# Slope and linearity of sound power (SP), directivity index (DI) and sound power directivity index (SPDI)

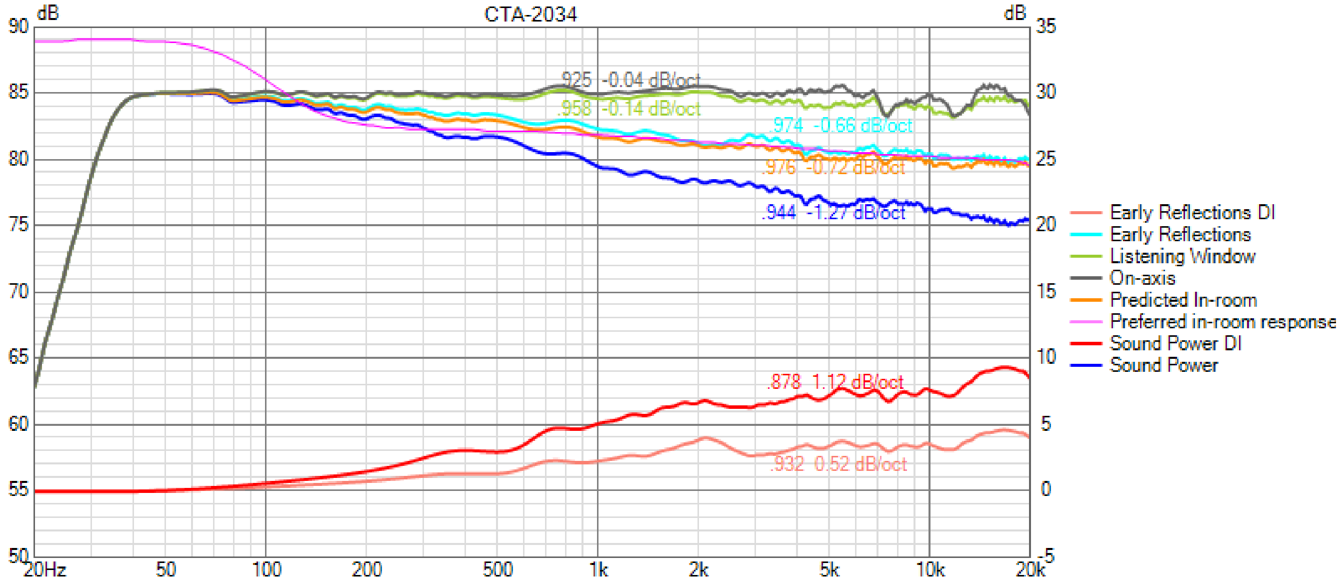
Some old study (referred by P. Tuomela 1998-2003) indicated that preferred slope of power response (SP) is -5...-6 dB from 200 to 12000 Hz i.e. -0.85...-1.02 dB/oct. Harman's listening tests preferred -6 dB from 100 to 10000 Hz i.e. -0.90 dB/oct. On-axis response of the speakers was presumably quite flat horizontal while making those conclusions. Few decades ago, power response was measured in reflecting room. It usually had some shelf up at low frequencies. Preferred in-room target response (/Olive) has significant bass boost too (though study was tiny). We can assume quite safely that **power response slope target** using modern wide band anechoic/NFS data could be a grade steeper with tolerance window such as **-0.9...-1.2 dB/oct** from 100 to 12000 Hz to support different reverberation times and spectrums, total directivities and listening distances. This value equals to +0.9...+1.2 dB/oct slope of directivity index (DI) with flat horizontal on-axis. SPDI has slightly smaller slope than DI because reference response is listening window instead of on-axis, so **SPDI slope target for flat horizontal on-axis would be +0.85...+1.1 dB/oct. Small (and linear) slope can be balanced with equalisation by lifting level at low frequencies, but steeper (or less smooth) slopes can't** without compromising diversity in listening position and room acoustics. Proper slope and shape of directivity index has higher possibilities to produce balanced sound to almost everywhere (except to corners) assuming that room acoustics is not harsh or damped at high frequencies.

Possible problem with combination of too steep slope of directivity index and previous power response slope target is too "hot" high frequencies to on-axis and listening window. Without heated on-axis at high frequencies, too steep slope of directivity produces too boomy and muffled sound in good acoustics with relatively short reverberation time - especially while casual listening when listener can be way off the spot: 60-180 degrees off-axis, in different room etc.

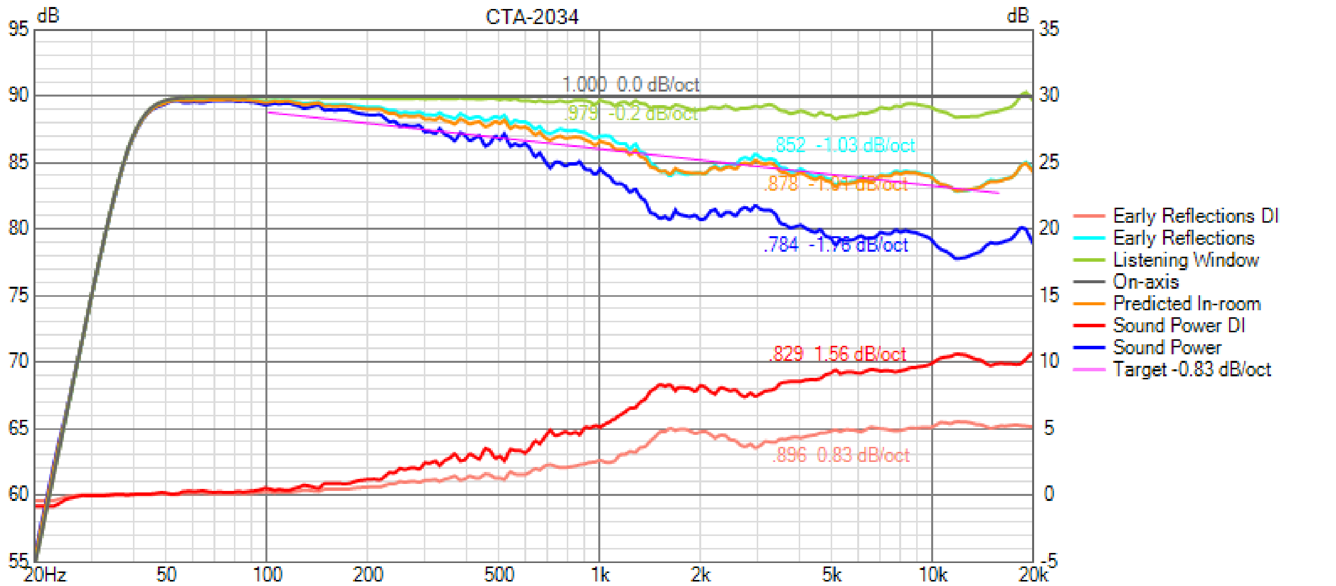
One common compromise or mistake which produces a step to directivity index is using omni-directional or side woofer(s) or small mid-woofer with otherwise directive speaker. Sub-woofer with low crossover frequency usually radiates to limited space which increases directivity index and can reduce error in power balance.

Reviews should be more critical for too steep directivity slopes and step(s) in directivity index. Slopes calculated from measured SP and SPDI should be visible. Range of SP and SPDI slope targets could be visible as tolerance window.

Slope and smoothness can be calculated for example with VituixCAD 2.0.120.0 or later:



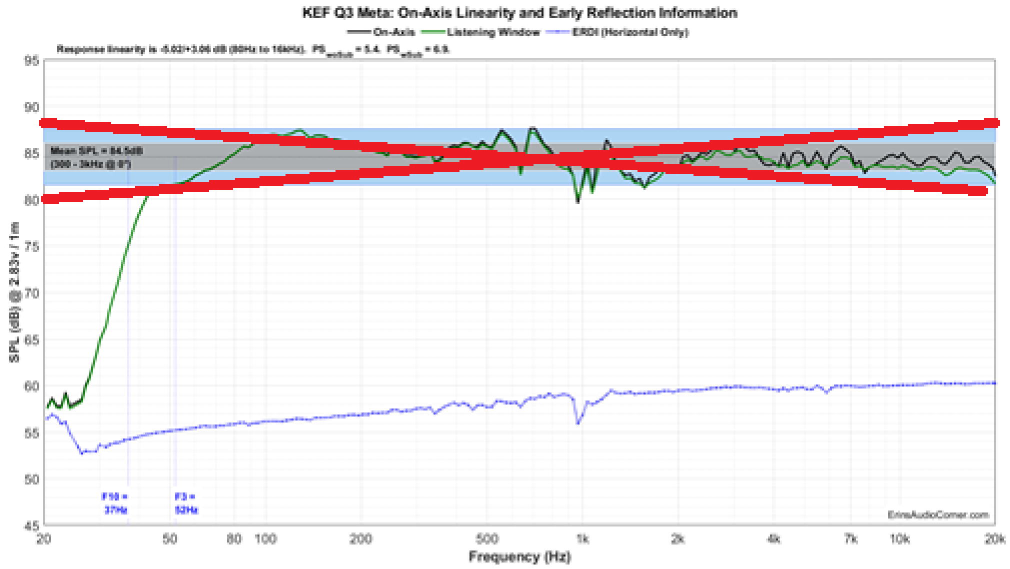

On-axis or listening window response can be normalized for power slope calculations with a crossover component:




## Slope and linearity of on-axis response (ON)

Slope of on-axis response depends on slope of directivity index i.e. mostly on speaker concept and acoustical design though crossover has some effect to slopes too. If slope of sound power directivity index (SPDI) is small such as less than 0.85 dB/oct, on-axis response should tilt down towards midrange to avoid too thin sound due to low relative power at low frequencies. On-axis can be flat horizontal if slope of SPDI is 0.85...1.1 dB/oct. So, on-axis response of all speaker types should not be evaluated using horizontal tolerance window with constant height in dB. It's okay for up to medium-sized conventional box speakers located to free space, but not by default for in/on-wall, in/on-ceiling, large conventional and constant directivity designs having smaller slope of directivity index.

Slope calculated from measured ON should be visible.




## Slope and linearity of listening window (LW)

Slope calculated from measured LW should be visible.

## Slope and linearity of predicted in-room response (PIR)

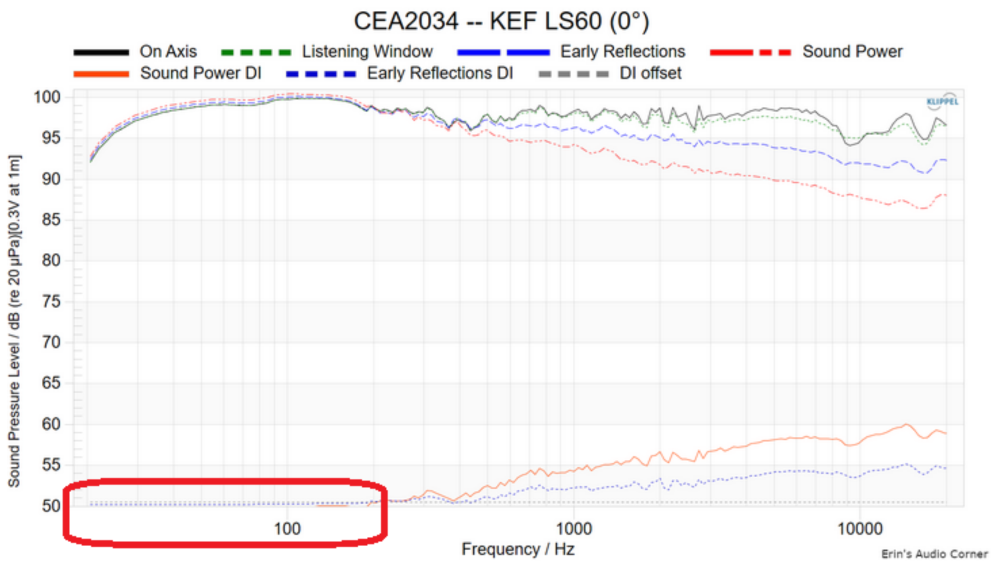
Slope of predicted in-room response is quite constant with different speaker concepts (conventional, in/on-wall, in/on-ceiling and CD). Typical values are -0.7±0.2 dB/oct. So, PIR is possible show with tolerance window. Tolerance window could be between preferred in-room target response slope of -0.5 dB/oct and preferred headphone target response slope of -0.9 dB/oct (both /Olive) to support different concepts, reverberation times and spectrums, total directivities and listening distances.

Slope of PIR calculated from the measurements should be visible.

Olive's studies suggest that narrow band deviations (NBD) in PIR should be as small as possible, and linear PIR is better than non-linear. Nothing exact. Audio Science Review and spinorama.org emphasize linearity as a target by drawing or calculating regression line over the response. ASR has been using word "ideal" for linear, but that's overstatement. Many natural acoustic phenomena are partly proportional to frequency - not logarithm of frequency, and off-axis response slopes with gentle corner down improve immunity to listening direction and therefore dimensions of listening triangle too. In addition, preferred in-room target response (/Olive) and X-Curve have gentle corner down at upper mid...low treble. So, I can't fully agree that off-axis responses and predicted in-room and other power averages should be perfectly linear instead of curve with gentle corner down at upper mid...low treble.

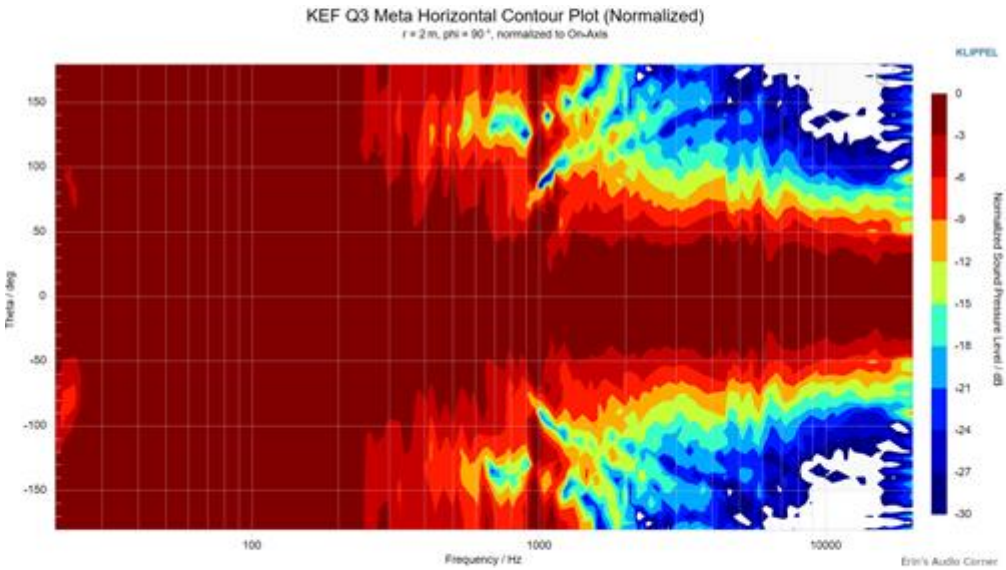
## CEA2034 Directivity Response

Directivity index traces should not be cropped at 0 dB to show possible problems with acoustical design.

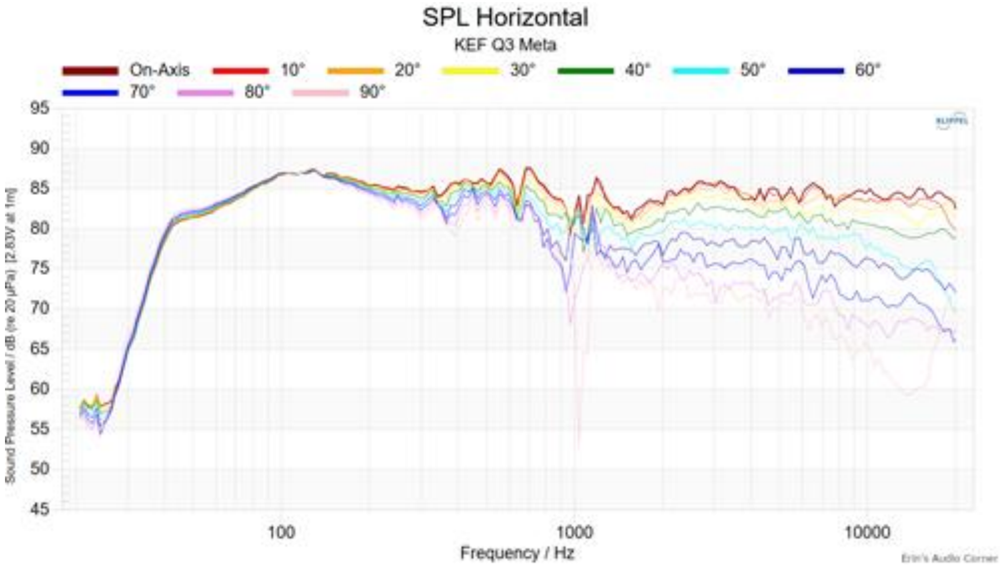



## Polar map

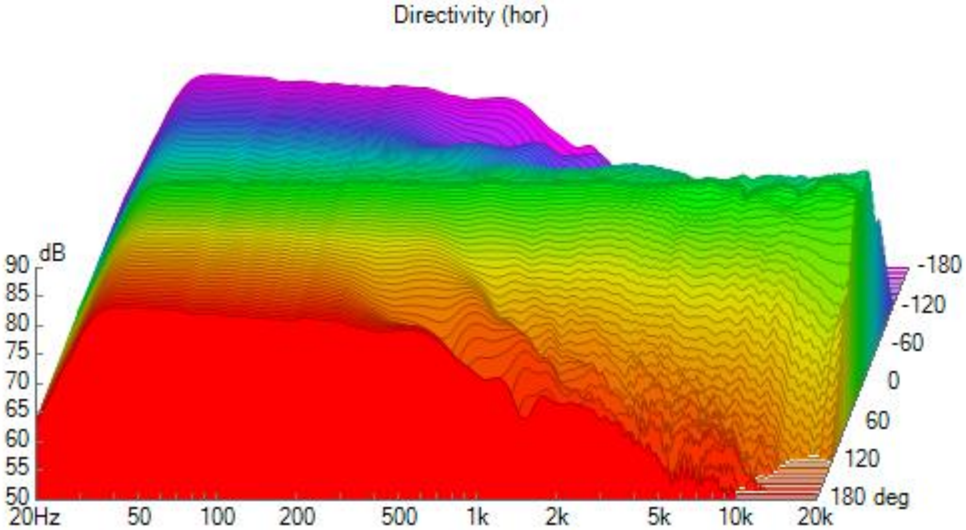
Normalized polar map shows directivity, but not original balance and dispersion: what kind of compromise manufacturer has done between on-axis and off-axis. This is significant especially if equalization is not available or DSP is not preferred due to otherwise pure analogue signal path.



Original (unnormalized) off-axis balance could be visible also as a polar map though line chart is shown.

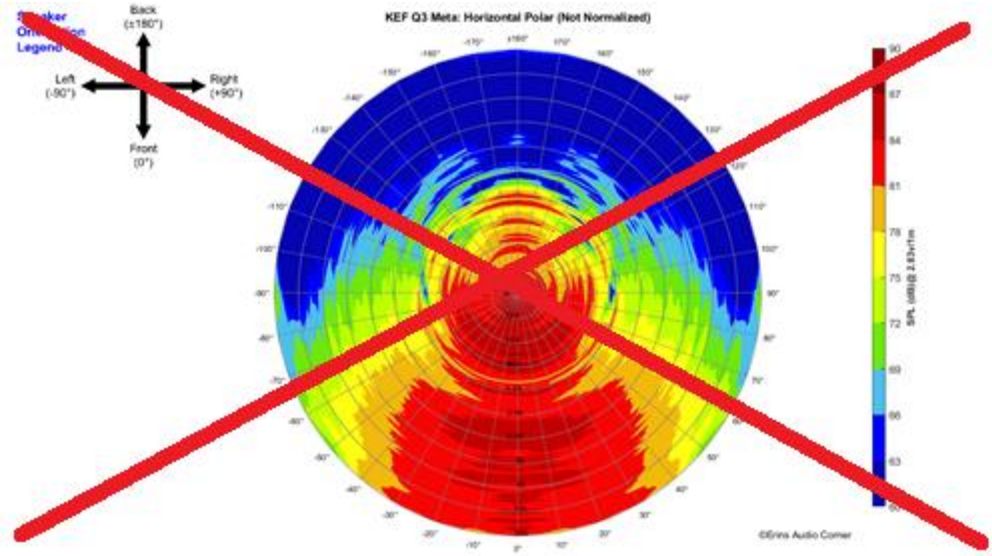



Axonometric waterfall (such as in MLSSA) is more visual, but does not have cursor or grid lines to verify f,dB -values without plotting application.



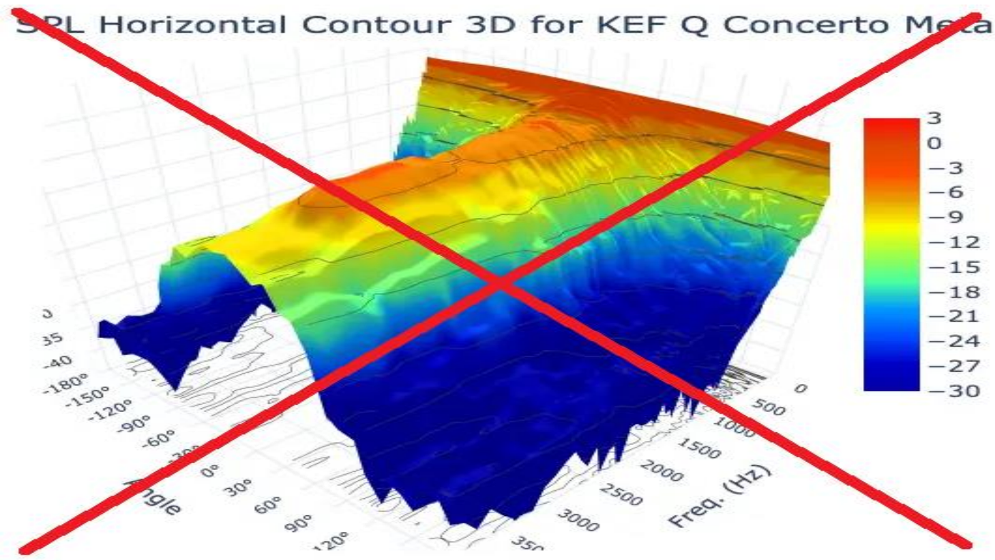

## Globe plot

This is the same as polar map but with truncated frequency and non-linear angle scale. Colourful but worthless as double information. The space is worth to use for something different and useful.




## Contour 3D

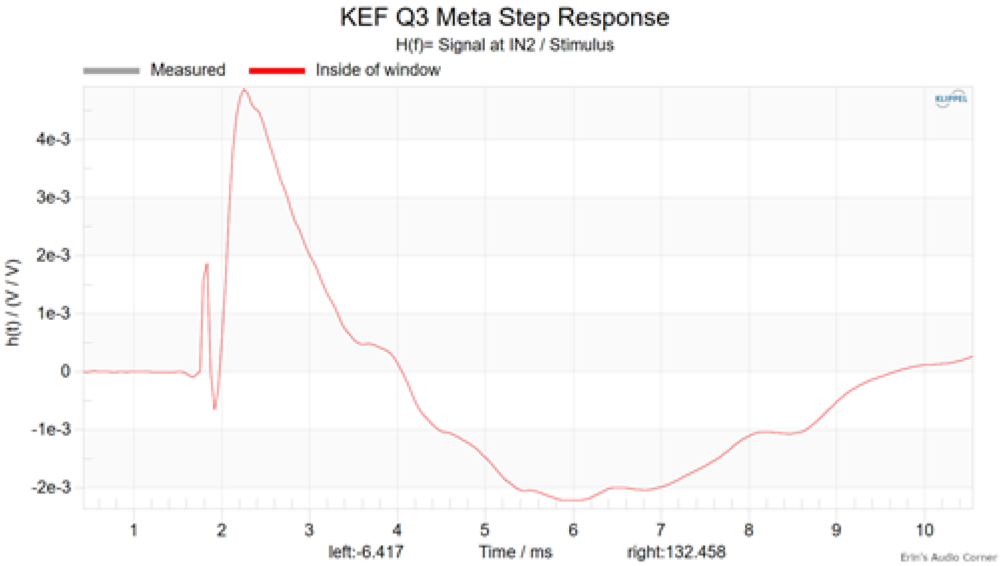
This is also quite colourful but worthless with linear truncated frequency scale.



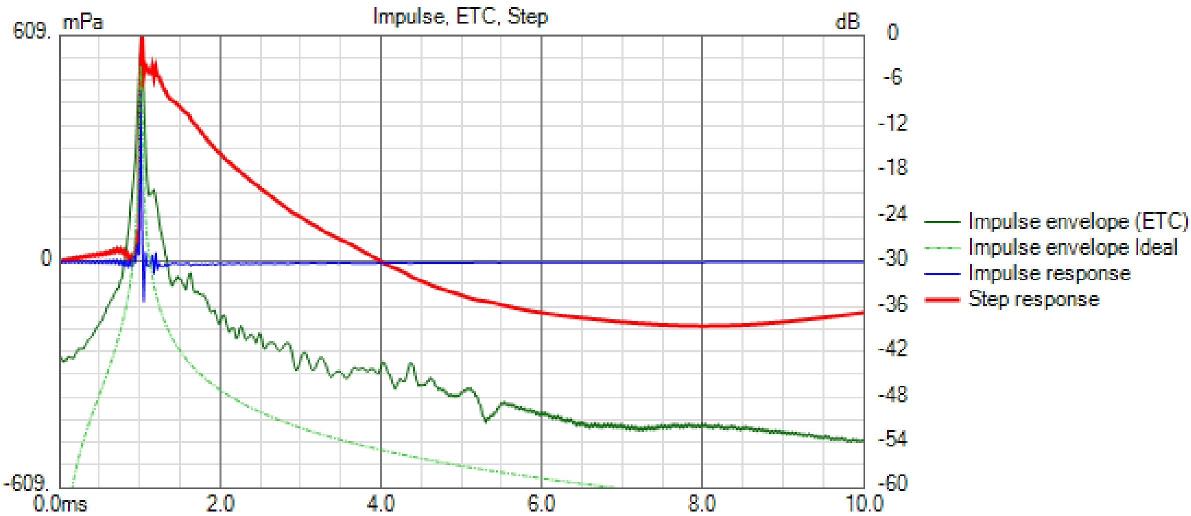

## Timing

Sound signal is local pressure deviation from the ambient atmospheric pressure as a function of time, so timing is fundamental quantity.

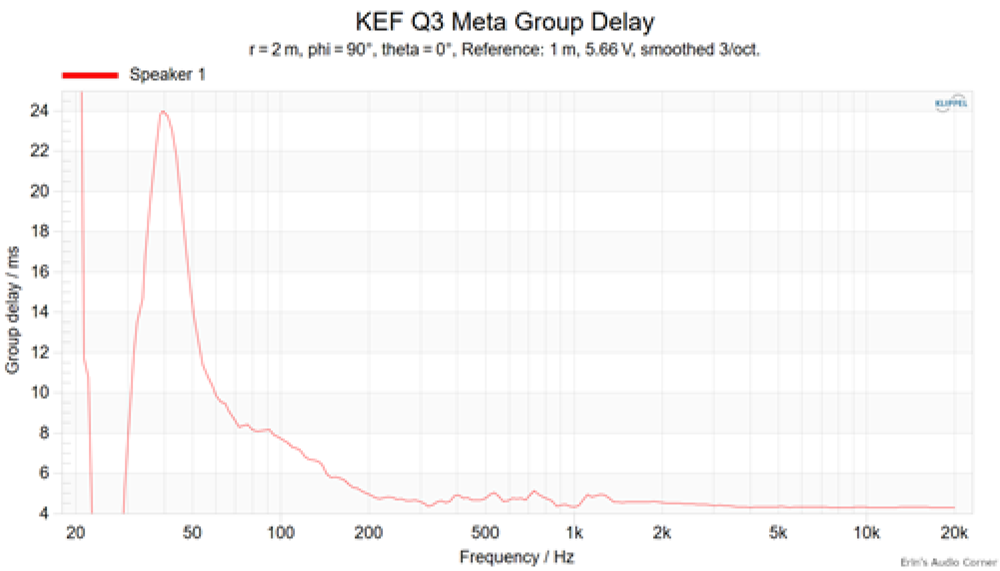
Step response shows something about timing, but imperfect step is difficult to understand and scale to quantity of timing error.



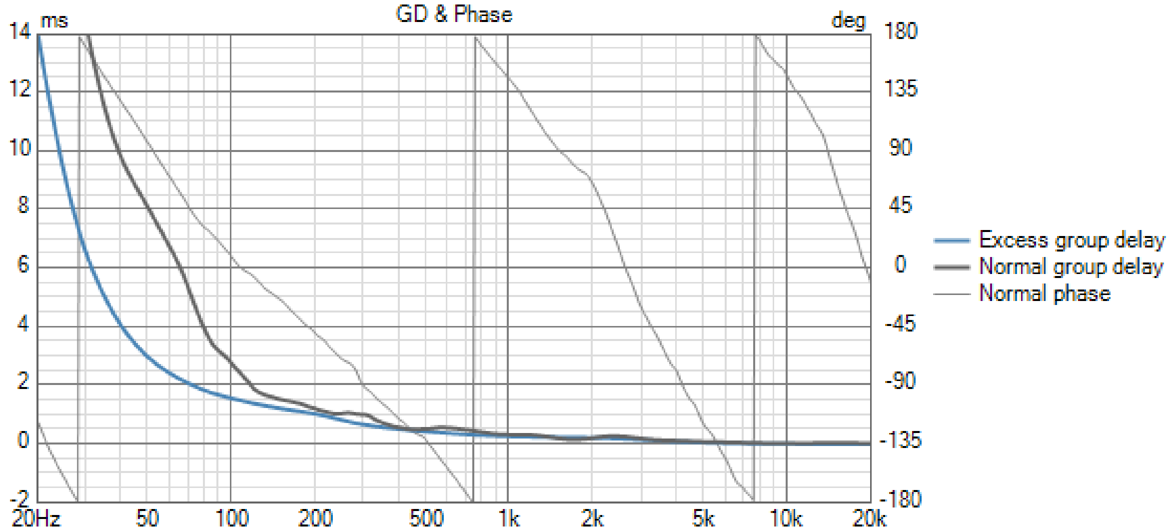

Measured and ideal impulse envelope could help to interpret step response, but imperfect is still difficult.




Normal group delay does not show timing "error" i.e. difference to group delay of minimum-phase response. So, this is quite worthless too.

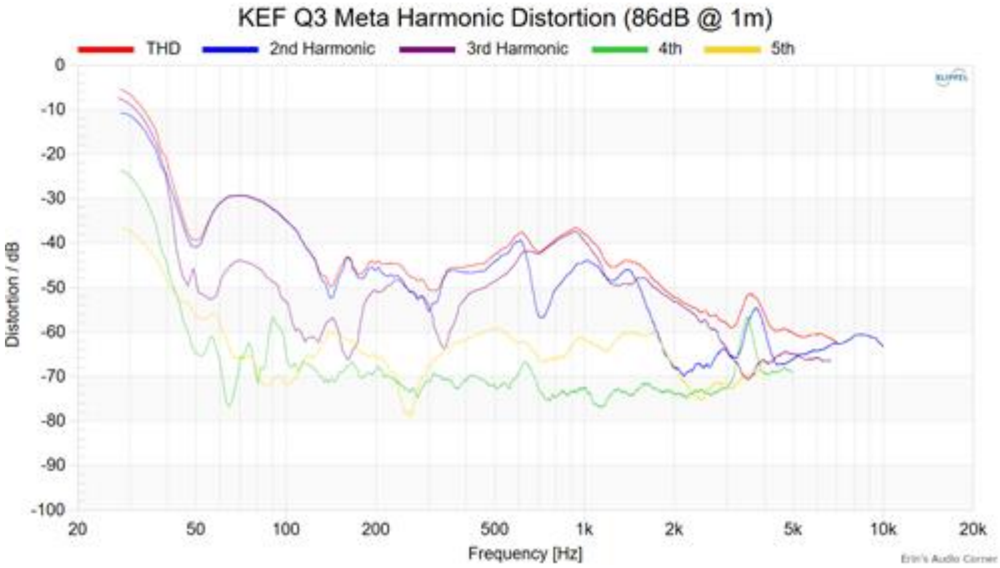


**Excess group delay** is the most valuable and direct timing graph, though it requires calculation with some assumptions about unknown response slopes.



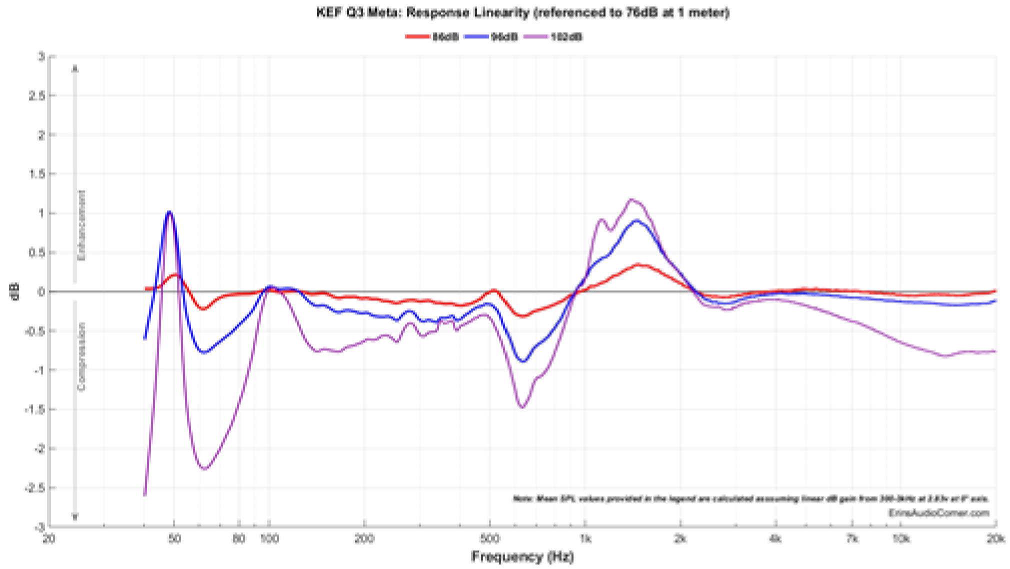

## Harmonic distortion

This graph is ok to show.



## Compression

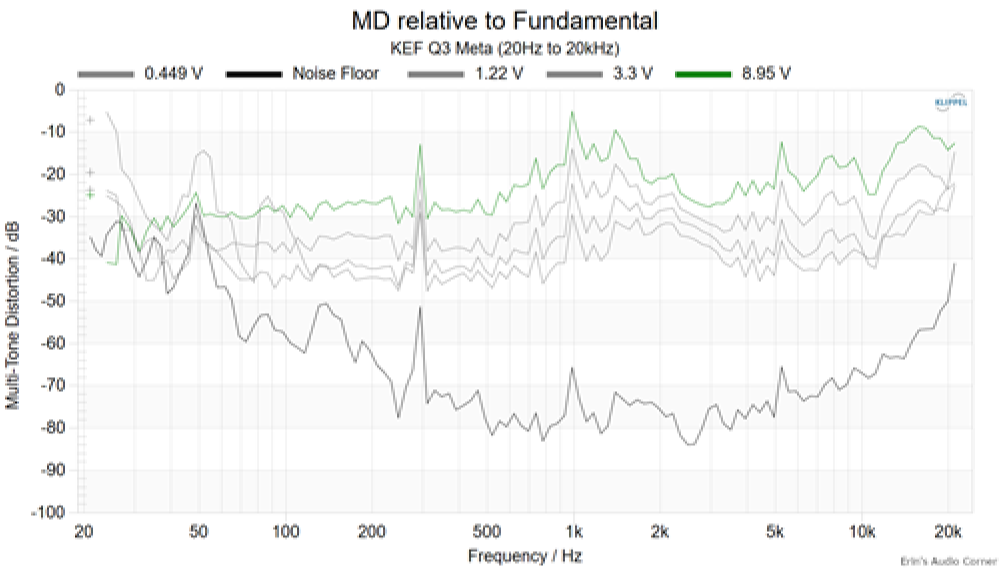
Response linearity with flat spectrum is okay, but it doesn't show directly how compression shapes response with signal closer to music program.




AES75 Music-Noise (ex. M-Noise) indicates better where compression starts with music though it probably contains relatively more bass than playlist of average metalhead. Compression plots with signal equalized to peak and RMS of Music-Noise or band-limited pink noise would be more realistic than signal with flat spectrum. Easiest is to use Music-Noise with Spectrum Analyzer, though it does not show distribution between fundamental and IMD products. Just changes in total magnitude spectrum.

## Multi-tone distortion

This graph is ok to show.




## Measurement data

Measurement data should be available for free for post processing, further analyses and statistical studies. Graphical tracing is slow and limited and difficult method due to art and writing over the graphs, and palettes with too lame or transparent colours. Publishers should export and share:

- All 70 or 142 frequency responses as 3-column (Hz, dB, deg) text files.
  Naming style; generic name hor/ver angle, CLIO, EASE, VACS or Monkey Forest 3D.
  Reference axis distance removed from phase responses to avoid excessive phase wrapping and align GD~0 ms at the top octave of on-axis response.
- Optional: Calculated LW, ER, PIR, SP, SPDI and ERDI as 2-column (Hz, dB) text files.
- Optional: Calculated front, side, rear, floor and ceiling bounce, and horizontal and vertical reflections as 2-column (Hz, dB) text files.
- Optional: Group delay and Excess group delay as 2-column (Hz, ms) text files.

Frequency range 20-20000 Hz or more, 48-96 points per octave.
Space or tab delimited.
Invariant number format: decimal character period (.), thousand separator none.

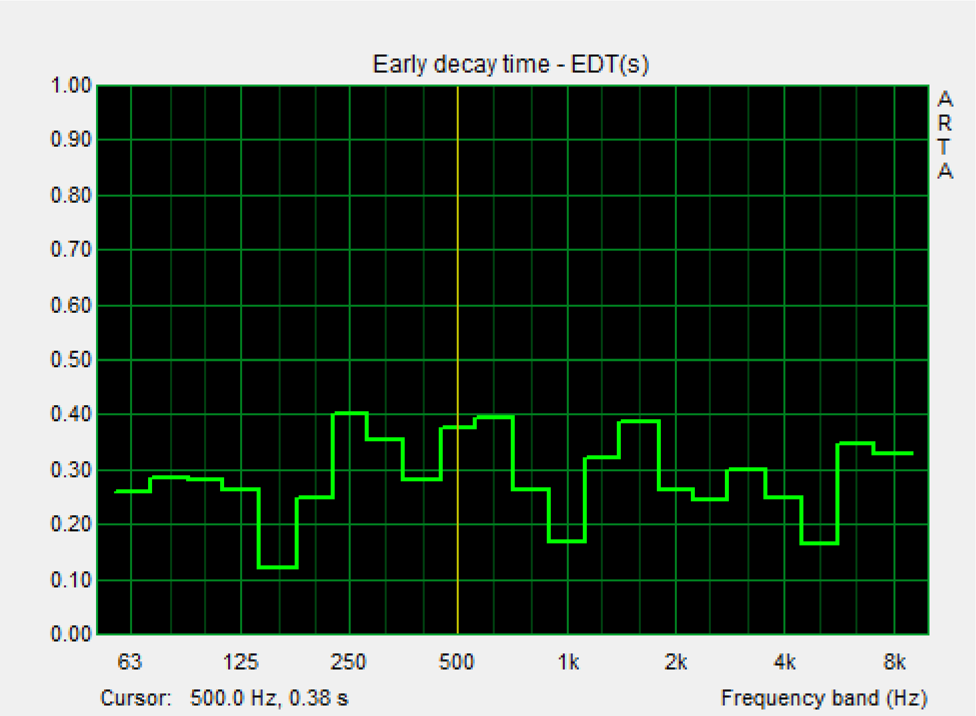
- Impulse response to on-axis as 32-bit IEEE mono wav or MLSSA text or 2-column (ms, Pa) text with original sampling rate and samples >= 32k.

## Room acoustics

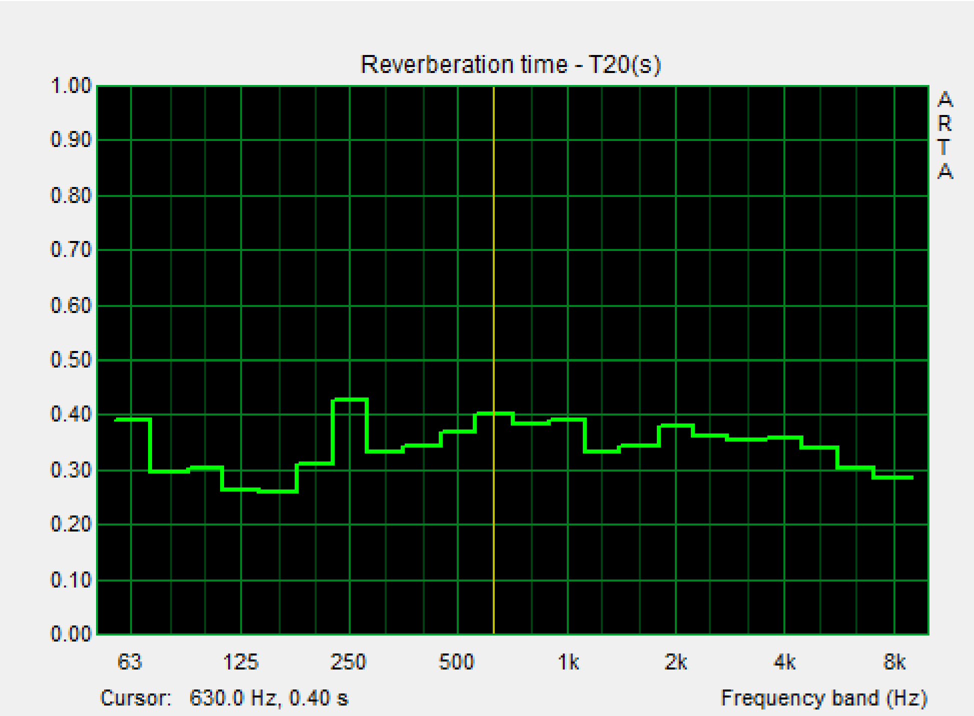
Subjective evaluations need measured acoustical parameters and description about listening room and locations for a reference. Otherwise, subjective impressions are difficult to translate to own experience and ignore in case environment or setup deviates too much from own preferences or possibilities. Acoustical parameters should be measured with some small conventional speaker at typical far field listening distance.

Bad acoustics should be fixed because speakers don't deserve bad review due to bad acoustics.

**EDT** spectrum with 1/3 oct. resolution to verify magnitude and smoothness of flutter echo:



RT60 as **T20** or **T30** with 1/3 oct. resolution to verify decay time and smoothness of reverberation:




Optional **STI** analysis to verify produced acoustical resolution.
This could be attached for tested loudspeaker to visualize magnitude and spectrum of achieved acoustical resolution. STI needs EDT for a reference.

MTF

| Oct.Band | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
|---|---|---|---|---|---|---|---|
| f1=0.63 | 0.999 | 0.998 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 |
| f2=0.80 | 0.998 | 0.996 | 0.998 | 0.998 | 0.998 | 0.997 | 0.999 |
| f3=1.00 | 0.997 | 0.994 | 0.997 | 0.996 | 0.997 | 0.996 | 0.998 |
| f4=1.25 | 0.994 | 0.988 | 0.994 | 0.993 | 0.994 | 0.992 | 0.996 |
| f5=1.60 | 0.990 | 0.981 | 0.990 | 0.988 | 0.990 | 0.987 | 0.994 |
| f6=2.00 | 0.986 | 0.972 | 0.985 | 0.983 | 0.986 | 0.982 | 0.991 |
| f7=2.50 | 0.978 | 0.957 | 0.976 | 0.973 | 0.979 | 0.972 | 0.986 |
| f8=3.15 | 0.969 | 0.939 | 0.967 | 0.963 | 0.971 | 0.961 | 0.980 |
| f9=4.00 | 0.950 | 0.908 | 0.949 | 0.944 | 0.956 | 0.942 | 0.969 |
| f10=5.00 | 0.931 | 0.876 | 0.931 | 0.925 | 0.941 | 0.924 | 0.959 |
| f11=6.30 | 0.902 | 0.834 | 0.906 | 0.898 | 0.922 | 0.900 | 0.944 |
| f12=8.00 | 0.860 | 0.780 | 0.874 | 0.861 | 0.897 | 0.872 | 0.925 |
| f13=10.00 | 0.813 | 0.718 | 0.844 | 0.824 | 0.870 | 0.847 | 0.906 |
| f14=12.50 | 0.752 | 0.626 | 0.813 | 0.785 | 0.839 | 0.823 | 0.884 |
| MTI | 0.911 | 0.863 | 0.918 | 0.909 | 0.931 | 0.914 | 0.953 |

| | |
|---|---|
| STI Male=0.92 | rated A+ |
| STI Female=0.92 | rated A+ |
| STIPA(IR)=0.92 | rated A+ |

## Listening tests

Should be done (also) in stereo. In/on-wall, in/on-ceiling, corner etc. designs as they are intended to be used. Locations of speakers and listener should be optimized to get good…the best performance.

Listen everywhere in the room and other rooms as well to evaluate effects of possible unbalanced power spectrum and omni band(s) in otherwise directive speaker.