THE AUDIO TOOLBOX

Analysts Firmware Package

User Manual

Version 4.07

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Introduction

This manual describe the use and operation of the functions in the Analysts Firmware Package.

Time Delay Analysis

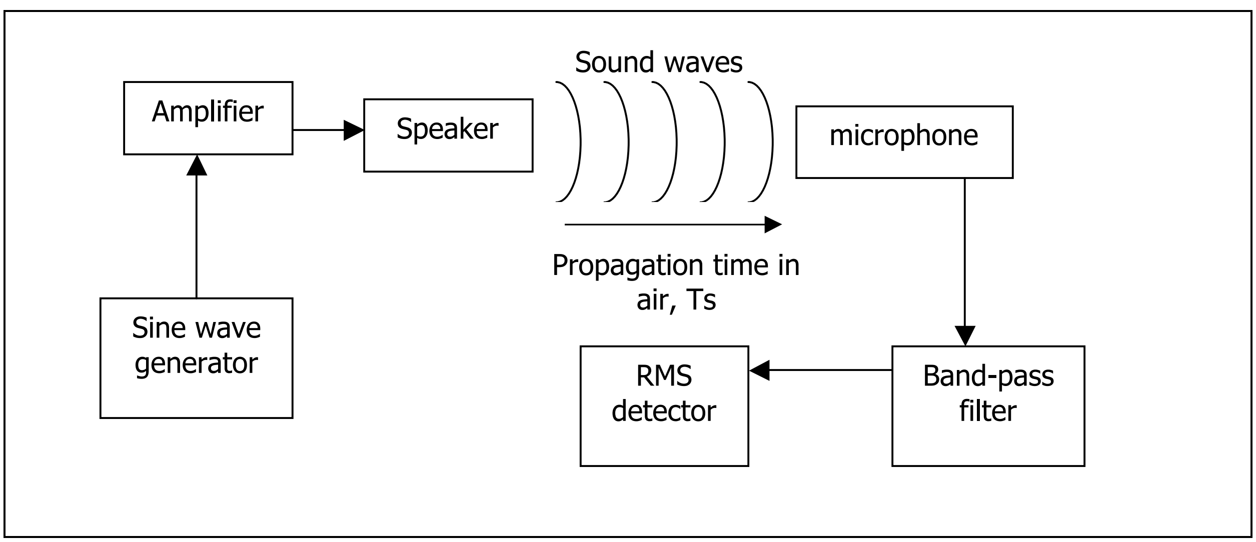
Description

Time Delay Analysis (TDA) is a method of testing the acoustic response of a system. TDA can be used to measure the response of a transducer, such as a speaker or a microphone, or an acoustic space. TDA is a noise-immune measurement technique, and can be used with success in both (somewhat) noisy environments, and reverberant spaces.

Although TDA runs completely self-contained in the Toolbox, transferring the TDA memories into TerraLink lets you view the graphs in 3D, increases the screen resolution, allows freely rotating the graphs and viewing them from other angles, and doing comparisons using reference graphs.

TDA Basics

As implemented in the Toolbox, TDA is measured directly, using a log swept sine wave output and a narrow band-pass filter on the input. To explain how TDA works, the diagram below shows the setup.



To use TDA properly, the time for the sound to travel from the speaker to the microphone must be known. This time is shown as Ts. The sine wave generator is swept through the region of the audio band we wish to examine, for example from 100Hz to 16kHz. If we did not have the band-pass filter, then all sound reaching the microphone would be summed in the RMS detector, and any noise or late-arriving signals due to reverberation or echoes in the room would contribute to false readings. With the band-pass filter sweeping with the generator, only the frequency currently being measured is summed by the RMS detector. Thus, noise is attenuated by the filter, resulting in more accurate readings.

However, since the sound arriving at the microphone is delayed by Ts, the band-pass filter sweep frequency needs to be delayed by Ts to match the arrival of the frequency being currently tested. Essentially, since the reverberant field contains all of the previously generated frequencies, attenuated at the RT60 rate, the filter allows the system to attenuate those frequencies and send to the RMS detector only the frequency currently being summed.

In the Toolbox, we use 1/12 octave data points for the TDA graphs. As the output sine wave is being swept, the input band-pass filter is also being swept, delayed by Ts. As each 1/12 octave boundary is reached, the RMS energy accumulated since the last boundary is recorded, and a new data point sum is begun. This adds a small amount (1/12 octave) of smoothing to the data.

The method described above is ideal for measuring the frequency response of speakers. In essence, TDA looks at the speaker as if it were in an anechoic chamber (ideally speaking), and so the effect of the room on the measurement is reduced. The amount of reduction depends on the steepness of the band-pass filter and the speed of the sweep. The filter in the Toolbox has variable Q (steepness), and can be set from a Q of 6 to a Q of 150. More information about filter Q and setting up the TDA function will be detailed in a section below.

Room Response

An interesting thing happens if the Ts time is increased. Say for example that the speaker was 1 meter from the microphone. Using the speed of sound in air, the time for sound to travel from the speaker to the microphone is 0.004 seconds, or 4 ms. If we add 100 ms to the Ts time, and delay the input filter by 104 seconds, the resulting graph shows the level of the swept sine wave 100ms after it is generated, or in other words we see what the sine wave looks like after decaying for 100ms. If this is subtracted from the Ts graph, the result is the amount of decay of sound in the room dB, by frequency. To see the decay at another time, just add that time to Ts and run the sweep.

Say now that we run 10 sweeps, each separated by 50ms. If the resulting 10 graphs are plotted in 3D, side by side, we get a good picture of the decay pattern of the room, by frequency, over time. Room modes appear as lobes that extend after other frequencies have decayed. The RT60 time for a particular frequency can be obtained by looking at the slope in the Z (time) axis for that frequency.

So, by running several sweeps we can get a 3D picture of the room response. This graph is sometimes called a waterfall graph.

Toolbox TDA Parameters

The TDA function on the Toolbox has a lot of flexibility. You can run one or more consecutive sweeps, page back and forth through the resulting graphs, use the cursor to inspect the graphs, and store them to the internal memories. You can set the distance from the microphone to the speaker, the offset time between sweeps, the Q of the filter, and the sweep rate in seconds per sweep. You can also specify the starting number of the sweep in memory, and the number of sweeps to run.

Setup Fields

When you first enter the TDA function, the Setup screen appears. This screen has the fields that you can use to setup the TDA test. Note that the Memory setup fields are on the main Run screen, so that you can manage memories and view their contents from the main screen with the graphical display.

The fields used to setup TDA are described below.

INPUT

As in other Toolbox acoustics functions, you can select the input source as MicL, MicH, ExtL, Ext, and ExtH. See the Toolbox documentation section on input ranges for more information.

INITIAL DELAY FIELD

You are required to enter the distance from the speaker to the microphone so that the TDA function can compute Ts and offset the input filter correctly with respect to the sweep generator. However, the value is not as critical as it is with some other Time Delay analysis methods, since we are sweeping an actual filter rather than deriving the response through a convolution of an impulse response, or determining response with a transfer function dual fft. These other methods require very accurate Ts measurements. With the Toolbox TDA method, an incorrect Ts time simply results in a graph that is shifted slightly on the frequency axis.

In the Toolbox TDA function, you can enter the distance in feet or meters. You can simply measure the distance with a tape measure, or you can use the Energy Time Graph to find the initial delay time.

SWEEP TIME

You can set the time for a single sweep from 7 to 30 seconds. Sweep time interacts with filter Q to define the space equivalent bandwidth, see below.

Since the sweeps roll continuously, you can let the sweeps run unattended, once the other parameters are defined.

SWEEP DELTA

This field controls the amount that each sweep after the first sweep is offset from the first sweep in time. Note that if you are doing a single sweep this field has no effect.

For example, if you want to create a set of waterfall graphs to show the decay pattern for a room, you may want 10 graphs spaced out in 50ms steps to show the first 500ms of decay. In that case, you would enter 50 in this field, along with 10 in the number of sweeps field. You may want less time resolution, if for example your room has a long decay time. You could create 10 graphs that cover 4 seconds by entering 250 in the Sweep Delta field. Each sweep would then be offset 250ms later than the previous sweep.

Note that the number of sweeps field is on the main Run screen, along with the other memory control fields.

Filter Q

The Filter Q field controls the steepness of the band-pass filter. A higher Q results in a filter with steeper slopes. In most cases, you will want to use a high Q value. A lower Q might be used to create a smoother curve, to see the big picture more easily. However, more information is shown with a higher Q filter.

Note also that the Toolbox TDA function uses a constant-Q filter. Other TDA platforms work with the equivalent of a constant-frequency filter. Constant Q can result in less problems with comb-filtering. See the section below on space equivalent bandwidth.

Offset Field

This field sets the amount of time to add between each sweep when running multiple sweeps. For example, to see one second of room decay response, in 10 curves, set the offset field to 100ms.

Gen Level Field

This field sets the generator level. The units are dBu.

Space Equivalent Bandwidth

In many cases it is useful to be able to control the distance beyond which TDA will reject input. In some systems this is called “time windowing”, referring to the time that it takes reflections to bounce off of surfaces. In TDA, we define a distance, called the “space equivalent bandwidth” (SEB). This distance is defined as the distance beyond which input is attenuated by at least 3 dB. This distance is a function of sweep speed and filter Q.

For example, with a Q of 36 and a sweep time of 8 seconds, the SEB is 7.3 feet. Thus, if your speaker is at least 7.3 feet from any other surface, the test results will effectively remove the effects of the room from the measurement. In fact, since the filter decays very rapidly, in many cases you will get good results at up to twice the SEB.

Also, the shorter the SEB distance, the more the rejection of spurious noise.

Space Equivalent Bandwidth is computed on the Setup screen and changes as you changed the fields that affect it (sweep speed and filter Q).

The formula for SEB is as follows:

SEB = B * [c / (df/dt)]

Where B is the filter bandwidth in Hz, c is the speed of sound, and df/dt is the sweep rate of the filter in units of Hz/sec. The units of SEB are the same as the distance units used in the speed of sound.

Run Fields

These fields are found on the main Run screen. Click on the word “Setup” to switch to this screen.

Run/Stop

Use this field to start the TDA test. To start a test, click to change the Stop to Run. To cancel a running test, click to change the Run to Stop.

TDA and Toolbox Memories

The TDA function can run up to 40 sweeps in a group and store them in the internal Toolbox memories. To understand how this works, refer to the screen picture as you read this section.

There are 4 fields that are used to control the memories used by the TDA function. The Memory field, which sets the starting memory number for a sweep, and is also used to view sweep graphs within a group, the Number of Sweeps field, which sets the number of sweeps to run and also is used to display the number of open memories following the starting memory number, the Delete Memories field ('x'), and the Store Memories field, which saves the memories in the flash chip. Unlike other Toolbox functions, you do not leave the TDA screen to work with memories, unless you need to delete non-TDA memories.

When you first enter the TDA function, all 40 stored memories are read from the non-volatile flash memory and are transferred to internal memory (RAM). As you run TDA sweeps the memories are stored in ram, and unless you save them into the flash chip before leaving the function, the new sweeps are lost.

You can store TDA sweeps only into blank memories. From within the TDA function, you can delete only TDA memories, so if there are not enough empty memory positions, you will need to erase memories before entering TDA. To do this, just drop into the Mem field on any function that supports memories, such as the RTA or FFT.

Memory Field

The TDA Memory field lets you scroll through all 40 memories. As you change from one memory number to the next, the memory type is shown next to the memory number. For example, if memory number 1 stores an RTA, you will see "RTA" next to the number. Blank memories show up as "---". A TDA sweep shows up as "T n", where n is the number of the sweep in the group of sweeps. Also, as you move through the memory numbers, the Sweeps field will always show the maximum number of empty memory positions available to store sweeps, starting with the memory number selected. Since the Toolbox will not allow you to overwrite stored memories, if you select for example an FFT memory, the Sweeps field will show 0. If, however, you have no memories stored, and you are on memory number 0, the sweeps field will show the maximum number of sweeps, 40.

Sweeps Field

The Sweeps field is used for 2 purposes: to display the maximum number of available sweeps, starting at the current Memory field number, and to set the number of sweeps that will be run consecutively when the TDA function starts running.

If you are measuring a speaker only, in most cases one sweep will be enough. But, if you are analyzing the decay of a room, you will want to do several sweeps.

Delete Memories (Del) Field

Clicking on the 'Del' field allows you to delete a set of TDA memories. A confirm box will appear to allow you to cancel the operation, or continue and delete the memories. All memories from the current TDA sweep through the last TDA sweep in the set will be deleted. Non-TDA memories cannot be deleted from this screen.

STORE MEMORIES (STO) FIELD

At any time, you can store the current memories back to the flash chip by clicking on the Sto field. A message will ask you to confirm storing all 40 memories. Note that if you do not store the memories before leaving the TDA screen, any data will be lost.

MEMORY EXAMPLE

For example, lets say you have an RTA in memory 5 and an FFT in memory 8, and a TDA sweep with 10 sweeps currently occupying memories 10 to 14. As you scroll through the memories using the Memory Field, you will see this values on the screen:

Memory number	Description	Sweeps Field
0	---	5
1	---	4
2	---	3
3	---	2
4	---	1
5	RTA	0
6	---	2
7	---	1
8	FFT	0
9	---	1
10	T 0	0
11	T 1	0
12	T 2	0
13	T 3	0
14	T 4	0
15	---	25
16	---	24
17	---	23
18	---	22
19	---	21

The reason that you see 25 in memory field 15 is that the Toolbox will only allow you to store TDA sweeps in unused memory positions. Of course, you can always change the Sweeps field to any value less than the maximum if you wish to perform fewer sweeps.

Working with TerraLink

The Toolbox TDA function is designed to work hand-in-hand with TerraLink. On the Toolbox screen, you can only see one sweep graph at a time. To understand a room response curve, you page back and forth through the memories and watch decay pattern, to see how the decay varies by frequency as you move through time. Although this works, seeing multiple graphs in 3D gives a much more intuitive and quicker understanding.

To use TerraLink for TDA analysis, just do the sweeps in the toolbox, store them in non-volatile memory, and transfer them to TerraLink. From TerraLink, you can bring up a set of TDA sweeps as a three-dimensional graph. The surface of the graph represents the decay curve for the room. You can rotate this graph and view it from the top, or look at in perspective. You can also switch between wire-frame view and solid view.

As with other TerraLink graphs, you can store TDA sweeps in project files on the computer hard drive, to keep an archive of TDA information, and to print or share with others.

You can also define a reference curve in TerraLink, and compare a TDA curve against the reference. This is particularly useful for doing production line testing of transducers, such as speakers and microphones.

How to Use TDA to Measure Speaker Response

- **Connect the output** Connect the output of the Toolbox to an amplifier and to the speaker that you wish to test. It is advisable to have a gain control at or before the amplifier, since the only way to control the speaker level during the TDA testing is to switch to the signal generator function and set the level from there.
- **Setup the microphone.** Mount the microphone on a mic stand and point it at the speaker. The microphone should be as far as possible from any solid surface, to minimize reflections. The TDA filters will help eliminate reflections, but they will work better given better input. Determine the speaker to microphone distance, either by measuring, or by running the Energy Time Graph. Enter this number in the TDA distance field. Set the input field to MicL, unless you are running extremely high SPL levels.
- **Set up the speaker.** Set the speaker at least 4 feet from any surface.
- **Set the Initial Delay.** Set this field to the distance to the speaker.
- **Set the offset field.** This field has no effect since we are only running 1 sweep.
- **Set the sweep time.** Start with 8 seconds. This is a good trade-off between SEB and low frequency energy.
- **Set the filter Q.** Set this field to 36.
- **Set the generator level.** Set the Gen Level field to an appropriate level.
- **Select a memory.** Use the TDA memory field to locate a free memory. You need only 1 free memory location.
- **Set the number of sweeps.** Set this field to 1.
- **Run the test.** Click on the S to change it to R. The sweep will begin.
- **Read the results**. Check the graph for level. If you get the word "Overload", reduce the speaker volume. If you get "Low input" or the level is below 60dB or so, raise the speaker volume. You can read the results directly on the screen using the cursor.
- **Store memory**. If desired, click STO to store this sweep into the internal flash memory.

How to Use TDA to Measure Room Response

- **Connect the output** Connect the output of the Toolbox to an amplifier and to the speaker. It is advisable to have a gain control at or before the amplifier, since the only way to control the speaker level is to switch to the signal generator function and set the level there.
- **Setup the microphone.** Mount the microphone on a mic stand and point it at the speaker. Determine the speaker to microphone distance, either by measuring, or by running the Energy Time Graph. Enter this number in the TDA distance field. Set the input field to MicL, unless you are running extremely high SPL levels.
- **Set the Initial Delay.** Set this field to the distance to the speaker.
- **Set the sweep time.** Start with 10 seconds.
- **Set the filter Q.** Set this field to 17. This will result in a smoother set of graphs.
- **Set the generator level.** Set the Gen Level field to an appropriate value.
- **Select a starting memory.** Use the TDA memory field to locate a free memory with enough available sweeps for the series of graphs. At least 6-10 sweeps will probably be useful.
- **Set the number of sweeps.** Set this field to the number of sweeps that you want to run, as determined in the step above.
- **Run the test.** Click on the S to change it to R. The sweep will begin.
- **Read the results**. Check the graph for level. If you get the word "Overload", stop the test and reduce the speaker volume. If you get "Low input" or the level is below 60dB or so after one sweep, stop the test and raise the speaker volume. You can read the results directly on the screen using the cursor. You can use the memory field to page through the stored graphs once the test is complete. Thus, you can quickly scroll back and forth to observe the pattern of decay of sound in the room.
- **Store memory**. If desired, click STO to store this set of sweeps into the internal flash memory. Then, you can transfer these memories into TerraLink for further analysis and viewing.

How to Use TDA to Measure Microphones

- **Connect the output** Connect the output of the Toolbox to an amplifier and to the speaker. It is advisable to have a gain control at or before the amplifier, since the only way to control the speaker level is to switch to the signal generator function and set the level there.
- **Setup the microphone.** Mount the microphone on a mic stand and point it at the speaker. Determine the speaker to microphone distance, either by measuring, or by running the Energy Time Graph. Enter this number in the TDA distance field. Set the input field to MicL, unless you are running extremely high SPL levels.
- **Set the Initial Delay.** Set this field to the distance to the speaker.
- **Set the sweep time.** Start with 20 seconds. Use a longer time for the most accurate results, or a shorter time for a quick reading.

- **Set the filter Q.** Set this field to 50.
- **Set the generator level.** Set the Gen Level field to an appropriate value.
- **Select a memory.** Use the TDA memory field to locate a free memory.
- **Set the number of sweeps.** Set this field to 1.
- **Run the test.** Click on the S to change it to R. The sweep will begin.
- **Read the results**. Check the graph for level. If you get the word "Overload", reduce the speaker volume. If you get "Low input" or the level is below 60dB or so, raise the speaker volume. You can read the results directly on the screen using the cursor.
- **Store memory**. If desired, click STO to store this sweep into the internal flash memory.

Multi-Band RT60

Description

This function allows you to quickly test 9 bands of RT60 times with one measurement.

Theory

The Toolboox multi-band RT60 is a direct rather than derived measurement. It works by pulsing wide-band pink noise on and off, applying octave band filters to the input, and measuring the decay time for each octave band.

How to Use

- **Setup the test**. Connect the Toolbox output to an amplifier and speaker. Setup the Toolbox microphone as far as possible from the speaker, but avoid setting up the microphone near any room boundaries or large objects, if possible. Also, if the room being tested will be used with a sound system, you may want to route the Toolbox output through this system. Just make sure that there is no EQ or signal processing such as compressors or limiters in the signal path.
- **Set the speaker distance**. Enter the distance between the microphone and speaker. Just get to within +/- 0.3 meters for good results.
- **Set the cycle time**. This field controls the time between cycles (tests). For higher reverb times, set a larger value.
- **Adjust the levels**. Set the RT60 mode to Min. This will measure the residual room noise level. You will get the best results in a quiet room. After the dB levels settle down, switch to Max mode. This will turn on the signal generator and pink noise will routed to the output. Adjust the amplifier level to get as loud a signal as possible, without overloading the input or distorting the signal chain or speaker. You will see the decay range displayed while you are setting up this test. The higher the value, the better. At least 30dB is recommended to get good results. 40 ro 50dB is better.
- **Run the test**. Change the mode to run. The pink noise generator will be cycled on and off. As results are computed, they will be averaged for more accurate readings. Allow several cycles, to let the readings stabilize.
- **Read the results** When the results have settled down, change the mode to Hold. This way you can read the results off the screen directly, in ms.

Applications

Determine RT60 times for a room quickly.

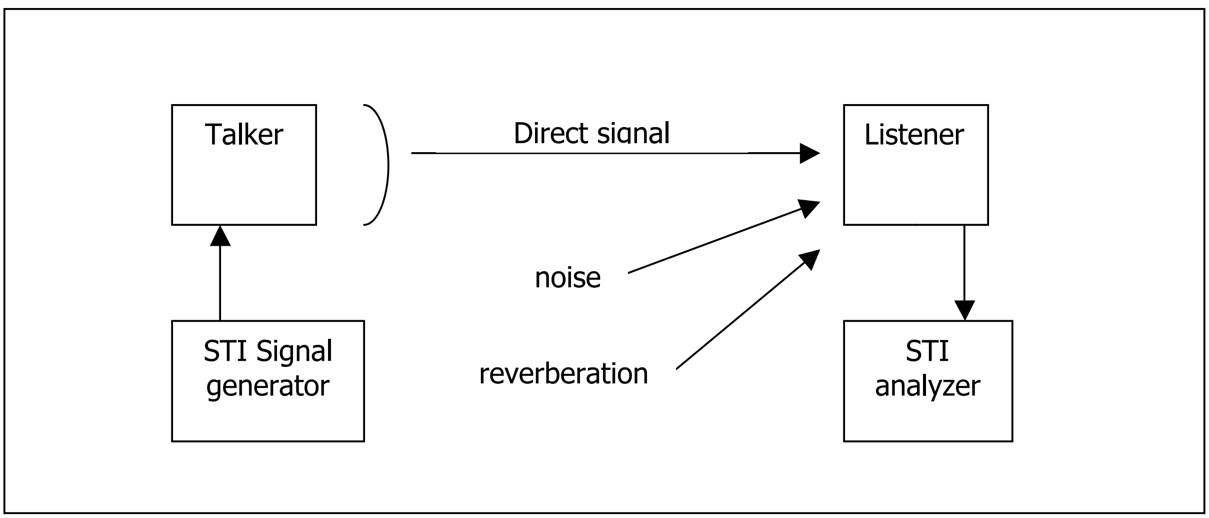
STIPA

Description

STIPA is a speech intelligibility measurement derived from the more extensive STI standard. STI specifies 98 data points, each an octave band of pink noise modulated by a slow sine wave envelope. Octave bands from 125Hz to 8000Hz are specified, and for each octave band, up to 9 different sine wave modulations. For a single data point, imagine generating octave band pink noise and changing the volume from off to maximum to follow a slow sine wave. The combined STI signal for a set of points sounds like a steam locomotive.

For each data point, the amount of the modulation that is lost in an acoustic space is measured, either directly or indirectly, and from this "loss of modulation" the speech intelligibility is derived. Things that can affect loss of modulation are primarily reverberation time in the room and the noise level, in the particular octave band being analyzed.

After the modulation loss numbers have been computed for each data point, they are combined mathematically to arrive at a single value. This value is referred to as "STI" and ranges from 0.0 (no speech intelligibility) to 1.0 (best possible speech intelligibility.



STI TEST SETUP

STIPA is a subset of STI that uses 9 data points, spanning the 125HZ to 8000Hz octave bands, but using only one modulation speed for each data point. STIPA has been shown statistically to correlate well with STI, even though it has 1/10th the data points.

The Toolbox STIPA implementation is unique, using our own STIPA excitation signal and proprietary DSP algorithms for determining loss of modulation. In use, the TerraSonde STIPA test signal is played, typically from a CD, and the signal is sampled for 15 seconds. The STIPA value is calculated and shown on the screen.

How to Use

To use STIPA, you need to play the STIPA test signal through a speaker, and then use the Toolbox microphone to measure the STIPA signal in the room. If you are testing a specific installed system, such as a fire evacuation sound system, send the signal through the system amplifier and speaker.

- **Setup the connections**. Connect the STIPA test signal to the speaker system. Play the test signal and adjust for appropriate level. In some cases, a test level SPL will be specified. Otherwise, typically a nominal level such as 70-80dB SPL is used.
- **Start the test.** Click on the Run field to begin the test. Wait for 15 seconds for the test to complete. While the test is running, the test microphone should remain in the same position, and the noise level in the room should remain stable.
- **Read the results.** After the test is complete, you will see a set of signal to noise (s/n) and m values. Also, the final STI value is shown. If a condition was detected that prevents getting an accurate value, you may see the message "low input" or "overload" on the screen, and the data values are not shown.

Applications

Evacuation sound system speech intelligibility tests.

ADA compliance.

Function Unlock Procedure

Description

Each function in the Analysts Firmware package is unlocked individually. Unlock codes may be purchased from TerraSonde for just the features that you need. You will need to supply the serial number for your unit to get an unlock code.

How to unlock a function

- **Obtain unlock code.** Get your unlock code from TerraSonde. You will need to supply the serial number for the unit or units that you need unlock codes for. Each Toolbox requires a unique unlock code, and the codes for each function within a Toolbox are unique.
- **Enter unlock code.** Go to the Settings function, under the Utilities menu. Select the Unlock sub-menu. Select the function name in the field. Now enter each of the 8 digits in the unlock code field. A digit may be the numbers 0-9 and the letters a-f. Just click on the field and spin the encoder to set the digit.
- **Save the code.** When you exit the Settings screen the unlock codes that you have entered will be stored into the flash memory chip. The codes will stay in non-volatile memory, and will not be disturbed, even if you upgrade the firmware in your Toolbox.

> Note: If you change to another firmware package, for example standard or *Studio firmware, you will need to re-enter your unlock codes when you re-load the Analysts Firmware.*

You can now use the functions that you have unlocked.