QUEST TECHNOLOGIES

IS YOUR FIRE ALARM OR MNS EFFECTIVE?

SPEECH INTELLIGIBILITY

AUGUST 2007

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INTRODUCTION

Clearly understanding a live or a recorded mass notification system (or voice alarm system) during a fire or a threatening situation is essential for the safety of a facility's occupants.

What if you were in a 20-floor high rise building and the mass notification system announced a chemical spill in the building? The alarm system specifically advised the contaminated area was on the south-side of the 7th floor and advised to evacuate the building by using the north-side stairwell. If this was not intelligible, or clearly communicated, than lives could be lost. Ensuring safety of individuals is a number one concern for building owners.

This document is intended as a primer to understand how speech intelligibility is measured and addresses the following: basic principles of sound and speech path, factors influencing the test, how and what to test when deploying STI-PA testing, scales (or measurement results) to consider, what the standards recommend, and possible solutions to low test results.

SOUND WAVES

Understanding sound

External background noise (or overall sound pressure level) can distract one's attention and interfere with verbal communication. Ultimately, background noise can mask (or hide) speech. Understanding what sound is and the range of sound the human ear detects is an important component of how speech intelligibility is measured.

When sound is transmitted in the air, it creates alternating positive and negative pressures (compressions/rarefactions). Imagine playing a chord on a guitar. As it is plucked, the string will move over time. As the string moves to position 2, it compresses the air molecules. As it moves to the last position, it rarifies the air molecules.

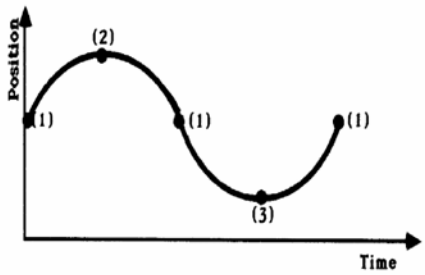

Figure 1: Sound pressure wave

This compression and rarefaction causes sound. The diagram above shows one sound wave cycle.

Range of Speech

The human ear is capable of responding to frequencies ranging from approximately 20 Hz to 20 kHz. This range is also generally considered the range of speech.

Critical elements of speech

Speech encompasses two elements (or spectra). The first spectra are the sounds we hear which is referred as the sound path. This spectrum covers a wide range of frequencies from about 100 Hz to 10 kHz and detects the lower-mid frequency ranges instead of the higher frequencies. The range is represented by seven octaves which has center bands ranging from 125 Hz to 8 kHz.

The second element of speech is referred to as the modulation spectrum. The sound we hear in speech is not only composed of the sound path over the octave bands; but, it is also composed of words. These words can be broken into syllables and phonemes. These phonemes are at a low modulating frequency and are called the modulation spectrum.

Speech Comprehension

Imagine sitting in a large, outdoor band shelter with the hum of car engines, distortion from the speakers, and ambient noise from the audience shouting and clapping around you. An announcement is broadcasted over the PA system and you strain to catch the intent of the message.

The listeners speech comprehension is diminished by the ambient noise and the distortion of the system. So, how does one ensure that a message is clear and intelligible in all situations?

The best methodology is to measure the "intelligibility" of the system.

SPEECH INTELLIGIBILITY

STI-PA Testing

In essence, any noise which masks the talker-to-listener path is evaluated and a recommended measurement is computed at the end of an intelligibility test.

Speech intelligibility testing is a method to measure if a mass notification system (MNS) is clear, precise, and audible or *intelligible*. One type of quantitative test used to measure speech intelligibility is called Speech Transmission Index - public address (STI-PA).

NFPA-72 defines STI-PA

According to the NFPA-72, "a mass notification system is designed to alert and protect people. The desirable system provides protected personnel with concise, accurate, timely, and well-directed messages that communicate how they should behave during a variety of emergency situations" (cited from NFPA-72: "National Fire Alarm Code®", 2002 Edition).

FACTORS INFLUENCING STI-PA

Determine intelligibility of a MNS

People interpret and decipher speech even over background noise, also referred to as "signal-to-noise" ratio.

With the speech transmission index testing, there are a handful of factors that are accounted for during a study which are:

- **Signal-to noise ratio** - is the comparison (or ratio) of the intended signal to the amount of the noise (or unintended sound). Usually, indicated mathematically as: $\frac{S}{S+N}$
- **Reverberation** - A collection of sound reflecting or diminishing to the original source. This is typically the case in large, enclosed buildings such as gymnasiums, auditoriums, or sport arenas where sound reflects or echoes off of the surrounding environment and slowly decays as sound is absorbed by the walls and air, creating reverb time.
- **Distortion** - is any unwanted sound due to an alteration in the sound . If there is a significant source of distortion, such as distortion from an amplifier or speakers, this will diminish the clarity of speech/message.

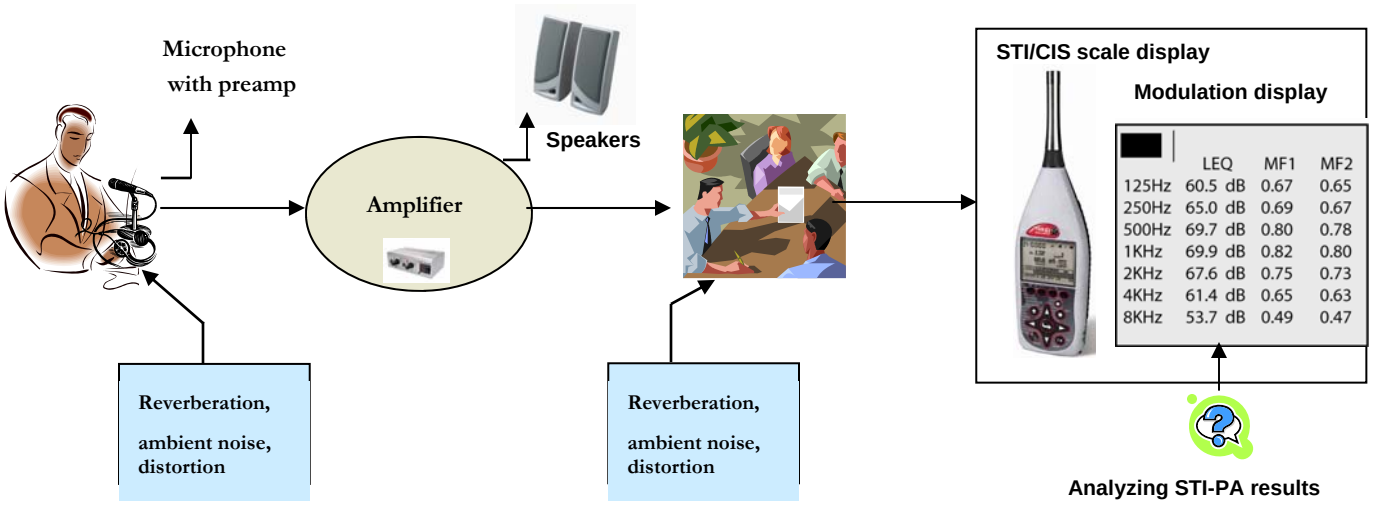

Figure 2: A look inside testing a Mass Notification System (MNS) and factors influencing a typical testing environment.

MEASURING STI-PA

A test signal is played through a mass notification system (PA system). The test signal is made up of 7 octave band signals which encompasses a combination of vowels and syllables from common speech. There are 14 modulating frequency tones that emulate your speech pattern. This is referred as the modulating transfer function (MTF).

With the STI-PA test signal enabled, the frequency is determined in combination with the range of fluctuations in speech (from the simulated speech-like signal) and incorporates interfering noise (i.e., distortions, signal-to-noise ratio, and reverberation). The average of the MTF is computed and the results is a value between 0 and 1 which represents the quality or intelligibility of the mass notification system.

What does the MTF represent?

MTF values indicate if the appropriate level of modulation in a speaker's voice is at a good level from the perspective of the listeners receiving the message. A high MTF value indicates the listeners received the message with no distortions or interference. A low MTF represents a considerable reduction of intelligibility from a combination of reverberation and/or masked noise.

Causes of STI-PA reduction

From MTF values, you can assess the cause of reduction of an intelligibility test. If the study reveals constant MTF values, this represents the cause as background noise. If the study displays decreasing MTF values, this indicates reverberation. MTF values which decrease and then increase signifies an echo present in the intelligibility testing.

SETTING UP A STI-PA TEST

There are a couple key factors to consider when setting up a speech intelligibility test.

1st Factor: Zones

First factor is to consider, "where do I measure speech intelligibility?" A building or stadium can be broken into rooms or "zones". Each "zone" has a room with one or more alarm points. In some situations, one room may have more than one alarm point or may have a change in ceiling height (such as various hotel rooms or an atrium or a balcony seating versus lower level seating). In those instances, each section would be considered a zone and each zone would be tested.

2nd Factor: Building Map

After determining the "zones" in your building, it is recommended to design a map of the key zones/ rooms. Generally, a zone is a 20X20 ft area. If the room is larger than 20X20 ft, it is recommended to take another measurement in this section. Some buildings have hundreds of rooms, such as hotels, and have similar built rooms. In these situations, you would take measurements in the various classes of rooms such as in a standard room, executive room, and banquet halls.

WHEN TO CONDUCT A STI-PA STUDY?

Scenario 1

You are at a facility which will not be disrupted by playing the test signal through the PA system during the peak time or "normal" time of the day/night. In this scenario, you would set the meter to STI-PA and select either STI scale or CIS scale and run your study at your zone areas.

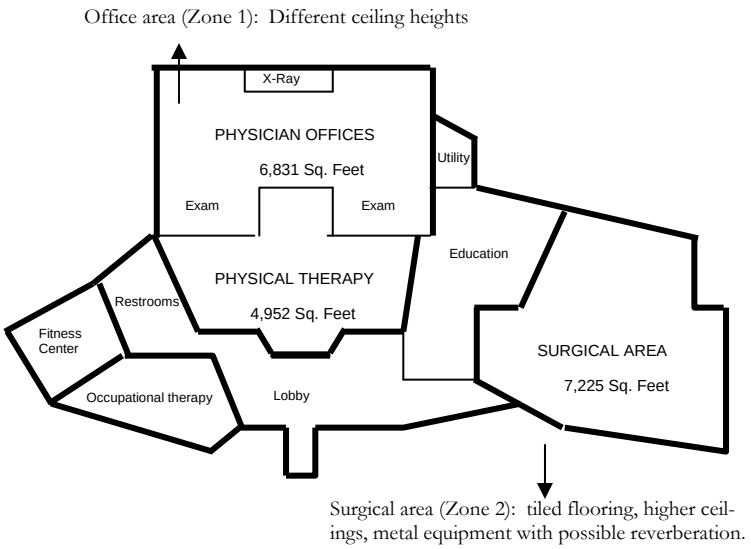

Figure 3: Areas/Rooms
Different types of rooms are considered "Zones" and each area is typically tested for speech intelligibility. For buildings with similar zones, such as a medical center , rooms in different classifications are each tested (i.e., exam room, physical therapy room.)

Scenario 2

In other situations, running a test tone through a PA system during business hours could be distracting and not feasible for your environment. In this situation, it is recommended to follow the steps outlined below.

STEP 1: First, take sample background noise measurements during business hours using Quest's Verifier or SoundPro meters in the designated zones. The meter will save up to four "captured curves" and will store them in the "post processing" field of the STI-PA menu.

STEP 2: Second, using the meter, select the appropriate captured curve you wish to apply during your off-hour testing.

STEP 3: Enable the test signal and run your speech intelligibility tests in the applicable zones.

✍ ***Note:*** *Since you selected a curve in step two, it will automatically factor in the results of the STI-PA results. If you wish to change the curve in different zones, see step 2 and then proceed to step 3.*

STI SCALE OR CIS SCALE?

Both Speech Transmission index scale (STI) and Common Intelligibility scale (CIS) measurement methods are practical and highly time efficient with 15 second run-time results. According to the NFPA-72 code and IEC-60849 Annex A (International Electortechnical Commission), these are both highly accurate, quantitative methodologies.

While NFPA-72 recommends that Mass Notification Systems (MNS) should be intelligible, for gerneral practices and methodologies it references the IEC-60849 and the IEC60268-16 standards as the sources for characteristics, computing, and measuring intelligibility.

STI

The STI-value (speech intelligibility index) is a weighted average of the response to the fluctuating modulation frequencies. The results are illustrated in Figure 4 below.

STI is a measurement scale which indicates single value results in which ***zero*** correlates with ***complete unintelligibility*** and ***one*** equates to ***perfect intelligibility.*** Figure 4 is a guideline to understand the STI rating scale.

STI	00 - 0.30	0.3 - 0.45	0.45 - 0.60	0.60 - 0.75	0.75 - 1.00
scale	Unacceptable	Poor	Fair	Good	Excellent

Figure 4: STI Scale

CIS

Another method to report intelligibility results is to use the Common Intelligibility Scale (CIS) . It was created to map all methods (i.e., STI, percentage of articulation loss of consonants, word lists) to the same scale so that results could be compared.

Generally, if the results of CIS scale is ***zero*** this indicates ***complete unintelligibility***. The opposite side is a value of ***one*** correlates to ***perfect intelligibility***. A CIS rating of .7 corresponds to an STI value of .5.

CIS	00 - 0.48	0.48 - 0.65	0.65 - 0.78	0.78 - 0.88	0.88 - 1.00
scale	Bad	Poor	Fair	Good	Excellent

Figure 5: CIS Scale

QUEST'S STI-PA Meter

(Verifier or SoundPro SE or DL series with STI-PA option):

Instrument displays "Excellent" rating on a STI-PA scale with an 0.80 value. As indicated above on the graphical display, any STI value under .5 rating is considered "Poor" and not an acceptable intelligibility value (with a CIS scale, anything .7 or above is acceptable) according to NFPA 72 code .

WHAT DO THE CODES SAY?

Currently in the United States, there are four codes/standards which define speech intelligibility and also provide recommendations and methodologies to accurately test a mass notification system. The following standards may reference each other for specific terms and/or calculation measurements.

NFPA 72 code

The NFPA 72,"National Fire Alarm Code®", (2002) code 7.4.1.4 states that, mass notification systems (or emergency alarm systems) "shall be capable of the reproduction of prerecorded, synthesized, or live (i.e., microphone, telephone handset, and radio) messages with ***voice intelligibility***."

Figure 6: STI-PA results screen

NFPA 72 code (Continued)

The code then states, "voice intelligibility" should be measured in accordance with guidelines in Annex A of IEC 60849, Second Edition: 1998, Sound Systems for Emergency Purposes. When tested in accordance with Annex B, Clause B1, of IEC 60849, the system should exceed the equivalent of a common intelligibility scale (CIS) score of .70.

IEC standard

The (International Electrotechnical Commission) IEC 60268-16 (3rd Edition; 2003-05) recognizes and defines four methods to rate the quality of speech intelligibility that include: RASTI, STI, STITEL, and STI-PA. Of these four, the NFPA 72 code directly references STI measurement in Annex A and the CIS scale in Annex B, clause B1, of IEC 60849 standard.

ANSI standard

With the (American National Standards Institute) ANSI S.3.5—1997 standard, one can determine speech intelligibility by implementing the calculations, theory, and instructions from this code.

DOD code

The (Department of Defense) DOD Uniform Facilities Criteria (UFC) 4-021-01 Draft 20 (9/06) code is a detailed plan addressing the design, deployment, and annual testing of a mass notification system. This detailed document specifies that in the beginning fiscal year of 2004, "a mass notification system is required in all new inhabited buildings" (according to UFC 4-021-01, draft 20 9/2006).

As the NFPA 72 code references the IEC standard; likewise, the DOD's standard references the NFPA 72 as the source for "implementing national design standards".

OBSTACLES: LOW TEST RESULTS?

If low scores are revealed after testing, what are some corrective actions which you can take to make your system intelligible? A low STI or CIS value may indicate one of the following issues.

☒ Inordinate noise reverberation or echoes (see "A" below).

☒ Insufficient number of acoustical speakers or inadequate speaker coverage deployed uniformly in the buildings "zones" (see "B" below).

☒ Insufficient speaker power (see "C" below).

(A). One solution for echoes and excessive reverberation is to add sound absorbing materials such as drapes, more furniture, or ceiling tiles. This will help deter the reverberation and perhaps lead you to better STI-PA results. Another solution is to move suspended speakers closer to the occupants (i.e., like in a stadium or a church) and then lower the volume on the speakers.

(B). A solution to correcting inadequate speaker coverage is to increase the number of speakers in the building's zones or increase the power of the signal. Another option is to is to increase the speaker power and/or adjust the sound level based on the background noise.

(C). For insufficient speaker power, increasing the mass notification system's audio power and ensuring the building has adequate number of speaker coverage in each zone is a possible solution.

Other Obstacles

Some new buildings or renovated buildings may be tested initially before the building is completed. A word of caution: one should realize that if all the furnishings and installation of the flooring (i.e., carpeting) is not completed prior to testing, the results may either pass or fail depending on the situation. When there are changes in occupancy and ambient noise levels, a second test should be conducted in order to verify if the mass notification is indeed intelligible and compliant.

Emergency evacuation: ensuring your mass notification system is intelligible.

Figure 7: Up to Code?

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About Quest

Quest Technologies is a manufacturer of high quality instruments with customers in over 70 countries worldwide. Quest has built a strong reputation of rugged and reliable instrumentation and software systems that monitor and evaluate occupational and environmental health and safety hazards including noise, vibration, heat stress, indoor air quality, and toxic combustible gasses. Quest monitoring instruments serve a variety of occupations and industries with clients in mining, research, enforcement, military, education, insurance, and manufacturing business sectors.

The illustration below depicts obstacles that mask the quality of the speech path when conducting a STI-PA test. The first phase (A) addresses the presence of background noise in the building/environment. The test signal is then broadcasted through the mass notification system (or PA system) via speakers (refer to B and C). Internal noise, such as HVAC systems, quality of speakers, or reverberation on concrete walls, are factored in to determine the overall intelligibility of each zone (refer to D and E).

STI-PA measurement speech path

Evaluates speech spectrum and acoustic spectrum

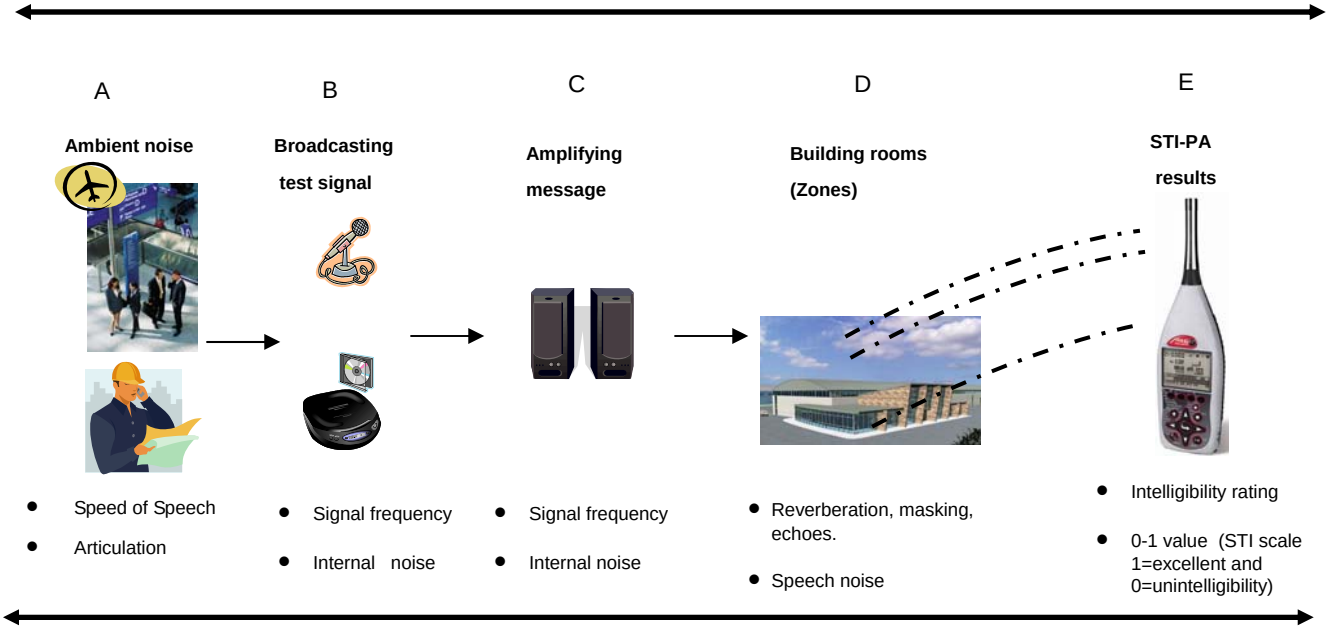

Figure 8: AT a Glance: Speech Path