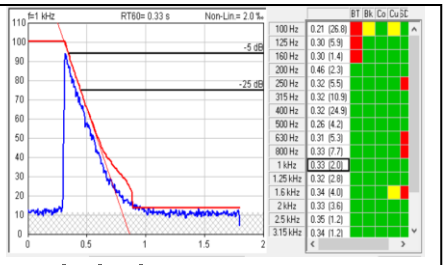
RT60 Reverberation Time



Technical note

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Premise

With the publication of the new series of UNI EN ISO 16283 standards, the entire reference system for building acoustics measurements in operation has been completely rewritten.

In relation to the evaluation of reverberation time, the normative reference referred to by these new standards is constituted by UNI EN ISO 3382-2-2008.

Version 3 of NoiseWorks contains the procedures and calculation methods required by the ISO 16283 series and supports the measurement of reverberation time as required by ISO 3382-2.

Reverberation Time Measurement in NWWin3

The measurement of reverberation time has always been included in the NoiseWorks software as a basic function since the first versions; over the years the calculation algorithms have been improved and various types of control have been added aimed at reducing the various artefacts often produced by this type of measurement.

In 2008, with the arrival of ISO 3382-2 which provided a more accurate definition for the calculation parameters of reverberation times, many manufacturers of sound level meters decided to include in their instrumentation also the specific functions dedicated to the direct measurement of reverberation.

As a consequence, it was necessary to adapt the data import functions of NWWin3 to support reverberation measurements acquired directly from sound level meters and considering the particularity of the measurement, it was also thought to add the possibility of direct control of the sound level meter to allow complete management via.

Managing Reverberation Measurements in NWWin3

In NoiseWorks there are 3 distinct modes of handling reverberation time measurements:

- Real-Time Execution Mode
- Direct import mode
- Post-processing mode

In Real-Time execution mode, the NWWin3 software completely controls all the measurement phases of the Larson Davis LxT, 831 or 831C sound level meter in order to allow a predefined sequence of interrupted noise or impulse acquisitions, from which the reverberation times for the individual octave or 1/3 octave bands are then automatically calculated and displayed in both graphic and numerical form, complete with 5 quality indicators to indicate the correct execution of the measurement.

With the direct import mode, the NWWin3 software connects via USB interface to the Larson Davis 831 or 831C sound level meter and in the ‘RT60 Measurement’ mode, the reverberation measurement files previously acquired in the field are downloaded directly with the sound level meter equipped with the appropriate 831-RT option.

The post-processing mode was added to NWWin3 more recently, in order to allow a recalculation of the reverberation times on measurements already acquired previously or calculated directly by the sound level meter. The same mode can be used to correct a posteriori, some particularly critical situations that have escaped the various controls of the automatic calculation algorithms.

The post-processing function is also able to extract the reverberation time directly from the ‘time histories’ regardless of whether it is interrupted noise, impulsive excitation or whether they are made up of single events or sequences of multiple events.

REAL-TIME MODE

The Real-Time mode for measuring reverberation time involves controlling the sound level meter connected to the PC.

To open the window that allows direct connection to the instrument, start from the Start menu and locate the NWWin3 group; inside it, select the command “LD LxT - 831 – 831C”.

Connect to the instrument and select the RT60 Mode from the Measure tab of the multifunction bar. In the window that appears, select “Executing a new measurement in Realtime”.

The settings window opens as in Figure 1, where the operator has the possibility of setting the basic parameters for the RT60 measurement.

- Octave Band measuring in 1/1 octave or 1/3 octave.
- Set the lower and upper frequency band.
- Type of sound source between interrupted noise or an impulsive signal.
- The acquisition speed as ‘Delta time’, selectable between 2.5, 5, 10 and 20 milliseconds.
- The frequency band on which to detect the threshold level to activate the trigger; usually the 2.5 or 3.15 kHz band is recommended to reduce frequent voice interference.
- The trigger threshold level for event recognition, which should not be understood as a maximum value but as an average value; suggested values can be 55 - 65 dB for interrupted noise and 65 – 75 dB for impulses.
- The Pretrigger duration should be set between 0.3 and 0.5 seconds, while the Measure duration should be set in relation to the presumed maximum reverberation time and increased by 1/4..

The “Schroeder Backward Integration” option is activated only for the Signal Type is Impulse to impulse (Integrated impulse response method, point 5.3 of ISO 3382-2).

The “Accept all new measurements automatically” option deactivates the request for operator consent to accept or reject each individual measurement during the measurement; in construction sites where random disturbances are common, this function allows you to reject an acquisition contaminated by extraneous noise.

Fig.1- RT60 measurement parameter setting window

The “Use average of decays between positions” function performs the average between the decays detected in the individual microphone positions as ‘Ensemble Averaging’ (preferred method point 5.2.2 of ISO 3382-2) or as a recalculation on a new decay curve obtained from the synchronized average of the individual samples of the decays of each measurement position. By deactivating this function, the average reverberation time between the microphone positions is calculated as a simple arithmetic mean.

2.3 RT60 acquisition and calculation

Once the basic setting of the measurement parameters is completed, by pressing ‘OK’, a graphic/numeric window will open ready to start the acquisition of measurements for the direct calculation of the RT60 reverberation time.

The sound excitation source, whether interrupted noise or pulsed, is controlled separately; the Trigger function allows the measurement system to detect the excitation sound signal and automatically capture its decay. This solution allows greater operational freedom in the field, not tying the control of the noise source to the measurement system. (no cable between the sound level meter and the sound source).

To start the Real-Time measurement of the reverberation time, just click on the “Run” button and activate the interrupted noise source or generate an impulse; once the sound event has been identified, the NWWin3 software automatically extracts the portion of the signal useful for the calculation and represents it graphically in terms of the decay of the ‘time history’ of a 1/1 or 1/3 octave band, as shown in Fig.2.

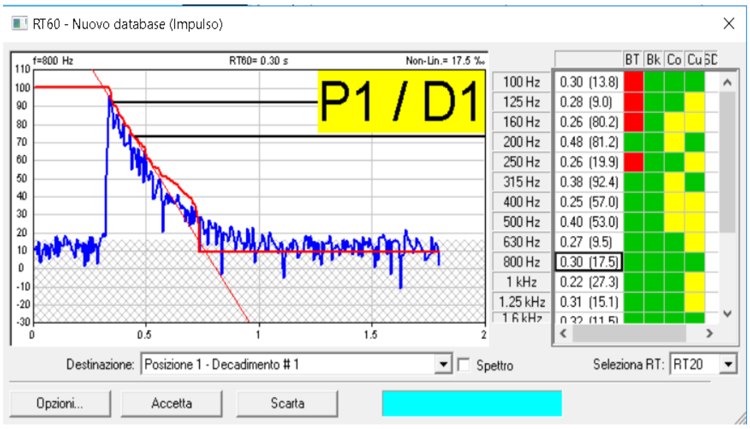

Fig.2- T20 decay window at 800 Hz, single pulse excitation.

The operator can now click on the reverberation times shown in the table on the side and for each frequency band, he will have the possibility to observe the corresponding decay; to the right of the numerical table, the condition of 5 quality indicators is shown with the colors green <ok>, yellow, <attention> and red, <problems>, always referable to the requests of ISO 3382-2.

If the judgment on the quality of the measurement is poor in relation to either the observation of the decays or for the quantity of red squares in the indicator map, the operator can click on the 'Discard' button and repeat the acquisition generating a new sound event.

In favorable measurement conditions, it is possible to deactivate the control function for the acceptance of individual measurements and thus it is possible to perform excitation / acquisition sequences more quickly in the various microphone stations. Once the acquisition sequence is finished in the first station, it is sufficient to click on 'Stop' to then activate with a subsequent 'Run' the new sequence relating to station number two and so on.

At the end of the acquisition sequence, the average reverberation time spectrum of the entire environment is available, which can be verified as the average decay for individual frequency bands or as the average for each microphone position or even for each individual acquisition, so that it is easy to trace back to identify any anomalous decay and eliminate it from the global average.

The graph in Fig.3 shows the decay of the same 1/3 octave band of 800 Hz already displayed in Fig.5, to highlight the effect of the average of the decays operated by the 'Ensemble averaging' function; the decay in Fig.5 is very jagged compared to the same one in Fig.6, captured after an average of 9 'D9' decays performed in 3 different 'P3' microphone positions; in the numerical table, the number indicated in brackets after each reverberation time refers to the correlation coefficient between the calculated linear decay and the result of the Backward Integration curve; the lower this index, the more accurate the calculated RT60 value is, compared to the measured decay curve. In the reported case we can see that the reverberation at 800 Hz was equal to 0.30 seconds with a 'non-linearity' of 17.5% and became 0.32 s with a non-linearity reduced to 2.0% after an average on 9 x 3 = 27 decays. Also note the difference in the comparison between the two quality indicator maps, almost all green for the averaged measurement except for three red squares at 100, 125 and 160 Hz for the BT>16 indicator (ref.: point 7.3 of ISO 3382-) since these measured reverberation values are lower than the electrical response time of the corresponding 1/3 octave filters. (for example, for the 100 Hz band the minimum filter time would be about 0.7 s while the measured one is 0.60 s)

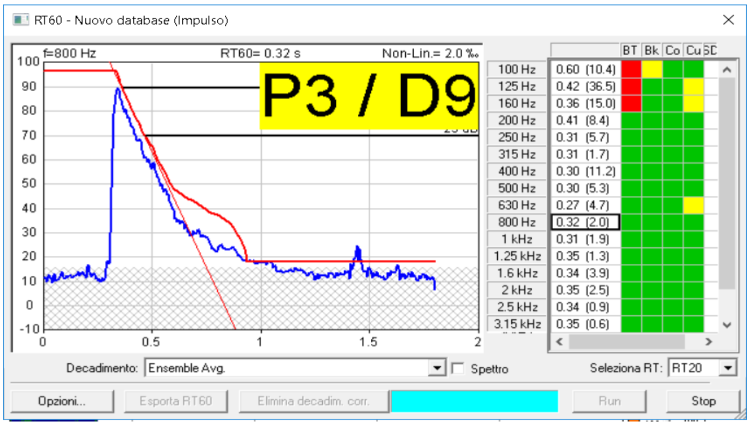

Fig.3- Average of decays. Average of the ninth pulse D9 in position 3, P3

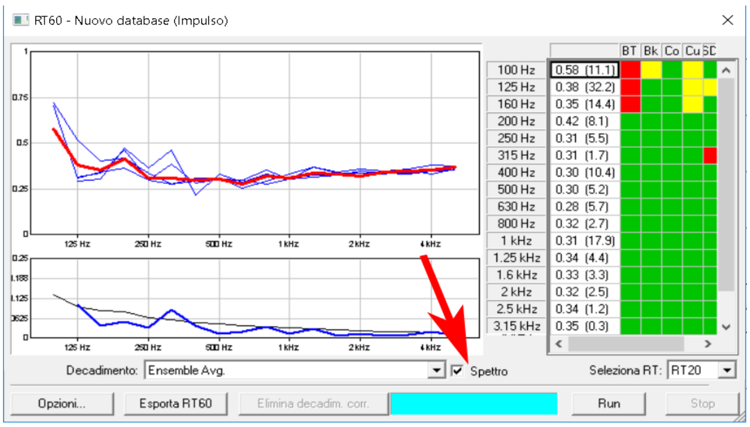

Fig.4- Reverberation time spectrum with standard deviation.

By checking the 'Spectrum' box, shown in Fig.4, you switch from the graphic mode that displays the decays, to the mode that displays the reverberation spectrum with the corresponding 'Standard Deviation'.

The reverberation spectrum is shown in a graphic where the bands in 1/1 or 1/3 octave are indicated on the x-axis and the scale in seconds is shown on the y-axis. The average spectrum is shown with a red trace, while the blue traces of the average spectra corresponding to each microphone station are superimposed; this graphic mode allows an easy comparison to verify whether there have been obvious anomalies in the calculation of the reverberation on the various frequency bands and, if so, which of the measurement stations was involved.

To examine all the reverberation spectra corresponding to the global average (ensemble averaging) or to those of the individual stations or to select any spectrum with artifacts, to be eliminated from the average, you need to open the selection window called “Decay” and then scroll up or down to select the desired element.

RT60 with impulse noise and result correction

The example shown highlights some of the prerogatives associated with the graphical representation of the results and the quality indicators, used to identify various forms of problems that can interfere with the common automatisms used for the calculation of reverberation time measurements.

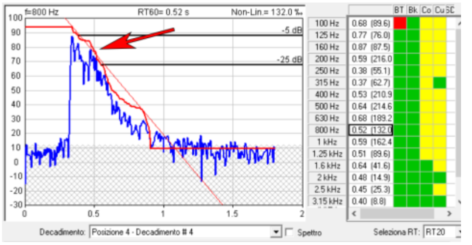

Fig.5- Decay with impulsive disturbance.

In the case in question, only one measurement out of 20 was affected by an external impulsive noise, which overlapped with the acoustic excitation impulse generated by a clapper; the decay at the frequency of 800 Hz is shown in Fig. 5, where the interference on the decay, caused by the extraneous noise impulse, can be observed indicated by the red arrow; the quality indicators ‘Co’ correlation coefficient and ‘Cu’ decay curvature indicator highlight a ‘yellow’ attention state for almost all frequencies.

However, if we look at the influence of this single disturbed measurement on the averaged set of all the other 19 measurements, Fig.6, we could consider it negligible, since the indicators ‘Cu’ and ‘Co’ have once again returned to ‘green’, although for the frequencies from 315 to 1500 Hz the standard deviation gives us an alarm index. At 800 Hz the averaged reverberation is equal to 0.35 s while previously in the disturbed measurement it was equal to 0.52 s.

Moving on to the visualization of the average of the reverberation spectra, reported in Fig. 7, it is possible to note that while the spectra of three microphone stations give superimposable results, the spectrum of position 4 indicated by the red arrow, gives significantly higher values, for all those frequency bands where the quality indicator 'standard deviation' highlighted the alarm condition in red. The graph placed under the reverberation spectrum, reports the standard deviation values for frequency band superimposed on an ideal curve that indicates the expected values for diffuse field conditions; the blue trace of the standard deviation should never be higher than the black reference curve, at least for the frequencies higher than the Schroeder frequency which in the case in question is set at approximately 250 Hz.

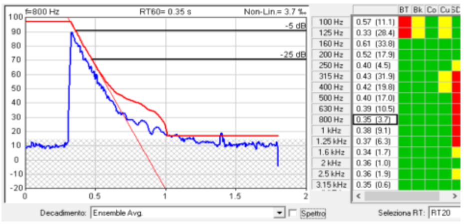

Fig.8- Average of decays with disturbance

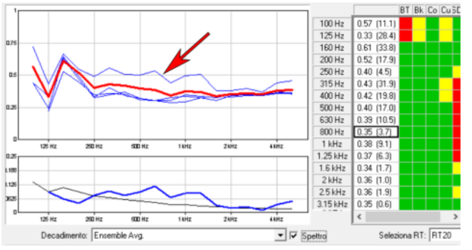

Fig.7- Average RT60 spectrum with noise

In Fig.8 the reverberation spectra of position 4 are represented, that is, those containing the measurement with the disturbance, which is selected here and indicated with the black dotted curve. The interference on the other measurements detected in the same position is very evident in relation to the average spectrum, reported with the red trace.

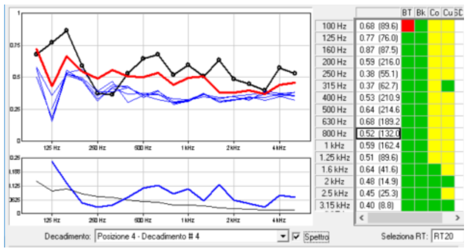

Fig.8- RT60 spectrum position 4 with disturbance

Fig.9 finally shows the situation where the measurement with the disturbance has been removed with the “Remove Current Decay” button, obtaining a map of quality indicators that is almost completely green and a standard deviation graph completely below the ideal reference curve.

RT60 with interrupted noise

The Real-Time execution mode allows to measure the reverberation time both with impulsive excitation and with interrupted noise; although impulsive excitation, together with the impulse integration method or 'Backward Integration', is the most practical, fast and most accurate system, when reverberations have to be evaluated for frequencies lower than the 100 Hz band, excitation by interrupted noise should always be preferred, better if provided by two sources and two separate noise generators..

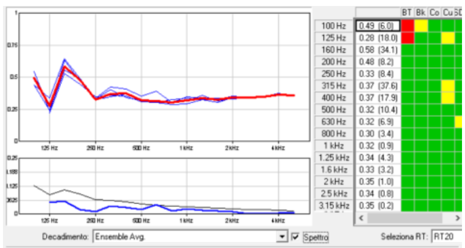

Fig.9- Average RT60 spectrum without noise.

When using interrupted noise, it is however important to keep in mind some important rules to avoid possible sources of artifacts in the RT60 calculation.

Generally, the major problems with the use of interrupted noise excitation arise when measurements are performed in small environments with regular walls, such as most common domestic rooms; in these situations it is better not to use a high acquisition speed but for example to choose a speed of 20 ms rather than 5 ms; with this choice one tries to reduce the fast fluctuations of the noise level present on the low frequency bands; these fluctuations together with the response modes of the environment at low frequencies, can generate difficulties in synchronizing the overall averages and difficulties in finding the point where the signal is interrupted or in defining the point from which one must start the decay calculation discarding the first 5 dB.

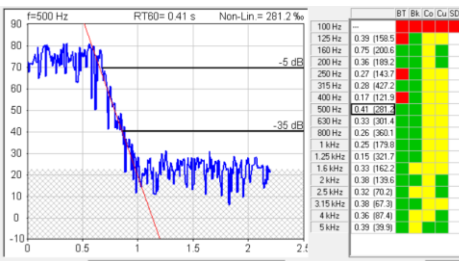

Fig.10- RT60 noise interrupted delta 5 ms

The example reported in Fig.10 highlights the typical situation relating to the decay on the 500 Hz band of an interrupted noise, acquired with a sampling every 5 ms; level fluctuations even higher than 10 dB are evident.

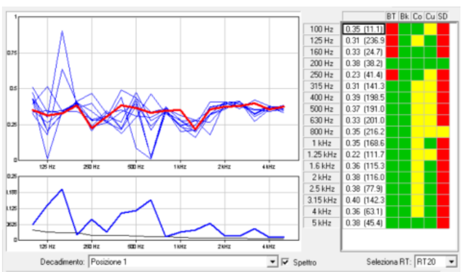

Fig.11- Delta 5 ms interrupted noise spectrum

For these evaluations of the RT60 with interrupted noise, the corresponding reverberation spectra for the individual 10 measurements and for their average are reported in Fig.11; the dispersion of the results is significant, highlighted in yellow by the indicators 'Co' correlation coefficient and 'Cu' curvature indicator as well as by the indicator 'SD' standard deviation, red for almost all frequency bands and well above the reference curve, as can be observed in the corresponding representation (lower graph).

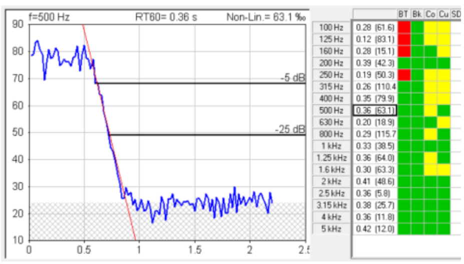

Fig.12- RT60 noise interrupted delta 20 ms

Fig.12 shows the same measurement reported in Fig.10 but acquired with a sampling of 20 ms; with a slower sampling, all the fluctuations present on the decay of the noise signal are practically cancelled and the definition of the starting points at -5dB and the end of the calculation at -25dB are now identifiable without uncertainty.

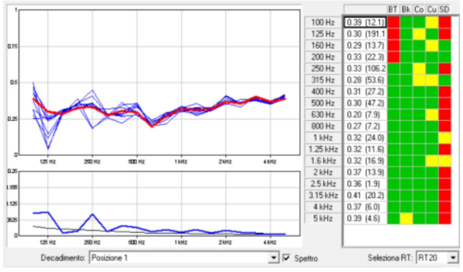

Fig.13- Delta 20ms interrupted noise spectrum

The result as reverberation spectra of the single measurements and their average for a 20 ms acquisition is shown in Fig.13 where by comparing the situation of the various quality indicators with the corresponding ones in Fig.15 it is possible to realize the improvements obtained simply by adjusting the sampling time, while a similar comparison with the indicators in Fig.13 gives further confirmation on the better reliability of the results using the integrated impulse method compared to the interrupted noise method.

DIRECT IMPORT MODE FROM SOUND LEVEL METER

The Larson Davis 831 sound level meter has a specific ‘RT60’ option that allows direct measurements to be taken for reverberation time evaluation; this option stores the reverberation measurements in the sound level meter’s memory as files with the RA Room Acoustics extension..

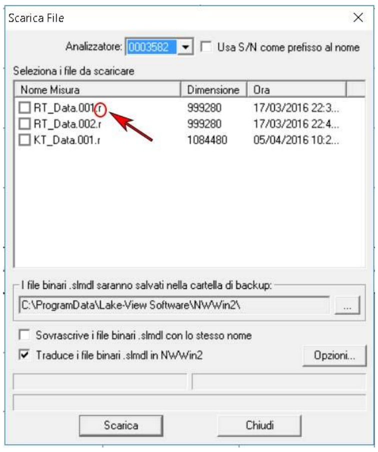

Fig.14- RT60 file selection on the 831

With the sound level meter connected, download the measurements performed in RA mode, as shown in figure 14.

All RT60 files relating to reverberation measurements generated directly in the field using the ‘RA’ option of the 831 sound level meter are not directly compatible with the NWWin3 software; they must first be displayed in RT60 mode of the NWWin3 831 driver in order to convert them to the required format.

Converting ‘.r.slmdl’ files

To proceed with the conversion of ‘.r.slmdl’ files, use the “Load r.slmdl” command from the ribbon.

If the file is loaded correctly, the entire measurement structure is reported with a subdivision of the measurement positions and the number of measurements for each position; the operator still has the possibility of checking a second time each single decay and the average of the decays for the various measurement positions to then decide whether to transfer the complete reverberation measurement of all the single decays or only for the reverberation spectrum as RT20 or RT30 to the basic module of NWWin3.

POST-PROCESSING MODE

In this mode it is possible to build the RT60 measurement starting from the original time history measurements and directly extracting the decays. The program allows to have one or more decays in each time history.

To create the new reverberation time measurement, use the “Reverberation Time” command from the ISO tab of the ribbon.

As shown in Fig.16, set the desired parameters for the new reverberation time measurement.

Once the new measurement is created, use the “Add” button to include the decays found in the time history measurements; a window opens as in figure 17.

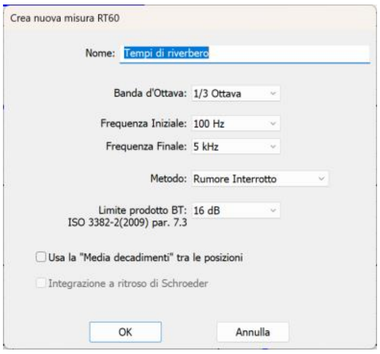

Fig.16- Setting new RT60 measure.

The “Microphone Position” drop-down window indicates to which position the imported time histories will be added. When the RT60 measurement is new, only the “>>> Add new position” text can be selected; this item must be selected later to start a new position.

The drop-down window at the bottom called “Selection Mode” contains the items “Full”, “Fixed length” and “Variable length”. The Full item is the one to be used when the time histories contain only one decay.

By selecting one of the listed time histories, the corresponding trace over time can be observed in the graph, with the decay of the linear global level. If the time histories have only one decay each, it is possible to select more than one “time history” and perform a multiple insertion in one shot.

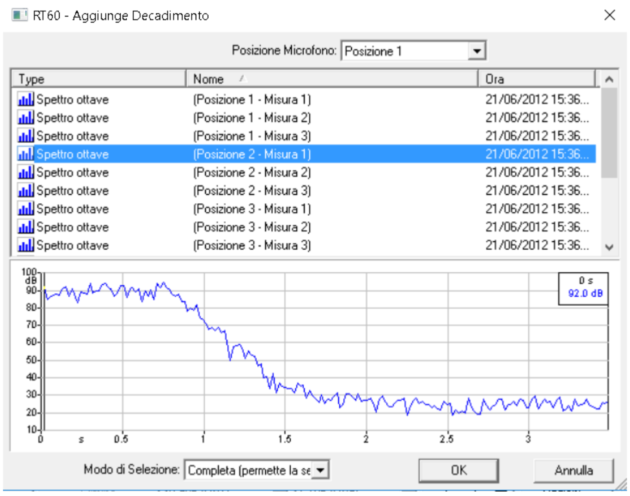

Fig.17- RT60 Time History Selection Window

To obtain the reverberation time calculation, it is now sufficient to click on the ‘OK’ button; the selection window will be closed and the RT60 window will be updated as shown in Fig.18, with the results of the reverberation time calculations conducted on the selected time history.

The RT60 window is now complete with a numerical table showing the reverberation values for each 1/3 octave band, together with the corresponding correlation coefficients shown in brackets, followed by the quality indicators, displayed with the colours red, yellow and green on a five-column grid in relation to the problems detected in the calculation. In the same window it is possible to display one or more profiles of the various decays in graphic form; the selection of the frequency band of the graph is done by clicking on the reverberation time shown in the numerical table. The display of multiple graphic windows, each for individual frequency bands, can be selected in the ‘combo box’ which shows the items: ‘Single’, ‘Multiple 2x2’, Multiple 3x3’, ‘Multiple 4x4’ and so on.

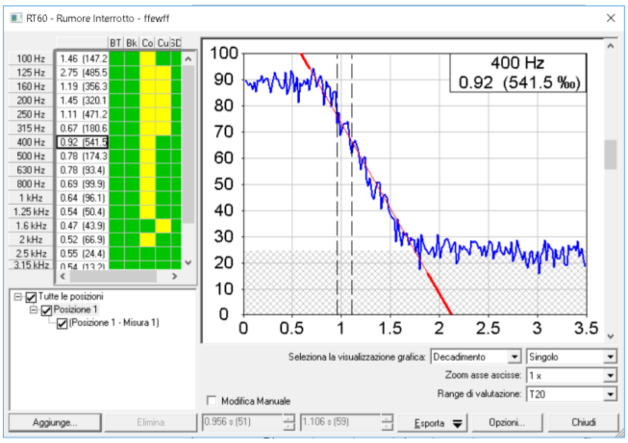

Fig.18- RT60 calculation results on selected time history.

The “Evaluation Range” field allows you to view the results of the calculation performed on a decay range of 20 dB (T20), rather than on 30 dB (T30), always discarding the first 5 dB of decay; if the automatic identification of the calculation points, used to determine the best decay line, should fail, for example as in the case of a correlation coefficient that is too high such as that indicated in Fig.18 in brackets equal to 541.5 %o, it is possible to enable the ‘Manual Edit’ function and drag the two cursors along the decay line using the mouse to select the positions best suited to minimizing the correlation coefficient. Interventions with the ‘Manual Edit’ function are generally more frequent on calculations performed on single decays obtained with interrupted noise than those obtained with the impulse method.

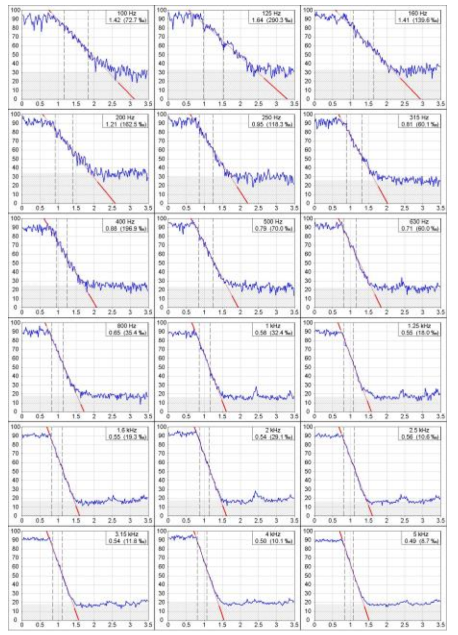

Fig.19- Export as .jpg

The export function allows to generate image files in JPG, DIB, BMP, WMF format with the complete series of all decays as shown in Fig.19; exporting as TXT or DIF generates a data file containing the RT60 values for each frequency band in addition to the corresponding Standard Deviation.

In the RT60 calculation window, in correspondence with the item ‘Select Graphic Display’, choosing ‘Spectrum’ rather than ‘Decay’, it will be possible to display the reverberation time spectrum in graphic form with the abscissa axis in third octave bands and the ordinate axis in seconds; under the reverberation spectrum graph, the graph of the standard deviation between measurements belonging to the same position or between the various measurement positions is inserted, in relation to the selection that the operator can make on the window relating to the measurement structure, positioned at the bottom left; in the standard deviation graph, a thin black curve indicates the ideal response condition for a diffuse field; the standard deviation of the complete reverberation time measurement should always show standard deviation values not higher than the reference curve reported, at least for all frequencies higher than the Schroeder frequency of the measured environment.

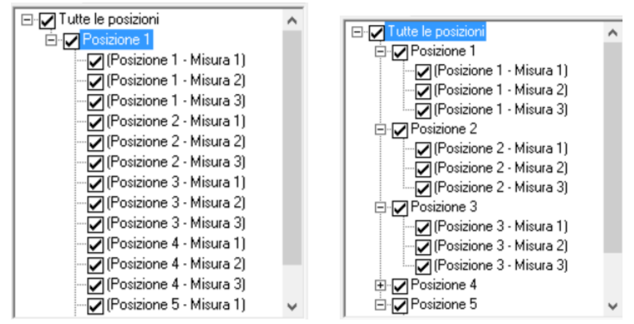

Fig.20- RT60 measurement structure, position / measurement.

The organization of the structure for the calculation of the RT60 is decided by the operator during the selection of the previously imported measurement files; the operator can decide for a simple sequential structure as shown in the left table of Fig.20 or follow the criterion of dividing the measurements based on the different microphone positions distributed in the environment as shown in the right table, or even based on a different positioning of the sound source.

The tree structure that displays the complete organization of the measurement, shows a 'checkbox' corresponding to each measurement or group of measurements that allows the operator to control the influence of each measurement or group of measurements on the final result or even to permanently eliminate a measurement altered by artefacts.

At the end of the operations, the window is closed by clicking on the 'Close' button. If the measurement has been modified, you will be asked if you want to keep the changes. You then return to the basic module of the NWWin3 software where the new measurement generated with the RT60 calculation module is reported in the list of the 'Document Content' window.

If ‘T20’ was selected when closing the RT60 module, then the exported RT60 values will be those corresponding to a calculation on the first 20 dB of decay, if ‘T30’ was selected, then the RT60 values will be those of a calculation performed on 30 dB of decay. (Norms usually require the value of ‘T20’).

RT60 calculation in NWWin3 on multiple decays

The following example refers to the import of files with time histories containing multiple decays or with sequences of impulsive excitations or series of successive ignitions and interruptions of the sound source with interrupted noise; it does not matter whether the events are temporally equally spaced or at random distances.

Why consider the calculation of reverberation on time histories containing sequences of impulsive or interrupted noise sound excitations? In general, to simplify the acquisition procedures for this type of evaluation; for example, it is sufficient to have a sound level meter capable of acquiring spectra in 1/3 octave with a cadence of at least 10-20 ms. and not a sound level meter equipped with specific functions for measuring the reverberation time; the operator has greater freedom in generating the sound excitation of the environment or, especially in the case of pulse excitation, he can start the measurement by himself and then generate the pulses using a clapper, moving freely in the environment and changing the position of the microphone, always having a processing that allows him to easily eliminate all the disturbances and to select only the significant portions of the signal for the calculation of the reverberation. In the case of the measurement with excitation via a sound source with interrupted noise technique, complete freedom is available between signal generator and acquisition and the operator can activate and interrupt the sound source at his complete discretion.

Even for time histories containing multiple decays, to access the RT60 calculation function with the NWWin3 software, proceed with the creation of the RT60 measurement as done for single decays.

By clicking on the measurement list, the corresponding time history is displayed in the graph below, showing us as a profile of the global level over time, the number and type of sound events and their temporal sequence.

Once we have selected the file we are interested in processing, to calculate the RT60, we will initially have to choose whether to perform a manual selection of the decay portion or whether to use a pre-set time window; this setting is made with the 'Selection Mode' field, choosing 'Variable Length' or 'Fixed Length'.

With 'Variable Length' (Fig. 21), I have the possibility of a free selection by dragging the mouse on the portion relating to a decay, while by choosing 'Fixed Length', it is possible to define a time window with a fixed opening in seconds, which will be used for the selection of the various decays belonging to the same time history.

We then proceed by selecting with the mouse, the portion of decay that concerns the first event; if the variable selection has been chosen, it is necessary to pay attention in the case of interrupted noise, to select the decay in its entirety or with a portion of stable level preceding the decay followed by a portion relative to the background noise; in the case of impulsive excitation, the individual impulses must be selected completely.

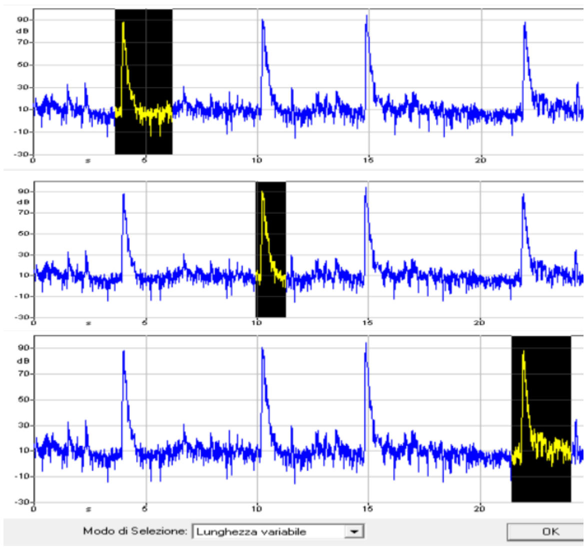

Fig.21- Pulse Selection with Variable Length

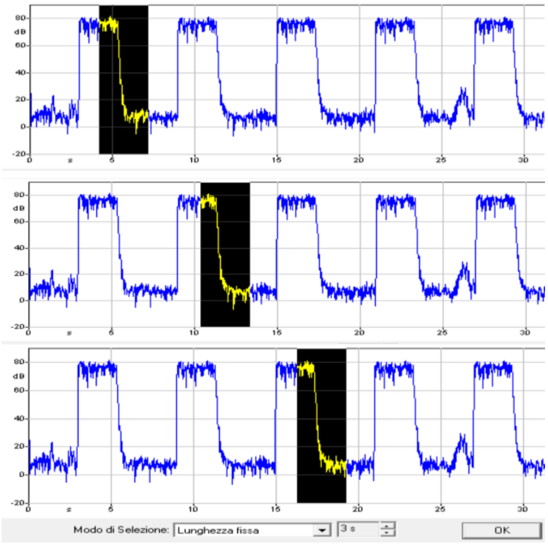

Fig.22- Variable Length Decay Section

In the case of a measurement file performed with impulsive excitation, we proceed with the same procedures described above with the precaution of selecting the entire pulse, including a small portion preceding the pulse itself; in the sequence shown in Fig.21, it is possible to observe the use of the Variable Length selection used for the selection of three decays.

NOTE: Why should one not use Backward Integration or Schroeder integration on the decays associated with interrupted noise measurements?

You will not find an easy answer to this question even by expertly surfing the Web.

To clarify the issue, I report with six graphs in Fig.23, the decay relative to the interrupted noise measured on the 1/3 octave of 1.6 kHz; the three graphs on the left are calculated with the application of Backward Integration while those on the right are calculated without an integration process. The backward integration process, visualized by the red trace, clearly shows that this process continues even when the excitation sound level of the environment is reached, present before the interruption of the signal; the red curve of the integrated signal therefore continues to increase and will increase even more if we take into account for our calculation, a greater duration of the excitation signal or that part of the signal that precedes the interruption instant.

In fact, the determination of the -5 dB point from which the RT60 calculation begins is heavily influenced by the result of the backward integration and the position of the arrows on the left graphs highlights the effect in relation to a duration of the noise level preceding the interruption equal for the three graphs to 0.3, 0.7 and 0.8 seconds.

The calculation of the RT60 with the application of the backward integration provides 0.59, 0.92 and 1.12 seconds for the three different conditions to which the values of 0.53, 0.53 and 0.58 seconds correspond for the calculation without Backward Integration; on the various graphs, the decay line highlights very well the extent of the errors introduced by the backward integration process.

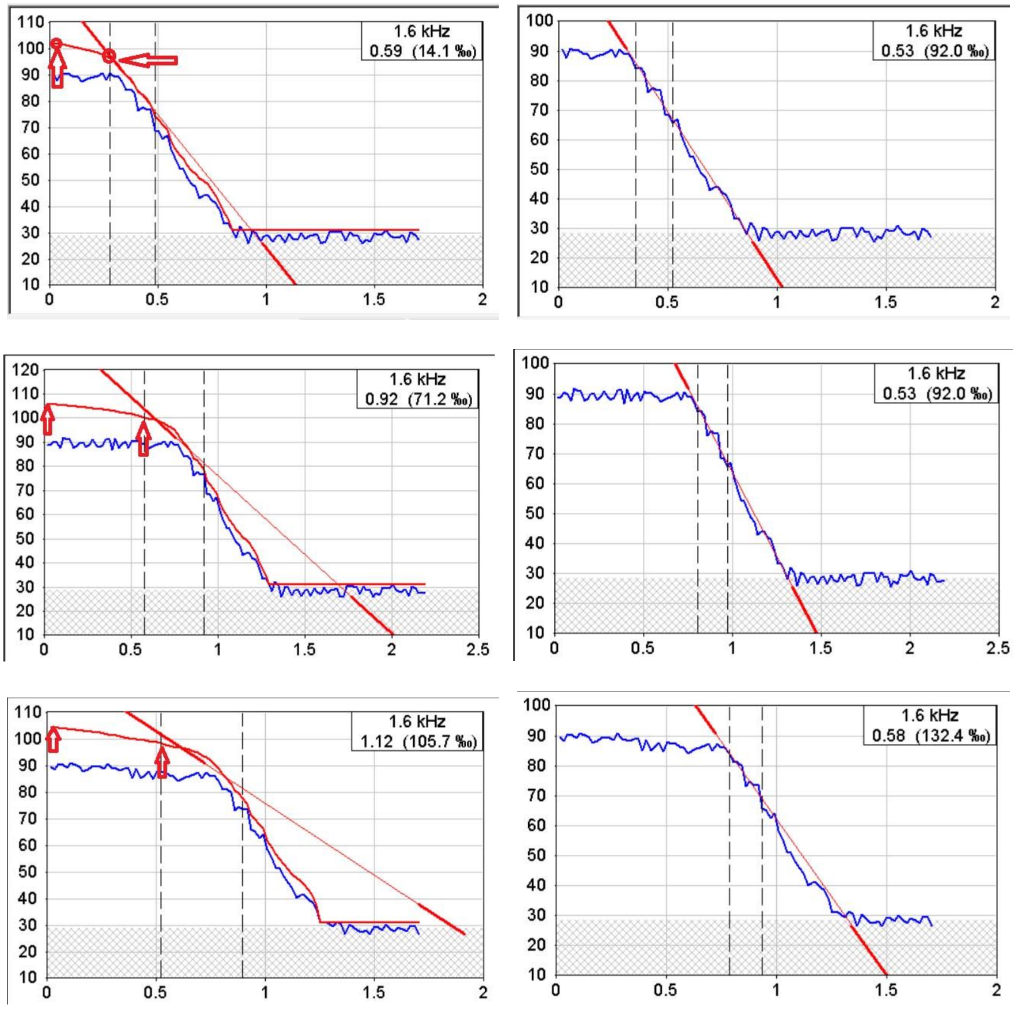

Fig.23- Decay at 1.6kHz with and without Backward integration and different excitation duration.

The situation is completely different when Backward integration is applied to an impulsive excitation as shown in Fig.24; the backward integration process at the start of the impulse is no longer powered, stabilizing the process on a constant level (in our example indicated by the two red arrows at 90 dB) from which it will always be easy to determine the -5 dB point of start of calculation for the values of 'T20' and 'T30'.

Fig.24- Backward Integration on Impulse Decay.