS instead of STI.

e) Intelligibility predictions drop significantly when the direct path for the sound is blocked by a physical barrier, such as with a door.

f) A rule of thumb for installers of audio equipment is 4,000 cubic feet (20' x 20' x 10' ceiling) will generally result in acceptable intelligibility absent any distortion caused by the communications system and absent unusual room features (e.g. high ambient noise or reflective surfaces). Conditions beyond this might challenge intelligibility predictions depending on the actual environment and the design of the system.

Table 2: Field Test 1, Office Building, Measurement Points from Teams C and D

Test Facility: Field Test #1, Office Building Date: 20 August 2008 Time: 6:00 PM

Meas Point	Description	SPL dBa	STI	CIS	Meas Point	Description	SPL dBa	STI	CIS
C1	2nd Flr, Corridor, by Rm 148	60	.70	.85	D1	5th Flr, Elevator lobby		.62	.79
C2	2nd Flr, Rm 148, door open	50	.75	.88	D2	5th Flr, Corridor by gallery		.62	.79
C3	2nd Flr, Rm 148, door closed	39	Err	Err	D3	5th Flr, Corridor by Rm 402		.65	.81
C4	2nd Flr, Corridor, by Rm 147	66	.84	.92	D4	5th Flr, Rm 407		.62	.79
C5	2nd Flr, Rm 147, door open	52	.64	.81	D5	5th Flr, Entrance area to Rm 410		.74	.87
C6	2nd Flr, Rm 147, door closed	37	.62	.79	D6	5th Flr, Elevator lobby gallery		.35	.54
C7	2nd Flr, Rm 146, door open	54	.71	.85	D7	5th Flr, Elevator lobby		.57	.76
C8	2nd Flr, Rm 146, door closed	41	.70	.85	D8	5th Flr, Elevator lobby		.62	.79
C9	2nd Flr, Corridor, by Rm 146	73	.84	.92	D9	5th Flr, Corridor by Rm 401		.62	.79
C10	2nd Flr, Corridor, by Rm 145	62	.78	.89	D10	5th Flr, Rm 402		Err	Err
C11	2nd Flr, Rm 145, door open	52	.59	.77	D11	5th Flr, Corridor by Rm 407		.60	.78
C12	2nd Flr, Rm 145, door closed	39	.50	.70	D12	5th Flr, Corridor by Rm 407		.60	.78
C13	2nd Flr, Corridor, by Rm 144	59	.73	.86	D13	5th Flr, Entrance area to Rm 410, door open		.74	.87
C14	2nd Flr, Rm 144, door open	52	.61	.79	D14	5th Flr, Entrance area to Rm 410 by Conf Rm		.35	.54
C15	2nd Flr, Rm 144, door closed	40	.62	.79	D15	5th Flr, Entrance area to Rm 410, door closed		Err	Err
C16	2nd Flr, Corridor, by Rm 143	59	.64	.81	D16	5th Flr, Copy Rm by Rm 416		Err	Err
C17	2nd Flr, Rm 153, door open	47	.59	.77	D17	5th Flr, Corridor by Rm 415		.73	.86
C18	2nd Flr, Rm 153, door closed	38	Err	Err	D18	5th Flr, Corridor by Rm 413		.65	.81
C19	2nd Flr, Rm 154, door open	49	.74	.87	D19	5th Flr, Corridor by Stairwell A East		Err	Err
C20	2nd Flr, Rm 154, door closed	40	Err	Err	D20	5th Flr, Corridor by Rm 419		Err	Err
C21	2nd Flr, Rm 143, door open	50	.71	.85	D21	5th Flr, Corridor by Rm 422		Err	Err
C22	2nd Flr, Rm 143, door closed	45	Err	Err	D22	5th Flr, Corridor by Rm 425		.50	.70
C23	2nd Flr, Corridor, by Rm 142	59	.66	.82	D23	5th Flr, Corridor by Rm 429		.72	.86
C24	2nd Flr, Rm 142, door open	53	.67	.83	D24	5th Flr, Board Rm		Err	Err
C25	2nd Flr, Rm 142, door closed	44	.24	.38	D25	5th Flr, Kitchen by Rm 429		.59	.77
C26	2nd Flr, Corridor, by Rm 141	62	.72	.86					
C27	2nd Flr, Rm 141, door open	52	.65	.81					
C28	2nd Flr, Rm 141, door closed	44	Err	Err					
C29	2nd Flr, Rm 140, door open	55	.77	.89					
C30	2nd Flr, Rm 140, door closed	44	Err	Err					
C31	2nd Flr, Corridor, by Rm 140	69	.86	.93					
C32	2nd Flr, Rm 155	57	.66	.82					
C33	2nd Flr, Corridor, by Rm 139	62	.64	.81					
C34	2nd Flr, Rm 139, door open	59	.64	.81					
C35	2nd Flr, Rm 139, door closed	43	.55	.74					
C36	2nd Flr, Rm 156, door open	53	.63	.80					
C37	2nd Flr, Rm 156, door closed	44	.54	.73					
C38	2nd Flr, Rm 138, door open	52	.66	.82					
C39	2nd Flr, Rm 138, door closed	43	Err	Err					
C40	2nd Flr, Rm 157, door open	52	.62	.79					
C41	2nd Flr, Rm 157, door closed	43	Err	Err					
C42	2nd Flr, Corridor, by Rm 138	58	.70	.85					
C43	2nd Flr, Rm 137, door open	48	.50	.70					
C44	2nd Flr, Rm 137, door closed	41	Err	Err					
C45	2nd Flr, Rm 158, door open	49	.46	.66					
C46	2nd Flr, Rm 158, door closed	47	.10	.00					
C47	2nd Flr, Corridor, by Rm 137	57	.62	.79					
C48	2nd Flr, Rm 136, door open	50	.41	.61					
C49	2nd Flr, Rm 136, door closed	49	.35	.54					
C50	2nd Flr, Rm 159, door open	48	.44	.64					

Table 3: Field Test 1, Office Building, Measurement Points from Teams E

Test Facility: Field Test #1, Office Building Date: 20 August 2008 Time: 6:00 PM

Meas Point	Description	SPL dBa	STI	CIS
E1	2nd Flr Atrium	65	.34	.53
E2	2nd Flr Atrium, Reading #1	66	.44	.64
	2nd Flr Atrium, Reading #2		.42	.62
	2nd Flr Atrium, Reading #3		.48	.68
E3	2nd Flr Atrium, Reading #1	66	.39	.59
	2nd Flr Atrium, Reading #2		.38	.58
	2nd Flr Atrium, Reading #3		.41	.61
E4	2nd Flr Atrium, Reading #1	65	.26	.41
	2nd Flr Atrium, Reading #2		.26	.41
E5	2nd Flr Atrium, Reading #1	63	.26	.41
	2nd Flr Atrium, Reading #2		.29	.46
	2nd Flr Atrium, Reading #3		.29	.46
E6	2nd Flr Atrium, Reading #1	64	.25	.39
	2nd Flr Atrium, Reading #2		.21	.32
	2nd Flr Atrium, Reading #3		.25	.39
E7	2nd Flr Atrium, Reading #1	65	.33	.52
	2nd Flr Atrium, Reading #2		.29	.46
	2nd Flr Atrium, Reading #3		.28	.44
E8	2nd Flr Atrium, Reading #1	65	.25	.39
	2nd Flr Atrium, Reading #2		.28	.44
	2nd Flr Atrium, Reading #3		.29	.46
E9	2nd Flr Atrium, Reading #1	65	.30	.47
	2nd Flr Atrium, Reading #2		.27	.43
	2nd Flr Atrium, Reading #3		.27	.43
E10	2nd Flr Atrium, Reading #1	64	.34	.53
	2nd Flr Atrium, Reading #2		.35	.54
	2nd Flr Atrium, Reading #3		.33	.52
E11	2nd Flr Atrium, Reading #1	64	.35	.55
	2nd Flr Atrium, Reading #2		.35	.55
	2nd Flr Atrium, Reading #3		.35	.55
E12	2nd Flr Atrium, Reading #1	64	.31	.49
	2nd Flr Atrium, Reading #2		.32	.50
	2nd Flr Atrium, Reading #3		.33	.52
E13	2nd Flr Atrium, Reading #1	65	.31	.49
	2nd Flr Atrium, Reading #2		.34	.53
	2nd Flr Atrium, Reading #3		.34	.53
E14	2nd Flr Atrium, Reading #1	65	.35	.54
	2nd Flr Atrium, Reading #2		.33	.52
	2nd Flr Atrium, Reading #3		.35	.54
E15	2nd Flr Atrium, Reading #1	64	.30	.47
	2nd Flr Atrium, Reading #2		.25	.39
	2nd Flr Atrium, Reading #3		.23	.36
E16	2nd Flr Atrium, Reading #1	65	.28	.44
	2nd Flr Atrium, Reading #2		.28	.44
	2nd Flr Atrium, Reading #3		.30	.47
E17	2nd Flr Atrium, Reading #1	65	.31	.49
	2nd Flr Atrium, Reading #2		.27	.43
	2nd Flr Atrium, Reading #3		.27	.43
E18	2nd Flr Atrium, Reading #1	65	.28	.44
	2nd Flr Atrium, Reading #2		.25	.49
	2nd Flr Atrium, Reading #3		.24	.38
E19	2nd Flr Atrium, Reading #1, top of stairs	65	.24	.38
	2nd Flr Atrium, Reading #2, top of stairs		.26	.41
	2nd Flr Atrium, Reading #3, top of stairs		.23	.36
E20	2nd Flr Atrium, Reading #1	65	.19	.29
	2nd Flr Atrium, Reading #2		.21	.32
	2nd Flr Atrium, Reading #3		.24	.38
E21	2nd Flr Atrium, Reading #1	65	.28	.44
	2nd Flr Atrium, Reading #2		.27	.43
	2nd Flr Atrium, Reading #3		.26	.41
E22	2nd Flr Atrium, Reading #1	64	.17	.24
	2nd Flr Atrium, Reading #2		.28	.44
	2nd Flr Atrium, Reading #3		.28	.44
E23	2nd Flr Atrium, Reading #1	64	.27	.43
	2nd Flr Atrium, Reading #2		.34	.53
	2nd Flr Atrium, Reading #3		.33	.52
E24	2nd Flr Atrium, Reading #1	64	.33	.52
	2nd Flr Atrium, Reading #2		.33	.52
	2nd Flr Atrium, Reading #3		.35	.54
E25	Winding Atrium Stair, from 2nd Flr to 1st Flr	66	.22	.34
	Winding Atrium Stair, from 2nd Flr to 1st Flr		.24	.38
	Winding Atrium Stair, from 2nd Flr to 1st Flr		.22	.34
E26	Winding Atrium Stair, from 2nd Flr to 1st Flr	67	.25	.39
	Winding Atrium Stair, from 2nd Flr to 1st Flr		.27	.43
	Winding Atrium Stair, from 2nd Flr to 1st Flr		.29	.46
E27	1st Flr Atrium Elevator Lobby, Reading #1	66	.33	.52
	1st Flr Atrium Elevator Lobby, Reading #2		.37	.57
	1st Flr Atrium Elevator Lobby, Reading #3		.34	.53
E28	1st Flr Atrium Elevator Lobby, by elevator	69	.62	.79
E29	1st Flr Atrium Elevator Lobby, by elevator	66	.33	.52
E30	1st Flr Atrium Elevator Lobby, Reading #1	67	.34	.53
	1st Flr Atrium Elevator Lobby, Reading #2		.34	.53
	1st Flr Atrium Elevator Lobby, Reading #3		.33	.52
E31	1st Flr Atrium Elevator Lobby, Reading #1	68	.29	.46
	1st Flr Atrium Elevator Lobby, Reading #2		.35	.55
	1st Flr Atrium Elevator Lobby, Reading #3		.27	.43
E32	1st Flr Atrium Elevator Lobby, Reading #1	67	.32	.50
	1st Flr Atrium Elevator Lobby, Reading #2		.29	.46
	1st Flr Atrium Elevator Lobby, Reading #3		.33	.52
E33	1st Flr Atrium Corridor to Cafeteria, Reading #1	67	.33	.52
	1st Flr Atrium Corridor to Cafeteria, Reading #2		.26	.41
	1st Flr Atrium Corridor to Cafeteria, Reading #3		.24	.38
E34	1st Flr Atrium Corridor to Cafeteria, Reading #1	69	.40	.60
	1st Flr Atrium Corridor to Cafeteria, Reading #2		.38	.58
	1st Flr Atrium Corridor to Cafeteria, Reading #3		.37	.57
E35	1st Flr Atrium Corridor to Cafeteria	70	.51	.71
E36	2nd Flr Winding Handicap Ramp, Reading #1	65	.29	.46
	2nd Flr Winding Handicap Ramp, Reading #2		.26	.41
	2nd Flr Winding Handicap Ramp, Reading #3		.24	.38
E37	2nd Flr Winding Handicap Ramp, Reading #1	68	.35	.54
	2nd Flr Winding Handicap Ramp, Reading #2		.44	.64
	2nd Flr Winding Handicap Ramp, Reading #3		.41	.61
E38	2nd Flr Atrium Elevator Lobby, by elevator	68	.41	.61
	2nd Flr Atrium Elevator Lobby, by elevator		.38	.58
	2nd Flr Atrium Elevator Lobby, by elevator		.41	.61
E39	2nd Flr Atrium Elevator Lobby, by elevator	66	.34	.53
	2nd Flr Atrium Elevator Lobby, by elevator		.35	.54
	2nd Flr Atrium Elevator Lobby, by elevator		.33	.52
E40	2nd Flr Atrium Lobby by guard desk, Reading #1	65	.33	.52
	2nd Flr Atrium Lobby by guard desk, Reading #2		.31	.49
	2nd Flr Atrium Lobby by guard desk, Reading #3		.37	.57
E41	2nd Flr Atrium Lobby by guard desk, Reading #1	66	.35	.54
	2nd Flr Atrium Lobby by guard desk, Reading #2		.34	.53
	2nd Flr Atrium Lobby by guard desk, Reading #3		.33	.52
E42	2nd Flr Atrium Lobby by guard desk	66	.28	.44
E43	2nd Flr Atrium Lobby by guard desk	66	.31	.49
E44	2nd Flr Atrium Lobby by guard desk	64	.32	.50
E45	2nd Flr Atrium Lobby by guard desk	64	.34	.53
E46	2nd Flr Atrium Lobby by guard desk	65	.29	.46
E47	2nd Flr Atrium Lobby by guard desk	64	.23	.36
E48	2nd Flr Atrium Lobby by guard desk	66	.27	.43
E49	2nd Flr Atrium Lobby by guard desk	65	.28	.44
E50	2nd Flr Atrium Lobby by guard desk	64	.26	.41
E51	2nd Flr Atrium Lobby by guard desk	64	.21	.32
E52	2nd Flr Atrium Lobby by guard desk	64	.24	.38
E53	2nd Flr Atrium Lobby by guard desk	64	.29	.46
				.
				.

g) Tall ceilings, such as in the atrium, are especially challenging to achieving acceptable intelligibility predictions, unless in the immediate direct field of the speaker.

h) Surface characteristics in the area being tested that reflect sound (e.g., glass, marble, tile floors, etc) will challenge the ability to achieve acceptable intelligibility predictions.

i) Ambient background noises are a challenge to achieving acceptable intelligibility predictions. For example, measurement points F19 and F20 were taken at the same location once with minimal ambient background noise (STI = 0.55) and again after a local air compressor activated (STI = 0.30).

j) The intelligibility measurements in Stairwell-A-East (measurement points F2, F3, F4, F5, and F6) suggest that in some respects, intelligibility has a loose correlation to smoke propagation. The speaker was at the bottom of the stairwell where it had its highest intelligibility reading, and as expected dropped off at each level proceeding upward. However, at the top of the stairwell it rose due to the noise banking at the top, similar to a smoke plume.

Table 4: Field Test 1, Office Building, Measurement Points from Teams E and F

Test Facility: Field Test #1, Office Building Date: 20 August 2008 Time: 6:00 PM

Meas Point	Description	SPL dBa	STI	CIS
E54	4th Flr, Atrium walkway	65	.30	.47
E55	4th Flr, Atrium walkway	65	.29	.46
E56	4th Flr, Atrium walkway	67	.48	.68
E57	4th Flr, Atrium walkway	65	.25	.39
E58	4th Flr, Atrium walkway	64	.30	.47
E59	4th Flr, Atrium walkway	64	.29	.46
E60	4th Flr, Atrium walkway	64	.32	.50
E61	4th Flr, Atrium walkway	64	.32	.50
E62	4th Flr, Atrium walkway	64	.30	.47
E63	4th Flr, Atrium walkway	64	.21	.32
E64	4th Flr, Atrium walkway	65	.27	.43
E65	4th Flr, Atrium walkway	65	.35	.55

Meas Point	Description	SPL dBa	STI	CIS
F1	1st Flr, Corridor by loading dock	67	.70	.85
F2	1st Flr, Stairwell A East at 1st landing	70	.50	.70
F3	2nd Flr, Stairwell A East landing at door	64	.37	.57
F4	3rd Flr, Stairwell A East landing at door	56	.35	.54
F5	4th Flr, Stairwell A East landing at door	53	.24	.38
F6	5th Flr, Stairwell A East landing at door	50	.27	.43
F7	1st Flr, Corridor by Rm 029	63	.64	.81
F8	1st Flr, Elevator lobby by elevator	66	.37	.57
F9	1st Flr, Elevator lobby by health club entrance	68	.42	.62
F10	1st Flr, Fitness center by TV	59	.56	.75
F11	1st Flr, Fitness center by speaker	64	.70	.85
F12	1st Flr, Fitness center in men's locker Rm	67	.69	.84
F13	1st Flr, Corridor by Library, door open	60	.49	.69
F14	1st Flr, Rm 011 in center of Rm	57	.55	.74
F15	1st Flr, Rm 011 by speaker	63	.70	.85
F16	1st Flr, Rm 013, Pump Rm, w/ pumps on	75	.07	-.15
F17	1st Flr, Storage Rm beyond Rm 008	46	.54	.73
F18	1st Flr, Rm 007 Boiler Rm, Compressor off	62	.46	.66
F19	1st Flr, Rm 007 Boiler Rm, Compressor off	62	.55	.74
F20	1st Flr, Rm 007 Boiler Rm, Compressor on	68	.30	.48
F21	1st Flr, Corridor by Library, door closed	68	.42	.62
F22	1st Flr, Kitchen	58	.60	.78
F23	1st Flr, Kitchen	69	.42	.62
F24	1st Flr, Cafeteria at far end	61	.60	.78
F25	1st Flr, Cafeteria	61	.58	.76
F26	1st Flr, Cafeteria	61	.58	.76
F27	1st Flr, Cafeteria	61	.59	.77

4) REVIEW OF FIELD TEST #2

4.1) Background.

The second of the three field tests occurred in a shopping mall comprised of two primary levels. This test was conducted on the morning of 21 August 2008 between the hours of 6:00 am and 10:00 am.

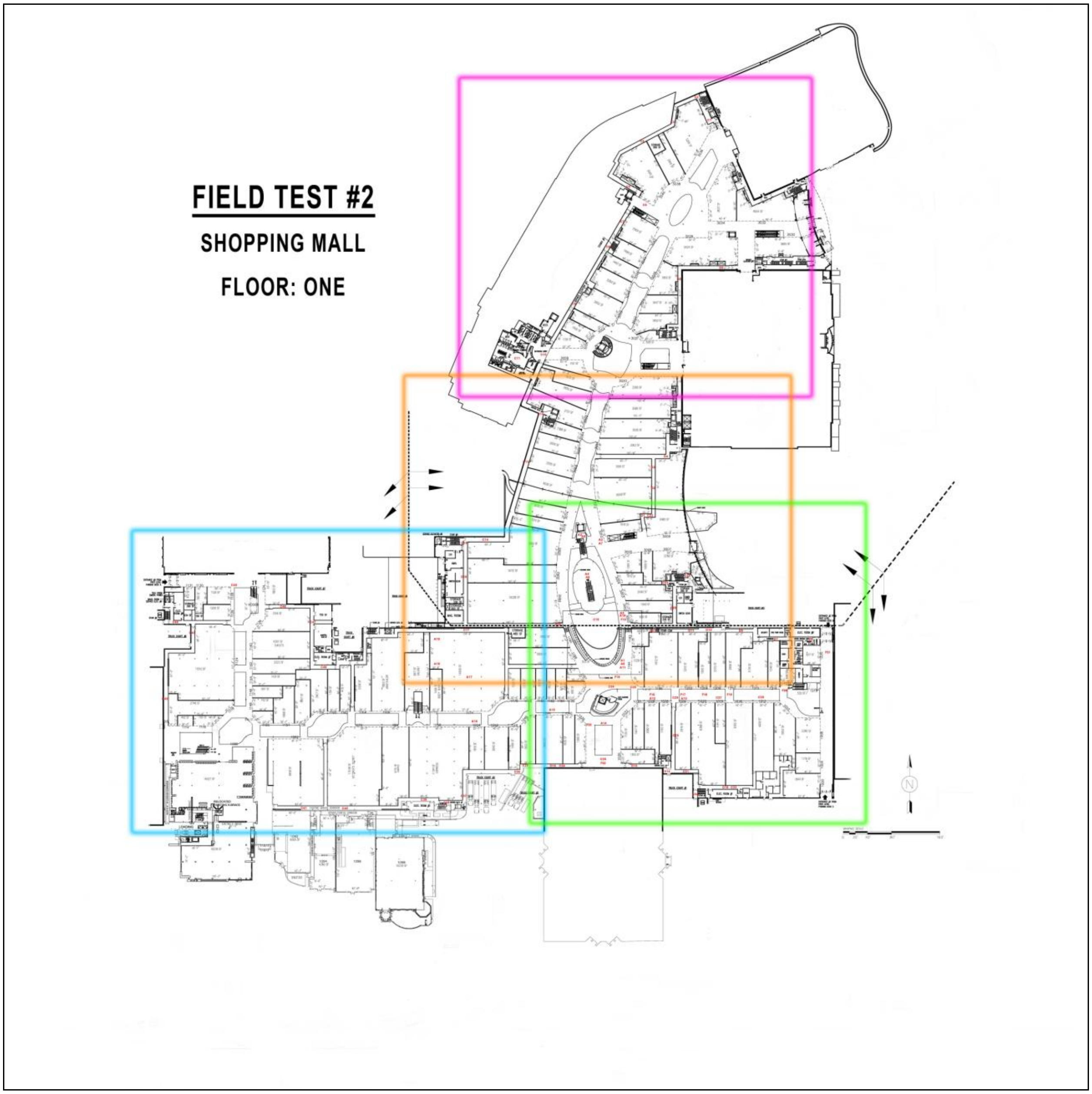

Figure 9, Field Test 2, Shopping Mall, Floor One Overview

The individual stores officially opened at 10:00 am for shoppers, but the common areas of the mall were accessible to the public during the time to the test. Thus, although some members of the public were present, the number of occupants was well below what would be expected during peak occupancy conditions. Thus, the test work was done during a time of day that did not reflect the maximum ambient background noise levels.

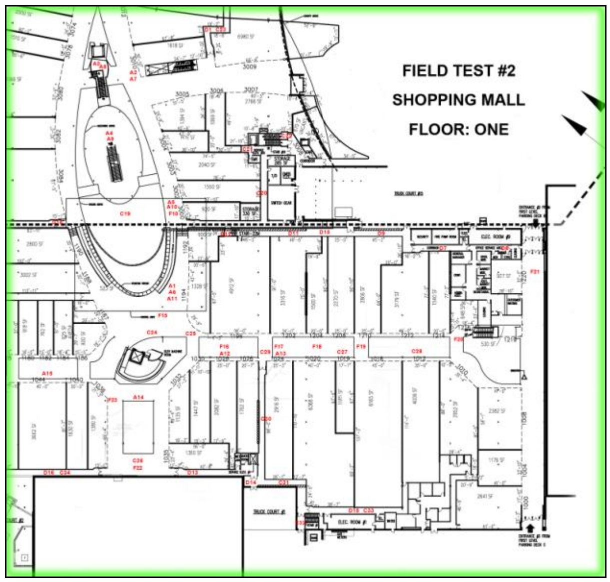

Figure 10, Field Test 2, Shopping Mall, Floor One, East Quadrant

Field Test #2 occurred in the same two-day time period as Field Test #1, and conveniently was in the same geographical vicinity. The meeting that was held in conjunction with these two field tests considered the information resulting from both field tests. This helped to establish the conceptual basis for the test protocol and to identify outstanding technical issues. Field Test #3, still as yet forthcoming, would address these technical concerns and focus on refining the details of the test protocol.

4.2) Facility and Equipment.

The facility used in field test #2 had two operational floors. All site construction was finished and the building was in its normal operational status at the time of the test. The overall occupancy classification, according to NFPA 101, Life Safety Code, is “Mercantile Occupancy”; with certain portions of the facility also having additional occupancy requirements (e.g. restaurant with more than 50 people as an assembly), depending on their incidental use.

Field test #2 had various features that would be expected in a typical enclosed shopping mall type facility. This includes the primary common areas, the individual stores, and service corridors. Additional miscellaneous areas throughout the facility included: meeting rooms, kitchen areas, offices, machinery spaces, and utility rooms. The primary common areas also included certain additional sources of ambient noise such as, at certain locations, fountains and running water, and kiosks that had their own independent background music that continued to play after the central sound system was de-activated.

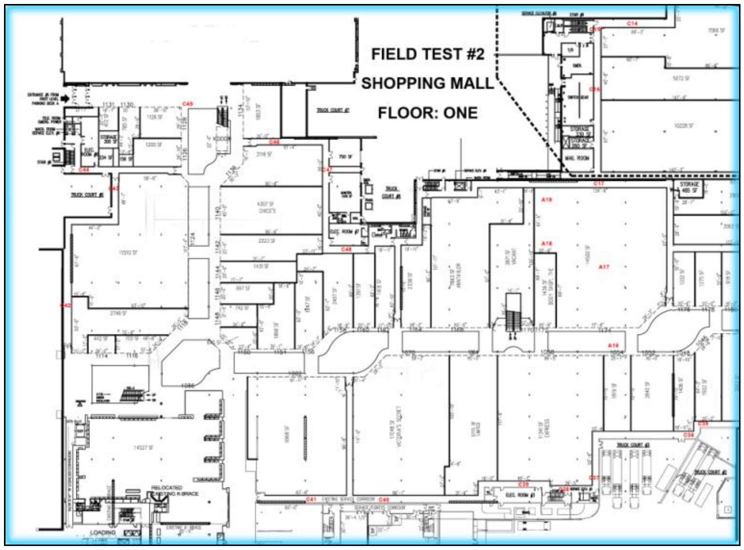

Figure 11, Field Test 2, Shopping Mall, Floor One, West Quadrant

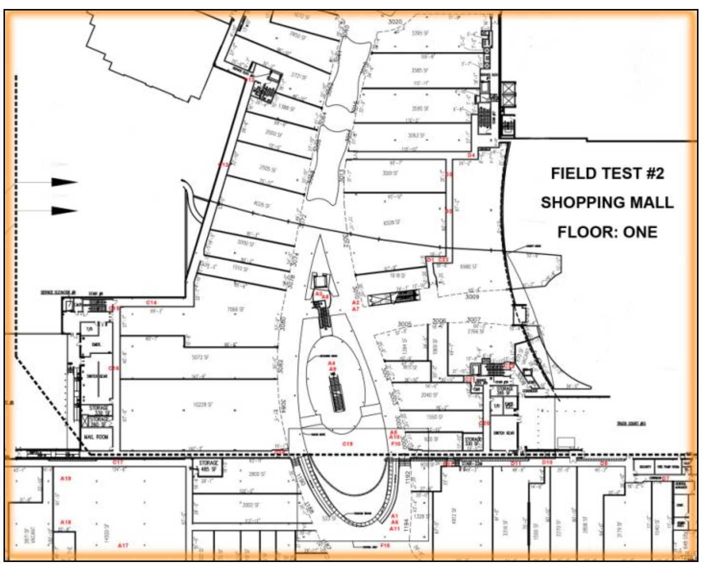

Figure 12, Field Test 2, Shopping Mall, Floor One, Central Quadrant

The mall was comprised of two fundamental portions, or wings, with the original wing extending East to West connected to a new wing extending North to South. These were connected in a "T" fashion comprising one a single indoor public mall that was very large. On busy shopping days the occupancy capacity was reported to be in the tens of thousands. The overall complex includes 270 retail outlets. At the time of the test, shoppers were not present and the mall was generally empty except for service personnel and a few morning mall walkers.

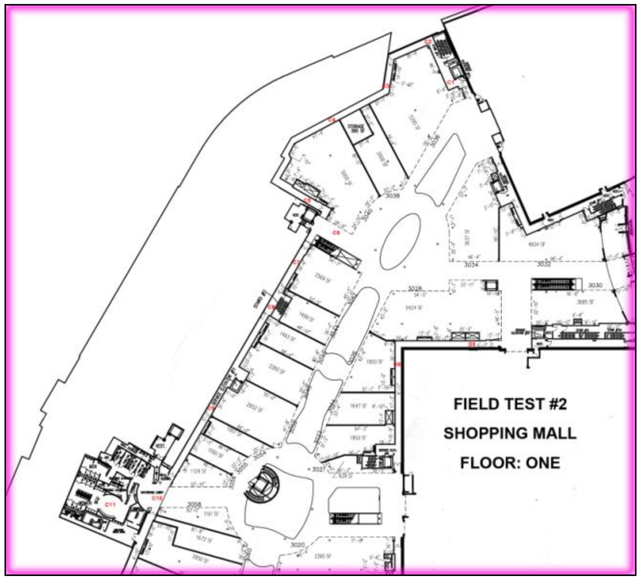

Figure 13, Field Test 2, Shopping Mall, Floor One, North Quadrant

Acoustical characteristics of the building activities varied, but the most anticipated challenges were expected to be the mall common areas, which included very high ceilings throughout and abundant metal, glass, tile and other reflective surfaces, as well as a water fountain. The ceiling height in this area was approximately 40' high.

Field Test #2 only focused on the main original and new wings of the shopping mall, and did not address outlying components of the overall facility, some of which, such as parking garages, had their own separate fire alarm systems. Each of the two primary mall wings had a separate fire alarm system, and they operated independently. This creates a relatively unusual situation where the two systems interface at the connection between the original wing and the new wing, since one system might operate but not the other. This is due to the enormous size of the overall complex.

The two fire alarm systems in the area where Field Test 2 was conducted were both designed to meet the audibility requirements of NFPA 72, National Fire Alarm Code. They both included a voice announcement feature to allow an incident commander to an emergency situation to broadcast "live" over either fire alarm system. Notification appliances used throughout the test area were strobe/speaker combinations. The two fire alarm systems were from two different manufacturers, although all the fire alarm equipment in each system was only from that respective manufacturer. In addition, the entire area was also equipped with a separate public address system designed to play background music and to make announcements under non-emergency conditions.

The test work proceeded by first testing the fire alarm system in the new mall wing, second the overall public address system, and third the fire alarm system in the original mall wing. This is reflected in the separated data recorded from any one team that is comprised of three separate sections, as shown in Tables 5 through 7.

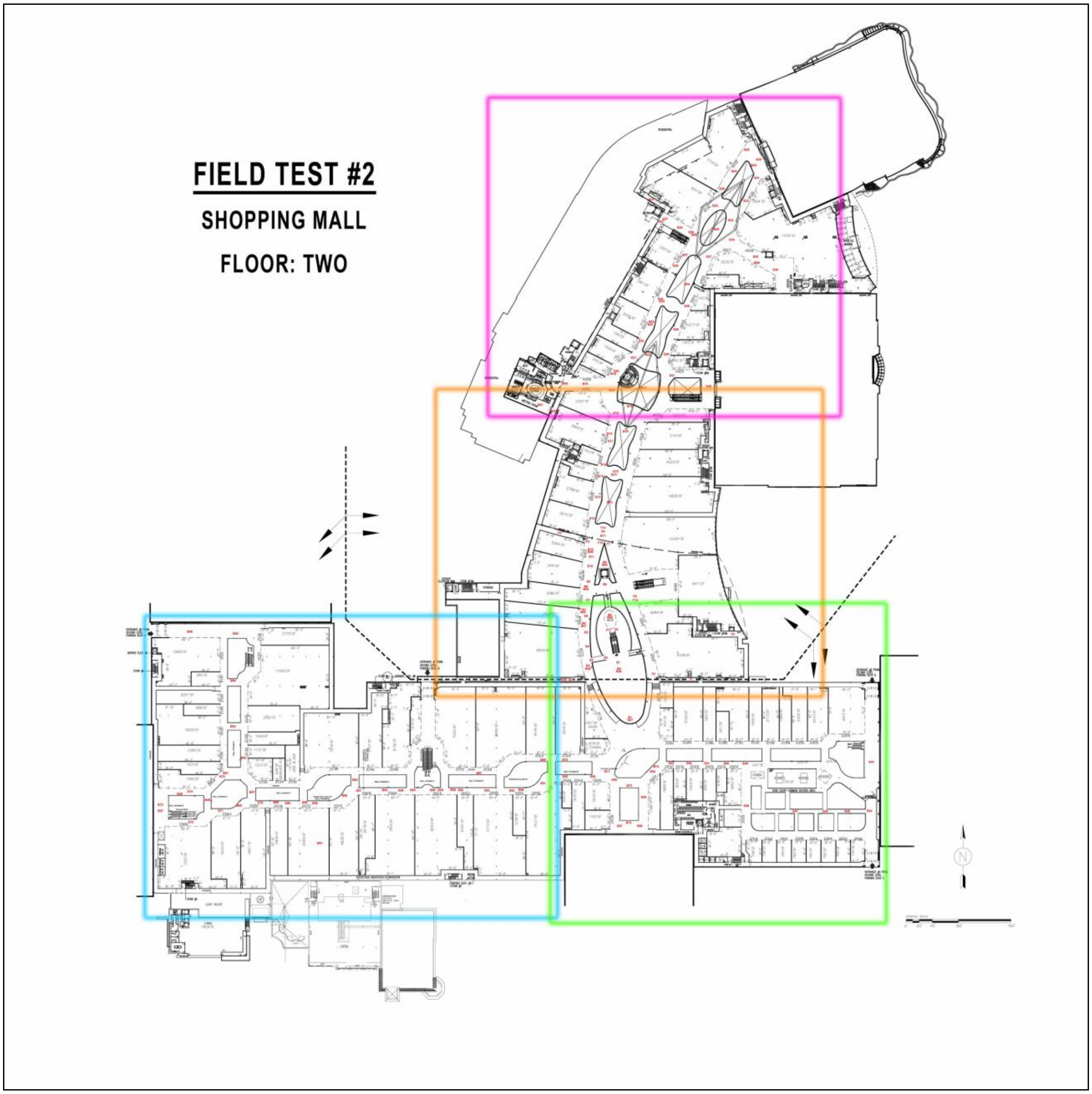

Figure 14, Field Test 2, Shopping Mall, Floor Two Overview

The measurement equipment used during the tests was comprised of six separate test meters and one talkbox all from a single manufacturer, and an additional test meter from another manufacturer. The test meters were used to measure the system intelligibility at any particular location, and the talkbox was used to transmit the STIPA test signal through the voice communication system.

4.3) Test Description.

Six test teams were established to collect measurement using the seven available test meters, and the approximate two dozen test participants were randomly assigned to a team. Each team was then given a designated portion of the shopping mall where they would implement the test protocol, splitting between the two mall levels and also between the public areas and the non-public areas such as the service corridors. The data collected is compiled in Tables 5 through 7 and the measurement locations illustrated in Figures 9 through 18.

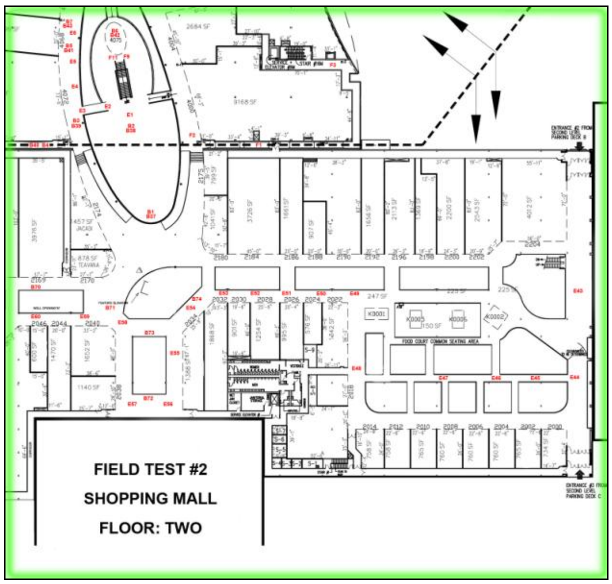

Figure 15, Field Test 2, Shopping Mall, Floor Two, East Quadrant

Due to the need to minimize the disruption to the building occupants, the primary test work was done prior to normal shopping hours during the time frame from 6:00 am to 10:00 am on 21 August 2008. Prototype forms were used to record the sound pressure levels and STI measurements throughout each assigned area.

This data was compiled into Tables 5 through 7. For each team the data is in three separate blocks which corresponds with: (1) the fire alarm system in the new wing; (2) the overall public address system; and (3) the fire alarm system in the original wing. Two of the teams did not record any valid test measurements during step (2), the activation of the public address system. The shaded entries in these tables represent the STI measurements that exceeded the threshold value of 0.45 STI or 0.65 CIS.

Prior to beginning the test, all normal procedures were followed to take the fire alarm system off-line and to arrange the transmission of the STIPA signal through the appropriate system. The STIPA signal was transmitted in the fire control center, which was a small concrete room near the mall central business office, located on the first floor in the East end of the original mall wing.

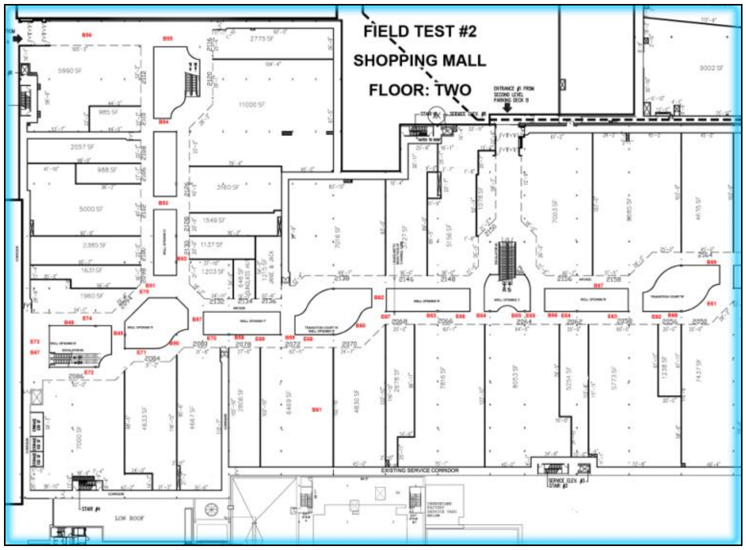

Figure 16, Field Test 2, Shopping Mall, Floor Two, West Quadrant

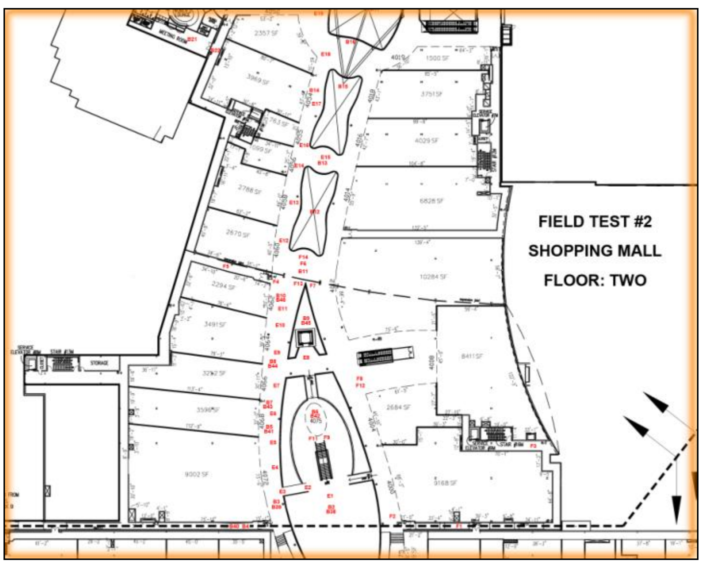

Figure 17, Field Test 2, Shopping Mall, Floor Two, Central Quadrant

The talkbox was arranged to transmit the STIPA test signal through the voice communication system in the same arrangement as used in Field Test #1. This was set at 85 dBA at a distance of 5" from the microphone. As was done in field Test #1, again it was agreed not to use direct tie-in of the test signal, but to play it into the microphone in the same manner as an actual human voice.

The draft test protocol was implemented and each team proceeded to record as many measurement points as possible during the available time. This was done in three steps with the STIPA test signal activated through the each system as follows: (1) the fire alarm system in the new wing; (2) the overall public address system; and (3) the fire alarm system in the original wing.

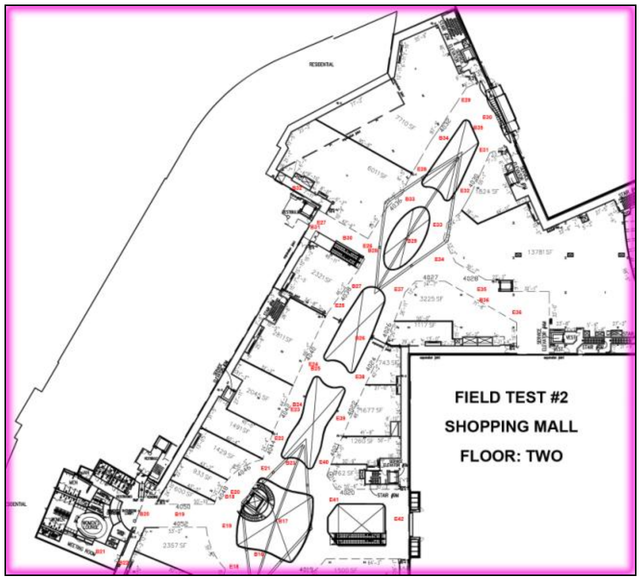

Figure 18, Field Test 2, Shopping Mall, Floor Two, North Quadrant

Measurements were recorded by each team at each measurement point and the intelligibility (STI) and audibility (dBA) were recorded. The values in Tables 5 through 7 include the intelligibility in both STI and in CIS units. It is noted that these measurements were made without normal ambient background sound pressure levels (noise) when most of the buildings occupants were not in the building (i.e., off-hours), and ideally these data results should be adjusted to account for normal ambient background noise.

As was the case with Field Test #1, during Field Test #2 the definition of Acoustically Distinguishable Spaces, and precisely where intelligibility should be measured, had not yet been well established. Thus, each team took measurements with the intent of trying to collect data that would be most useful for identifying outstanding technical concerns and revising the draft test protocol. Areas that received additional focus included: common public mall areas, corridors, and certain smaller store and backroom locations.

Table 5: Field Test 2, Shopping Mall, Measurement Points from Teams A and B

Test Facility: Field Test #2, Shopping Mall Date: 21 August 2008 Time: 6:00 AM

Meas Point	Description	SPL dBa	STI	CIS
A1	Mall West - LLevel, Center Atrium, 1194	70	.31	.49
A2	Mall West - LLevel, Center Atrium, 3010	72	.33	.52
A3	Mall West - LLevel, Center Atrium, escalator	74	.35	.54
A4	Mall West - LLevel, Center Atrium	74	.37	.57
A5	Mall West - LLevel, Center Atrium, 3000	74	.38	.58
A6	Mall West - LLevel, Center Atrium, 1194	75	.34	.53
A6	Mall West - LLevel, Center Atrium, 1194 (PA)	69	.34	.53
A7	Mall West - LLevel, Center Atrium, 3010 (PA)	71	.30	.48
A8	Mall West - LLevel, Center Atrium, esc (PA)	70	.24	.38
A9	Mall West - LLevel, Center Atrium (PA)	70	.28	.45
A10	Mall West - LLevel, Center Atrium, 3000 (PA)	71	.31	.49
A11	Original Mall – LLevel, Mall by 1194	75	.34	.53
A12	Original Mall – LLevel, Mall by 1028	75	.35	.54
A13	Original Mall – LLevel, Mall by 1024	76	.38	.58
A14	Original Mall – LLevel, Mall by 1032	74	.28	.45
A15	Original Mall – LLevel, Mall by 1040	76	.40	.60
A16	Original Mall – LLevel, Mall by 1054	77	.40	.60
A17	Original Mall – LLevel, In Store 1174	69	.55	.74
A18	Original Mall – LLevel, Store 1174 in Rear	66	.50	.70
A19	Original Mall – LLevel, Store 1174 Dressing Rm	74	.60	.78
B1	Original Mall - ULevel, Center Atrium	76	.26	.41
B2	Mall West - ULevel, Center Atrium	74	.34	.53
B3	Mall West - ULevel, Mall by 4072	74	.34	.53
B4	Mall West - ULevel, Corridor by 4072	73	.55	.74
B5	Mall West - ULevel, Mall by 4068	73	.27	.43
B6	Mall West - ULevel, Mall by 4075	73	.26	.41
B7	Mall West - ULevel, Mall by 4066	73	.41	.61
B8	Mall West - ULevel, Mall by 4064	74	.37	.57
B9	Mall West - ULevel, Mall by 4012	74	.27	.43
B10	Mall West - ULevel, Mall by 4062	74	.45	.65
B11	Mall West - ULevel, Mall by 4014	73	.32	.51
B12	Mall West - ULevel, Mall by 4058	72	.34	.53
B13	Mall West - ULevel, Mall by 4056	73	.33	.52
B14	Mall West - ULevel, Mall by 4054	73	.44	.64
B15	Mall West - ULevel, Mall by 4018	73	.32	.51
B16	Mall West - ULevel, Mall by 4019	73	.29	.46
B17	Mall West - ULevel, Mall by 4019	73	.30	.48
B18	Mall West - ULevel, Mall by 4048	75	.32	.51
B19	Mall West - ULevel, Mall by 4050	77	.44	.64
B20	Mall West - ULevel, Foyer by Restrooms	77	.45	.65
B21	Mall West - ULevel, Mtg Rm by 4051	71	.55	.74
B22	Mall West - ULevel, Corridor by 4051	72	.52	.72
B23	Mall West - ULevel, Mall by 4046	73	.30	.48
B24	Mall West - ULevel, Mall by 4042	74	.43	.63
B25	Mall West - ULevel, Mall by 4040	74	.31	.49
B26	Mall West - ULevel, Mall by 4024	72	.27	.43
B27	Mall West - ULevel, Mall by 4038	73	.29	.46
B28	Mall West - ULevel, Mall by 4036	73	.31	.49
B29	Mall West - ULevel, Mall by 4036	73	.30	.48
B30	Mall West - ULevel, Foyer by 4036	73	.35	.54
B31	Mall West - ULevel, Foyer by 4036	75	.40	.60
B32	Mall West - ULevel, Corridor by 4036	79	.57	.76
B33	Mall West - ULevel, Mall by 4036	73	.32	.51
B34	Mall West - ULevel, Mall by 4032	75	.35	.54
B35	Mall West - ULevel, Mall by 4030	76	.37	.57
B36	Mall West - ULevel, Mall by 4027	75	.36	.56

Meas Point	Description	SPL dBa	STI	CIS
B37	Original Mall - ULevel, Center Atrium (PA)	71	.22	.34
B38	Mall West - ULevel, Center Atrium (PA)	71	.24	.38
B39	Mall West - ULevel, Mall by 4072 (PA)	72	.23	.36
B40	Mall West - ULevel, Corridor by 4072 (PA)	61	.30	.48
B41	Mall West - ULevel, Mall by 4068 (PA)	47	.29	.46
B42	Mall West - ULevel, Mall by 4075 (PA)	72	.28	.45
B43	Mall West - ULevel, Mall by 4066 (PA)	73	.32	.51
B44	Mall West - ULevel, Mall by 4064 (PA)	73	.36	.56
B45	Mall West - ULevel, Mall by 4012 (PA)	73	.32	.51
B46	Mall West - ULevel, Mall by 4062 (PA)	73	.33	.52
B47	Original Mall - ULevel, Mall by 2086	77	.42	.62
B48	Original Mall - ULevel, Mall by 2086	77	.36	.56
B49	Original Mall - ULevel, Mall by 2084	77	.31	.49
B50	Original Mall - ULevel, Mall by 2080	77	.34	.53
B51	Original Mall - ULevel, Mall by 2098	78	.32	.51
B52	Original Mall - ULevel, Mall by 2100	79	.41	.61
B53	Original Mall - ULevel, Mall by 2016	76	.26	.41
B54	Original Mall - ULevel, Mall by 2110	78	.33	.52
B55	Original Mall - ULevel, Mall by 2112	79	.29	.46
B56	Original Mall - ULevel, Mall by 2112	80	.36	.56
B57	Original Mall - ULevel, Mall by 2080	77	.33	.52
B58	Original Mall - ULevel, Mall by 2078	77	.32	.51
B59	Original Mall - ULevel, Mall by 2072	78	.39	.59
B60	Original Mall - ULevel, Mall by 2070	77	.33	.52
B61	Original Mall - ULevel, Mall by 2072	80	.54	.73
B62	Original Mall - ULevel, Mall by 2068	75	.30	.48
B63	Original Mall - ULevel, Mall by 2066	73	.27	.43
B64	Original Mall - ULevel, Mall by 2148	73	.24	.38
B65	Original Mall - ULevel, Mall by 2064	73	.24	.38
B66	Original Mall - ULevel, Mall by 2062	73	.30	.48
B67	Original Mall - ULevel, Mall by 2156	75	.42	.62
B68	Original Mall - ULevel, Mall by 2056	76	.29	.46
B69	Original Mall - ULevel, Mall by 2164	76	.36	.56
B70	Original Mall - ULevel, Mall by 2168	73	.31	.49
B71	Original Mall - ULevel, Mall by 2040	74	.31	.49
B72	Original Mall - ULevel, Mall by 2038	75	.31	.49
B73	Original Mall - ULevel, Mall by 2034	74	.29	.46
B74	Original Mall - ULevel, Mall by 2032	74	.23	.36

Table 6: Field Test 2, Shopping Mall, Measurement Points from Teams C and D

Test Facility: Field Test #2, Shopping Mall Date: 21 August 2008 Time: 6:00 AM

Meas Point	Description	SPL dBa	STI	CIS
C1	Mall West - LLevel, Corridor by 3036	75	.56	.75
C2	Mall West - LLevel, Corridor by 3036	72	.65	.81
C3	Mall West - LLevel, Corridor by 3036	73	.62	.79
C4	Mall West - LLevel, Corridor by 3038	72	.50	.70
C5	Mall West - LLevel, Corridor by 3040	75	.54	.73
C6	Mall West - LLevel, Mall by 3040	76	.35	.54
C7	Mall West - LLevel, Corridor by 3042	70	.58	.76
C8	Mall West - LLevel, Corridor by 3046	73	.65	.81
C9	Mall West - LLevel, Corridor by 3052	70	.60	.78
C10	Mall West - LLevel, Mall by 3056	79	.42	.62
C11	Mall West - LLevel, Foyer by 3058	73	.69	.84
C12	Mall West - LLevel, Corridor by 3062	73	.55	.74
C13	Mall West - LLevel, Corridor by 3068	69	.52	.72
C14	Mall West - LLevel, Corridor by 3080	72	.54	.73
C15	Mall West - LLevel, Corridor by Stair	52	.39	.59
C16	Mall West - LLevel, Corridor by 3084	72	.56	.75
C17	Mall West - LLevel, Corridor by 1174	77	.54	.73
C18	Mall West - LLevel, Corridor by 3084	75	.58	.76
C19	Mall West - LLevel, Mall by 3084	75	.27	.43
C20	Mall West - LLevel, Corridor by 3000, (PA)	76	.58	.76
C21	Mall West - LLevel, Corridor by 3003, (PA)	72	.58	.76
C22	Mall West - LLevel, Corridor by 3003 Stair, (PA)	50	.46	.66
C23	Mall West - LLevel, Corridor by 3010, (PA)	68	.49	.69
C24	Original Mall - LLevel, Mall by 1194, (PA)	75	.22	.34
C25	Original Mall - LLevel, Mall by 1194, (PA)	75	.22	.35
C26	Original Mall - LLevel, Mall by 1035, (PA)	67	.19	.29
C27	Original Mall - LLevel, Mall by 1019, (PA)	67	.18	.25
C28	Original Mall - LLevel, Mall by 1012, (PA)	67	.56	.23
C29	Original Mall - LLevel, Mall by 1024	76	.65	.34
C30	Original Mall - LLevel, Corridor by 1026	77	.46	.66
C31	Original Mall - LLevel, Corridor by 1024	76	.55	.74
C32	Original Mall - LLevel, Corridor by 1020 Stair	76	.34	.53
C33	Original Mall - LLevel, Corridor by 1020	72	.56	.75
C34	Original Mall - LLevel, Corridor by 1040	77	.51	.71
C35	Original Mall - LLevel, Corridor by 1046	76	.45	.65
C36	Original Mall - LLevel, Corridor by 1048	85	.54	.73
C37	Original Mall - LLevel, Corridor by 1058	67	.42	.62
C38	Original Mall - LLevel, Corridor by 1058	82	.49	.69
C39	Original Mall - LLevel, Corridor by 1058	83	.43	.63
C40	Original Mall - LLevel, Corridor by 1070	82	.44	.64
C41	Original Mall - LLevel, Corridor by 1082	82	.51	.71
C42	Original Mall - LLevel, Corridor by 1114	79	.46	.66
C43	Original Mall - LLevel, Corridor by 1124	84	.47	.67
C44	Original Mall - LLevel, Corridor by 1131	76	.45	.65
C45	Original Mall - LLevel, Mall by 1128	80	.24	.38
C46	Original Mall - LLevel, Corridor by 1136	78	.56	.75
C47	Original Mall - LLevel, Corridor by 1140	84	.55	.74
C48	Original Mall - LLevel, Corridor by 1160	79	.43	.63

Meas Point	Description	SPL dBa	STI	CIS
D1	Mall West - LLevel, Corridor by 3010	65	.58	.76
D2	Mall West - LLevel, Corridor by 3012	69	.57	.76
D3	Mall West - LLevel, Corridor by 3013	68	.62	.79
D4	Mall West - LLevel, Corridor by 3014	70	.54	.73
D5	Mall West - LLevel, Corridor by 3028	64	.57	.76
D6	Mall West - LLevel, Corridor by 3026	69	.65	.81
D7	Original Mall - LLevel, Corridor by 1214	76	.56	.75
D8	Original Mall - LLevel, Corridor by 1220	80	.70	.85
D9	Original Mall - LLevel, Corridor by 1210	69	.49	.69
D10	Original Mall - LLevel, Corridor by 1208	78	.53	.72
D11	Original Mall - LLevel, Corridor by 1202	72	.46	.66
D12	Original Mall - LLevel, Corridor by 1196	72	.46	.66
D13	Original Mall - LLevel, Corridor by 1035	73	.58	.76
D14	Original Mall - LLevel, Corridor by 1026	66	.47	.67
D15	Original Mall - LLevel, Corridor by 1018	68	.62	.79
D16	Original Mall - LLevel, Corridor by 1040	75	.49	.69

4.4) Observations.

The following are the general observations that were noted in Field Test #2:

a) Intelligibility values were relatively good in service corridors and in certain non-public areas. This was consistent through each of the three steps of the test, with the new wing fire alarm system, the overall public address system, and the original wing fire alarm system.

b) Intelligibility values were relatively good in several individual stores where test teams were able to gain access (e.g. test points A17, A18, A19, & B21).

c) Intelligibility values were consistently low throughout the public mall common areas of the facility, in both the new and original wings. This was consistent through each of the three steps of the test, with the new wing fire alarm system, the overall public address system, and the original wing fire alarm system.

d) The nominal variation in readings throughout the public mall common areas is assumed to be due to the proximity with a particular nearby speaker emitting the STIPA test signal.

e) The public address system was designed to provide background music and had many more speakers located throughout the public mall common areas of the facility than did the fire alarm systems. However, the system appeared to have been balanced to provide a uniform level of background music for privacy enhancement and not set up for general voice announcements. Also, the acoustical characteristics of the public mall common areas was so challenging that, combined with the system set-up, the STI predictions for the public address system were similar to those of the fire alarm system.

f) Measurement point F23 was taken approximately 6" from the speaker and predicted an STIPA of .75, indicating an appreciable degradation of the test signal through the system. A further review of this situation raised question on how the talkbox and test signal were being played at the Command Center, and that possibly an echo was being introduced within this small room and being transmitted throughout the system during the test. This was further debated with the indication that regardless of a background echo, this is representative of conditions that would be experienced by an incident commander during an emergency situation. Due to time constraints, further tests were not accomplished that might have identified the cause for the low results, such as a bandwidth test for the system or a reverberation time test for the command center.

g) One team utilized two meters side-by-side from two different manufacturers, and no appreciable difference was noted in the predictions provided by each meter.

Table 7: Field Test 2, Shopping Mall, Measurement Points from Teams E and F

Test Facility: Field Test #2, Shopping Mall Date: 21 August 2008 Time: 6:00 AM

Meas Point	Description	SPL dBa	STI	CIS
E1	Mall West - ULevel, Center Atrium	71	.31	.49
E2	Mall West - ULevel, Center Atrium	72	.29	.46
E3	Mall West - ULevel, Atrium footbridge	72	.28	.45
E4	Mall West - ULevel, Mall by 4072	73	.31	.49
E5	Mall West - ULevel, Mall by 4072	73	.31	.49
E6	Mall West - ULevel, Mall by 4068	75	.36	.56
E7	Mall West - ULevel, Mall by 4066	76	.39	.59
E8	Mall West - ULevel, Center Mall by Elevator	75	.40	.60
E9	Mall West - ULevel, Mall by 4064	76	.49	.69
E10	Mall West - ULevel, Mall by 4064	74	.40	.60
E11	Mall West - ULevel, Exit by 4062	73	.41	.61
E12	Mall West - ULevel, Mall by 4060	73	.34	.53
E13	Mall West - ULevel, Mall by 4058	73	.31	.49
E14	Mall West - ULevel, Mall by 4056	74	.35	.54
E15	Mall West - ULevel, Center bridge	72	.28	.45
E16	Mall West - ULevel, Mall by 4055	74	.33	.52
E17	Mall West - ULevel, Mall by 4054	72	.33	.52
E18	Mall West - ULevel, Mall by 4052	73	.44	.64
E19	Mall West - ULevel, Mall by 4052	74	.43	.63
E20	Mall West - ULevel, Mall by 4048	72	.36	.56
E21	Mall West - ULevel, Mall by 4046	73	.45	.65
E22	Mall West - ULevel, Mall by 4044	72	.36	.56
E23	Mall West - ULevel, Mall by 4042	72	.38	.58
E24	Mall West - ULevel, Mall by 4040	70	.27	.43
E25	Mall West - ULevel, Mall by 4038	69	.25	.40
E26	Mall West - ULevel, Top of escalator by 4036	71	.36	.56
E27	Mall West - ULevel, Elevator lobby by 4036	74	.48	.68
E28	Mall West - ULevel, Mall by 4032	72	.29	.46
E29	Mall West - ULevel, Mall by 4032	72	.31	.49
E30	Mall West - ULevel, Mall by 4031	75	.41	.61
E31	Mall West - ULevel, Mall by 4031	75	.39	.59
E32	Mall West - ULevel, Mall by 4030	73	.33	.52
E33	Mall West - ULevel, Center Mall	72	.31	.49
E34	Mall West - ULevel, Mall by 4027	72	.35	.54
E35	Mall West - ULevel, Elevator lobby by 4028	70	.31	.49
E36	Mall West - ULevel, Mall by 4027	70	.41	.61
E37	Mall West - ULevel, Mall by 4027	72	.31	.49
E38	Mall West - ULevel, Mall by 4024	72	.41	.61
E39	Mall West - ULevel, Mall by 4022	73	.34	.53
E40	Mall West - ULevel, Mall by 4021	73	.40	.60
E41	Mall West - ULevel, Center Corridor by 4020	72	.43	.63
E42	Mall West - ULevel, Mall by 4020	75	.40	.60
E43	Original Mall – ULevel, Mall by 2204	75	.30	.48
E44	Original Mall – ULevel, Mall by 2000	72	.37	.57
E45	Original Mall – ULevel, Mall by 2002	72	.33	.52
E46	Original Mall – ULevel, Mall by 2006	73	.37	.57
E47	Original Mall – ULevel, Mall by 2010	74	.48	.68
E48	Original Mall – ULevel, Mall by 2018	71	.39	.59
E49	Original Mall – ULevel, Mall by 2022	73	.28	.45
E50	Original Mall – ULevel, Mall by 2024	74	.27	.43
E51	Original Mall – ULevel, Mall by 2026	73	.24	.38
E52	Original Mall – ULevel, Mall by 2028	73	.26	.41
E53	Original Mall – ULevel, Mall by 2032	74	.30	.48
E54	Original Mall – ULevel, Mall by 2034	73	.26	.41
E55	Original Mall – ULevel, Mall by 2034	74	.32	.51
E56	Original Mall – ULevel, Mall by 2034	76	.37	.57
E57	Original Mall – ULevel, Mall by 2038	77	.37	.57
E58	Original Mall – ULevel, Mall by 2040	74	.30	.48
E59	Original Mall – ULevel, Mall by 2040	75	.30	.48
E60	Original Mall – ULevel, Mall by 2046	77	.46	.66
E61	Original Mall – ULevel, Mall by 2050	75	.30	.48
E62	Original Mall – ULevel, Mall by 2056	75	.28	.45
E63	Original Mall – ULevel, Mall by 2058	74	.28	.45

Meas Point	Description	SPL dBa	STI	CIS
E64	Original Mall – ULevel, Mall by 2062	73	.27	.43
E65	Original Mall – ULevel, Mall by 2064	73	.27	.43
E66	Original Mall – ULevel, Mall by 2066	73	.29	.46
E67	Original Mall – ULevel, Mall by 2068	73	.28	.45
E68	Original Mall – ULevel, Mall by 2072	76	.31	.49
E69	Original Mall – ULevel, Mall by 2078	75	.28	.45
E70	Original Mall – ULevel, Mall by 2080	75	.25	.40
E71	Original Mall – ULevel, Mall by 2084	77	.32	.51
E72	Original Mall – ULevel, Mall by 2086	77	.31	.49
E73	Original Mall – ULevel, Mall by 2090	76	.32	.51
E74	Original Mall – ULevel, Mall by 2094	76	.30	.48
E75	Original Mall – ULevel, Mall by 2098	76	.26	.41
F1	Mall West - ULevel, Corridor East	72	.56	.75
F2	Mall West - ULevel, Mall by East Corridor	71	.31	.49
F3	Mall West - ULevel, Corridor East	72	.51	.71
F4	Mall West - ULevel, Mall by West Corridor	72	.24	.38
F5	Mall West - ULevel, Corridor West	70	.56	.75
F6	Mall West - ULevel, Mall by West Corridor	70	.27	.43
F7	Mall West - ULevel, Mall by Elevator @ spkr	70	.41	.61
F8	Mall West - ULevel, Mall by East Corridor	71	.36	.56
F9	Mall West - ULevel, Mall at Atrium Center	70	.26	.41
F10	Mall West – LLevel, Mall by East Corridor, (PA)	72	.37	.57
F11	Mall West - ULevel, Mall at Atrium Center, (PA)	72	.30	.48
F12	Mall West - ULevel, Mall by East Corridor, (PA)	72	.40	.60
F13	Mall West - ULevel, Mall by Elevator, (PA)	75	.36	.56
F14	Mall West - ULevel, Mall by West Corridor, (PA)	74	.36	.56
F15	Original Mall – LLevel, Mall Center	78	.47	.67
F16	Original Mall – LLevel, Mall Center East	76	.31	.49
F17	Original Mall – LLevel, Mall Center East	76	.30	.48
F18	Original Mall – LLevel, Mall Center East	76	.30	.48
F19	Original Mall – LLevel, Mall Center East	76	.42	.62
F20	Original Mall – LLevel, Mall Center East	74	.23	.36
F21	Original Mall – LLevel, Mall Center East	76	.33	.52
F22	Original Mall – LLevel, Mall Center	74	.33	.52
F23	Original Mall – LLevel, Mall Center 6" from spkr	94	.75	.88

5) REVIEW OF FIELD TEST #3

5.1) Background.

The third and final field test occurred in an industrial facility. This test was conducted over the course of an entire day on 9 September 2008 between the hours of 8:00 am and 5:00 pm, with follow-up testing on 10 September 2008 to record final data during fully operational conditions with peak ambient noise levels.

This last field test built upon the information gathered in Field Tests #1 and #2. A meeting held in conjunction with Field Test #3, and immediately preceding the collection of data, established the final details of Field Test #3 and the test parameters. This resulted in the drafting of six specific test sequences.

The overall purpose of Field Test #3 was similar to the earlier field tests, and that was to prepare for the upcoming NFPA 72 ROC meetings by refining the conceptual basis and associated details of the proposed test protocol, and to address the outstanding technical concerns that had been identified earlier.

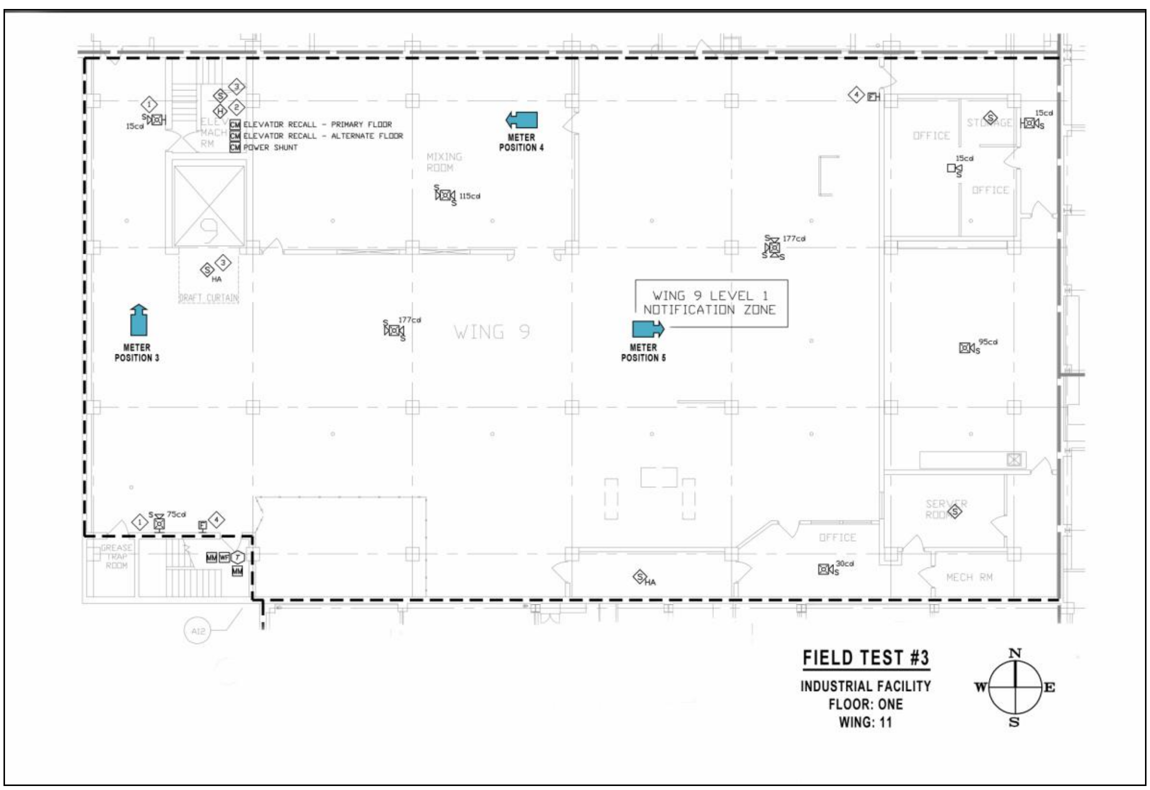

Figure 19, Field Test 3, Industrial Facility, Floor One, Wing 9

The four basic task groups that were appointed as a result of Field Test #1 and #2 were still operational and their subject matter remained as the four fundamental topical areas of discussion. Re-summarizing, these four task groups and the subjects they addressed were:

a) Set-Up Protocol Task Group. Address test set-up where a test is required, and establish test parameters. Clarify the proper talkbox setup for testing of a system that uses pre-recorded content or manual announcements or both. Establish a repeatable baseline for the talkbox setup based on sound pressure level (dBA) and distance between the talkbox and microphone.

b) Where-and-When Required Task Group. Address where intelligibility measurements are required, with specific attention to where audibility is required but intelligibility is not required. Address when testing is required in relation testing a new facility based on partial occupancy before the building is occupied, and testing in its final acoustic configuration.

c) Acoustically Distinguishable Spaces Task Group. Define characteristics to establish test areas. Clarify the definition and description of acoustically distinguishable spaces, recognizing that sound pressure level measurements (in dBA) do not necessarily equate to STIPA measurements.

d) Performance Requirement Task Group. Clarify pass/fail criteria, and distinguish the level of precision required for the STI measurements.

5.2) Facility and Equipment.

The facility used in Field Test #3 had three operational floors, although only one level was used for the collection of intelligibility test data. The entire building was fully occupied and operational at the time of the test (i.e. not under construction). The overall occupancy classification, according to NFPA 101, Life Safety Code, is "Industrial Occupancy"; with certain portions of the facility also having additional occupancy requirements (e.g. cafeteria as assembly, offices as business, etc), depending on their incidental use.

The facility used in field test #3 served as a technical center to evaluate prototype manufacturing processes for the agricultural-based consumable food industry. Overall the building had an appreciable number of offices and small laboratories, with the majority of the plant effectively an industrial occupancy comprised of multiple prototypical scaled-down manufacturing processes. All intelligibility testing was limited to this portion of the facility involving an industrial setting.

The areas involved in the collection of intelligibility data were of concrete construction with painted surfaces, and although the ceiling heights had some variations throughout the complex, in the area that testing was done they were approximately 12 feet. Portions of the test area were open spaces large enough for forklift equipment to readily operate, surrounding localized heavy industrial processing machinery.

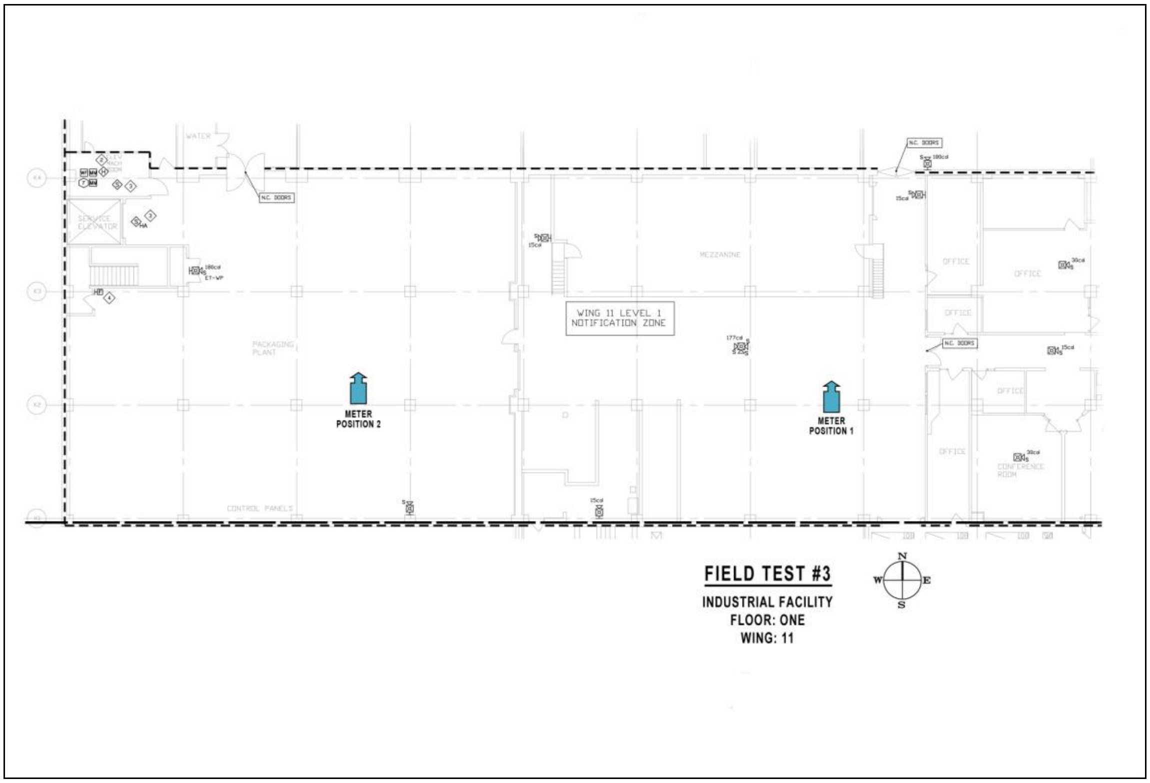

Figure 20 Field Test 3, Industrial Facility, Floor One, Wing 11

The general acoustical characteristics of the test areas were primarily highly reflective concrete surfaces. When the machinery and prototype-processing equipment was not operating the test areas had a reasonable level of ambient background noise such that normal conversation could be readily understood. When the machinery and prototype-processing equipment was operating, the elevation of the sound pressure levels was appreciable in some areas, and provided a significant challenge to speech intelligibility.

The test areas were restricted to only qualified employees, i.e., were not accessible to the general public or employees without appropriate clearance. Thus, while the acoustical challenges might have been more severe than the facilities involved with Field Tests #1 and #2, the only exposed occupants would be employees trained in special emergency procedures, and this argues for a lesser need for more rigorous levels of speech intelligibility.

The test facility was equipped with an NFPA 72, National Fire Alarm Code compliant fire alarm system. This included a voice announcement feature to allow an incident commander to an emergency situation to broadcast "live" over the fire alarm system. Notification appliances throughout the test portion of the facility were strobe/speaker combinations, all from a single manufacturer.

The measurement equipment used during the tests was comprised of six separate test meters and one talkbox, from two separate manufacturers. The test meters were used to measure the system intelligibility at any particular location, and the talkbox was used to transmit the STIPA test signal through the voice communication system.

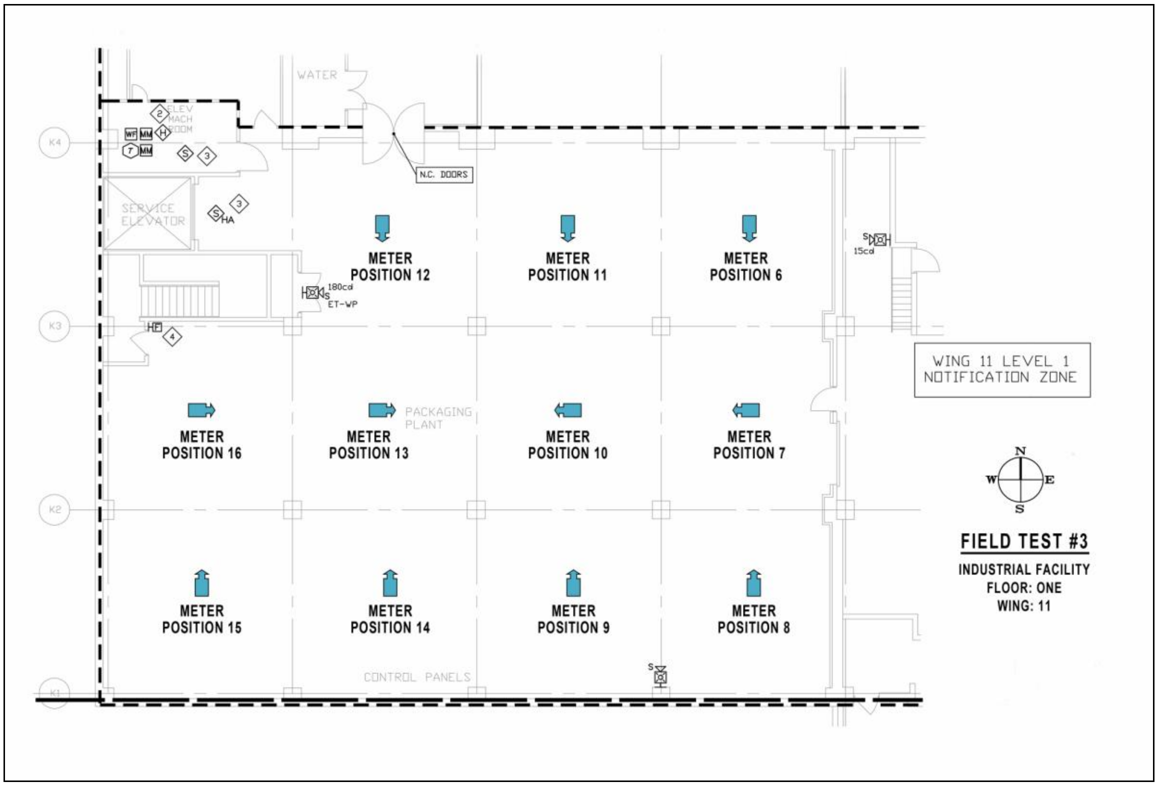

Figure 21, Field Test 3, Industrial Facility, Floor One, Wing 11, Packaging Plant

5.3) Test Description.

A meeting held prior to the initiation of Field Test #3 established the specific test parameters that would be used. A series of six specific test sequences was agreed upon, and these are summarized in Table 8.

The first test sequence involved a bench test without going into the field. Test sequence 2 addressed the talk-box setup. Test sequences 3 and 4 were paired together, and test sequences 5 and 6 were likewise paired together. A description of each test sequence follows.

Prior to beginning the data collection of Field Test #3, five test teams were established based on the participants qualified to use the available test meters, and the approximate two dozen test participants were randomly assigned to a team. Each team was then given a designated assignment for each test sequence. The measurement locations are illustrated in Figures 19 through 21. The data collected is compiled in Tables 9 through 12 and illustrated in Figures 22 through 26. The following describes the details of each test sequence.

Table 8: Summary of Test Sequences Used in Field Test #3

Test Sequence 1:	Equipment Bench Calibration Check
Test Sequence 2:	Comparison Test of Output-Based-Talkbox versus Input-Based-Talkbox
Test Sequence 3:	Test Measurement Repeatability
Test Sequence 4:	Control Room Microphone Test
Test Sequence 5:	Operational (Occupied) versus Non-Operational (Unoccupied) Test
Test Sequence 6:	Full "Acoustically Distinguishable Space" Test

Test Sequence 1

The purpose of Test Sequence 1 was to implement a bench calibration check of the acoustical measuring equipment that would be used to collect data. Test Sequence 1 implemented the portion of the draft test protocol describing this procedure, and required the use of a piston phone, also sometimes referred to as a calibrated microphone tone generator or Audio Source Unit (ASU). Test Sequence 1 was an extra step based on the availability of the necessary equipment, and normally the steps would be instead to check that the equipment is within its calibration date, test its accuracy of dB measurements using a calibrated piston phone generating 94 dB at 1000Hz, and then implement the test protocol.

The Intelligibility Test System for Test Sequence 1 consists of both the piston phone and the measurement meter (i.e. STI-PA audio recording and field test meter or analyzer). Each meter was tested at 94 dBA at 1,000 hz. The following describes the steps used for Test Sequence 1 of Field Test #3:

a) Calibration procedure was performed in a quiet meeting room (45 dBA or less) without any extraneous sounds or any talking, music, etc.
b) STI-PA Test Tone CD was inserted into the Talkbox CD player.
c) Talkbox loudspeaker was placed upright in the Talkbox foam and moved to approximately 1" from the leading edge of the Talkbox microphone holder fixture.
d) Power was applied to the Talkbox before activating the Talkbox or pressing Play on the CD player.
e) Volume level of the Talkbox CD player was set to approximately ¾ full volume.
f) ASU was activated and the Talkbox CD put into the PLAY mode. At this time the STI-PA sound was heard.
g) Meter was activated and set to the SPL A Fast measurement mode.

h) Analyzer’s microphone was placed so that the tip of the microphone was pointed at the approximate center of the Talkbox speaker, perpendicular to the front plane of the speaker approximately 1 inch away. The analyzer microphone was not placed against the Talkbox microphone holder, since this can lead to induced noise and make calibration difficult.
i) Speaker’s volume was adjusted so that the STI-CIS Analyzer’s dB reading was approximately 92 dBA. This is equivalent to approximately 60 dBA at 1 meter.
j) Analyzer was kept in approximately the same position, place into the STI mode, and 3 separate STI readings were taken.
k) Equipment was deemed to be working properly since the average of the three STI readings was greater than 0.96.

<u>Test Sequence 2</u>

Significant debate focused around clarifying and standardizing the initial talkbox setup. This debate provided the basis for Test Sequence 2, referred to as the Comparison Test of Output-Based-Talkbox vs. Input-Based-Talkbox. One group of participants favored a more rigorous yet arguably more complex approach (i.e. output-based), while the other group of participants argued for a more straight-forward approach that was easier to implement and of repeatable reliability (i.e. input based).

Table 9: Summary of Test Sequence 2, at Field Test #3

	Location	Team A Position 1	Team B Position 2	Team C Position 3	Team D Position 4	Team E Position 5
	Ambient dBA	76	67	77	91	76
Recorded, 10 sec	Tone dBA	104	90	100	102	82
	Voice dBA	92	77	92	96	76
100 dBA @ 1” (=68dBA @ 1M)	dBA	92	78	92	93	89
	STIPA	0.43	0.48	0.47	0.47	0.40
97 dBA @ 1” (=65dBA @ 1M)	dBA	83	70	85	92	86
	STIPA	0.40	0.46	0.41	0.34	0.31

Five test teams were deployed at five different measurement points within the same localized area. Specifically, this test was conducted using positions 1 through 5 as shown in Figures 19 and 20. Team “A” was designated as the “test control team”, and their measurements would be used to balance the test measurements between the Output-Based approach and the Input-Based approach. The remaining four test teams would take additional measurements at different locations to provide an acceptable depth of data. Each team performed the following tasks and took the following measurements:

<u>Initial Measurements</u>

a) Measure ambient noise at each assigned test location.

b) Activate the voice evacuation system, first with alert tone and then with pre-recorded message.
c) Measure test alert tone in dBA at each assigned test location.
d) Measure dBA of pre-recorded voice using time weighted average dBA over 10 seconds at each assigned test location.
e) Deactivate the voice evacuation system.

<u>Output-Based Setup</u>

f) Set-up microphone with talkbox and set system for live voice .
g) Activate STIPA signal through voice communication system.
h) Set talkbox volume to produce the same dBA as the pre-recorded voice (based on Team "A" location). (Note: this resulted in a STIPA dBA level of 100 dBA @ 1", which equates to 68 dBA @ 1 meter).
i) Measure ambient noise with STIPA signal in dBA at each assigned test location.
j) Predict (measure) intelligibility (STIPA) using meter at each assigned test location.
k) Deactivate the voice evacuation system.

<u>Input-Based Setup</u>

l) Re-set the talkbox to produce 97 dBA @ 1" from microphone (Note: this equates to 65 dBA @ 1 meter)
m) Activate STIPA signal through voice communication system (repeat step g).
n) Measure ambient noise with STIPA signal in dBA at each assigned test location (repeat step i).
o) Predict (measure) intelligibility (STIPA) using meter at each assigned test location (repeat step j).
p) Deactivate the voice evacuation system (repeat step k).

The results of Test Sequence 2 are summarized in Table 9. These results compare favorably between each of the five test positions. More importantly, the values in Table 9 demonstrate that either the Output-Based approach of the Input-Based approach can be used, but the actual input level of the test signal will impact the field results. In this case, intelligibility improved when the input to the emergency communications system microphone was higher. This will not always be the case as the results depend on the equipment and the acoustic environment. With some systems, an elevated talking volume at the microphone can cause clipping and distortion. Also, in some acoustic environments a higher sound pressure level of the STIPA signal could cause reverberation that would ultimately reduce the intelligibility prediction.

<u>Test Sequence 3</u>

The purpose of Test Sequence 3 was to establish a level of confidence with the general repeatability of measuring speech intelligibility. This test sequence repeated the last five steps (l through p) of Test Sequence 2, with each test team rotating from one position to the next so that each team took measurements at each location. The following were the steps taken for Test Sequence 3:

a) Re-set the talkbox to produce 97 dBA @ 1" from microphone (Note: this equates to 65 dBA @ 1 meter)
b) Activate STIPA signal through voice communication system.
c) Measure ambient noise with STIPA signal in dBA at each assigned test location.
d) Predict (measure) intelligibility (STI) using meter at each assigned test location.
e) Rotate each team to the next test position, and repeat the steps c and d, until each team has taken measurements at all five test positions.
f) Deactivate the voice evacuation system.

The results of Test Sequence 3 are summarized in the top portion of Table 10. The "+" and "-" symbols following each table entry indicates if it's greater or less than the average value. It is noted that there is a relatively acceptable level of consistency between the values recorded by each team. One team, Team C, had values that were consistently high, which raised questions concerning their methods or their equipment.

Table 10: Summary of Test Sequence 3 and 4, at Field Test #3

Test	Measurement Location	Average[1]		Team A		Team B		Team C		Team D		Team E	
		dBA	STI	dBA	STI	dBA	STI	dBA	STI	dBA	STI	dBA	STI
3	Position 1	91.6	0.41	90-	0.44+	92+	0.34-	93+	0.42+	92+	0.41	91-	0.43+
3	Position 2	78.2	0.43	78-	0.43	77-	0.47+	80+	0.40-	78-	0.39-	78-	0.45+
3	Position 3	89.2	0.44	89-	0.41-	88-	0.45+	91+	0.48+	89-	0.44	89-	0.44
3	Position 4	93.8	0.48	93-	0.49+	93-	0.47-	96+	0.45-	94+	0.51+	93-	0.48
3	Position 5	90.8	0.34	91+	0.30-	91+	0.31-	92+	0.30-	89-	0.35+	91+	0.46+
4	Position 1	91.4	0.34	90-	0.30-	90-	0.42+	93+	0.35+	92+	0.30-	92+	0.32-
4	Position 2	76.6	0.47	75-	0.45-	75-	0.47	80+	0.49+	76-	0.46-	77+	0.50+
4	Position 3	88.4	0.44	86-	0.47+	87-	0.44	91+	0.44	89+	0.44	89+	0.43-
4	Position 4	93.6	0.42	92-	0.37-	93-	0.38-	96+	0.45+	95+	0.47+	93-	0.43+
4	Position 5	89.8	0.35	89-	0.39+	89-	0.35	91+	0.35	89-	0.33-	91+	0.35

Note 1: These measurements were taken with the STIPA test signal.
Note 2: The "+" and "-" symbols following each table entry indicates if it is geater or less than the average value.

Test Sequence 4

The purpose of Test Sequence 4 was to eliminate the concern that a distortion of the STIPA test signal may be occurring at the control room. This concern theorized that possible degradation of the STIPA test signal might be occurring due to reverberation or echoes within the control room itself, as the signal was being transmitted through the voice communication system microphone.

This concern arose from the earlier Field Test #2. Specifically, measurement point F23 of Field Test #2 was taken approximately 6" from the speaker and predicted an STIPA of .75, indicating an appreciable degradation of the test signal through the system. A further review of the situation raised question on how the talkbox and test signal were being played at the Command Center, and that possibly an echo was being introduced within this small room and being transmitted throughout the system during the test.

To address this concern, Test Sequence 3 was repeated but with a 1 inch acoustically absorbing foam box constructed around the talkbox and voice communication microphone in the Command Center. The purpose was to eliminate all possible reverberation or echo in the Command Center that could possibly be re-transmitted through the voice communication system.

The results of Test Sequence 4 are summarized in the bottom portion of Table 10. The "+" and "-" symbols following each table entry indicates if it's greater or less than the average value. It's noted that the average values measured between Test Sequence 3 and Test Sequence 4 track closely, suggesting that, at least in the Field Test 3 venue, this concern for reverberation or echo through the Command Center microphone was not a problem.

Test Sequence 5

The intent of Test Sequence 5 was to implement the approach to be used in areas that are not able to tolerate the STIPA signal during their fully operational or occupied conditions. This scenario is considered to be common, since most occupancies (e.g. office buildings, shopping malls, industrial facilities, etc) may have a concern about disruption caused by playing the STIPA test signal over the voice communication system for an extended period of time during peak occupancy. For example, the facilities in Field Test #1 and #2 both had concerns on disruption to their respective occupants.

Table 11: Summary of Test Sequence 5 and 6, at Field Test #3

	1) AUDIBILITY Empty Rm w/ STIPA Signal dBA (measured)						2) INTELLIGIBILITY Empty Rm w/ STIPA Signal STI (measured)						3) AUDIBILITY Empty Rm w/o STIPA Signal dBA (measured)						4) AUDIBILITY Occupied Rm w/o STIPA Signal dBA (measured)						5) CORRECTED INTELLIGIBILITY Calculated per Values 1 thru 4 STI (calculated)					
	Team						Team						Team						Team						Team					
Measurement Point	A	B	C	D	E	Avg	A	B	C	D	E	Avg	A	B	C	D	E	Avg	A	B	C	D	E	Avg	A	B	C	D	E	Avg
Position 6	75	75	77	76	74	75.4	0.45	0.45	0.42	0.40	0.41	0.426	60		69	64	64	64.25	82		89	83	83	84.25	0.42		0.36	0.39	0.40	0.393
Position 7	76	75	80	77	77	77	0.44	0.50	0.47	0.43	0.44	0.456	62		70	62	65	64.75	81		85	83	84	83.25	0.43		0.45	0.38	0.43	0.423
Position 8	76	77	81	78	77	77.8	0.47	0.51	0.53	0.48	0.51	0.5	62		71	65	64	65.5	79		83	75	84	80.25	0.43		0.49	0.44	0.49	0.463
Position 9	77	75	80	77	78	77.4	0.45	0.52	0.50	0.53	0.48	0.496	63		67	63	65	64.5	73		84	75	79	77.75	0.45		0.44	0.51	0.46	0.465
Position 10	72	75	79	76	77	75.8	0.46	0.42	0.43	0.42	0.46	0.438	62		73	62	63	65	76		84	76	81	79.25	0.44		0.43	0.40	0.42	0.423
Position 11	74	76	79	77	76	76.4	0.45	0.49	0.54	0.49	0.51	0.496	63		63	63	62	62.75	80		84	77	85	81.5	0.45		0.54	0.48	0.45	0.48
Position 12	80	79	83	81	81	80.8	0.56	0.54	0.61	0.57	0.60	0.576	63		66	65	64	64.5	74		80	73	81	77	0.55		0.62	0.56	0.59	0.58
Position 13	72	78	78	78	79	77	0.44	0.47	0.31	0.48	0.43	0.426	65		68	66	65	66	78		81	76	78	78.25	0.44		0.30	0.47	0.43	0.41
Position 14	78	76	78	76	76	76.8	0.49	0.42	0.46	0.45	0.45	0.454	64		71	64	66	66.25	74		82	74	78	77	0.49		0.46	0.43	0.43	0.453
Position 15	73	73	76	74	75	74.2	0.32	0.40	0.37	0.47	0.41	0.394	64		69	65	66	66	75		80	71	78	76	0.29		0.36	0.46	0.39	0.375
Position 16	72	74	76	75	74	74.2	0.34	0.38	0.41	0.42	0.42	0.394	67		72	65	65	67.25	71		82	74	76	75.75	0.34		0.40	0.42	0.41	0.393

This approach utilizes the Sample Test Form B included in Annex A. Measurement positions 6 through 16 were used, and these are shown in Figure 21. Five measurement teams would start the test sequence, but only 4 teams would complete it since each team will also need the necessary software to calculate the corrected STIPA (Team "B" would not finish the test). The following was the procedure established for Test Sequence 5:

<u>*Non-Occupied* Measurements *with* STIPA Signal</u>

a) During conditions when the test area is not occupied, deploy the test teams to their initial recording positions.
b) Set-up the STIPA talkbox at the Command Center to produce 97 dBA @ 1" from microphone (Note: this equates to 65 dBA @ 1 meter)
c) Record the Non-Occupied ambient audibility (dBA) at each measurement position for each team.
d) Record the Non-Occupied ambient intelligibility (STI) at each measurement position for each team. Note: these values need to be saved in each team's software for calculating the corrected STI.
e) Rotate each team to the next test position, and repeat the steps c and d, until each team has taken measurements at all eleven test positions.
f) Deactivate the STIPA test signal.

<u>*Non-Occupied* Measurements *without* STIPA Signal</u>

g) Record the Non-Occupied ambient audibility (dBA) at each measurement position for each team.
h) Rotate each team to the next test position, and repeat the step g, until each team has taken measurements at all eleven test positions.
i) Recess the test teams to return when the test area is fully occupied and operational

<u>*Occupied and Operational* Measurements *without* STIPA Signal</u>

j) During conditions when the test area is fully occupied and operational, deploy the test teams to their initial recording positions.
k) Record the Occupied and Operational ambient audibility (dBA) at each measurement position for each team.
l) Rotate each team to the next test position, and repeat the step k, until each team has taken measurements at all eleven test positions.
m) Recess the test teams for post processing calculations

<u>Corrected STI Calculation</u>

n) Post-process the data and calculate the corrected STI at each measurement position for each team.

The results of Test Sequence 5 are summarized in Table 11. These tabulated values are also shown graphically in Figures 22 through 26, using a graph for steps 1 through 5 of Test Sequence 5. The results for corrected STI in Table 11 generally agree with what is anticipated based on the conditions when the test area is fully operational.

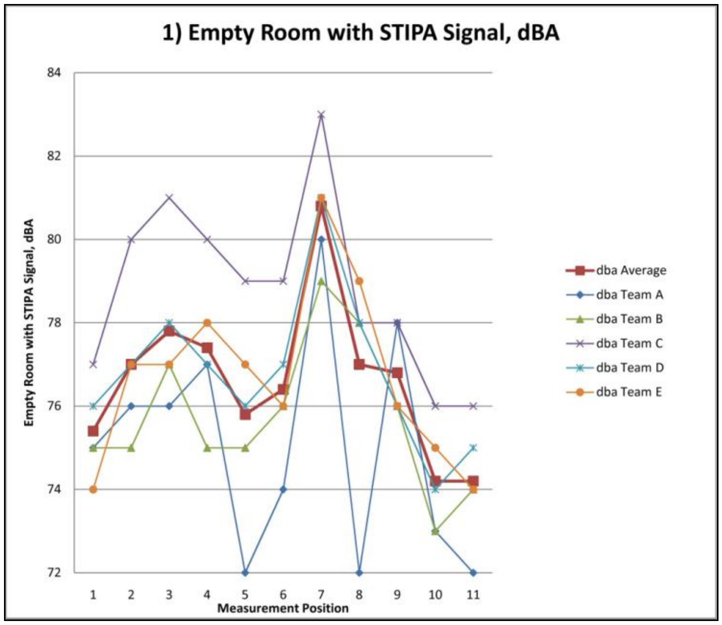

Figure 22: Values for Step 1 (Audibility) for Test Sequence 5 and 6, at Field Test #3 (Empty Room with the STIPA Signal, measured in dBA)

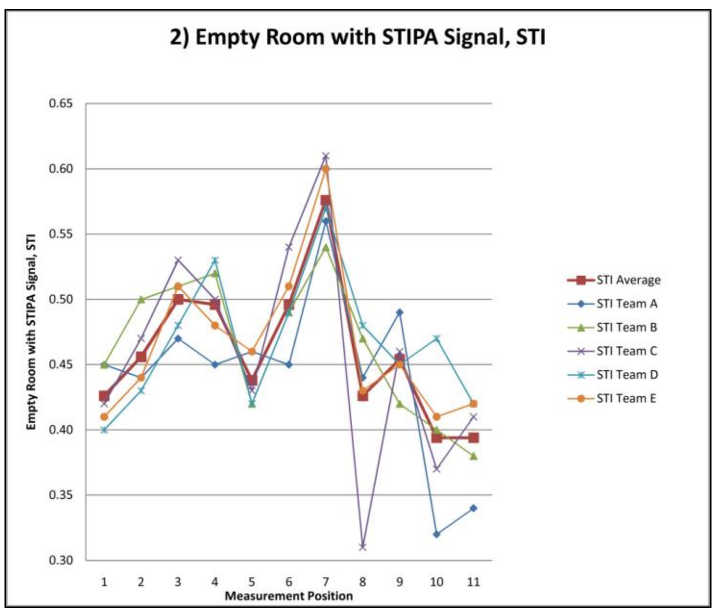

Figure 23: Values for Step 2 (Intelligibility) for Test Sequence 5 and 6, at Field Test #3 (Empty Room with the STIPA Signal, measured in STI)

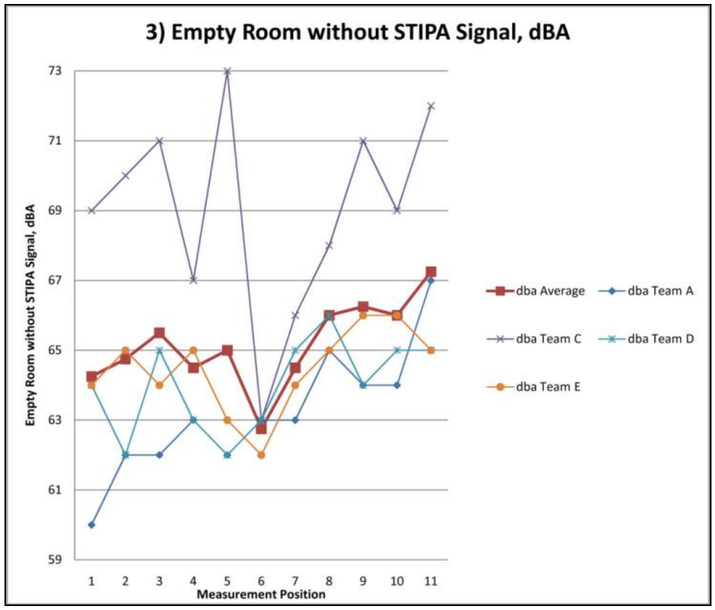

Figure 24: Values for Step 3 (Audibility) for Test Sequence 5 and 6, at Field Test #3 (Empty Room without the STIPA Signal, measured in dBA)

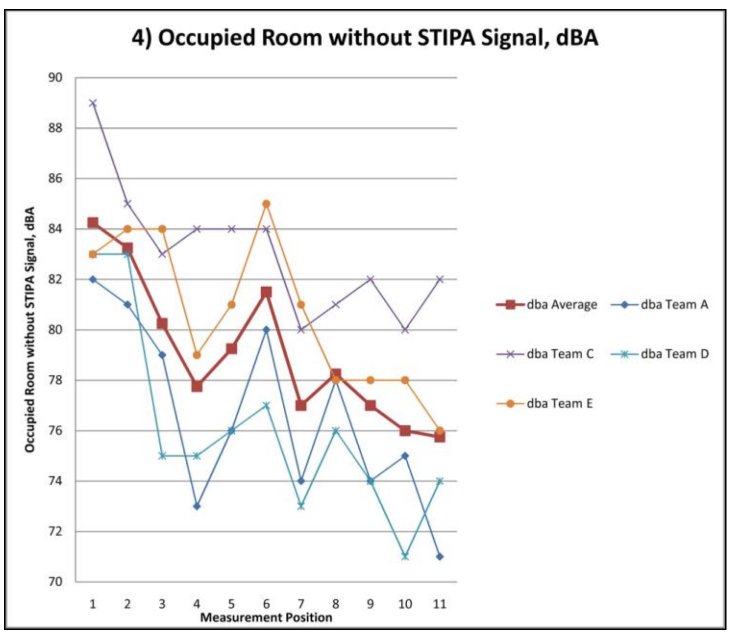

Figure 25: Values for Step 4 (Audibility) for Test Sequence 5 and 6, at Field Test #3 (Occupied Room without the STIPA Signal, measured in dBA)

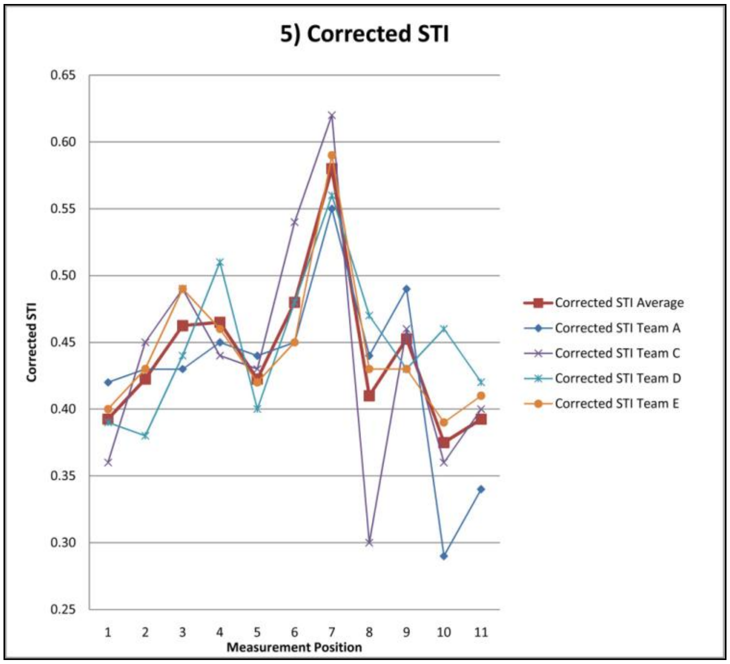

Figure 26: Values for Step 5 (Corrected Intelligibility) for Test Sequence 5 and 6, at Field Test #3
(Calculated based on steps 1 through 4, for corrected STI)

Test Sequence 6

Test Sequence 6 was combined into Test Sequence 5 and these two tests synergistically co-exist. The purpose of Test Sequence 6 is review the variability of multiple measurement points for a single Acoustically Distinguishable Space, and further, to clarify if the number of measuring points seems realistic. Initially, Test Sequence 5 was going to be implemented over one or possibly several measurement positions. But it was combined to include the 11 measurement points required by Test Sequence 6.

The measurement positions required by the latest draft of the Test Protocol (at that time) indicated that eleven would be required for this particular Acoustically Distinguishable Space. These were marked on the floor with tape and coincided with the column bays, and their locations are shown in Figure 21. Interestingly, an informal poll was taken among those participating in this test sequence and asked how many measurement points seemed reasonable for this particular test area, and the collective response was that four would seem to be sufficient rather than the eleven that the draft test protocol (at that time) required.

Manual recordings were made of dBA and STI at the time they were taken, but later in the post-analysis these did not precisely match the values that were recorded by the software. The reason for this discrepancy in the few cases it occurred is not clear, but the values ultimately used for the calculation were based on those recorded in the software.

Table 12 illustrates the delta for each value, i.e., the difference between the maximum values and the minimum values for each measurement point for all the teams. The variability in the data is likely due to the varied conditions between the time when one team measures to the time when the next team measures (e.g. machinery turning on and off, or cycling). It is also possible there is a variation in meters, although this is assumed to be minimal based on the calibration checks of the equipment. To test the impact of the "human factor" in the data variation, would require having several perfectly matched and calibrated meters at the same point and at the same time, or using one meter and quickly have each person take a measurement (although there still could be variations in the ambient noise over the time it takes to record the measurement).

Table 12: Range Difference of Values for Test Sequence 5 and 6, at Field Test #3

Measurement Point	1) AUDIBILITY Empty Rm w/ STIPA Signal dBA (measured)	2) INTELLIGIBILITY Empty Rm w/ STIPA Signal STI (measured)	3) AUDIBILITY Empty Rm w/o STIPA Signal dBA (measured)	4) AUDIBILITY Occupied Rm w/o STIPA Signal dBA (measured)	5) CORRECTED INTELLIGIBILITY Calculated per Values 1 thru 4 STI (calculated)
Position 6	3	0.05	9	7	0.06
Position 7	4	0.04	8	4	0.07
Position 8	5	0.06	9	9	0.06
Position 9	3	0.08	4	11	0.07
Position 10	7	0.04	11	8	0.04
Position 11	5	0.09	1	8	0.09
Position 12	3	0.05	3	8	0.07
Position 13	7	0.17	3	5	0.17
Position 14	2	0.04	7	8	0.06
Position 15	3	0.15	5	9	0.17
Position 16	4	0.08	7	11	0.08

5.4) Observations.

The following are specific observations following the completion of the six test sequences of Field Test #3:

a) (Test Sequence 1: Equipment Bench Calibration Check) The Equipment Bench Calibration Check as outlined in the draft test protocol adequately achieved its technical objective of verifying the calibration of the test equipment, and seems reasonable from a field implementation perspective.
b) (Test Sequence 2: Comparison Test of Output-Based Talkbox vs. Input-Based Talkbox) A compromise was agreed to with regard to the test setup approach, and it was felt best to include and coordinate both the output-based talkbox approach and the input-based talkbox approach in the draft test protocol.
c) (Test Sequence 3: Test Measurement Repeatability) The results of the Test Measurement Repeatability demonstrated a relatively acceptable level of consistency between the values recorded by each team. The one team that had values that were

consistently high raised the question of possible operator error or equipment calibration problems.

d) (Test Sequence 4: Control Room Microphone Test) The average of the measured values track closely with those of Test Sequence 3, and thus indicate that, at least in the Field Test 3 venue, the concern for reverberation or echo through the Command Center microphone was not a problem.
e) (Test Sequence 5: Operational vs. Non-Operational Test) The results for corrected STI are in the realm of expectations for conditions when the test area is fully operational.
f) (Test Sequence 6: Full Acoustically Distinguishable Space Test) An informal poll was taken among those participating in this test sequence and asked how many measurement points seemed reasonable for this particular test area, and the collective response was that four would seem to be sufficient rather than the eleven that the draft test protocol (at that time) required. For the assignment of the ADS (acoustically distinguishable space), this needs to be a simple rule that everyone can readily embrace. For example, one rule of thumb that may have merit is to indicate that generally each ADS should not exceed 1600 ft^2.

The following are general observations following Field Test #3 and also taking into account Field Tests #1 and #2:

a) Ambient sound pressure levels were higher in Field Test #3 than in Field Test #1 and #2 due to the type of occupancy.
b) There was some scatter in the data that was collected, but this was not unexpected. Nevertheless, this raises a question on the level of precision that should be required. The use of multiple meters in this (and the other) Field Tests provided a good balance to compare the consistency of results.
c) Field Test #3 had specific acoustical challenges, as did all three of the facilities tested. It was noted that the type of occupancy is a significant variable.
d) The test sequence used in Field Test #3 provided helpful focus on the parameters required to enhance intelligibility performance. While there are many variables affecting the quality of speech, some are more challenging (e.g. rate of speech, etc) while others involve technical approaches that can be more readily standardized (e.g. system design).
e) Based on the observations of those participating in Field Test #3, it was agreed that the pass/fail criterion should use an average of 0.50 STI, with an absolute minimum measurement at any point of 0.45 (or other value acceptable to the AHJ).
f) The fire alarm industry has traditionally had a different design focus than acoustic systems (i.e. public address or music systems), and the advent of a test protocol may require a transformation of the industry to a higher quality in terms of how these systems are designed. The enhancement of equipment to meet intelligibility specifications may ultimately be market driven, but NFPA 72 needs to be sensitive to the market impact and approach these issues in parallel.

6) DEVELOPMENT OF TEST PROTOCOL

A primary deliverable for this project is the development of a draft Test Protocol for predicting the intelligibility of fire alarm and emergency communication systems. The Test Protocol is included in its entirety on pages 53 through 71 within this chapter. To distinguish the Test Protocol from other information within this report, these pages within this report contain a full double border, while the other pages within the report do not.

The Test Protocol contained herein is Draft #7, and this is the latest draft developed by this project. This is intended for consideration by the Technical Committees responsible for NFPA 72, National Fire Alarm Code. Specifically, this information is being forwarded to the Technical Committees responsible for Chapters on Emergency Communication Systems, Notification Appliances, and Inspection, Testing and Maintenance of NFPA 72, as well as the Technical Correlating Committee for the National Fire Alarm Code. This information was made available in time for consideration at the Report on Comments meetings for the 2010 edition of NFPA 72.

The development of this Test Protocol has been the result of extensive comments and feedback from the Project Technical Panel. The Panel was comprised of 13 members and sponsor representatives, and they have had three conference call meetings (8/Aug/08, 2/Sep/08, and 6/Oct/08) that included reviews of the draft Test Protocol. In addition, face-to-face meetings were held in conjunction with Field Test #1 and #2 (20-21/Aug/08) and again with Field Test #3 (8-10/Sep/08), and these meetings allowed further extensive discussion and debate.

In addition to the Project Technical Panel of 13 individuals that has provided direct guidance throughout the project, a larger participant group comprised of an additional 43 individuals has tracked the activities of the project and provided input at multiple stages. An invitation to participate with this project was published in several venues of the Fire Protection Research Foundation, and an invitation also was sent directly to all members of the applicable NFPA Technical Committees of NFPA 72. An appreciable number of these individuals attended and fully participated in the face-to-face meetings held in conjunction with each of the three field tests.

Between these meetings, comments on the Test Protocol were received individually and also as a result of the four task groups that were appointed to address the following key technical areas: Set-Up Protocol (TG 1); Where-and-When Required (TG2); Acoustically Distinguishable Spaces (TG3); and Pass/Fail Criteria (TG4). The information developed by these task groups has been significantly reworked and incorporated into the Test Protocol.

In summary, the Test Protocol contained herein is the result of an intense development process over the course of a three month period involving more than four dozen individuals, three field tests, and multiple meetings. The draft Test Protocol appears on the following pages.

INTELLIGIBILITY TEST PROTOCOL

(DRAFT #7)
7 October 2008

Test Protocol Table of Contents

1. ***Fundamentals of Test Protocol**

1.1. **Scope.**

1.1.1. ***STI/STIPA Measurement Method.** Where the method for measuring speech intelligibility is the Speech Transmission Index (STI), this test protocol should be followed.

1.1.2. **Other Methods.** Where the method for measuring speech intelligibility is the Phonetically Balanced Word test (PB), Modified Rhyme Test (MRT), or Speech Intelligibility Index (SII) method, the same methods for determining measurement locations should be used.

1.1.3. This test method for determining the intelligibility of fire alarm and emergency communications systems (ECS) is based on the measurement of STI as defined by IEC 60286-16.

1.2. **References.**

1.2.1. IEC 60268-16, "*Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index*", International Electrotechnical Commission, Geneva, Switz., 22 May 2003.

1.2.2. ISO 7240-19, "*Fire Detection and Alarm Systems --- Part19: Design, Installation, Commissioning and Service of Sound Systems for Emergency Purposes*", International Organization for Standardization, Geneva, Switz., 1st edition, 15 Aug 2005.

1.2.3. NEMA Standards Publication SB 50-2008, "*Emergency Communications Audio Intelligibility Applications Guide*", National Electrical Manufacturers Association, Rosslyn VA, 2008.

1.3. **Terminology.**

1.3.1. ***Acoustically Distinguishable Space (ADS):** An emergency communication system notification zone, or subdivision thereof, that may be an enclosed or otherwise physically defined space, or that may be distinguished from other spaces because of different acoustical, environmental or use characteristics such as reverberation time and ambient noise level. The *ADS* may have acoustical design features that are conducive for voice intelligibility, or they may be spaces where voice intelligibility may be difficult or impossible to achieve.

1.3.2. **ADS. See Acoustically Distinguishable Space.**

1.3.3. **Audibility Test.** Measurement of the sound pressure level of a tone signal in accordance with the requirements of NFPA 72.

1.3.4. **Intelligibility Test.** A test method used to predict how well speech will be understood by a listener.

1.3.5. **Occupied Ambient Sound Pressure Level.** The sound pressure level during the period of time when the building involved in the test is occupied and is reasonably close to having maximum background noise. For example, this may involve the operation of HVAC equipment, an industrial process, or a maximum number of occupants such as may occur in a place of public assembly.

1.3.6. ***STI or STIPA Test Signal.** An special audio signal that is played over the emergency communications system being tested.

1.3.7. **Talkbox.** An instrument usually consisting of a high quality audio speaker and a CD player or other method used to play an STI or STIPA test signal.

1.3.8. **Unoccupied Ambient Sound Pressure Level.** The sound pressure level during the period of time when the primary occupants of the facility are not present, or when ambient noise is not at its highest level.

1.4. *Acceptability Criteria. The intelligibility of an emergency communication system is considered acceptable if at least 90 percent of the measurement locations within each *ADS* have a measured STI of not less than 0.45 (0.65 CIS) and an average STI of not less than 0.50 STI (0.70 CIS).

1.5. *Limitations of Test Method.

1.5.1. ***Areas of high ambient sound pressure levels ("noise") may be incapable of meeting the acceptability criteria in 1.4.

1.5.2. ***Impulse sounds made during measurements may impact measurement accuracy or cause instrument error.

1.5.3. Natural variation in ambient noise levels may affect the results.

1.6. *General Requirements.

1.6.1. All necessary precautions should be taken with the facility owner to work with appropriately qualified staff when handling or performing any function with the emergency communications system control unit.

1.6.2. Testing impairment and record keeping requirements of NFPA 72, Chapter 10 should apply.

1.6.3. Test measurement results and other documentation should be maintained as required by the Authority Having Jurisdiction.

1.6.4. Impairment management procedures of NFPA 72, section 4.6 should be followed.

1.6.5. Test Participants. The test participants should include representatives of and/or coordination with the following: building owners; the organizations responsible for the fire alarm or emergency communications system design and installation; system equipment supplier and/or manufacturer; and the Authority Having Jurisdiction.

2. Pre-Planning

2.1. Facility Occupancy and Use.

2.1.1. Occupancy/Use Types. Prior to testing, the pre-planning effort should identify the occupancy or use type to better minimize disruption to the facility occupants during the test.

2.1.2. Normal Operational Time Periods. Prior to testing, pre-planning efforts should identify the operational time periods when the *Occupied Ambient Sound Pressure Level* and the *Unoccupied Ambient Sound Pressure Level* are most likely to occur.

2.1.3. *Testing Before Building Furnishing Completion. It may be necessary to perform testing to permit partial use before the building is in its final acoustic configuration. The results of intelligibility testing at this stage may differ from the final performance of the system. It might be necessary to work with the AHJ to develop a testing plan.

2.1.4. Facility Construction and Condition. Construction in the facility to be tested must be completed for areas that will be subject to intelligibility testing. This specifically requires that the command center and all locations of system microphones to be tested must be completed. Any location of remote system microphones not tested during this time must be noted and said locations must be fully tested with positive results within 90 days of area occupancy or as required by the authority having jurisdiction. Also, all building systems such as environmental conditioning systems should be completed and operational as they both produce noise and provide acoustic noise travel paths. In addition, all floor treatments and any acoustical wall or ceiling treatments must be in place.

2.1.5. System Under Test Status. The system under test must be completed for all areas where intelligibility testing will be done.

2.1.6. System Under Test Power. The system under test must be on permanent primary power source as defined in NFPA 72.

2.1.7. System Under Test Secondary Power. Secondary power, where required and/or provided for the system under test should be fully functional. If batteries are used for this purpose, batteries should be fully charged for a minimum of 48 hours prior to the commencement of any testing.

2.2. *Emergency Communication Equipment.

2.2.1. Emergency Communications System Control Panel. The System Under Test for the emergency communications system should be located and identified prior to testing, and the operation features necessary for testing should be clarified. Personnel who are authorized to access and service the control panel are needed for the testing and should be included within the team performing the tests. If necessary, notification to locations beyond the facility that is being tested (e.g. fire department or a supervising station) should be notified of the tests, and if appropriate, their automatic notification feature disabled. Upon completion of the tests the emergency communications system should be returned to its normal operating condition.

2.2.2. Test Set-up. The function and operation of the emergency communication system control unit should be reviewed with personnel authorized to access and operate this equipment. Information should be acquired about the design of the voice notification portion of the system, and whether it has zone capabilities that will allow minimal disruption to building occupants by testing each zone individually. The test plan should also specify whether other functions of the system, such as elevator recall and air handler control will be disabled during the testing of the emergency communications system.

2.2.3. System Under Test Calibration. The complete System Under Test audio path should be fully calibrated in accordance with manufacturer's instructions. On systems with adjustable technology, if manufacturer's instructions are not provided, the alternate calibration procedure offered below may be employed to calibrate the System Under Test.

2.2.3.1. Alternate Calibration Procedure.

2.2.3.1.1. This calibration is to be performed with the System Under Test on normal AC power, then checked with the system on secondary power (if so equipped).

2.2.3.1.2. The System Under Test amplifier output or the circuit being calibrated must have a minimum of a 1-watt load during the calibration process.

2.2.3.1.3. Perform pre-test occupant & remote monitoring station notification requirements specified in NFPA 72-2007, Chapter 10.

2.2.3.1.4. Introduce a 1 kHz sine-wave tone (+/- 100 Hz) into the system microphone. The tone should produce 90 dBA fast at a distance of 4 inches on-axis, perpendicular to the face of the microphone.

2.2.3.1.5. Place the System Under Test into manual paging mode (microphone "live" and connected to amplifier circuitry with notification appliance circuits active).

2.2.3.1.6. Using a 4-digit accuracy RMS meter, set on AC scale, set the output of the System Under Test audio notification appliance circuits to between 24 and 26 Vrms for 25.2 volt systems or between 69 and 71 Vrms for 70.7 volt systems.

2.2.3.1.7. Once System Under Test manual paging mode has been calibrated, pre-recorded tone (if so equipped) should then be tested by playing it through the System Under Test to ensure that there is no more than a 3 dBA difference between manual paging using the system microphone and the pre-recorded message. The dBA measurement should be made using an integrating/averaging meter and averaged over approximately 10 seconds of voice announcement to compensate for voice amplitude modulation.

2.2.3.1.8. On a System Under Test with more than one emergency paging microphone and/or pre-recorded message units, the primary units should be calibrated, then secondary units tested to ensure that they produce signals throughout the System Under Test at the same amplitude as the primary units.

2.3. Plans and Specifications

2.3.1. The approved plans and specifications for the system should be used to plan and document the tests.

2.3.2. Testing is best accomplished using large scale plans showing all notification appliances.

2.3.3. The plans should show the different system notification zones.

2.3.4. The type and location of the notification appliances used in the emergency communication system should be identified prior to testing.

2.3.5. Notification appliance symbols should differentiate the type of appliance where more than one type is used.

2.3.6. Notification appliances should symbols should include the design wattage for each speaker appliance.

2.3.7. The plans should show the ambient sound pressure levels used as a basis for the system design.

2.4. Assignment of Acoustically Distinguishable Spaces.

2.4.1. *ADSs* should be assigned prior to the test, and be subject to review by all test participants.

2.4.2. *ADS* assignments should be a part of the original design process. See the discussion in A.1.3.1.

2.4.3. The design drawings should be used to plan and show the limits of each *ADS* where there is more than one.

2.4.4. All areas that are intended to have audible occupant notification, whether by tone only or by voice are to be designated as one or more *ADSs*. See 1.3.1 and A.1.3.1

2.4.5. *The drawings or a table listing all *ADSs* should be used to indicate which *ADSs* will require intelligible voice communications and those that will not. The same drawings or table could be used to list audibility requirements where tones are used and to list any forms of visual or other notification or communications methods being employed in the *ADS*.

2.4.6. *ADS* layouts that differ from the original, approved design documents should be approved by the AHJ.

2.5. *Spaces Not Requiring Testing.

2.5.1. In situations where there are several *ADSs* that have the exact same physical and system configuration, it may be possible to test only a representative sample and then just check the others to confirm system and appliance operation. For example hotel rooms with similar layouts or offices of similar size and furnishings where each has a speaker appliance. In these cases there would be no expected difference in system intelligibility. The only possible problem would be one where an appliance was not operational or tapped at the incorrect wattage. These problems would be apparent by a basic “listening” test.

2.5.2. *Not all *ADSs* will require speech intelligibility testing. Some areas may be designed for notification, but not for voice communication. Notification may be accomplished by tone-only signaling or by a pre-alert tone preceding a voice message. See 2.4.5 and A.2.4.5.

2.5.3. Of the *ADSs* that do require intelligible voice communications some will require speech intelligibility testing and other may only require audibility testing.

2.5.4. Testing of intelligibility might not be required in buildings and areas of buildings that are not acoustically challenging and that meet the audibility requirements of NFPA 72. Spaces that are not considered to be acoustically challenging include, traditional office environments, hotel guestrooms, spaces with carpeting and furnishings that reduce reverberation and other smaller spaces where a speaker appliance is installed in the space.

2.6. Measurement Points within an ADS.

2.6.1. Measurements should be taken at an elevation of 5 ft (1.5 m)or at any other elevation deemed appropriate if the area is subject to normal occupant access (e.g. elevated walkways).

2.6.2. *The number and location of measurement points in each *ADS* should be planned and based on the area and volume of the space and the speaker appliance location within the space. The location of noise sources, egress paths and the locations of personnel in the space must also be considered.

2.6.3. If multiple measurement points are required within an *ADS*, they should be separated by about 40 ft (12.2 m).

2.6.4. No more than one third of the measurement points within an *ADS* should be on the axis of a speaker.

2.6.5. See 1.4 for the requirements for averaging the results at different measurement points within and *ADS*.

2.6.6. Measurement points should be shown on plans or otherwise described in a way that permits future testing at the same locations.

2.7. Test Method – Occupied versus Unoccupied

2.7.1. It is possible to conduct STI measurements when the area is occupied or when it is not occupied. In this document “occupied” versus “unoccupied” is intended to be consistent with the definitions in section 1.3 for *Occupied Ambient Sound Pressure Level* and for *Unoccupied Ambient Sound Pressure Level.*

2.7.2. The preferred procedure is to conduct the STI/STIPA test in the presence of the *Occupied Ambient Sound Pressure Level.* See Section 5.4.

2.7.3. Where the test method is measuring the STI using the STIPA test signal, the STIPA test signal can be played through the system and the STI can be measured and the data saved by the test instrument when the area is either not occupied or when the background ambient conditions are not the *Occupied Ambient Sound Pressure Level*. It is also necessary to measure and save the un-occupied ambient sound level at each measurement location. Then, during occupied times, take and save ambient sound level measurements. The three data sets are combined by software provided by the speech intelligibility test instrument manufacturer to calculate the corrected STI for the area.

3. Test Equipment Calibration for Testing using the STIPA Test Signal

3.1. General.

3.1.1. The calibration of the STI test instrument is done in accordance with this section using a *Talkbox* or in accordance with manufacturer’s instructions.

3.1.2. The Intelligibility Test System consists of a *Talkbox* and STI-PA test meter (analyzer) all from one manufacturer. Units from other manufacturers should not be interchanged unless said units have been tested by a recognized testing laboratory for compatibility (see A.1.3.6).

3.1.3. *Prior to performing any intelligibility testing or intelligibility system calibration, verify that the test meter's microphone, *Talkbox* and analyzer are within calibration date as listed on the unit's calibration tag.

3.2. Calibration Procedure.

3.2.1. The following procedures should be performed at the commencement and conclusion of intelligibility testing. If the following procedure differs from that recommended by the manufacturer of the test equipment, follow the manufacturer's calibration test procedure.

3.2.2. Perform these calibration procedures in a quiet room (45 dBA or less) without any extraneous sounds or any talking, music, etc.

3.2.3. Start STI-PA test tone as instructed by the manufacturer.

3.2.4. Apply power to the *Talkbox* and then activate the STIPA test signal.

3.2.5. Turn on the analyzer and set it to SPL A Fast measurement mode.

3.2.6. Place the analyzer's microphone approximately one inch, on axis, from the *Talkbox*. Do not place the analyzer microphone against any hard surface – this can lead to induced noise and affect the calibration.

3.2.7. Adjust the *Talkbox* volume so that the STI Analyzer's reading is approximately 92 dBA.

3.2.8. Keeping the analyzer in approximately the same position, measure the STI. Note that some meters display STI measurements using the CIS scale while some can display results in either STI or CIS units. See A.1.4 for an explanation of the CIS scale.

3.2.9. The equipment is working properly if the reading is greater than 0.91 STI or 0.96 CIS. Up to 3 tests can be performed. If the system does not pass after 3 tests, it should be returned to the manufacturer for repair or recalibration.

4. Talkbox Set-up

4.1. Input Test Signal

4.1.1. The input test signal must be configured to produce the proper level by utilizing either the Microphone Input Method or the Direct Input Injection Method.

4.1.2. *Most emergency communications systems have microphones for manual voice communication and should be tested using the microphone test method. Systems that do not have microphones and that only play pre-recorded voice announcements may be tested using the direct input injection method.

4.1.3. Direct Input Injection Method for Test Signals.

4.1.3.1. With this method the STI or STIPA test signals are pre-recorded in the emergency communications system hardware in the same way as the pre-recorded voice messages and at the same input levels. Alternately, the test signal may input to the system via input jacks or terminals.

4.1.3.2. The input level of the test signal must be tested by the emergency communications system (ECS) listing agency as being the same as the pre-recorded voice levels or must be calibrated using the ECS equipment manufacturer's instructions.

4.1.3.3. For ECS systems that permit voice messages to be custom recorded, the L_{eq} of the recorded voice over a period of 10 seconds or the length of the voice message should be measured and should be within 3 dB of the prerecorded STI or STIPA test signal to ensure that it is at the correct level.

4.1.3.4. Field measurements of the STI are made using the procedure in Section 5.

4.1.4. Microphone Input Method for Test Signals.

4.1.4.1. With this method, a recording of the STI or STIPA test signal is played into the system microphone using a *Talkbox*.

4.1.4.2. The *Talkbox* is set up and calibrated per section 4.2 and field measurements of the STI are made using the procedure in Section 5.

4.2. *Calibrating the Input Test Signal for the Microphone Input Method

4.2.1. General.

4.2.1.1. There are two methods for setting the level of the STI or STIPA test signal at the input microphone.

4.2.1.2. Method 1 sets the volume of the input test signal to match that of speech level under normal conditions.

4.2.1.3. Method 2 sets the volume of the input test signal so that the dBA output in the area under test is the same as that for a pre-recorded message.

4.2.1.4. *The room where the *Talkbox* and ECS microphone are located must be quiet.

4.2.1.5. Set up the *Talkbox* in accordance with the manufacturer's instructions.

4.2.2. Method 1 – Matching Speech Level

4.2.2.1. The intent of this method is to set the *Talkbox* or audio source input level to the emergency communications system microphone to match that of an average person speaking into the microphone.

4.2.2.2. Set the analyzer (meter) to measure sound pressure level, A-weighted, Fast.

4.2.2.3. Start the STI or STIPA test signal and hold the meter at a distance of one meter on-axis from the *Talkbox* or audio source.

4.2.2.4. *Set the *Talkbox* volume (level) so that the meter registers 65 dBA at a distance of one meter. This setting should not change for the remainder of the testing.

4.2.2.5. *Place the microphone of the emergency communications system at a distance from the *Talkbox* as recommended by the microphone or ECS manufacturer.

4.2.2.6. Begin field testing in accordance with section 5.

4.2.3. Method 2 – Matching Recorded Message Level

4.2.3.1. The intent of this method is to set the *Talkbox* or audio source input level into the emergency communications system microphone so that the output at a location in the area under test is the same as the level of prerecorded messages played by the system.

4.2.3.2. The sound pressure level produced by the *Talkbox* while playing the STI or STIPA test signal should be matched with the sound pressure level of the pre-recorded voice message.

4.2.3.3. Two people will be needed to perform the calibration procedure. One person needs to be present at the *Talkbox* while the other person needs to operate the analyzer at a typical location in the facility.

4.2.3.4. At a typical location in the facility, position the analyzer so that the instrument's microphone is approximately five feet above the finished floor.

4.2.3.5. Set the analyzer (meter) to measure sound pressure level, A-weighted, Fast.

4.2.3.6. Activate the pre-recorded voice message from the ECS.

4.2.3.7. The decibel reading at the analyzer will be somewhat erratic due to the nature of speech signals.

4.2.3.8. Record the highest dB reading the system produces.

4.2.3.9. Do not move the analyzer from the test location.

4.2.3.10. Turn off the pre-recorded voice message.

4.2.3.11. Place the microphone of the emergency communications system at a distance from the *Talkbox* as recommended by the microphone or ECS manufacturer (see A.4.2.2.5).

4.2.3.12. Start the *Talkbox* STI or STIPA test signal.

4.2.3.13. Adjust the *Talkbox* sound level until the field measurement of the test signal is +/- 3 dB of the level generated when the pre-recorded voice message was played and measured. This setting should not change for the remainder of the testing.

4.2.3.14. Begin field testing in accordance with section 5.

5. STI/STIPA Test Procedure

5.1. General. This test procedure permits testing during either occupied conditions or during unoccupied conditions. See 2.7.

5.2. Power. The System Under Test should be tested on secondary power for a minimum of 15 minutes and then on primary power for the remainder of the testing.

5.3. System Operation. Where two *ADSs* are adjacent to each other and not separated by physically barriers that significantly prevent noise penetration from one *ADS* to another, the notification appliances in both *ADSs* should be operating during the testing. It is acceptable during intelligibility testing to silence or disable other notification zones that would not potentially interfere with each other. However, regular testing per NFPA 72 would require that all circuits be operated simultaneously at some time during testing to ensure proper operation and to verify power requirements.

5.4. Occupied Testing.

5.4.1. Testing must be done during a period of time when the area is occupied and is reasonably close to having maximum background noise.

5.4.2. Set-up the *Talkbox* in accordance with section 4 and start the STI or STIPA test signal.

5.4.3. At each measurement point in each *ADS* measure the STI.

5.4.4. Document the results on plans or forms in a way that accurately describes the measurement point and that permits future testing at the same locations.

5.5. Unoccupied Testing.

5.5.1. General. Testing of speech intelligibility in the presence of the *Occupied Ambient Sound Pressure Level* is the preferred method. However, for various reasons, including disruption of normal work, it may be desirable to only do “silent” testing during occupied periods and to do testing with the STI or STIPA test signal during unoccupied or less occupied conditions.

5.5.2. Number of Tests. This test method requires three different measurements at each measurement point, typically made during two site visits. The data for each measurement is saved in a format in accordance with the instrument manufacturer’s requirements. The three data files are then post-processed using software provided by the instrument manufacturer to arrive at the final corrected STI.

5.5.3. Occupied Ambient Noise Measurement.

5.5.3.1. At each measurement point in each *ADS* measure the *Occupied Ambient Sound Pressure Level*.

5.5.3.2. Save the measurement data in accordance with the instrument manufacturer’s requirements to permit post-processing of the data.

5.5.3.3. Document the results in writing on plans or forms in a way that accurately describes the measurement point and that permits future testing at the same locations.

5.5.4. **Unoccupied Ambient Noise Measurement.**

5.5.4.1. At each measurement point in each *ADS* measure the *Unoccupied Ambient Sound Pressure Level*.

5.5.4.2. Save the measurement data in accordance with the instrument manufacturer's requirements to permit post-processing of the data.

5.5.4.3. Document the results in writing on plans or forms in a way that accurately describes the measurement point and that permits future testing at the same locations.

5.5.5. **Unoccupied STI Measurement.**

5.5.5.1. Set-up the *Talkbox* in accordance with section 4 and start the STI or STIPA test signal.

5.5.5.2. At each measurement point in each *ADS* measure the uncorrected STI.

5.5.5.3. Save the measurement data in accordance with the instrument manufacturer's requirements to permit post-processing of the data.

5.5.5.4. Document the results in writing on plans or forms in a way that accurately describes the measurement point and that permits future testing at the same locations.

5.5.6. **Post Processing.**

5.5.6.1. The corrected STI is arrived at by post-processing of the Occupied Ambient Noise Measurement, the Unoccupied Ambient Noise Measurement and the Unoccupied STI Measurement. In effect, the measured STI (uncorrected) is being corrected by adding in the effects the actual expected (occupied) ambient noise.

5.5.6.2. The post processing procedure or software provided by the instrument manufacturer must be used to calculate the final corrected STI for each measurement point.

5.5.6.3. Document the results in writing on plans or forms in a way that accurately describes the measurement point and that permits future testing at the same locations.

5.5.6.4. Documentation of the final results for each point should include the results of all three measurements and the final corrected STI value. The manufacturer's software revision should also be included in the results documentation.

6. Post Test Procedures

6.1. Test Closure. Upon completion of all testing, the emergency communications system should be returned to its normal operating condition.

6.2. *Results.

6.2.1. For each *ADS*, summarize the results in accordance with the performance requirements of 1.4.

6.2.2. For an *ADS* that had multiple measurement points or that had multiple measurements at only one measurement point, calculate the average per 1.4 and list the average and the minimum measurement per 1.4 in the results summary.

6.3. Documentation.

6.3.1. The test results should be fully documented and provided to the building owner, the emergency communications system contractor, the system designer, the Authority Having Jurisdiction, and any other individual or organization deemed appropriate.

6.3.2. In addition to the requirements for test documentation contained in NFPA 72 Chapter 10, the test results should include:

a) Building location and related descriptive facility information;

b) Names, titles and contact information for individuals involved in test;
c) Dates and times of tests;
d) A list of testing instruments, including manufacturer's name, model, serial number, and date of most recent calibration;
e) Technical description of emergency communications system;
f) Identification of *ADSs*;
g) Locations of specific measurement points (in a list or on a set of drawings);
h) Site definition of ambient sound pressure levels;
i) STI/STIPA measurements at each measurement point;
j) Final corrected STI/STIPA values where the post-processing procedure is used;
k) Indication of whether or not the test met the pass/fail criteria; and
l) Record of system restoration;
m) Any additional information to assist with future evaluation of system performance.

6.3.3. If appropriate, the Plans and Specifications addressed in 2.3 should be updated based on the results of the test.

Annex A Explanatory Material

Annex A is not a part of the recommendations of this document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1 This document describes when, where and how to test for speech intelligibility. It does not provide any significant advice on how to design and install an emergency communications system to achieve speech intelligibility. It is also not the intent of this test protocol to describe how to interpret results or how to correct systems or environments that contribute to poor speech intelligibility. For information on these subjects, consult with system manufacturers, audio experts, design guides and other literature. See also NEMA Standards Publication SB 50-2008, "Emergency Communications Audio Intelligibility Applications Guide", National Electrical Manufacturers Association, Rosslyn VA, 2008.

A.1.1.1 There are several methods that measure the Speech Transmission Index (STI). One method common to the emergency communications system industry uses a test signal referred to as STIPA – STI-Public Address.

A.1.3.1 All parts of a building or area intended to have occupant notification are subdivided into *ADSs* as defined. Some *ADSs* may be designated to have voice communication capability and require that those communications be intelligible. Other spaces may not require voice intelligibility or may not be capable of reliable voice intelligibility. Each is still referred to as an *ADS*.

In smaller areas, such as under 400 Sq Ft., walls alone will define the *ADS*. In larger areas, other factors may have to be considered. In spaces that might be subdivided by temporary or movable partitions, such as ballrooms and meeting rooms, each individual configuration should be considered a separate *ADS*. Physical characteristics such as a change in ceiling height of more than 20% or change in acoustical finish, carpet in one area and tile in another, would require those areas to be treated as separate *ADSs*. In larger areas there may be noise sources that require a section be treated as a separate *ADS*. Any significant change in ambient noise level or frequency might necessitate an area be considered a separate *ADS*.

In areas of 85 dBA or greater ambient sound pressure level, meeting the pass/fail criteria for intelligibility might not be possible and other means of communication might be necessary. So, for example, the space immediately surrounding a printing press or other high noise machine may be designated as a separate *ADS* and the design may call for some form of effective notification, but not necessarily require the ability to have intelligible voice communication. The aisles or operator's control stations may be separate *ADSs* where intelligible voice communication might be desired.

Significant differences in furnishings, for example an area with tables, desks or low dividers adjacent to an area with high shelving would require separate consideration. The entire desk area could be a single ADS whereas each area between shelving could be a unique ADS. Essentially, any noteworthy change in the acoustical environment within an area will mandate consideration of that portion of the area to be treated as a separate ADS. Hallways and stairwells will typically be considered as individual ADS.

Spaces confined by walls with carpeting and acoustical ceilings can be deemed to be one *ADS*. An *ADS* should be an area of consistent size and material. A change of materials from carpet to hard tile, the existence of sound sources such as decorative waterfalls, large expanses of glass, changes in ceiling height are all factor that might separate one *ADS* from another.

Each *ADS* may require different components and design features to achieve intelligible voice communication. For example, two *ADSs* with similar acoustical treatments and noise levels may have different ceiling heights. The *ADS* with the lower ceiling height might require more ceiling mounted speakers to ensure that all listeners are in a direct sound field. See Figure A.1.3.1. Other *ADSs* might benefit by the use of alternate speaker technologies such as line arrays to achieve intelligibility.

An *ADS* that differs from another because of the frequency and level of ambient noise might require the use of speakers and system components that have a wider frequency bandwidth than convention emergency communications equipment. However, designers should not use higher bandwidth speakers in all locations unless needed to overcome certain acoustic and ambient conditions. This is because the higher bandwidth appliance will require more energy to perform properly. This increases amplifier and wire size and power supply requirements.

Some spaces may be impractical to achieve intelligibility and in such event alternatives to voice evacuation may be required within such areas.

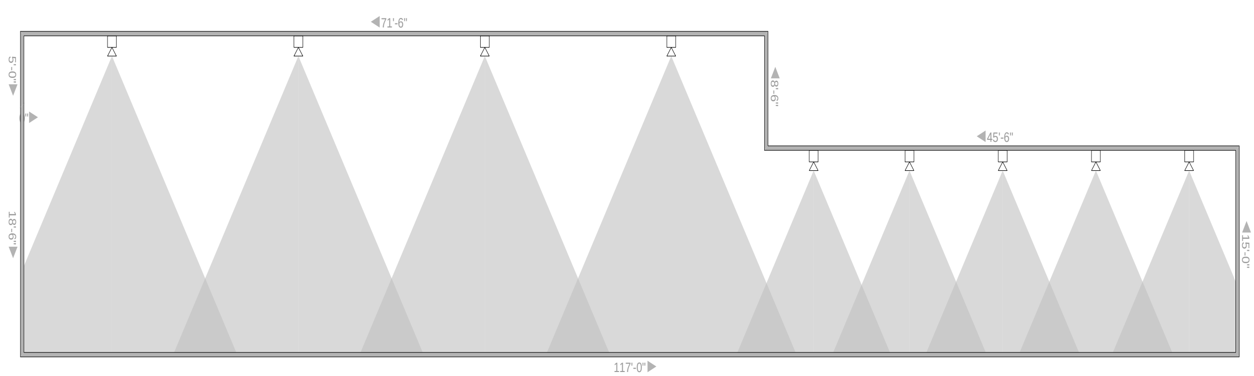

Figure A.1.3.1: Illustration Demonstrating the Effect of Ceiling Height

There may be some areas of a facility where there are several spaces of the same approximate size and wit the same acoustic properties. For example, there may be an office space with multiple individual offices, all with one speaker each. If one or two are satisfactorily tested there is no need to test all of them for speech intelligibility.

A.1.3.6 Instruments that measure STI using a STIPA signal use a special signal that consists of signals in seven octave bands. The sound in each octave band is modulated using two (separate) modulation frequencies. The STI and STIPA have been standardized in IEC 60268. However, at the present time, the implementation of the measurement software and correlations with the test signal may differ between instrument manufacturers. Therefore, until there is further standardization only the test signal recommended by the instrument manufacturer should be used with their instrument. Although the STIPA test signals may sound similar, there may be speed or other differences that affect results if one manufacturer's test signal is used with another manufacturer's instrument.

A.1.4 Speech intelligibility is not a physical quantity like meters, feet, Amperes, Volts or even decibels. It is a benchmark of the degree to which we understand spoken language, and as such is a complex phenomenon affected by many variables (Ref: Jacob, K. & Tyson, T., "Computer-Based Prediction of Speech Intelligibility for Mass Notification Systems", SUPDET 2008, Fire Protection Research Foundation, Mar 2008). There are two basic categories of intelligibility testing: 1) Subject (human) based testing and 2) instrument based test methods. Test methods that use human subjects are only statistical predictions of how well speech might be understood at any other time for any other group of listeners. Several subject based test methods have been extensively researched, tested for reliability and standardized. Examples include the Phonetically Balanced (PB) word scores (256 words or 1000 words) and Modified Rhyme Test (MRT). (Ref: ANSI S3.2-1989, "Method for Measuring the Intelligibility of Speech over Communication Systems". Ref: ISO/TR 4870, "Acoustics – The Construction and Calibration of Speech Intelligibility Tests").

Subject based test methods can gauge how much of the spoken information is correctly understood by a person or group of persons for that particular test. When properly done, that resulting value is a prediction of how much of the spoken word will be correctly understood by others at some other time. Therefore, the results of speech intelligibility testing are usually described as predictions, not measurements. However, most users of the instruments refer to the results as measurements, not as predictions. Since the use of portable instruments is the more common method in the alarm and emergency communications industries, in this document, the results will be referred to as measurements to avoid confusion. However, in scientific and general acoustic literature, readers may see the measured values correctly referred to as predictions.

Several instrument based methods for predicting speech intelligibility have been extensively researched, tested for accuracy and repeatability, and the methods have been standardized, most notably the Speech Intelligibility Index (SII) (formerly the Articulation Index, AI), Speech Transmission Index (STI), and Speech Transmission Index for Public Address (STIPA) (Ref: IEC 60268-16, "Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index", 2003. Ref: ANSI/ASA S3.5, "American National Standard Methods for Calculation of the Speech Intelligibility Index", 1997). Accuracy is how close the meter corresponds to actual human test results. Thus, even though an instrument is used, the results are subjective in that they correlate to how humans perceive the quality of speech.

Each of the established methods for measuring speech intelligibility has its own scale. The Common Intelligibility Scale (CIS) was developed in 1995 to show the relationship between the different methods and to permit codes and standards to require a certain level of performance while permitting any of the accepted measurement methods to be employed (Ref: Barnett, P.W. & Knight, A.D., “The Common Intelligibility Scale”, Proceedings of the Institute of Acoustics, Vol. 17, Part 7, 1995). The Speech Transmission Index (STI) is widely used and has been implemented in portable equipment using a modified method called STIPA (STI Public Address). For this reason, the performance metrics cited in this document use units of STI with units of CIS in parentheses. The relationship between the two is: CIS = 1-log10 (STI). Relationships between other methods can be found in the literature (Ref: IEC 60849, Annex B, Sound Systems for Emergency Purposes, Feb 1998).

If an *ADS* is small enough to only require one measurement location (see the requirements for measurement point spacing), the result must be 0.50 STI (0.70 CIS) or more for the *ADS* to pass the requirement for speech intelligibility. This is based on the requirement for an average of 0.50 STI (0.70 CIS) or more in that *ADS*. Therefore, a single measurement of 0.45 STI (0.65 CIS) would not be considered acceptable, because that one measurement would be below the minimum required average of 0.50 STI (0.70 CIS) in that *ADS*.

If the value at that one measurement location were less than 0.50 STI (0.70 CIS), additional measurements could be taken at that same single measurement location. As with simple sound pressure level measurements, intelligibility measurements at any point will vary. If the average of all the measurements at that location were 0.50 STI (0.70 CIS) or more, the *ADS* would pass the requirement for speech intelligibility.

Some *ADS*s may require multiple measurement points due to their larger size. (See the requirements for measurement point spacing.) However, even in a small *ADS* where one measurement point would be permitted, a designer may intend that multiple measurements be made because of conditions that might result in specific points having intelligibility scores below the minimum. Where an *ADS* has multiple measurement locations, the requirement is that at least 90% of the measurement locations have value not less than 0.45 STI, (0.65 CIS) and that all measurement points average to 0.50 STI (0.70 CIS) or greater. This allowance reasonably assures that a listener can move within the ADS to a location where the speech intelligibility is acceptable.

The use of an average intelligibility score as a part of the requirement permits a wider range of measured values within an *ADS* than would a simple minimum requirement. A range of permitted values is not appropriate since there is no need for an upper limit for intelligibility – prefect intelligibility is certainly acceptable.

The requirement that only 90% of the measured points in the *ADS* meet the minimum and that the average for the entire *ADS* be 0.50 STI (0.70 CIS) or greater recognizes that in any space, with any system and any set of acoustic conditions, there may be points where the intelligibility score may be below the minimum. See also the discussion on the definition of an *ADS* and how some *ADS*s may be designated to not require speech intelligibility at all. For example, in a room that is otherwise similar from an acoustics standpoint, the space around a loud machine may be one *ADS* while the rest of the room is a separate *ADS*. The *ADS* surrounding the machine may be designed to have some form of occupant notification, but not to have intelligible voice communications. This type of *ADS* designation permits the remainder of the room to be scored without being penalized by the fact that intelligible communication near some loud sound sources may not be possible.

The intelligibility performance requirement cited herein intentionally uses two decimal points. Portable instruments that use the STIPA method for measuring the Speech Transmission Index (STI) generally have a precision on the order of 0.02 to 0.03 (Ref: Sander J. van Wijngaarden and Jan A. Verhave, Past Present and Future of the Speech Transmission Index, Chapter 9, Measurement and Prediction of Speech Intelligibility in Traffic Tunnels Using the STI, p113, TNO Human Factors, The Netherlands, 2002.). Other methods that measure STI may have a greater measurement precision. Other measurement methods, such as Modified Rhyme Test (MRT), Phonetically Balanced Word (PB) lists and Speech Intelligibility Index (SII) also have levels of precision in the hundredths when properly conducted and scored. However, there might be slight variations in measured values between any two meters or between any two persons taking measurements with the same instrument, or between any two listener panels when using subject based test methods. This is true for any measurement method or instrument, including simple scales for measuring length or mass.

Measurements should be made and recorded using two decimal places. Averages can be calculated to three decimal points and rounded. The calculated average value should be rounded to the nearest five-hundredths (0.05) to reflect possible measurement errors and the intent of the requirement (Ref: Mapp, P., "Systematic & Common Errors in Sound System STI and Intelligibility Measurements", Convention Paper 6271, Audio Engineering Society, 117th Convention, San Fran, CA, 28-31 Oct 2004. Ref: Peter Mapp, Past Present and Future of the Speech Transmission Index, Chapter 8, Practical Application of STI to Assessing Public Address and Emergency Sound Systems, TNO Human Factors, The Netherlands, 2002.). For example, averages of 0.475 – 0.525 STI would all be rounded to report an average of 0.50 STI (0.70 CIS). The minimum value permitted for all but 10% of the measurement locations in an *ADS* must be 0.45 STI (0.65 CIS) or greater. For example, values of 0.44 STI are below the minimum, they are not rounded up to 0.45 STI.

A.1.5 Fire alarm systems designed in accordance with UL 864 and fire alarm speakers designed in accordance with UL 1480 are only tested for and only required to produce frequencies of 400 to 4,000 Hz. Speech, however, includes a wider range of frequencies. Speech intelligibility measurements using STI and STIPA include octave band measurements that range from 125 Hz to 8000 Hz. STI results are most dependant on the 2000, 1000, 500 and 4000 Hz octave bands (in order of weighting) and to a lesser extent the 8000 and 250 Hz octave bands and to an even lesser extent, the 125 Hz band (again, in order of weighting).

While the lower and higher octave bands in STI calculations are weighted much less than the others, under certain acoustic conditions, systems that do not produce the highs and the lows can produce speech intelligibility that is less than desired. This does not imply that all systems should use equipment capable of greater bandwidth sound reproduction. While the larger frequency response will probably sound better and be more intelligible to a listener, it may not be necessary for the minimum desired performance. The use of equipment with higher bandwidth will require an increase in power supplies, amplifiers and wire sizes to drive the speaker appliances.

A.1.5.1 In areas where the ambient sound pressure level exceeds 90 dBA, speech satisfactory speech intelligibility is difficult to achieve with conventional communications equipment and design practice. A better system design might include alternate communications methods, such as signs and displays or might involve providing occupant notification, but not communication at that location.

A.1.5.2 Impulse sounds such as accidentally tapping the meter microphone, or a nearby door slamming may cause a measurement error. Some meters will display an Error message. If an impulse sound occurs during the measurement, consider taking another measurement to check the results. This process is analogous to ignoring temporary sound sources, as permitted by NFPA 72 when taking sound pressure level measurements.

A.1.6 The qualified staff should be identified on the system design documents. Acceptable evidence of qualifications or certification should be provided when requested by the authority having jurisdiction. Qualified personnel should include, but not be limited to, one or more of the following:

(a) Personnel who are factory trained and certified for fire alarm system design of the specific type and brand of system addressed by this test protocol;
(b) Personnel who are certified by a nationally recognized certification organization acceptable to the authority having jurisdiction; or
(c) Personnel who are registered, licensed, or certified by a state or local authority.

A.2.1.3 For example, until acoustical treatments such as carpeting, ceiling tiles and other furnishings are in place, the system may be partially tested to meet audibility requirements but not necessarily intelligibility requirements. Other test plans or mitigating procedures might be permitted.

A.2.2 As discussed in A.1.3.1, not all *ADS*s will require or be capable of intelligible voice communications. It is the designer's job to define areas that will have voice communication versus those that may have tone-only signaling as well as which spaces will have strobes, textual signage or other forms of notification and/or communication. This document intends that "notification" mean any form of notification, not just voice communication, whether audible, visual or using some other human sense.

There might be applications where not all spaces will require intelligible voice signaling (Ref: NFPA 72, National Fire Alarm Code, 2007, Section A.7.1.4). For example, in a residential occupancy such as an apartment, the authority having jurisdiction and the designer might agree to a system that achieves the required audibility throughout but does not result in intelligible voice signaling in the bedrooms. The system would be sufficient to awaken and alert. However, intelligibility might not be achieved in the bedrooms with the doors closed and the sounder in the adjacent hallway or room. In some cases this can require that messages repeat a sufficient number of times to ensure that occupants can reach a location where the system is sufficiently intelligible to be understood. Systems that use tone signaling in some areas and voice signaling in other areas would not require voice intelligibility in those areas only covered by the tone.

A.2.5 Buildings and areas of buildings that are not acoustically challenging such as traditional office environments, hotel guestrooms, dwelling units, and spaces with carpeting and furnishings generally meet intelligibility levels if the audibility levels are consistent with the requirements of NFPA 72, National Fire Alarm Code. Performing intelligibility testing might not be necessary in these areas. Areas of a typical building that may be acoustically challenging could include vehicle parking levels and large lobby areas with hard floors and wall surfaces, stairs and other spaces with high reverberation. Intelligibility meeting the requirements in this document may be difficult to achieve throughout these spaces. Specialized sound system design procedures, principles and equipment may be necessary to achieve speech intelligibility in high noise areas or areas with challenging acoustics. Alternatively, intelligibility could be provided near exits and within specific areas (elevator lobby of a parking level) where occupants can obtain clear instructions after being alerted. This is done, in part, by the proper planning and designation of *ADS*s.

Factors that influence the decision to measure speech intelligibility include:

Possible reasons not to test speech intelligibility:

- Distance listener to speaker less than 30 feet in the room (assuming proper audibility and low reverberation)
- Ambient sound level is less than 50 dBA and the average SPL of the voice message is 10 – 15 dBA fast greater.
- No appreciable hard surfaces (e.g. glass, marble, tile, metal, etc)
- No appreciable high ceilings (i.e. ceiling height equals speaker spacing at a ratio of 1:1 optimal or 1:2 max)

Possible reasons not to test Intelligibility, except possibly for spot sample testing:

- Space has been acoustically designed by individuals having skills sufficient to properly design a voice/alarm system for the occupancy to be protected. (e.g. space has been designed using commercially available computer modeling software acceptable to AHJ)

Possible reasons to test:

- Appreciable hard surfaces (e.g. glass, marble, tile, metal, etc)
- Appreciable high ceilings (e.g. atriums, multiple ceiling heights)

A.2.5.2 By definition, an *ADS* is relatively uniform in acoustic characteristics. However, speech intelligibility will vary at different points within an *ADS* depending primarily on distance to noise sources and distance to speaker appliances. Generally, in smaller spaces up to about 40 ft x 40 ft, one measurement location will be sufficient. The location should not be directly in front of a wall mounted speaker or directly under a ceiling mounted speaker. Neither should it be in the far corner right next to walls or windows. Generally, try to stay about 5 to 10 ft away from vertical surfaces that reflect sound. In larger spaces, a grid of about 40 ft x 40 ft can be used as a starting guide then adjusted for the locations of machines and other obstructions and for speaker appliance locations. See A.1.4 for additional discussion on measuring points and the averaging of results in an *ADS*.

A.2.6.2 Testing when the area is occupied and when the ambient sound level is at or near its expected maximum is preferred because it is easier. However, it does involve playing of a test signal through the emergency communications system for the duration of the test. When testing using the STIPA signal, the signal is a continuous noise signal. Other methods that measure STI use a swept tone that must be repeated for each measurement location. The alternate procedure is to test and save the STI measurement data during un-occupied times, measure and save the un-occupied sound level and then take and save ambient sound level measurements during occupied times. The three data sets are combined by software to calculate the corrected STI for the area. Testing using this method requires three measurements at each measurement location, but does not subject occupants to constant test signals. The choice of testing occupied versus un-occupied for intelligibility is the same as for audibility testing of tone signaling systems and is based on convenience versus disruption of normal use of the space. However, unlike audibility testing, intelligibility testing is less likely to contribute to the Cry Wolf Syndrome because the test signal is not the same as the evacuation tone, which would be sounded throughout testing of a tone signaling system. [REF: Schifiliti, Robert P., "Fire Alarm Testing Strategies Can Improve Occupant Response and Reduce the "Cry Wolf" Syndrome," NEMA Supplement in Fire Protection Engineering, Society of Fire Protection Engineers, Bethesda, MD 20814, Fall 2003.] and [REF: Brezntiz, S., "Cry Wolf: The Psychology of False Alarms", Lawrence Erlbaum Associates, Hillsdale, NJ, February 1984.]

A.3.1.3 All audio test equipment, including ANSI Type 2 sound pressure level meters required by NFPA 72 for audibility testing, require regular calibration to known, traceable standards. The portable meters used to measure STI using the STIPA test signal must meet or exceed ANSI Type 2 meter requirements. In addition, the STIPA test signal and the meter algorithm for measuring the received signal and calculating the modulation transfer function to arrive at the STI must be tested by a certifying laboratory for accuracy to the IEC standard for STI.

A.4.1.2 By putting the STI or STIPA test signal into the system via the system microphone, the ECS system is being tested from end-to-end or source to target. If an ECS system has the test signal pre-recorded in its hardware, playback of that test signal would not be testing the microphone and the part that feeds the microphone signal into the system.

A.4.2 Of the two methods for setting the test signal input to the system microphone, the method that sets the level to match that of a person speaking into the microphone is the one required by IEC 60268-16, *Sound system equipment — Part 16: Objective rating of speech intelligibility by speech transmission index*, the standard that defines STI and STIPA.

In theory, the two methods for setting up the *Talkbox* should result in the *Talkbox* being set at approximately the same sound level. The ECS should be designed and configured so that input to the microphone results in the same output level that any pre-recorded announcements would produce.

A.4.2.1.4 An emergency command center will not be free of noise during an actual emergency. However, for testing purposes, the room should be relatively free of extraneous noises that could affect the results. The purpose of the tests is to establish the baseline capability of the system and acoustic environment to support intelligible communications. Good design practice for an emergency command center is to isolate the space so that only emergency command personnel have access. In addition the location of the microphone for manual input should be such that background discussions and noise are minimized.

A.4.2.2.4 The distance from the microphone to the *Talkbox* should be documented so that future tests can be set up consistently. Most microphone manufacturers or ECS equipment manufacturers will state a recommended distance for a person to hold the microphone when talking. Some microphone use chin guards or some physical means to help users know when they are holding the microphone at the correct distance. If the manufacturer has not recommended a talking distance, four inches is recommended as a guide.

A.4.2.2.5 A level of 60 dBA at one meter is required by IEC 60268-16, Sound system equipment — Part 16: Objective rating of speech intelligibility by speech transmission index, the standard that defines STI and STIPA and is considered a normal speech level. While 60 dBA at one meter is documented as "normal" speech, in areas where there is background noise, the Lombard effect causes a person to talk at an elevated volume. For this document, the committee chose to use 65 dBA as more representative of speech levels during emergency situations. It is recommended that at least one field STI measurement be made at both 60 dBA and 70 dBA at one meter talking level to test the effects of elevated voice level.

Sound pressure level increases 6 dB whenever the distance is halved. So, the test could be set up so that he *Talkbox* level achieves 65 + 6 = 71 dBA at a distance of ½ meter. The Table A.4.2.2.5 shows different dB levels at distances that would be equivalent to 65 dBA at one meter.

Table A.4.2.5.6 Audibility equivalent to 65 dBA at a distance of one meter

r (M)	r (in.)	L_P (dB)		r (M)	r (in.)	L_P (dB)		r (M)	r (in.)	L_P (dB)
0.00	0.1	117		0.10	4	85		0.28	11	76
0.01	0.2	111		0.13	5	83		0.30	12	75
0.01	0.5	103		0.15	6	81		0.50	20	71
0.03	1	97		0.18	7	80		0.61	24	69
0.04	1.5	93		0.20	8	79		1.00	39.37	65
0.05	2	91		0.23	9	78		2.00	78.80	59
0.08	3	87		0.25	10	77				

A.6.2 It is also not the intent of this test protocol to describe how to interpret results or how to correct systems or environments that contribute to poor speech intelligibility. However, depending on the instrument used, it may be possible to examine intermediate data retained by the instrument to determine possible causes and their effects on STI results. Consult with the instrument manufacturer to determine if the instrument has the capability to display or save the intermediate STI modulation indices and octave band measurement results and for instructions on how to interpret those data.

7) SUMMARY AND CONCLUSIONS

7.1) General.

This chapter summarizes the primary conclusions from this project. These conclusions are separated into the following three groups, from broad focus to narrow focus: Fundamental Concepts, Field Test Observations, and Draft Test Protocol.

7.2) Fundamental Concepts.

Conclusions relating to the fundamental concepts of intelligibility include:

a) The project has generated a repeatable Test Protocol that is a good measure of system performance, demonstrating that intelligibility can be readily measured in a practical manner.
b) The "where and when" to implement intelligibility testing has evolved to be the single most fundamental issue on this subject. Specifically, audibility (dBA) and intelligibility (STIPA) are separate and distinctly different characteristics and both are important. However, it may not be required to measure intelligibility in all areas, while it is more important that the system is audible in most or all areas.
c) The fire alarm industry has traditionally had a different design focus than acoustic systems (i.e. public address or music systems), and the advent of a test protocol may require a transformation of the industry to a different level of quality in terms of how these systems are designed.
d) The intelligibility measurements suggest that in some respects, intelligibility has a loose correlation to smoke propagation (ignoring smoke buoyancy). Intelligibility predictions drop significantly when the direct path for the sound is blocked by a physical barrier, such as with a door. The measurement in a particular five story stairwell had a speaker only at the bottom where it had its highest intelligibility reading, and as expected dropped off at each level moving upward toward the top floor. However, at the top of the stairwell it rose due to the noise banking at the top, similar to a smoke plume.

7.3) Field Test Observations.

Conclusions relating to the observations derived from all three field tests are:

a) All three Field Tests had specific acoustical challenges, including: tall ceilings (e.g. atriums), surface characteristics (e.g., glass, marble, tile floors, etc), and ambient background noise (e.g. machinery, crowd of occupants). The type of occupancy directly relates to the acoustical challenges, and thus is important.
b) Intelligibility predictions (measurements) were relatively strong in smaller tighter areas such as corridors and individual moderately sized rooms, but consistently challenged throughout in large open areas or areas with large ceiling heights.

c) The results of the field tests from a repeatability perspective showed a relatively acceptable level of consistency between the values recorded. There was some scatter in the data that was collected, but this was not unexpected and within acceptable tolerances.
d) While there are many variables affecting the intelligibility of speech, some are more challenging (e.g. rate of speech, etc) while others involve technical approaches that can be more readily standardized (e.g. using the STIPA test signal).
e) The degradation of intelligibility predictions can be the result of multiple factors, but for convenience these can be summarized in the following three groups: 1) signal to noise (S/N) ratio; 2) distortion; and 3) decay (e.g., echoes, reverberation, etc).
f) In one application two meters side-by-side from two different manufacturers were used, and no appreciable difference was noted in the predictions provided by each meter.

7.4) Draft Test Protocol.

Conclusions from the three Field Tests that directly affect the draft Test Protocol, in addition to the details that have been directly incorporated into the revised Test Protocol, include:

a) It was agreed that the pass/fail criterion should use a weighted average of 0.50 STI, with an absolute minimum measurement at any point of 0.45 (or other value acceptable to the AHJ).
b) Initial talkbox set-up is critical, and this needs to be standardized for repeatability of the test protocol. The “Microphone Input Method” rather than the “Direct Input Injection Method” for the Talkbox set-up is preferred (assuming there is a command center microphone), since it more realistically replicates actual conditions similar to fire service personnel speaking directly into a microphone.
c) A compromise was agreed to with regard to the test setup approach, and it was felt best to include and coordinate in the draft Test Protocol both the Matching Speech Level approach (i.e. Input-Based Talkbox), and Matching Recorded Message Level approach (i.e. Output-Based Talkbox).

8) RECOMMENDATIONS

The following are the recommendations from this report:

a) Additional work on the "where and when" question is needed, to determine the required levels of intelligibility. This is arguably the most fundamental item to that has not yet been fully resolved to come out of this project. This is as much a design question as a test question, with the underlying philosophical need to clarify how many notification appliances are needed, where should they be located, and how well do we expect them to perform? A need exists to more clearly indicate, for both design and testing purposes, where and when intelligibility, as well as audibility, are required for fire alarm and emergency communications systems in any particular occupancy.

b) Consider developing abbreviated field guidance to assist designers, users, enforcers, and others with judging the ability of an area to require and handle intelligibility. This is an extension of the preceding item, and would take into account the occupancy, building characteristics, occupant load, and other features in addition to the features of the fire alarm and emergency communications system. Specifically, it would be helpful to identify each of these features and clarify its importance and possible impact on achieving required levels of intelligibility.

c) Three field tests were conducted involving diverse occupancies. However, this is still limited information and has to be extrapolated to other occupancies. It would be helpful to continue collecting data for other occupancies to continue refining the Test Protocol.

d) Further study of the Talkbox set-up would be helpful to clarify the virtues of each of the two basic approaches: Matching Speech Level approach (i.e. Input-Based Talkbox), and Matching Recorded Message Level approach (i.e. Output-Based Talkbox).

e) Clarification is needed as to how different test measuring equipment from different manufacturers will function together. In particular, can the meters measuring intelligibility from one manufacturer be properly used with the Talkbox from another manufacturer?

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ANNEX A: DATA ENTRY FORMS

The following are the data entry forms used for field tests in this project, and they were refined over the course of the project.

SPEECH INTELLIGIBILITY TEST FORM A

Use **Form A** where STI/STIPA tests are conducted during occupied times with the normal expected background noise. Record the *occupied sound pressure level* in dBA, the dBA of the STI/STIPA test signal and the resulting STI or CIS value.
Use **Form B** where STI/STIPA tests are conducted during non-occupied conditions and the occupied ambient noise is measured at a different time and the results post-processed to get a corrected STI or CIS value.

Facility Name: ______________________________ **Date** ____________ **Page** ____ **of** ____

Facility Address: ______________________________

Tests Done By: ______________________________

Meter Id. & Calibration Date: ______________________________

Indicate whether measured values are in units of ☐ STI or ☐ CIS.

ADS	Point	Description (floor, room, etc.)	Ambient dBA	STI-STIPA Signal	
				dBA	STI/CIS

SPEECH INTELLIGIBILITY TEST ADS RESULTS (FORM A)

Figure A-1: Test Form A, Page 1 of 3

Use **Form A** where STI/STIPA tests are conducted during occupied times with the normal expected background noise. On this *Results* form, record the number of points measured in each ADS, the minimum measured STI or CIS value and the average STI or CIS value.
Use **Form B** where STI/STIPA tests are conducted during non-occupied conditions and the occupied ambient noise is measured at a different time and the results post-processed to get a corrected STI or CIS value.

Facility Name: ______________________________ **Date** ____________ **Page** ____ **of** ____

Facility Address: ______________________________

Tests Done By: ______________________________

Meter Id. & Calibration Date: ______________________________

Speech intelligibility is considered acceptable if at least 90 percent of the Acoustically Designated Spaces (ADS) have a measured STI of not less than 0.45 (0.65 CIS) and a average STI throughout the ADS of not less than 0.50 (0.70 CIS).

Indicate whether measured values are in units of ❑ STI or ❑ CIS.

ADS	Description (floor, room, etc.)	# of Points	STI/CIS		Pass/ Fail
			Min.	Ave.	
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F

Figure A-2: Test Form A, Page 2 of 3

SPEECH INTELLIGIBILITY TEST RESULTS SUMMARY (FORM A)

Use **Form A** where STI/STIPA tests are conducted during occupied times with the normal expected background noise.
Use **Form B** where STI/STIPA tests are conducted during non-occupied conditions and the occupied ambient noise is measured at a different time and the results post-processed to get a corrected STI or CIS value.

Facility Name: ____ **Date** ________________ **Page** ____ **of** ____

Facility Address: ____

Tests Done By: ____

Meter Id. & Calibration Date: ____

Indicate whether measured values are in units of ❑ STI or ❑ CIS.

On hold pending resolution of pass/fail criteria edits.

Figure A-3: Test Form A, Page 3 of 3

SPEECH INTELLIGIBILITY TEST FORM B

Use **Form B** where STI/STIPA tests are conducted during non-occupied conditions and the occupied ambient noise is measured at a different time and the results post-processed to get a corrected STI or CIS value. Record the *occupied sound pressure level* in dBA on the form below and save the measurement data in accordance with the meter manufacturer's instructions. Record the ambient sound pressure level immediately prior to conducting the STI/STIPA test in dBA on the form below and save the measurement data in accordance with the meter manufacturer's instructions. Record the dBA of the STI/STIPA test signal and the STI or CIS value for the test. Post-process the data to "add" the effects of the *occupied sound pressure level* to arrive at the resulting corrected STI or CIS value. The order of testing may vary except that the test ambient measurements must be under the same conditions as the ST/STI/PA tests.

Use **Form A** where STI/STIPA tests are conducted during occupied times with the normal expected background noise.

Facility Name: ______________________ **Date** __________ **Page** ____ **of** ____

Facility Address: ______________________

Tests Done By: ______________________

Meter Id. & Calibration Date: ______________________

Indicate whether measured values are in units of ❑ STI or ❑ CIS.

ADS	Point	Description (floor, room, etc.)	Occ. Amb. dBA	Test Amb. dBA	STI-STIPA Signal		
					dBA	Uncorr. STI/CIS	Corr. STI/CIS

Figure A-4: Test Form B, Page 1 of 3

Speech Intelligibility Test ADS Results (Form B)

Use **Form B** where STI/STIPA tests are conducted during non-occupied conditions and the occupied ambient noise is measured at a different time and the results post-processed to get a corrected STI or CIS value. On this *Results* form, record the number of points measured in each ADS, the minimum corrected STI or CIS value and the average STI or CIS value. Use **Form A** where STI/STIPA tests are conducted during occupied times with the normal expected background noise.

Facility Name: ______________________________ **Date** ____________ **Page** ____ **of** ____

Facility Address: ______________________________

Tests Done By: ______________________________

Meter Id. & Calibration Date: ______________________________

Speech intelligibility is considered acceptable if at least 90 percent of the Acoustically Designated Spaces (ADS) have a measured STI of not less than 0.45 (0.65 CIS) and a average STI throughout the ADS of not less than 0.50 (0.70 CIS).

Indicate whether measured values are in units of ❑ STI or ❑ CIS.

ADS	Description (floor, room, etc.)	# of Points	Corrected STI/CIS		Pass/ Fail
			Min.	Ave.	
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F
					❑P ❑F

Figure A-5: Test Form B, Page 2 of 3

SPEECH INTELLIGIBILITY TEST RESULTS SUMMARY (FORM B)

Use **Form B** where STI/STIPA tests are conducted during non-occupied conditions and the occupied ambient noise is measured at a different time and the results post-processed to get a corrected STI or CIS value.
Use **Form A** where STI/STIPA tests are conducted during occupied times with the normal expected background noise.

Facility Name: ____ **Date** ________________ **Page** ____ **of** ____

Facility Address: ____

Tests Done By: ____

Meter Id. & Calibration Date: ____

Indicate whether measured values are in units of ☐ STI or ☐ CIS.

On hold pending resolution of pass/fail criteria edits.

Figure A-6: Test Form B, Page 3 of 3