

Noxturnal Snoring – Frequency Evaluation and Reporting package

Customer Support Document

Version 2.0

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Nox T3™, Nox A1™, and Noxturnal™ are manufactured by:

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This document introduces new viewing and scoring support tools in Noxturnal 5.1 to enhance reporting capabilities around snoring events adding frequency band information. In addition it summarizes content provided for import by Noxturnal software: “Snoring_Noxturnal_5.1_ver2.ndb”. The current focus is on Polygraphy studies and does not take Sleep Scoring into account (yet).

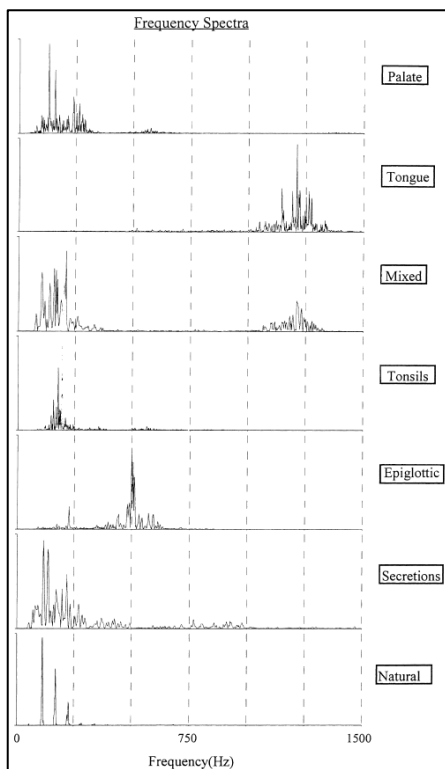
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1. Introduction

Nox Medical System provides state-of-the-art snoring analysis which results in more sensitive and accurate snoring detection based on the use of the build-in audio recording (*E.S. Arnardottir et al.: How to measure Snoring? A comparison of the microphone, cannula and piezoelectric sensor. J Sleep Res. (2015)*). As summarized in this publication “The sensitivity and positive predictive value of scoring snore events from the different sensors was compared to the chest audio: overhead audio (0.78, 0.98), cannula (0.55, 0.67) and piezoelectric sensor (0.78, 0.92), respectively. The chest audio was capable of detecting snore events with lower volume and higher fundamental frequency than the other sensors. The 200 Hz sampling rate of the cannula and piezoelectric sensor was one of their limitations for detecting snore events.”

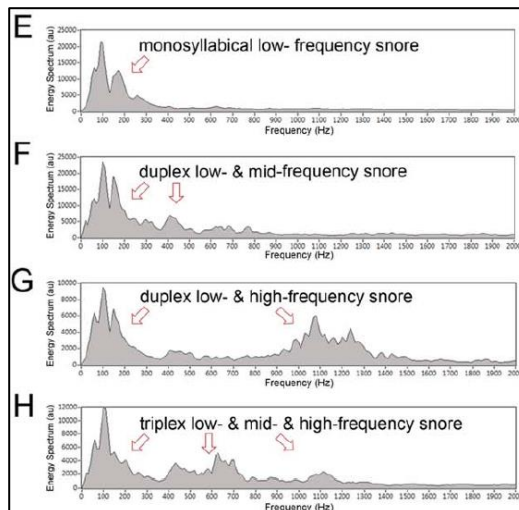
Research ongoing for more than a decade has shown the opportunity of correlating snore frequencies and its origin.



Representative sound frequency spectra of each type of snore recorded.

One of the early publications in this area (*S. Agrawal et al.: Sound frequency analysis and the site of snoring in natural and induced sleep. Clin. Otolaryng 27, 162-166, 2002.*) characterized some findings in the figure to the left.

Some more recent publications try to cluster snoring sounds in frequency bands and published an approach to a snoring map (*L.-A. Lee et al.: Energy Types of Snoring Sounds in Patients with Obstructive Sleep Apnea Syndrome: A Preliminary Observation. PLOS ONE, Vol. 7, Issue 12, e534811, December 2012.*). This approach is illustrated by the figure below: “Spectral analyses of full-night snoring sounds ... energy spectrum of an overnight snore map (E–H)”.



Increasing demand for individualized treatment and objective outcome control generated a lot of interest to receive additional information about snoring, in particular about its occurrence in different frequency bands, all based on the full audio signal recorded in ambulatory studies with Nox T3 and Nox A1 systems. That prompted new viewing, scoring and reporting tools to be offered.

2. Overview: From recorded signals via Analysis and Scoring to Enhanced Reporting about Snoring

2.1. Signal Acquisition

Nox T3 and Nox A1 systems always record an envelope signal of the full audio which is the base for adequate and sensitive snoring detection. The full audio signal (sampled and stored with 8 kHz) however has to be recorded and saved in order to analyze frequency information. This setting is available at the level of Device Profiles for Nox T3 and Nox A1.

- ❗ Please configure your Device Profiles and used Recording Types based on your own requirements for signals and sensors but enable the full audio acquisition.

2.2 Automatic Snore Event Detection

Noxturnal detects Snore events exclusively based on audio information, in particular on the dBc weighted audio volume in Decibels (stored at 100 Hz). Single Snore events form so called Snore Trains which stand for periods with multiple Single Snores meeting certain time conditions. Single Snore analysis and definition for Snore Trains can be customized.

- ❗ Single Snore and Snore Train analysis can be performed by the customizable Noxturnal detector. Automatically scored events should be checked for consistency. The audio playback function can be used to further assess Snore events in an acoustical manner.

2.3 Manual Frequency Band Analysis

Noxturnal is able to derive and display bandpass setting depending audio channels. In addition, these channels can also be visualized with their relative Powerbands value. Manual scoring needs to take place depending on the amount of signal content in these frequency bands.

- ❗ Use the provided views and events to display low / medium and high frequency band and to score prepared events according the Appendix A. Views and events can be customized further but please note that the defined events are used in the suggested report.

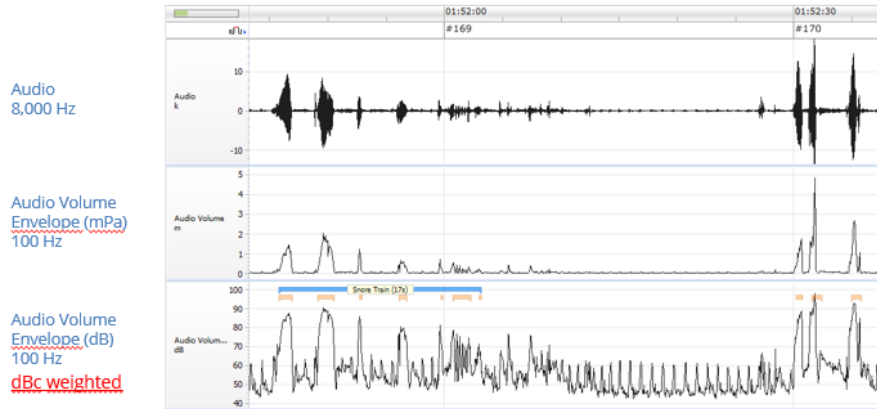
2.4 Customized Reporting on Snoring and Snore Frequency Information

Reporting of Snore events in combination with its frequency information is generated by the association tools in the Noxturnal reporting system. Single Snores will be checked for accordance with the different frequency bands. In addition, these can be reported either as related to respiratory events or independent. Several arbitrary decisions have been taken to define thresholds for time constraints. The setup has been discussed with different clinicians but may not satisfy all users in a similar manner. Please consult for details chapter 5 of this document.

- ❗ The current custom report has been defined in cooperation with clinicians interested in the snoring analysis. Criteria can be changed but would also require adjustments in reported variables. Only a reduced number of possible snore event conditions has been selected for reporting. The suggested report is part of the Appendix A.

3. Noxturnal - Automatic Snoring Detection and Frequency Band View

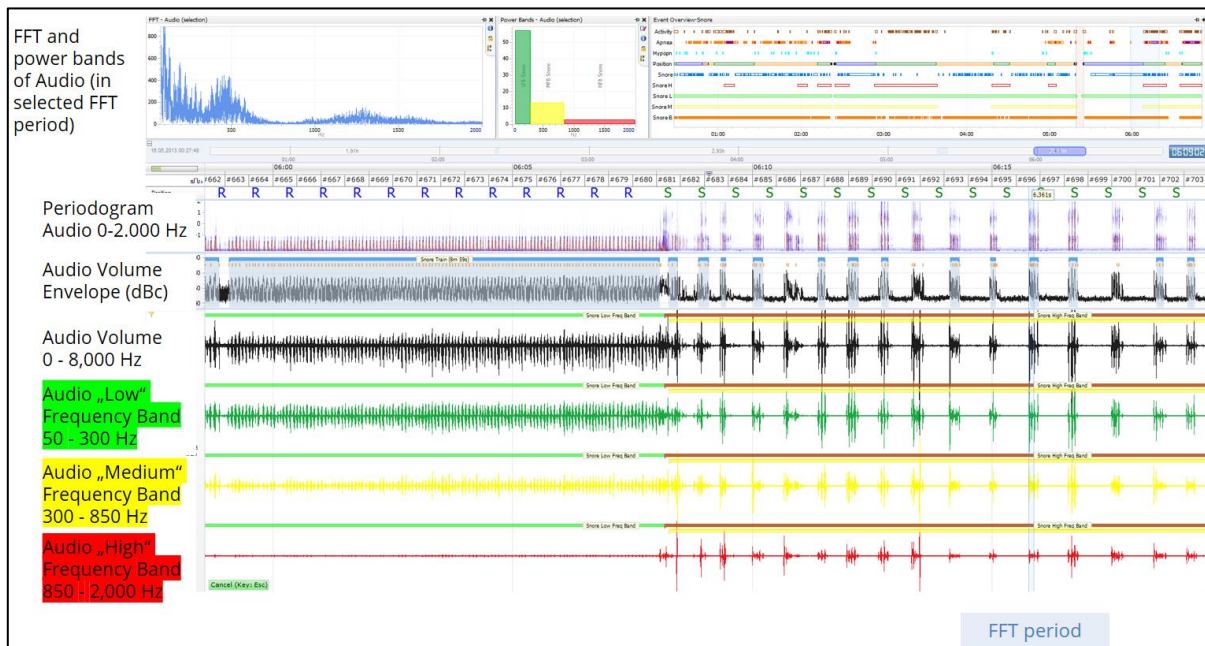
Noxturnal records a full audio signal with 8.000 Hz sampling. An envelope pressure signal of the audio is derived and stored with 100 Hz, followed by a conversion with dBc weighting to receive an audio envelop signal in dB. The automatic snore detection will be performed on this signal by either a fixed or relative dB threshold. A period of multiple Single Snores will be scored as Snore Train.



As of today, Noxturnal cannot score automatically (yet) the individual snore events in the different frequency bands but following frequency bands are derived (by FIR band pass filters) and displayed in a signal group with similar scaling properties:

- LFSB (Low Frequency Snoring Band): 50 – 300 Hz
- MFSB (Medium Frequency Snoring Band): 300 – 850 Hz
- HFSB (High Frequency Snoring Band): 850 – 2.000 Hz

Below figure (example for a 20 minutes window) shows these bands with an audio-periodogram above the audio envelop signal (dBc) with the automatically detected snoring events. A combination of FFT data for the selected period, the distribution into the frequency bands and a selected signal / event overview is configured for the top view area.



4. Frequency Band Scoring

As Snore events are not automatically scored to the frequencies bands a manual classification (for the snore periods) in the bands must take place. This can be performed in a rather rough manner as the reporting capabilities in Noxturnal will associate the Snore events with frequency information.

The window size can be chosen rather long (below e.g. 4 hours) and as shown in the picture below the information in the Relative Power Band Value (percent) supports a quick manual scoring in the frequency bands.



The first three signal are derivations from the full audio to show the power ratio of a certain frequency band (LFSB, MFSB, HFSB) to the total of the three. The scales therefore equal percentages: 1 ... to signify 100%; 0,5 to signify 50% and so on. The levels for the axis lines (red dotted lines) are set for easier decision making (NOTE: the 10% are arbitrary chosen for support):

- LFSB Power Ratio (Low Freq. Band): Scale 0 – 100% Axis Line: 10%
- MFSB Power Ratio (Medium Freq. Band): Scale 0 – 50% Axis Line: 10%
- HFSB Power Ratio (High Freq. Band): Scale 0 – 50%, Axis Line: 10%

Three event types have been created to score the snores within these Power Ratio derivations:

- Green → Snore with Low Frequency Band contribution → **Snore Low Freq Band**
- Yellow → Snore with Medium Frequency Band contribution → **Snore Med Freq Band**
- Red → Snore with High Frequency Band contribution → **Snore High Freq Band**

It is recommended to score first the “Snore Low Freq Band” as the red highlighted event for the “Snore High Freq Band” will overlay the green bar. Other more faded color options are possible but remain for customization by the user.

5. Custom Snoring Reporting including Frequency Band information

The scored information in the signal sheets could be used to create a huge set of parameters. The report information should however still fit a small number of pages and avoid going to extreme detail for all possible conditions. Therefore, the suggested report (see also Appendix A) combines a limited number of numeric and graphical representation for:

- Single Snores within and outside of Snore Periods
- Snores and coherence for specific frequency bands
- Snores related or unrelated to Respiratory events (customizable time dependency).

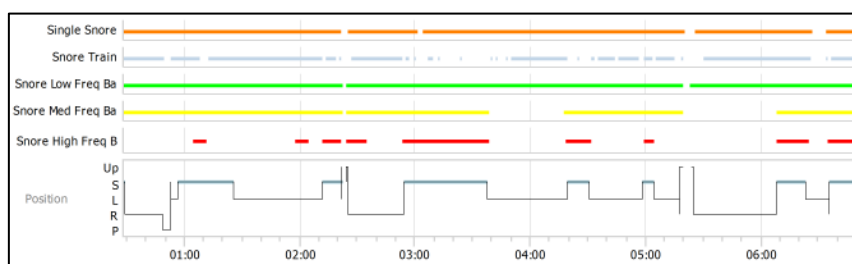
Following arbitrary decisions got taken:

1. Frequency bands are defined to 50 – 300 Hz, 300 - 850 Hz and 850 - 2.000 Hz (this “fits” frequency bands according the two cited publications in the introduction of the document).
2. Positional statistics are reported as “All” as well as the split into Supine / Left+Right / Prone.
3. Tables for frequency bands take into account Single Snores within Snore Trains only. This means that Snores outside of Snore periods are not analyzed / reported further. However, percentages are given on the base of all Single Snores.

Single Snores within Snore Periods (percentages compare to all S-Snores)

Reporting all snores which contain frequencies of	All positions			Supine		Left / Right		Prone	
	Count	Total time [s]	% of all S-Snores	Total time [s]	% of all S-Snores	Total time [s]	% of all S-Snores	Total time [s]	% of all S-Snores
Low Freq. (50-300 Hz)	2259	2837,8	86,6%	462,3	18,4%	2366,6	67,9%	8,9	0,3%
Medium Freq. (300-850 Hz)	1608	1987,9	61,7%	461,9	18,4%	1517,2	42,9%	8,9	0,3%
High Freq. (800-2.000Hz)	313	307,8	12%	196,6	8,1%	111,3	3,9%	0	0%

4. A relation of snore to respiratory events is defined as given for any Single Snore within a Snore Train which follows within 20 seconds after a respiratory (OSA) event. In contrast, it requires a minimum of 5 minutes to define Snore events as unrelated (outside of) to OSA events. Any Snore events not meeting one of these conditions will not get reported further.
5. The combination of different frequencies is presented independent from OSA relation (only).
6. For quick view the snores and frequency content is represented against the body position.



- i** The suggested report uses Noxturnals high flexibility and reporting capabilities for variables structured with several conditions. The resulting report represents an advanced level, but, can be used directly without experience in Noxturnal report setup. Using the feature to hover with the mouse over a displayed derived variable with the mouse will show the conditions for the variable. → Example:

Number of Single Snore events in Sleep that overlap Snore Train events that overlap Snore Low Freq Band events that are near Apnea or Hypopnea events which start 0 seconds before and up to 20 seconds after

6. Appendix A: The “Snoring Noxturnal_5.1_ver2.ndb” content – Required layouts, events and report

Views

Sheet Layouts (these include the derived signals):

- 20min Snore L,M,H and Periodogram
- Snore Score Bands Distribution
- Overview L,M,H Snore plus Period

Power Bands:

- LFB Snore
- MFB Snore
- HFB Snore

Workspace Layout:

- Snore Bands L,M,H for PG

Snore Analysis, Events and Event Groups

Customized Snore Detector

- Snore Modified ver0

Analysis Event Types:

- Snore Low Freq Band (in Group “Snore LoF”)
- Snore High Freq Band (in Group “Snore MeF”)
- Snore High Freq Band (in Group “Snore HiF”)

Event Group (use in Overview sheet):

- Snore Summary Freq (Label “Snore”)

Report Variables

- Library of required specific variables for the report (no need to be imported but made available for possible further reference, adjustments)

Report parts (Report Part Section “Snore Special ver1”)

- Short Trend Summary Snore and Pos - Graphics
- Single Snore Distribution to Resp Events - Graphics
- Single Snore Freq Band distribution - Graphics
- Single Snores in SP no OSA - Table
- Single Snores in SP - Table
- Single Snores in SP with OSA - Table
- Snore Indices General - Table

Report

- Snore Special L,M,H ver1 (3 pages)

Custom Fields for Recording library use

- Snore Frequency Band (→ see figure right)

7. Appendix B: Examples and information about derived traces, events and views

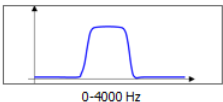
Snoring Detector Settings for “Snore Modified”

General Properties	Input Signals
Snore Detection Shortest Snore Duration: <input type="text" value="0.2"/> seconds Longest Snore Duration: <input type="text" value="2.5"/> seconds <input type="radio"/> Absolute Threshold: <input type="text" value="65"/> dB <input checked="" type="radio"/> Relative Threshold: <input type="text" value="5"/> * 14,0dB <small>* Times the average background activity</small>	
Snore Train Minimum Number of Snores: <input type="text" value="3"/>	
Validation <input checked="" type="checkbox"/> Test for inhalation overlap <input type="checkbox"/> Test center frequency <input checked="" type="checkbox"/> Exclude during movement	

Example signal derivation for frequency bands – LFSB (derived from full audio)

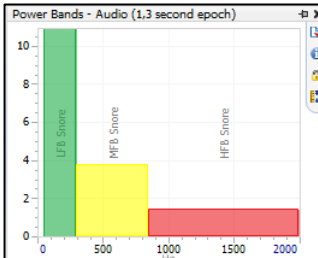
New Derived Signal

Select derived signal type

Filtering	Properties
FIR Filter Moving Average Powerline Filter General Derivative Integral Inverted Spectral AR Spectrum DFT Power Band Periodogram	Filter Design <input type="radio"/> Low Pass <input type="radio"/> High Pass <input checked="" type="radio"/> Band Pass <input type="radio"/> Band Stop  Pass frequency: <input type="text" value="50"/> to <input type="text" value="300"/> Hz Filter Size: <input type="text" value="1000"/> taps Signal Window: <input type="text" value="Hamming"/>

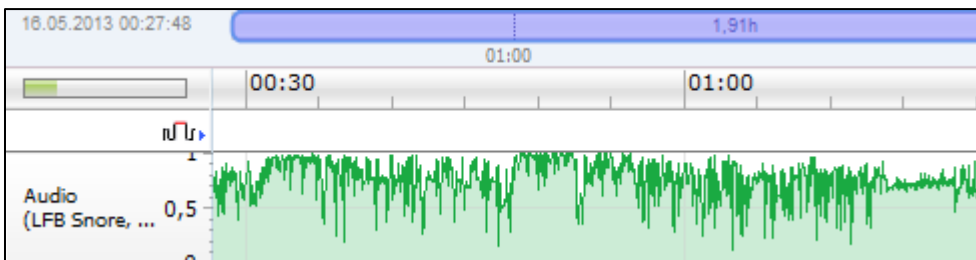
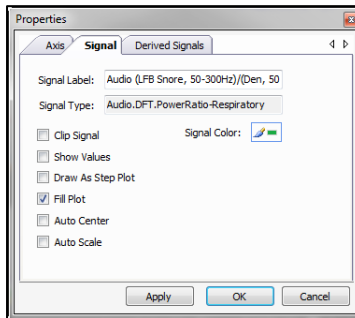
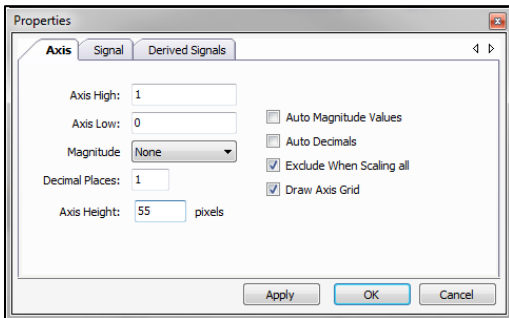
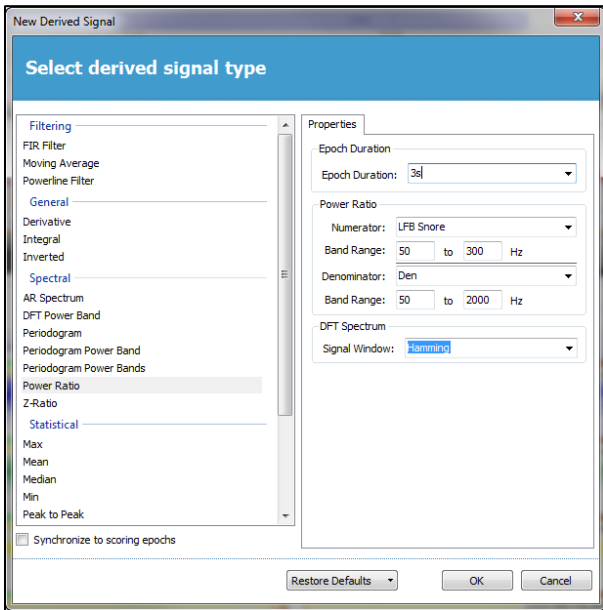
Custom Power Bands and properties for Power Band Views

Name	Range	Color
LFB Snore	50-300 Hz	Green
MFB Snore	300-850 Hz	Yellow
HFB Snore	850-2000 Hz	Red

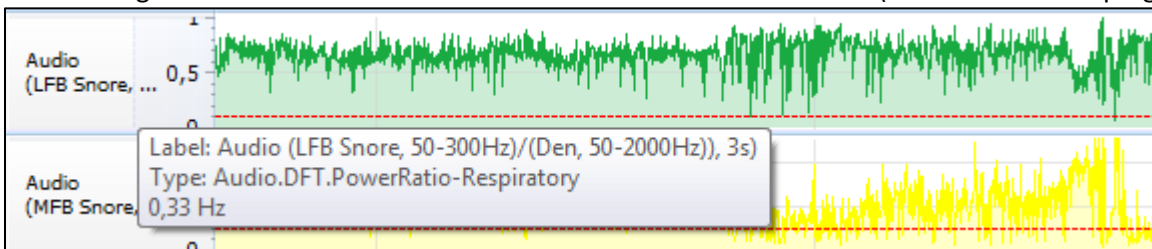


Powerband Properties		
<input type="checkbox"/>	Alpha	8-13 Hz
<input type="checkbox"/>	Beta	13-35 Hz
<input type="checkbox"/>	Delta	0.5-4 Hz
<input checked="" type="checkbox"/>	HFB Snore	850-2000 Hz
<input checked="" type="checkbox"/>	LFB Snore	50-300 Hz
<input checked="" type="checkbox"/>	MFB Snore	300-850 Hz
<input type="checkbox"/>	Theta	4-8 Hz

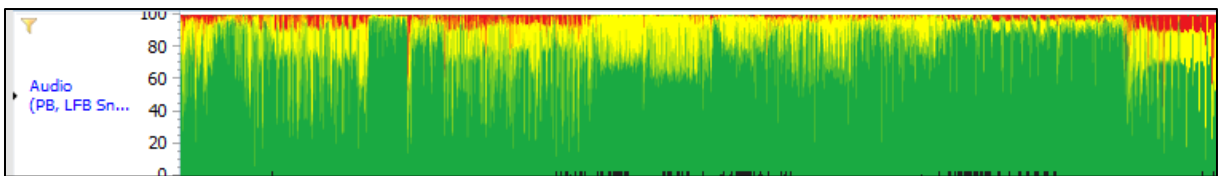
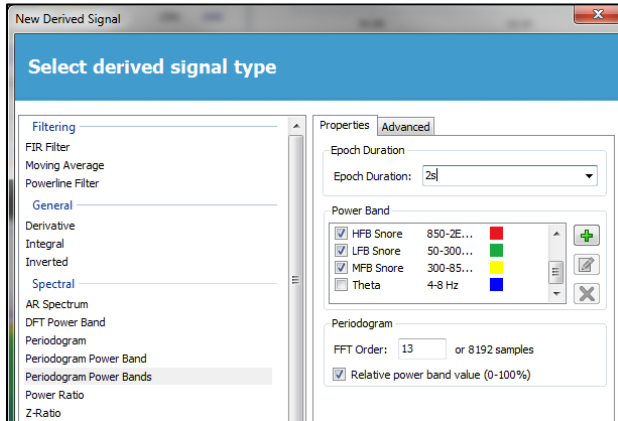
Relative Frequency Band Power Ratio View (derived from full audio)



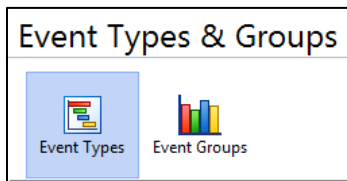
After adding similar derivation for MFB Snore Band and Axis Lines at 10% (label shown for top signal):



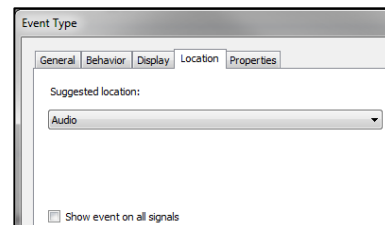
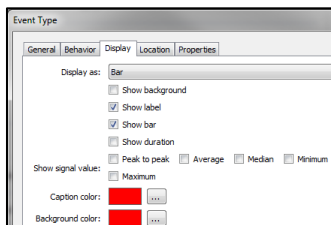
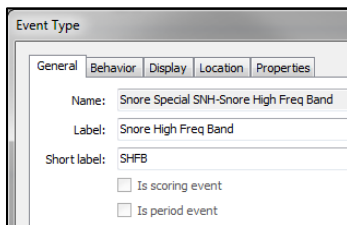
Relative Power Band View (derived from full audio)



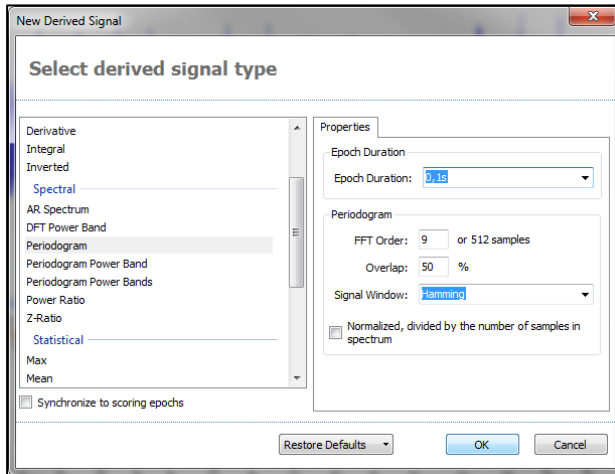
Frequency Band Events – example “Snore High Freq Band”



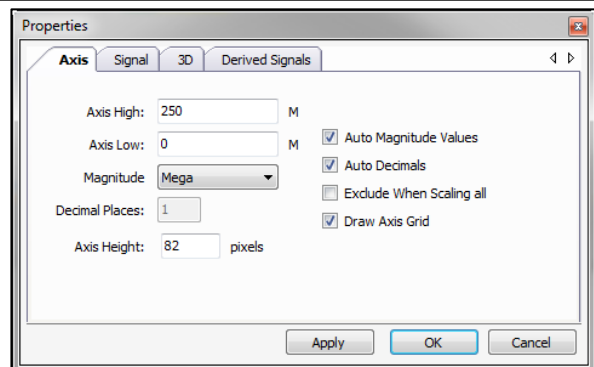
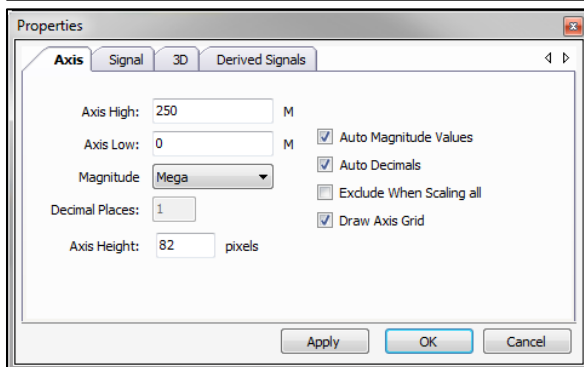
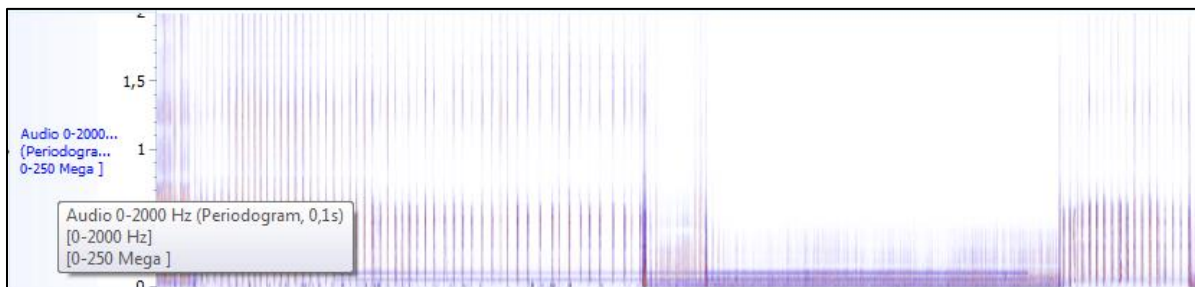
Event	Type	Default Duration	Shortcut Key
Snore HiF			
Snore High Freq Band	snore special snh-snore high freq band	10 s	
Snore LoF			
Snore Low Freq Band	snore special snl-snore low freq band	10 s	
Snore MeF			
Snore Med Freq Band	Snore Special SNM-Snore_Med_Freq_Band	10 s	



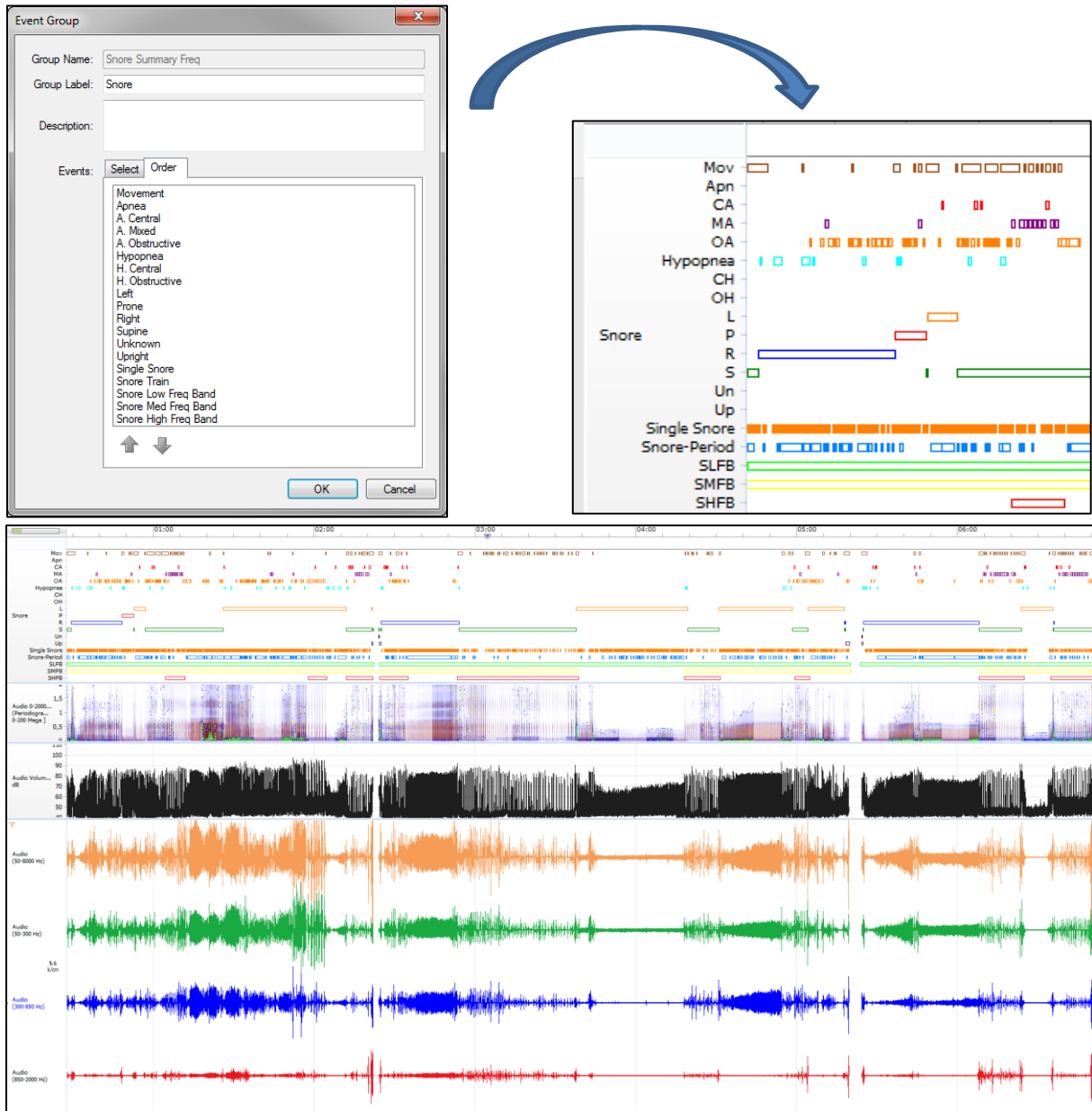
Custom Audio Periodogram (derived from full audio)



The 3-D resolution and color saturation in below periodogram can even manually changes quickly by the “magic hands”.



Complete Night Study Overview (incl. custom event group)



For questions or further information please contact support@noxmedical.com.