Visible Speech module

The Visible Speech module is based on the idea of presenting unaided and aided speech information related to the individual hearing impaired.

The module presents the information not in the audiogram format but in a graph that shows *sound pressure level, SPL [dB SPL]* vs. *frequency [kHz]*. All sound pressure levels are referred to the eardrum position.

1. Unaided condition (without a hearing aid):

A. Average normal hearing threshold
   1) First, the values are based on the *normal, monaural minimum audible field,* MAF_{mon} [dB SPL], calculated from the corresponding binaural values, MAF_{bin} [dB SPL] from ISO 226 (1987) using the *binaural*-to-*monaural conversion values* by Pavlovic, 1987/ ANSI S3.5-1997 – see table I
   2) Next, the free-field values are converted to corresponding values at the eardrum position by the *free-field*-to-*eardrum* conversion values described by Bentler & Pavlovic, 1989, - see table I or II
   (the conversion values correspond approximately to the values in IEC 959 international standard and represent the standardized 'open-ear response')

B. Individual audiometric data
   1) *The hearing thresholds, HTL*, and *the uncomfortable loudness levels, UCL,* are converted to SPL-values at the eardrum position by adding the audiometric values (dB HL) to the eardrum SPL-values for averaged normal hearing threshold established above – see 1A-2
   2) The area between the converted hearing threshold and the converted uncomfortable level curves corresponds to *the dynamic range* of residual hearing and is given in dB SPL at the eardrum

C. Standardized speech spectrum
   1) The *spectrum level* of normal speech in the free-field is taken from the SII-standard (ANSI S3.5-1997 – table 3, the missing data point at 125 Hz is estimated) – see table II
   2) From these values the one-third octave band frequency spectrum is calculated and used to represent a standardized speech spectrum – see table II
   3) The one-third octave band levels are converted to levels in the auditory band called the *critical ratio* using the *one-third-octave-*

band-to-*critical ratio conversion values* as described by Pavlovic, 1987 - see table II
(The speech spectrum is calculated for a frequency resolution that corresponds to the critical ratio because speech intelligibility is directly related to this spectral representation)

4) Using the *free-field*-to-*eardrum* conversion values (Bentler & Pavlovic, 1989) see table I or II, the standardized normal speech spectrum at the eardrum is calculated
5) The 30 dB dynamic range of the standardized speech signal, which represents the level distribution of short-term speech elements is found by adding +15 and -15 dB to the calculated speech spectrum
6) The final speech spectrum and its dynamic range is shown in the graph

D. Live-speech spectrum

1) By means of a microphone which is part of the Affinity instrument, speech signals in the environment – either from a talker next to the subject being tested or from a loudspeaker system - can be measured at the position of the *external* ear (behind the auricle i.e. corresponding to the microphone position in a standard BTE hearing aid)
2) The frequency spectrum of the speech signal is constantly calculated in one-third octave band levels
3) The one-third octave band levels are converted to levels in the *critical ratio* using the *one-third-octave-band*-to-*critical ratio* conversion values, described by Pavlovic, 1987 – see table II
4) The corresponding speech spectrum at the eardrum is found by using either the *microphone position*-to-*eardrum* conversion values described by Bentler & Pavlovic, 1989, - see table I, or the *individual 'open-ear response'*
5) The transformed speech spectrum is displayed in the graph

2. Aided condition (with a hearing aid)

A. 'Target' speech spectrum

1. The target speech spectrum for a non-linear hearing aid can not readily be estimated. Such an estimation depends namely on specific details about the hearing aid (e.g. number and bandwidth of the compression channels, the non-linear gain characteristics, the time constants etc.) as well as the used fitting rationale
2. The 'target' speech spectrum is therefore estimated in the following way: First, the target *insertion gain* is calculated using a widely accepted *linear* fitting rationale (NAL-R, Byrne & Dillon, 1986). Next, the 'target' speech spectrum is found by adding the target insertion gain to the standardized speech spectrum as calculated

above - see 1C-4, and displayed in the graph as the aided speech spectrum (target)

B. Aided live-speech spectrum
   1) By means of a probe microphone which is part of the Affinity instrument, *aided* speech from the environment – either from a talker next to the subject being tested or from a loudspeaker system - can be measured at the position of the eardrum with the hearing aid in place
   2) The frequency spectrum of the aided speech signal is constantly calculated in one-third octave band levels
   3) The one-third octave band levels are converted to levels in the *critical ratio* using the *one-third-octave-band*-to-*critical ratio* conversion values, described by Pavlovic, 1987 – see table II
   4) The measured aided live-speech spectrum is displayed in the graph

References

ANSI S3.5-1997. Methods for calculation of the speech intelligibility index. American National Standards Institute

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IEC 959. 1990. Provisional head and torso simulator for acoustic measurements on air conduction hearing aids. International Electrotechnical Commission

ISO 226. 1987. Acoustics – Normal equal loudness level contours. International Organization for Standardization

Pavlovic, C.V. 1987. Derivation of primary parameters and procedures for use in speech intelligibility predictions. J. Acoust. Soc. Am. 82, 2, 413-422

Center frequency	MAF_{bin} 1)	bin => mon 2)	MAF_{mon} 3)	FF => ED 4)	MAF_{mon} ED 5)	FF => BTE 6)	BTE => ED 7)
[Hz]	**[dB SPL]**	**[dB]**	**[dB SPL]**	**[dB]**	**[dB SPL]**	**[dB]**	**[dB]**
125	20,7	1,7	22,4	0,0	22,4	0,0	0,0
160	16,8	1,7	18,5	0,0	18,5	0,0	0,0
200	13,8	1,7	15,5	0,5	16,0	0,5	0,0
250	11,2	1,7	12,9	1,0	13,9	0,5	0,5
315	8,9	1,7	10,6	1,4	12,0	0,8	0,6
400	7,2	1,7	8,9	1,5	10,4	1,1	0,4
500	6,0	1,7	7,7	1,8	9,5	1,2	0,6
630	5,0	1,7	6,7	2,4	9,1	1,1	1,3
800	4,4	1,7	6,1	3,1	9,2	0,9	2,2
1000	4,2	1,7	5,9	2,6	8,5	0,3	2,3
1250	3,7	1,7	5,4	3,0	8,4	0,6	2,4
1600	2,6	1,7	4,3	6,1	10,4	2,5	3,6
2000	1,0	1,7	2,7	12,0	14,7	4,1	7,9
2500	-1,2	1,7	0,5	16,8	17,3	3,5	13,3
3150	-3,6	1,7	-1,9	15,0	13,1	2,8	12,2
4000	-3,9	1,7	-2,2	14,3	12,1	3,7	10,6
5000	-1,1	1,7	0,6	10,7	11,3	-1,2	11,9
6300	6,6	1,7	8,3	6,4	14,7	1,6	4,8
8000	15,3	1,7	17,0	1,8	18,8	3,3	-1,5

1) Minimum Audible Field (binaural), MAF_{bin} - ISO 226 (1987)
2) Binaural to monaural conversion - Pavlovic, 1987. NB: In the SII-standard (ANSI S3.5-1997) the values are replaced by the mean value = 1.7
3) Minimum Audible Field (monaural), MAF_{mon}
4) Free-Field to eardrum conversion - Bentler & Pavlovic, 1989 (based on Shaw 1974)
5) Minimum Audible Field (monaural), MAF_{mon}, at the eardrum
6) Free-field to BTE position - Bentler & Pavlovic, 1989
7) Microphone position to eardrum conversion - calculated as the difference between FF => ED and FF => BTE values

Table I

Center frequency	Normal Speech FF 1)	1/3-oct. BW	Normal Speech FF 2)	Critical Ratio 3)		1/3-oct. => CR	Normal Speech FF 4)	FF => ED 5)	Normal Speech ED 6)
[Hz]	**[dB SPL/Hz]**	**[Hz]**	**[dB SPL/1/3-oct.]**	**[dB]**	**[Hz]**	**[dB]**	**[dB SPL/CR]**	**[dB]**	**[dB SPL/CR]**
125	28,0	29	42,6	17,9	62	3,3	45,9	0,0	45,9
160	32,4	37	48,1	17,7	59	2,0	50,1	0,0	50,1
200	34,5	46	51,1	17,0	50	0,3	51,5	0,5	52,0
250	34,8	58	52,4	16,6	46	-1,0	51,4	1,0	52,4
315	34,0	73	52,6	16,6	46	-2,0	50,6	1,4	52,0
400	34,6	93	54,3	16,9	49	-2,8	51,5	1,5	53,0
500	34,3	116	54,9	17,2	52	-3,4	51,5	1,8	53,3
630	32,1	146	53,7	17,3	54	-4,3	49,4	2,4	51,8
800	28,3	186	51,0	17,8	60	-4,9	46,1	3,1	49,2
1000	25,0	232	48,7	18,2	66	-5,5	43,2	2,6	45,8
1250	23,0	290	47,6	18,8	76	-5,8	41,8	3,0	44,8
1600	20,2	371	45,8	19,5	89	-6,2	39,7	6,1	45,8
2000	17,3	464	44,0	20,2	105	-6,5	37,5	12,0	49,5
2500	13,2	580	40,8	21,5	141	-6,1	34,7	16,8	51,5
3150	11,6	731	40,2	22,6	182	-6,0	34,2	15,0	49,2
4000	9,3	928	39,0	24,0	251	-5,7	33,3	14,3	47,6
5000	5,3	1160	36,0	25,0	316	-5,6	30,3	10,7	41,0
6300	2,6	1462	34,2	26,2	417	-5,4	28,8	6,4	35,2
8000	1,1	1856	33,8	27,7	589	-5,0	28,8	1,8	30,6

1) *Spectrum level* of Normal speech at one-third-octave frequencies - SII-standard (ANSI S3.5-1997, table 3)
2) Normal Speech, one-third-octave spectrum in the Free-Field (Leq = 62.35 dB SPL)
3) Critical Ratio in dB - from Pavlovic, 1987 (based on Fletcher 1953 and Hawkins & Stevens 1950)
4) Normal Speech, Critical Ratio spectrum in the Free-Field
5) Free-Field to eardrum conversion values - Bentler & Pavlovic, 1989 (based on Shaw 1974)
6) Normal Speech, Critical Ratio spectrum at the eardrum

Table II