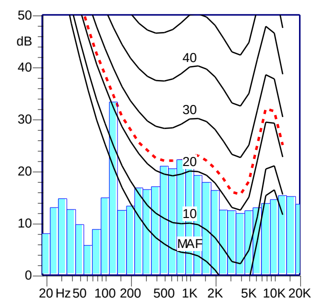
Recognition of tonal components (DM 16-03-98)



Technical Note

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Premessa

Extract from Ministerial Decree 16-03-98 Annex B Paragraph 10

Recognition of tonal components of noise

To identify the presence of Tonal Components (TC) in the noise, a spectral analysis is performed for normalized 1/3 octave bands. Only TCs that are stationary in time and frequency are considered. If sequential filters are used, the minimum of each band with a Fast time constant is determined. If parallel filters are used, the level of the stationary spectrum is highlighted by the minimum level in each band. To highlight TCs that are at the crossover frequency of two 1/3 oTCave filters, filters with greater selective power or alternative crossover frequencies can be used.

The analysis must be carried out in the frequency range between 20 Hz and 20 kHz. A TC is present if the minimum level of a band exceeds the minimum levels of adjacent bands by at least 5 dB. The correction factor KT as defined in point 15 of Annex A is applied only if the TC touches an isophonic equal to or higher than the highest level reached by the other components of the spectrum. The technical reference standard is ISO 266:1987.

Many years after the entry into force of the Ministerial Decree of 16 March 1998 and with greater experience resulting from the examination of the various critical situations in the application of the criterion for the recognition of tonal components, some useful functions have been added to the NoiseWorks software to provide the expert operator with a more versatile investigation tool for this type of research.

The measure for the recognition of tonal components

While in acoustic physics, the definition of tonal component corresponds to a sound energy, totally concentrated on a single frequency component, when instead we talk about tonal component recognition, aimed at evaluating the greatest disturbance generally associated with this type of sound source, we must carefully consider the criteria and measurement methods required by the applicable standards, regulations or specific laws.

The measurement aimed at recognizing tonal components is usually performed to evaluate a penalty to be attributed to the measured noise and for this purpose various types of standardized procedures have been studied over the years which, however, in the view of creating fast and simplified measurement and analysis methods, are characterized by some inevitable limitations.

To examine this situation in more detail we must take into consideration the regulatory reference constituted by the Decree of 16 March 1998, relating to the 'Techniques for detecting and measuring noise pollution' and specifically to paragraphs 10: Recognition of tonal components of noise and 11: Presence of low-frequency spectral components.

In measurement practice, considering the requirements of the Decree, measurements must be performed in 1/3 octave bands, comparing the tone level with the surrounding spectral components, using equipment with the following characteristics:

Class 1 integrating sound level meter compliant with IEC 61672 (corresponding to the old EN 60651/1994 and EN 60804/1994 now withdrawn) equipped with 1/3 octave parallel filters compliant with EN 61260/1993 (IEC 61260) for analysis from 20 Hz to 20 kHz.

Microphone sound level meter, calibrator and 1/3 octave filters must be accompanied by a valid calibration certificate or by the manufacturer for the first two years and subsequently one issued by a LAT calibration center, accredited by the national body responsible Accredia.

With these premises, we can list in the following 6 steps, all the procedures necessary to proceed in the search for tonal components:

1. Search for the position of the maximum level of the tonal component identified on the spectrum of the real-time analysis performed in 1/3 octave bands with fast constant.
2. Positioning the microphone at the previously identified point and at least 3 meters away from the operator.
3. Execution of the measurement with an analysis in 1/3 octave bands between 20 Hz and 20 kHz, without frequency weighting and with Fast time constant; the duration will be chosen in relation to the operation of the disturbance source.
4. Storing the spectrum of the minimums in Fast, related to each frequency band.
5. Recognition of tonal components as 1/3-octave bands, whose level exceeds the level of adjacent bands by at least 5 dB.
6. Comparison of the spectrum of the minimums with the isophonic curves of the ISO 226/87 standard; if one of the tonal components touches an isophonic equal to or higher than the highest reached by the other components of the spectrum, the correction factor K=3 dB is applied to the environmental noise. (K=6 if the tonal component is on bands lower than 200 Hz and present in the night period 22-06)

In confined spaces, we recall what is reported in the Decree, but often forgotten when carrying out measurements, that is, that in the presence of standing waves, the microphone must be placed in correspondence with the maximum sound pressure level of the sound component whose presence is to be demonstrated; this logically involves adequate preventive research to identify the required measurement position. (an operation that is rarely carried out!).

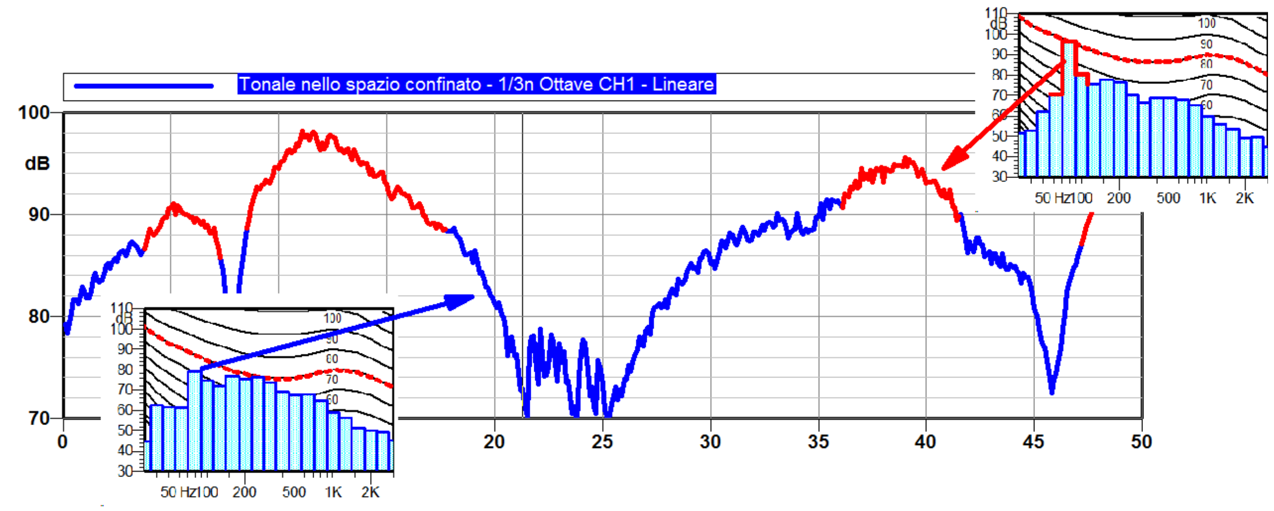


Fig.1- Variation of the 80Hz tonal level by moving the microphone slowly inside the disturbed room.
Trace in red: tonal present; trace in blue: tonal absent due to interference with standing waves.

The example described in the graph in Fig.1 shows the time history of a tonal component located around 80 Hz in relation to a scan performed by moving the microphone slowly inside the disturbed environment; from the level profile over time, one can easily observe the variations introduced by the presence of standing waves, which exceed 20 dB and which indicate that in some points of the environment the tonal component at 80 Hz almost disappears.

In the graph, the red profile trace refers to the positions in which the tonal is detectable according to the Ministerial Decree 16-03-98, while the blue trace refers to the positions where the tonal level drops because it is close to a node of the standing wave or because it is masked by an isophonic supported by higher level components at higher frequencies.

All this indicates that in large areas in the measurement environment it is not possible to obtain recognition of the tonal although it is present and perceptible but that it is always necessary to proceed with a careful search for the measurement position by moving with the sound level meter until an area is identified where the tonal shows a maximum level. It is important to remember that the method imposed by the Ministerial Decree 16-03-98, aims to identify the tonal components having a stationary character in time and frequency; this is the reason why the spectrum corresponding to the minimums detected in Fast for each band is used as the basis for analysis but as a consequence this method cannot identify the tonal components generated by an alarm siren (variation in frequency) and will fail even if the tonal component were to interrupt for a few seconds or fractions of a second.

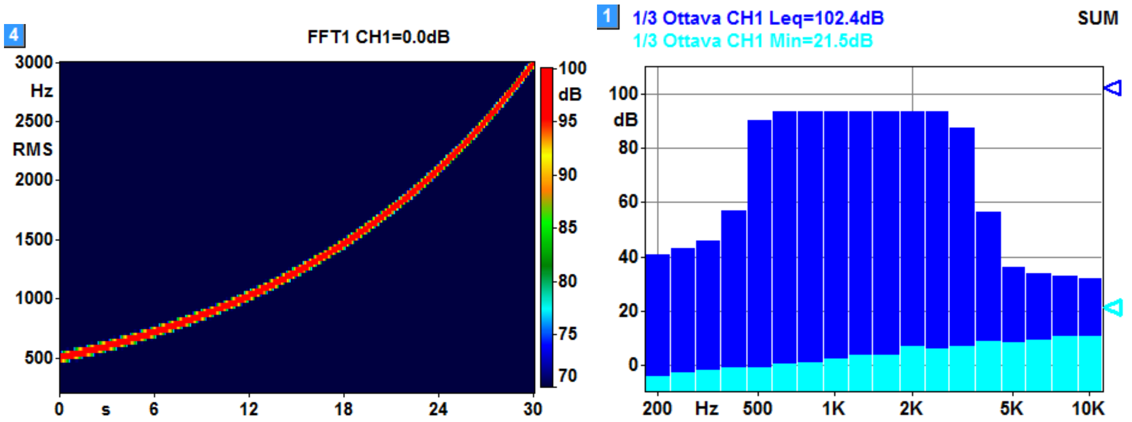


Fig.2- Sinusoidal scan 500-3000 Hz and relative 1/3 octave analysis with Leq spectrum and in-band minimum spectrum.

Fig.2 shows an example of a slow frequency scan between 500 Hz and 3 kHz performed in 30 seconds; the FFT spectrogram shows the gradual logarithmic scan performed by keeping the signal amplitude constant, while the spectral analysis in 1/3 octave bands highlights a Leq spectrum (blue bars) with constant amplitude from 500 to 3000 Hz and a spectrum of the minimum levels detected for each band using the Fast constant (blue bars) that corresponds to the background noise of the analyzer; no trace remains of the sequence of tonal components used in the scan!

An example of an interrupted tonal is described in Fig.3 where the component highlighted by the sonogram at the frequency of 1 kHz remains constant for the entire duration of the measurement but with a brief interruption of a few seconds; this condition produces a 1/3 octave Leq spectrum (blue bars) with the evident presence of the 1 kHz tonal but the spectrum of the minimums in the band (blue bars), is affected by the interruption and is also in this case flattened on the background noise of the analyzer. (Remember that the Leq spectrum should not be used for the search for tonals!)

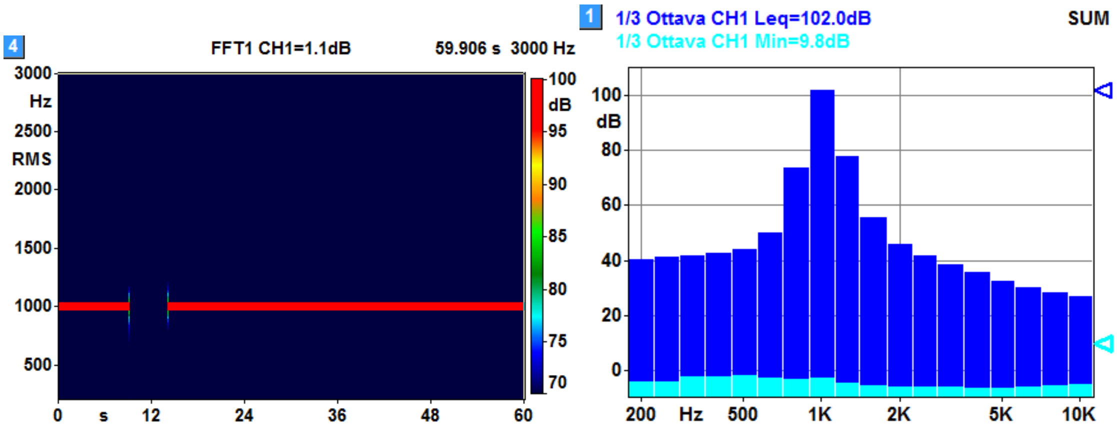


Fig.3- 1 kHz pure tone interrupted and corresponding 1/3 octave analysis with Leq spectrum and in-band minimum spectrum.

Differently, the spectrum of the minimums allows, compared to the corresponding Leq spectrum, the recognition of the presence of a tonal component even in the case in which other components should overwhelm or mask it for durations that can also be significant compared to the total measurement time.

The usefulness of using the spectrum of the minimums is that of being able to identify the tonals even in an environment characterized by noises of a variable type with the presence of transients and impulses such as those usually common in living environments and which can momentarily mask the perception of the tonal, which however then immediately becomes audible again in its persistence as soon as the transient ends and instead of finding oneself in a condition of greater quiet, one finds oneself hearing the re-emergence of the tonal.

The graph in Fig. 4 shows a condition of noise common in living environments where the disturbance of a forced ventilation system introduces two distinct tonal components at 125 and 400 Hz; the spectrogram shows the presence of the two tones with green-blue stripes corresponding to a level of about 30 - 40 dB and continuously present for the entire duration of the measurement; in the measurement period four distinct periods can be observed where the trace of the two tonal components is clearly covered by noise events with a more extended spectral content and with much higher levels as well as by some impulsive events.

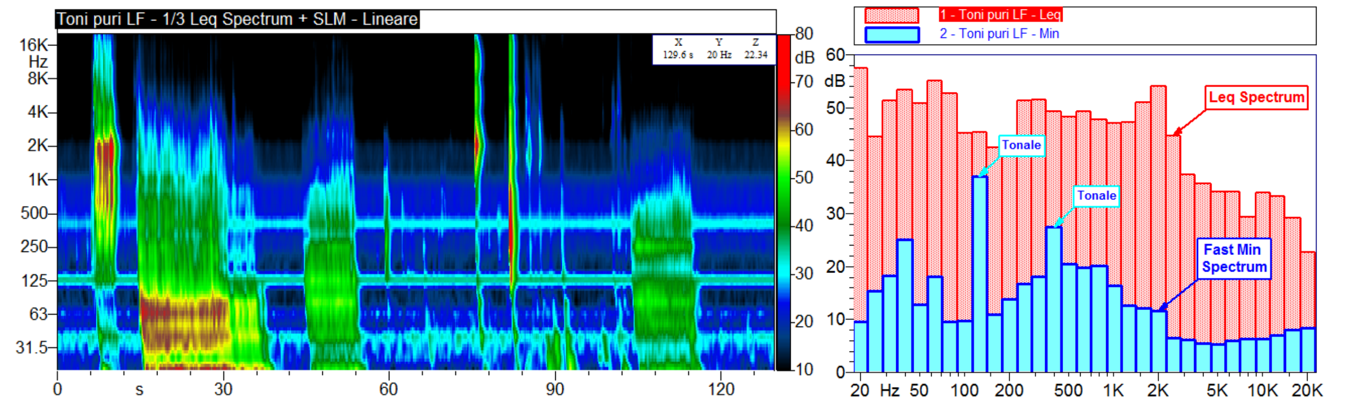


Fig.4- Continuous pure tones at 125 and 400 Hz overlaid by ambient noise with transient and impulsive characteristics. Comparison between Leq spectrum and Fast minima spectrum in band.

The situation described generates a Leq spectrum that does not allow the recognition of the presence of the tones that are present and clearly audible, while the spectrum of the minimums in the band is not influenced by transients or impulses and, being supported only by the components that are always present during the measurement, is able to show the presence of tones with continuous persistence.

Fig.5 displays the graph of the Fast minima spectrum in the band referred to the condition described above and compares it with the ISO 226 1987 isophonic curves as required by the Ministerial Decree 16-03-98; the tonal component is identified in the 400 Hz band because it is the band that supports the dominant isophonic curve and is therefore labelled accordingly.

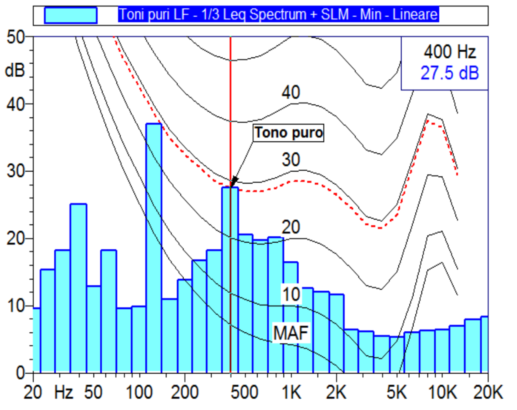


Fig.5- Comparison of the Fast minima spectrum in the band with the ISO 226-87 isophonic curves

Note: With the method used, even narrow bands of noise can be recognized as tonal components.

A criticality may arise when the tonal component is positioned at the intersection between two adjacent 1/3 octave bands; in this case, the DM 16-03-98 suggests the use of filters with greater selective power or alternative crossover frequencies. By discarding the alternative crossover frequency solution that would not comply with the IEC 61672 reference standard, one could use the analysis with 1/6

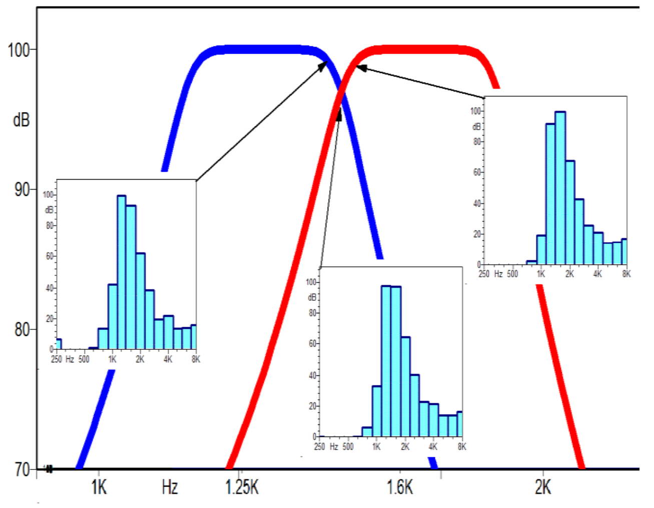


Fig.6- Spectra corresponding to a tonal with frequency close to and at the intersection of the 1/3 octave filters.

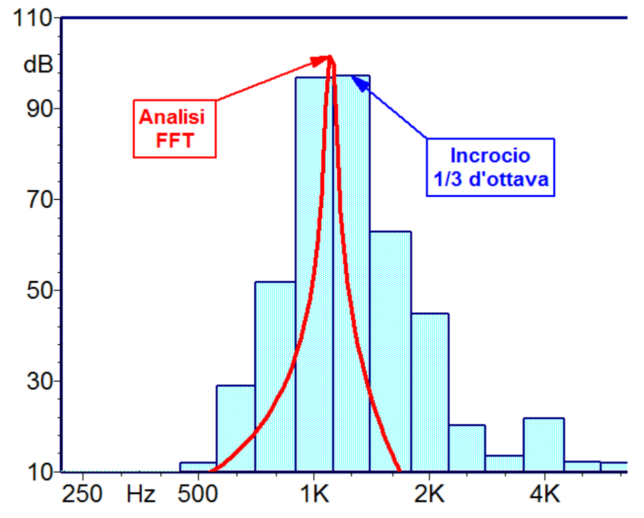


Fig.7- FFT analysis to identify the tonal component at the intersection of the 1/3 octave filters.

or 1/12 octave filters, which is now more common and available as an option in some portable analyzers, or the Fourier analysis, which is increasingly used in phonometric instruments. We recall that in this case, using 1/3 octave class 1 filters, the probability of having a condition with the tones at the intersection between the filters is approximately 16%.

Fig.6 shows the situation of what happens when the tonal corresponds to a frequency located near the intersection between two 1/3 octave filters; for frequencies close to the intersection, the band following the one representing the tonal tends to increase in level, until it reaches the same level at the intersection frequency and then decreases again when, by increasing the frequency, one moves away from the intersection. This situation reduces the condition of a delta level greater than 5 dB between bands adjacent to the one containing the tonal, preventing its recognition. To resolve this critical situation, the DM 16-03-98 considers the use of filters with greater selective power and in Fig.7, it is shown how in the presence of a pure tone positioned exactly at the intersection of two 1/3 octave bands which in these conditions assume equal amplitude, a narrow band FFT analysis (red trace) or with analysis filters with greater selectivity, allows us to perfectly highlight the masked tonal component..

The comparison with the ISO 266 isophonic curves highlights a possible limitation in the recognition of low frequency tonal components linked to the residual electrical noise level constituted by the preamplifier and microphone pair which tends to increase from 500 Hz towards high frequencies with a trend of approximately 3 dB/octave; for 1/2” 50 mV/Pa microphones, on the 1/3 octave of 4 kHz it is close to 5 dB and this makes it impossible to recognize tonal components that are below the isophonic of 12÷16 Phon, a limitation that however seems reasonable from the point of view of the lower limits of the dynamic range of current phonometric instrumentation. In Fig. 7 the spectrum of the minimums shows the lower limit for the recognition of the tonal component at 100 Hz; if the tonal component were to drop in level, the residual noise of the microphone which can be seen gradually rising on the medium-high frequencies, would prevent its recognition.

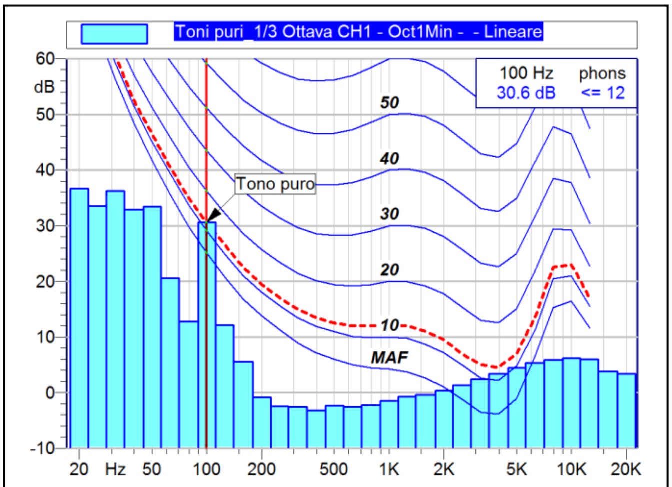


Fig.8- Isophonic 12, lower limit supported by the residual noise of the microphone/preamplifier pair.

On this topic it is also useful to add that if we consider the changes in the slope of the isophonic lines introduced by the most recent version of ISO 226 of 2003, we notice that the low frequencies are even more attenuated or in other words, the new version of ISO says that the perception of low frequencies at the same isophonic line is lower and to give an example, for a perception of 20 Phon at 100 Hz according to ISO 1987 36 dB were needed, now with ISO 2003 48 dB are needed, 12 dB more.

If we observe the graph in Fig. 9 where the isophonic lines corresponding to 20, 40 and 100 Phon are superimposed, we can notice that for frequencies lower than 63 Hz, the isophonic line of 20 Phon of the 1987 version and that of 40 Phon of the 2003 version practically correspond, indicating that there is a notable difference in evaluation between the two versions of ISO 226 for the same level of low frequency tones..

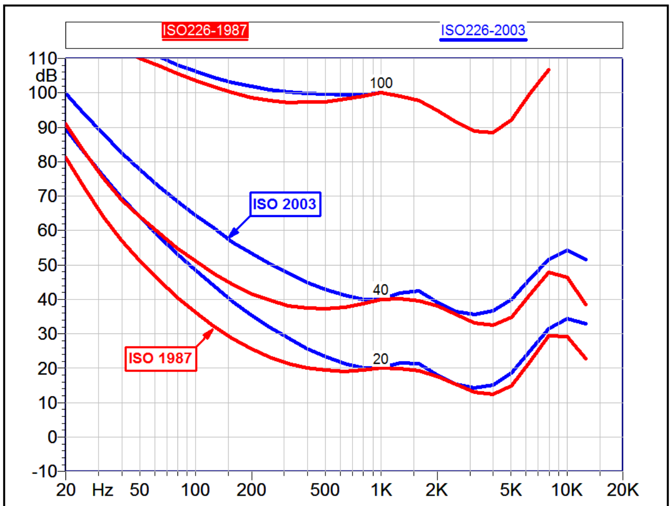


Fig.9- Comparisons between ISO-226 1987 red and ISO-226 2003 blue isophonic lines.

The major criticality that is however found in the use of isophonic curves, consists in the use of the curves as an evaluation of a possible masking effect between spectral components of noise, distributed on a certain band and tonal components very distant from this band. The interference with the residual noise of the microphone, described previously, is an example, but more often one can encounter conditions of concentrated noise at medium-low frequencies with important level tones at low frequency, which although clearly perceptible, cannot be recognized precisely because of improper use with the comparison with isophonic curves.

To better clarify the situation, let's recreate conditions in which the perception of a tonal tone occurs with certainty and verify the feedback provided by the criterion of comparison with isophonic tones.

In the first case, let's assume a noise of 59 dB mainly concentrated between 2 and 5 kHz and a tonal component at 100 Hz of only 41 dB; well, the tonal tone will be clearly perceived although the feedback in accordance with DM 16-03-98 will give a negative result, as shown in Fig. 10 where it can be easily observed that the entire area highlighted in pink is inhibited from recognizing tonal tones and in the case in question, the tonal tone of 41 dB at 100 Hz which is also perceived clearly, would not be identified even if it had a level of 65 dB!

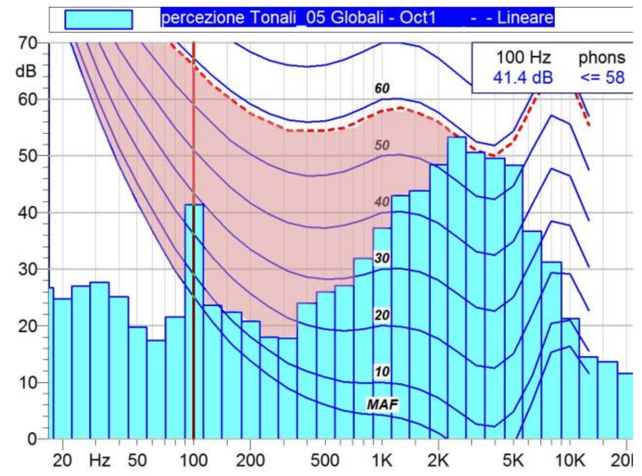


Fig.10- Pink Zone: Masking of ISO-226 Isophonics in the Search for Low-Frequency Tones.

A similar situation can also be found when the tonal is at a higher frequency than those supported by the dominant equal-tone and it is sufficient for this tonal to be of an octave higher to have a distinct perception of it even for levels much lower than those supported by the equal-tone; this second case is represented by Fig. 11 where the dominant equal-tone is supported by noise mainly distributed at medium and low frequencies and therefore inhibits the recognition of the tonal positioned in the 3150 Hz band which however is once again clearly perceptible even if at a level of almost 20 dB lower..

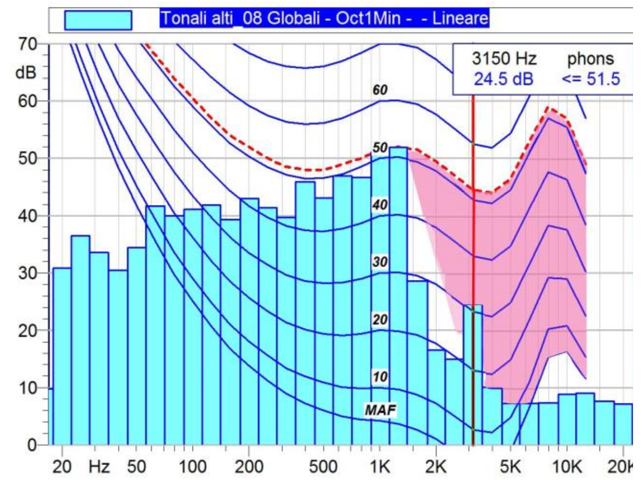


Fig.11- Pink Zone: Masking of ISO-226 Isophonics in the Search for High Frequency Tones.

It can be summarized by saying that the comparison with the isophonic curves, although indicating which are the levels of equal perception for the tonal components, does not fit the purposes of research of the tonals, as it was inserted in the DM 16-03-98.

Finally, to make the performance of the software NoiseWorks more versatile as a tool for investigation and recognition of the tonals, it was decided to add an automatic search function of the tonals over time; although this method has already been used in other applications, we have observed that in particular situations, it is of great help, especially when you have to examine long periods of time relating to measurements that come from unattended noise monitoring stations or in contexts where there may be tonal components coming from different sources that can manifest themselves with different durations and times.

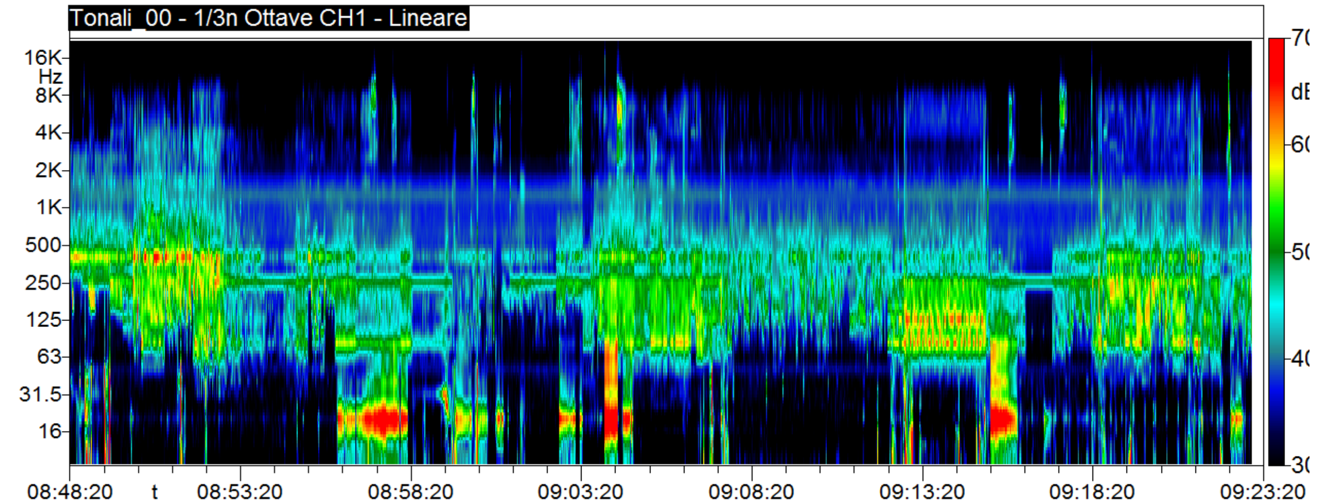


Fig.12- Noise spectrogram of a recirculation pump in a living environment; tone search on Leq spectra

For this purpose, we have reported the example relating to the noise generated by a water recirculation pump of a condominium heating system, as it was detected inside an office, where employees said they were disturbed by this type of source. The situation is interesting because the pump does not work continuously and that in the office there are also various other possible sources of noise with tonal components that overlap with the noise generated by normal work activity.

The spectrogram shown in Fig. 12 describes well the situation of a very complex environmental noise, with the presence for some periods of time, of a rather evident component positioned on the 250 Hz band.

To perform the search for tones over time, using the new functions added for this purpose in 'NWWIN3', it is possible to perform the selection on a wide range of options, inserted to offer the operator the necessary versatility and to be able to satisfy the variables currently present for this type of search in the legislation of the various nations of the European community.

If we now try to perform a tonal search on the measurement in Fig.12, choosing as a search parameter the sequence of 100 ms Leq Fast spectra, evaluated on a moving average interval of a few minutes, we will obtain a negative result, in the sense that not even one condition is found where the level in a 1/3 octave band exceeds the level of the adjacent bands by at least 5 dB. Fig.12 shows the result of this search, where none of the markers expected to highlight the presence of tonal components over time are reported on the spectrogram.

In Fig.13, the spectrogram reports the result of the search performed by choosing instead of the sequence of 100 ms Leq Fast spectra, a similar sequence of minimum Fast spectra in the band, always weighted with a moving average window set to times of a few minutes. With this setting, the ‘NWWIN3’ software identifies various periods where the conditions of exceedingly at least 5 dB between the level of the band with the tonal and the adjacent bands are respected; in correspondence with the identified periods and for the relative frequencies, a marker is inserted on the spectrogram in order to highlight the result of the search.

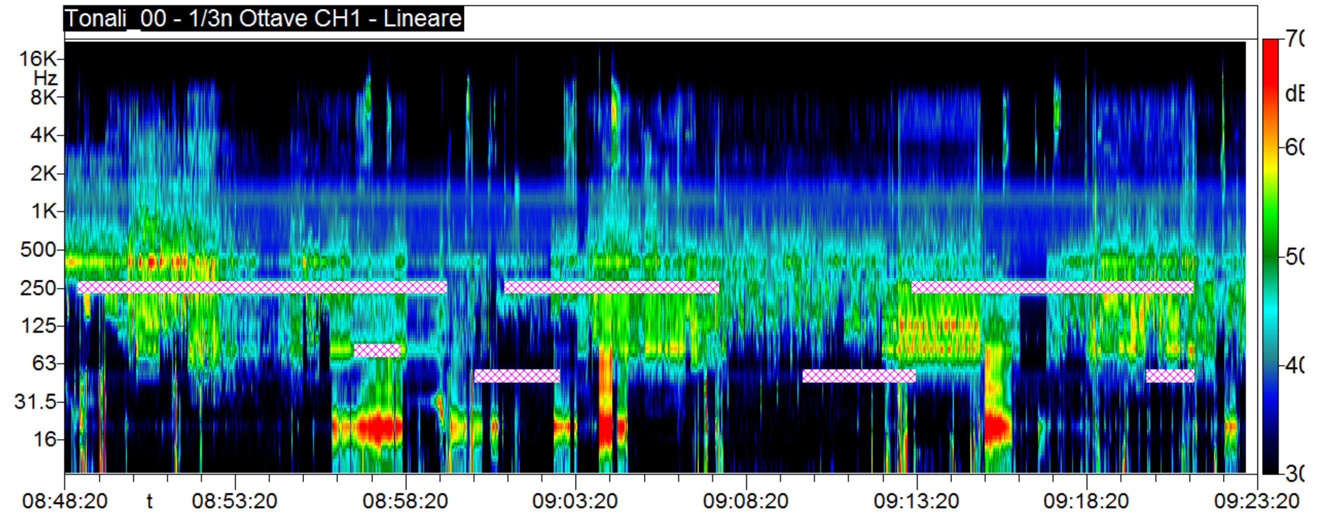


Fig.13- Spectrogram with markers of pure tone search on minimum spectra in Fast.

Looking at the tonal markers shown in Fig.13, it is noted that they identify multiple frequency bands, that the tonals are not continuously present, that in some periods more than one tonal may be present and that even in the presence of overlying environmental noise, the periods of presence of the tonals are identified with precision.

The operator can quickly perform a new search by changing the combination of the available options, memorizing or comparing the results obtained each time.

In NWWin3 the possibility of automatically generating a specific marker for pure tones has been added, allowing them to be masked for the periods of presence of the tonals or to extract only the periods with the presence of tonals.

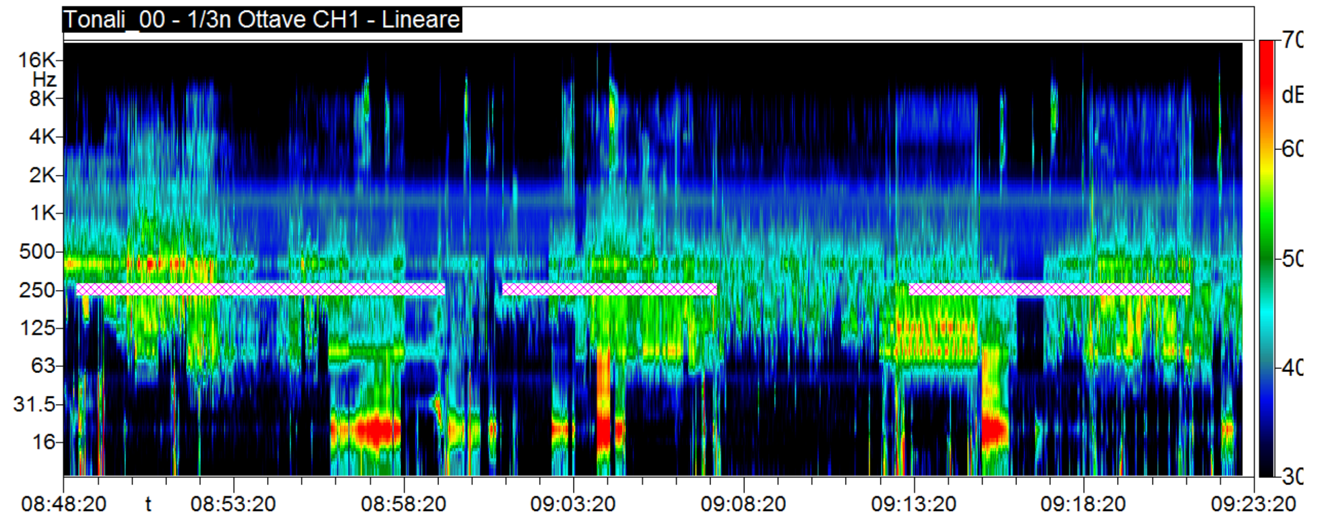


Fig.14- Spectrogram with pure tone markers on minimum spectra in Fast and comparison with the isophonics of ISO-226 1987.

In the spectrogram of Fig.14, the research was instead conducted with the same settings as the previous analysis but now enabling the comparison with the isophonics of ISO-226 1987 as requested by the Ministerial Decree 16-03-98; the result now shows the presence of only the tonal component identified on the 1/3 octave band of 250 Hz, corresponding exactly to the noise of the recirculation pump being investigated and the markers precisely mark the periods of activity and pause.

If it were now essential to cut a piece of measurement corresponding to a period of continuous operation of the source that generates the tonal, this is easily identifiable and by performing a simple selection, dragging the mouse on that period, we can extract the portion relating only to the first period of activity.

Fig.15 shows both the spectrogram corresponding to the extraction of the first continuous operating cycle of the recirculation pump, and the result of the tonal search conducted on the spectrum of the minimums in Fast and the relative comparison with the isophonics of ISO 226, in compliance with the requests of the Ministerial Decree 16-03-98.

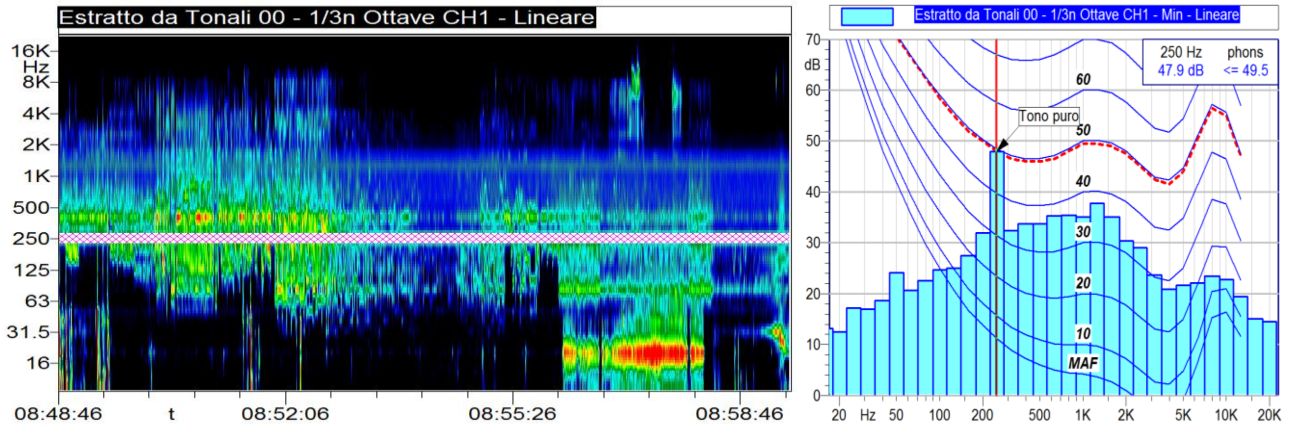
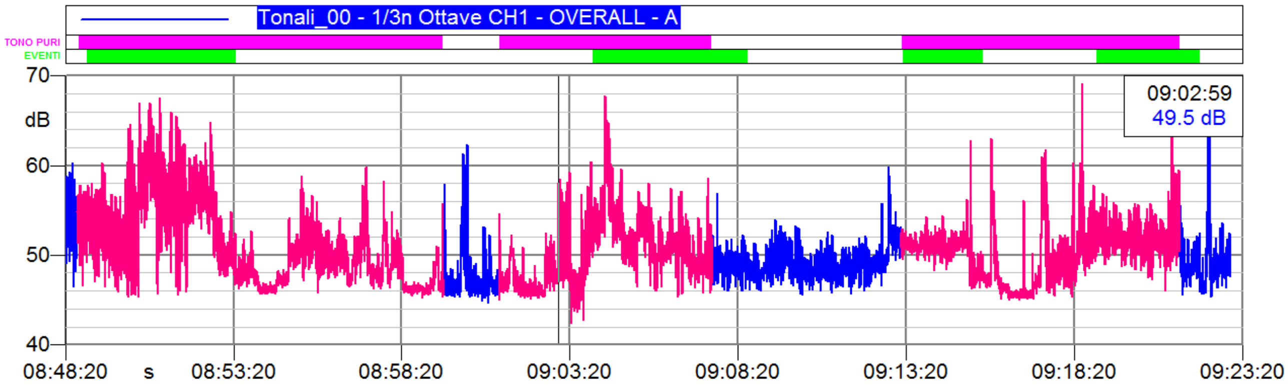


Fig.15- Spectrogram of a continuous pump operation cycle. Fast minimum spectrum in band, tonal at 250 Hz.

It is important to note that the usefulness and practicality of this type of investigation tool depends greatly on the speed with which the processing and graphic representations can be performed, since we often find ourselves having to manage huge amounts of data and if the software applications are not optimized for these objectives, the calculation times needed to generate the desired results can make any type of new investigation procedure unusable.

The function for the automatic recognition of tonal components over time can activate a marker which, in turn, can perform various tasks such as the one that allows for the application of an automatic masking on all the time periods in which there was the presence of tones, that of creating events corresponding to the same time periods, that of identifying the same periods with a different color on the time-history or that of appearing on the marker strip, usually positioned above the time-history and therefore being inserted into the corresponding table where durations and numerical values are reported with and without the contribution of the events associated with each individual marker.

In Fig.16 the LAF time-history is reported for the spectrograms examined previously with the marker strip inserted in the upper part of the graph, where we find the marker of the tonal components represented in purple, which also acts directly on the time-history trace and in green the sequence of 4 distinct events identified as exceeding the 52 dB threshold for a minimum duration of 30 seconds. In the part below the graph, the numerical table reports the global LAeq, LAmax and LAmin values, of the periods marked by the markers only, of the unmarked periods, of all the periods with tones, of those without tones and of all the events and of those not affected by the events.



Tonali_00 1/3n Ottave CH1 - OVERALL A				
Nome	Durata	Leq	Lmax	Lmin
Totale	00:34:39.500	52.0 dB	69.2 dB	42.4 dB
Senza Marcatori	00:07:33.300	49.9 dB	64.8 dB	44.7 dB
Tutti Marcatori	00:27:06.200	52.5 dB	69.2 dB	42.4 dB
Senza TONO PURI	00:09:15.700	49.7 dB	64.8 dB	44.7 dB
Tutti TONO PURI	00:25:23.800	52.6 dB	69.2 dB	42.4 dB
Senza EVENTI	00:20:09.600	49.9 dB	69.2 dB	42.4 dB
Tutti EVENTI	00:14:29.900	53.9 dB	67.8 dB	45.3 dB

Fig.16- Spectrogram of a continuous pump operation cycle. Fast minimum spectrum in band, tonal at 250 Hz.

Note: The tonal component recognition function in compliance with DL 16-03-98, automatically deactivates all other tonal component investigation functions described in this document in order to avoid any possible false interpretation of the recognition procedures.