TO SMOOTH OR NOT TO SMOOTH . . . .

Our first step in undertaking documentation of our products was to analyze what our competition had done and look for any commonality or standards in their measurement and/or presentation of the data. In the area of smoothing it became immediately clear that there was no standard and almost no consistency between even two manufacturers. To make matters worse the vast majority of manufacturers in our industry do not indicate what parameters (such as pen speed on analog recorders, sample rate of digital devices, percent octave related smoothing or even eyeball approximation by the art department) were used in smoothing their data. Yet most manufacturers and even customers agree that smoothing is generally bad. Some go so far as to call it cheating.

Manipulating data to make it legible on a chart, or more related to the phenomena the measurement is trying to represent, is a common practice in science, business and manufacturing. Scientists average data to make trends more visible, business people round percentages and dollars to significant decimal points and manufacturers set manufacturing tolerances based on averages and critical operating ranges. All of these forms of manipulation of data can be generically called smoothing. Smoothing is not inherently bad. It can make otherwise useless or confusing data useful. However, smoothing can be misused to make something look like something it is not. The key is using as little smoothing as possible to make a particular point and letting the reader know how much of what type of smoothing was used.

The audio industry lacks a standard for how much or how little data should be smoothed when presenting a particular form of information. For this reason, each manufacturer has taken it upon themselves to create their own company, or even product, standard. It is impossible to look at any two manufacturers' frequency response curves, for example, and compare them since each uses a different test method and smoothing standard. These smoothing "standards" often are not documented and vary from product to product within a manufacturer's product line. Sometimes smoothing is done so that curve relates better to what is actually heard. Sometimes it is done to prove a point, and many times it is done for competitive reasons; "Ours sounds better than theirs, so our curve needs to look at least as good as theirs or no one will buy ours no matter how good it sounds". This is the point where science becomes fiction and real data disappears.

For all the reasons stated above, "smoothing" has become a bad word in our industry. Very few manufacturers talk about it.

One of the few standards that does exist (in theory) is 1/3 octave and octave polars and isobars. By definition, a 1/3 octave polar shows the 1/3 octave average sound pressure level at several off axis points. The octave or 1/3 octave average is in itself a form of smoothing. Just look at the difference between a particular frequency's octave and 1/3 octave polar or isobar.

In general, octave isobars and polars will look smoother than the 1/3 octave even though both have the same center frequency. This is because there are more points being averaged in an octave average than in the 1/3 octave average. Even this "standard" is not complete. There is no standard for how many off axis points are measured, 5^{o}, 10^{o}, 15^{o}, or more. Also some manufacturers take the already averaged data and geometrically smooth the resulting polar pattern so it looks even smoother. So even our standards are not consistent.

There is some justification for the smoothing of frequency response curves - it makes them more representative of what we hear. This makes sense if that is the point the manufacturer is trying to make with the particular curve. But what if the manufacturer is trying to make the point that his system has good summing at crossover frequency? In this case the manufacturer might choose less smoothing to show just how good his product really is.

As you can see, the whole issue of smoothing is very involved and confusing. Our goal is to present accurate, documented, repeatable data. To this end, we have come up with the following standard and rationale for smoothing:

A.   All data is collected with frequency resolution at least 1/2 of the lowest frequency of interest or approximately 40 Hz (lower limit while eliminating first reflection), whichever is higher. This provides detailed, readable raw data that can later be smoothed to suit a particular purpose.

B.   Frequency response curves and distortion curves are smoothed 12.5% per octave (1/8 octave). This smoothing is needed for readability and to better represent what we actually hear.

C.   Devices that operate below 100 Hz have an additional measurement made from 20 Hz to 500 Hz or above using a 10 Hz or lower frequency resolution at a much closer distance. This greatly increases the differential between the direct sound to the microphone and the reflected sounds that are allowed into the measurement by the larger time window of the 10 Hz resolution. This also allows using the same minimal 12.5% per octave (1/8 octave) smoothing. At low frequencies there are little or no differences between near and far field measurements.

D. All directivity data is presented with no further smoothing as any further smoothing would be misleading and gloss over actual performance.

E.   All impedance curves are measured with 10 Hz frequency resolution or below at low frequencies and 20 Hz resolution above 200 Hz. This resolution provides the necessary detail to accurately show the impedance of the product under test.

Is What You See What You Get?

To gain a better understanding of how smoothing can be beneficial and how it can be misused, the following curves were prepared. These curves were all generated from a single test of a defective loudspeaker system. A defective system was chosen to show how problems can be covered up by smoothing.

Figure 1 shows a raw frequency response curve with 10 Hz frequency resolution. You can see the results of reflections in the low frequency and a smearing of high frequencies due to the high point density. Most people would agree that it is difficult to really judge the performance of this system from this curve.

Figure 2 shows how 1% smoothing equalizes point distribution and makes the high frequency information easier to read while the mid and low frequencies are virtually unaffected.

Figure 3 shows how 8.3% smoothing makes the data easy to read while maintaining a high degree of detail in all frequency bands. It more closely matches what we hear. We have chosen a slightly higher 12.5% smoothing (1/8 octave) to use for frequency response curves.

Figure 4 shows 33.3% smoothing - equivalent to 1/3 octave smoothing. It is clear that some of the detail is lost but the general shape of the curve remains the same.

Figure 5 shows 100%, one octave smoothing. You can see that all the detail is lost and the general shape of the curve has changed. If you compare the amount of detail in this curve with many manufacturers specification sheets you will see a lot of similarities.

Figure 6 shows 200%, two octave smoothing. This figure bears little resemblance to the raw data seen in Figure 1. Furthermore, if you read Figure 6 without also seeing the raw data, you would conclude that you are looking at a well behaved loudspeaker with a variance of +/- 3dB over its operating range, when in fact it is a defective speaker that was rejected by manufacturing testing.

Figure 7 shows that the insanity of smoothing can be taken to any length to make a curve look as flat as the tester would like.

Figures 8, 9 and 10 illustrate how vertical scale can affect resolution of data. The smoothing has been fixed at 8.3% for clarity's sake. One way to measure vertical scale is to compare it to the horizontal scale. Many manufacturers seem to hover around 30 to 40 dB vertically per horizontal frequency decade.

Figure 8 shows half the resolution or 60 dB per decade. Even though the octave smoothing has not changed, the data looks much smoother.

Figure 9 shows 30 dB per decade resolution as used by Community.

Figure 10 shows 18 dB per decade resolution. This makes the speaker look unusable even though it is the same data.

We hope this information helps clarify the confusing subject of smoothing. The bottom line is that very rarely can you compare two manufacturers' printed data unless you know how the device was tested and what type and amount of smoothing was performed on the data, and what resolution was used in the measurement.

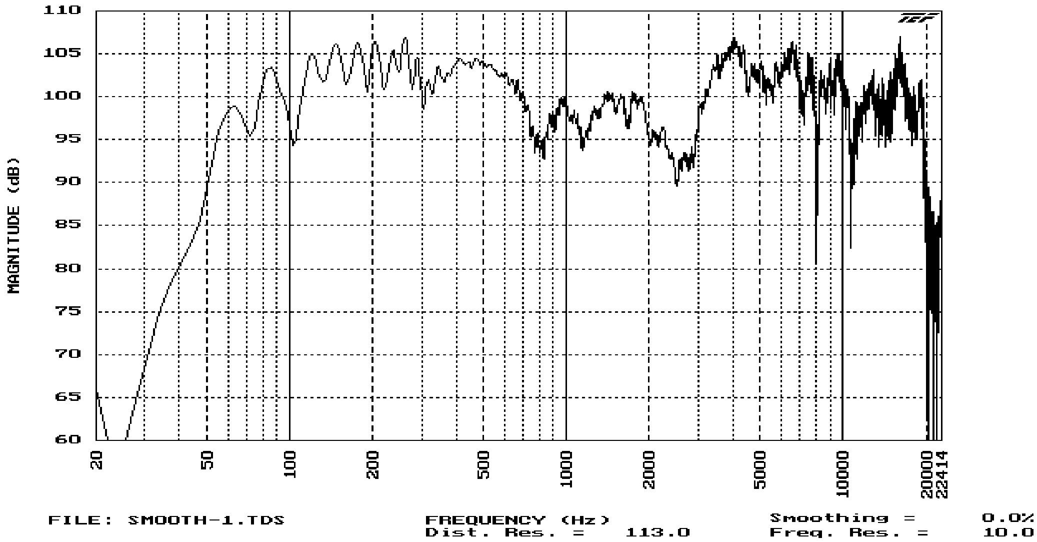

Figure 1. Raw Data

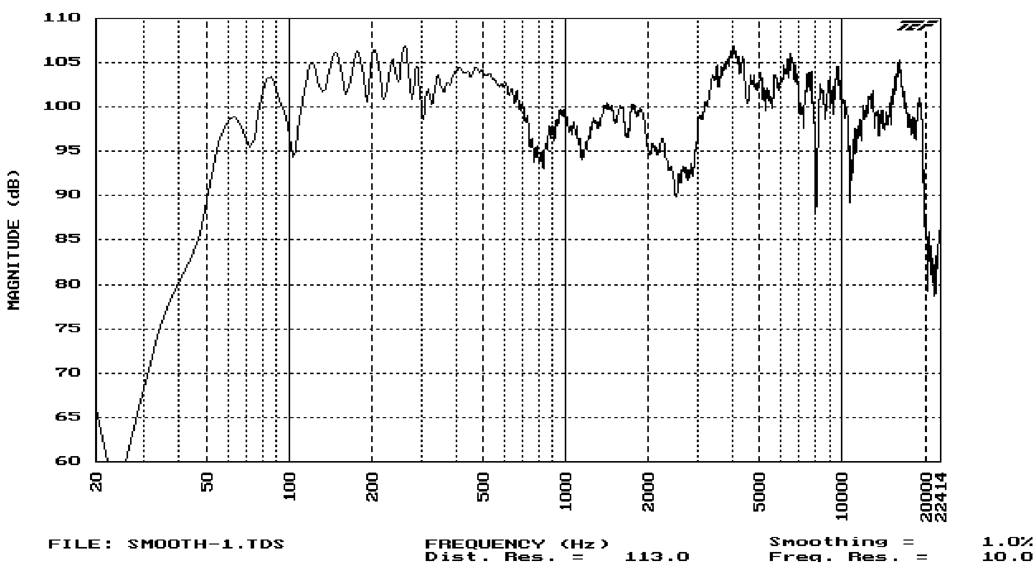

Figure 2. 1% Smoothing

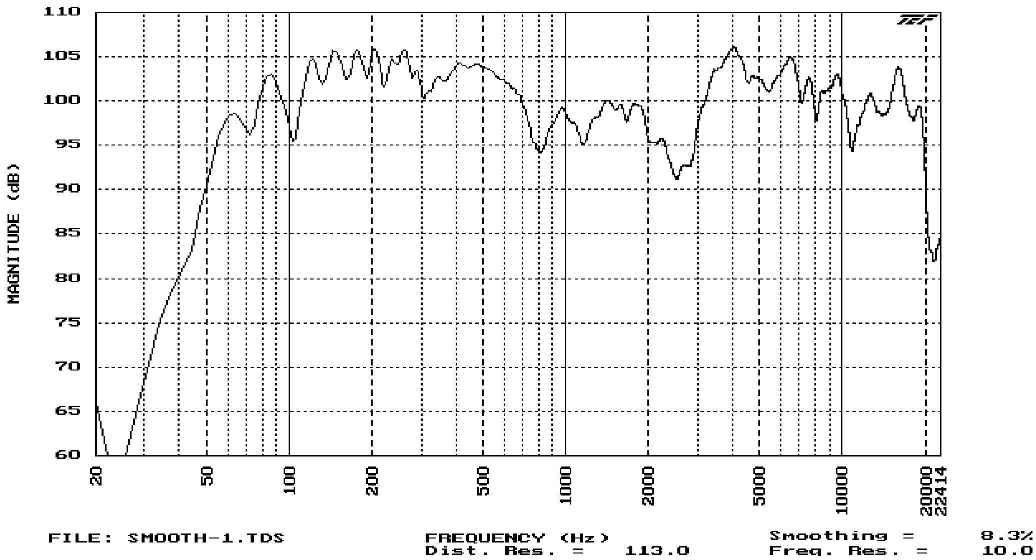

Figure 3. 8.3% (1/12 Octave) Smoothing

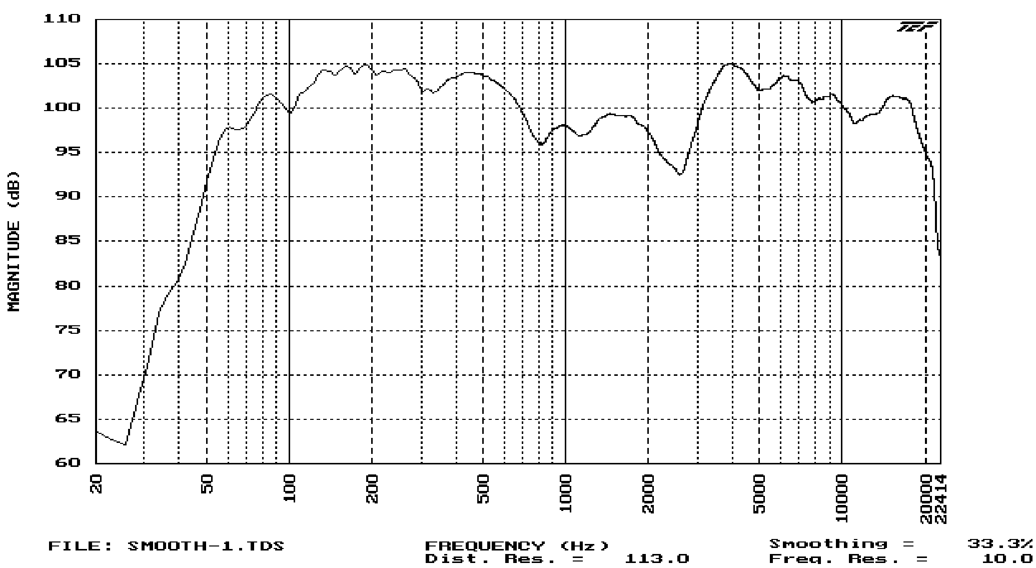

Figure 4. 33.3% (1/3 Octave) Smoothing

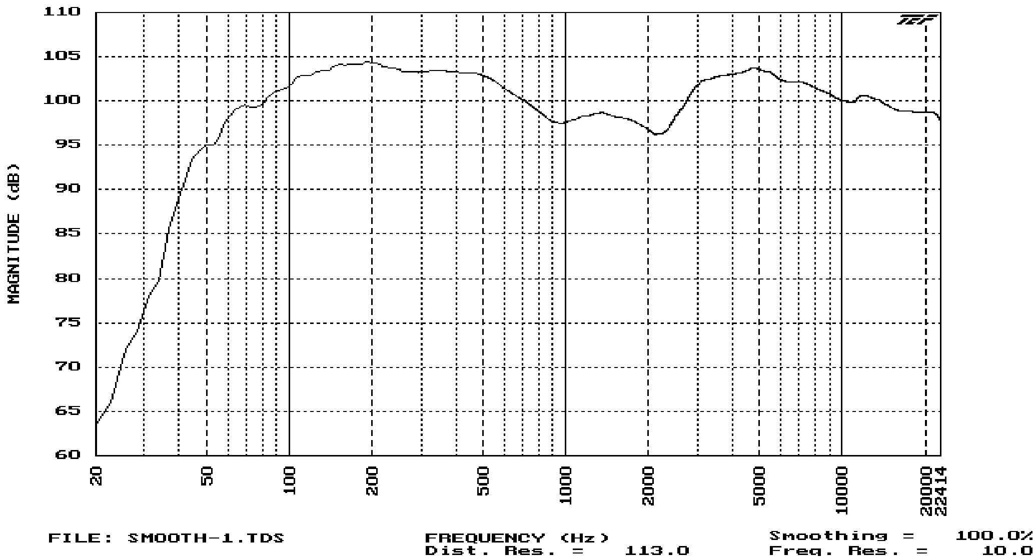

Figure 5. 100% (1 Octave) Smoothing

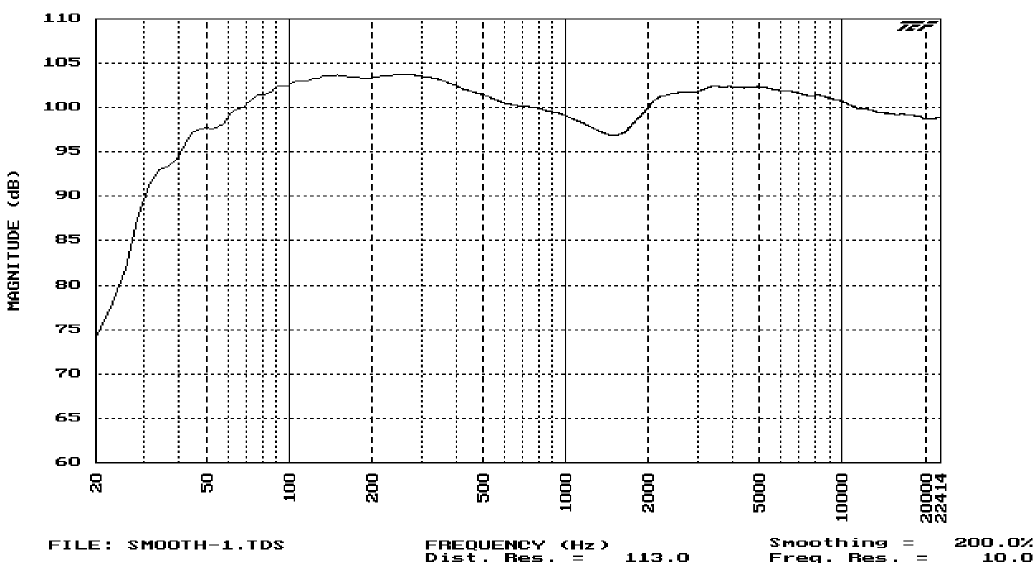

Figure 6. 200% (2 Octave) Smoothing

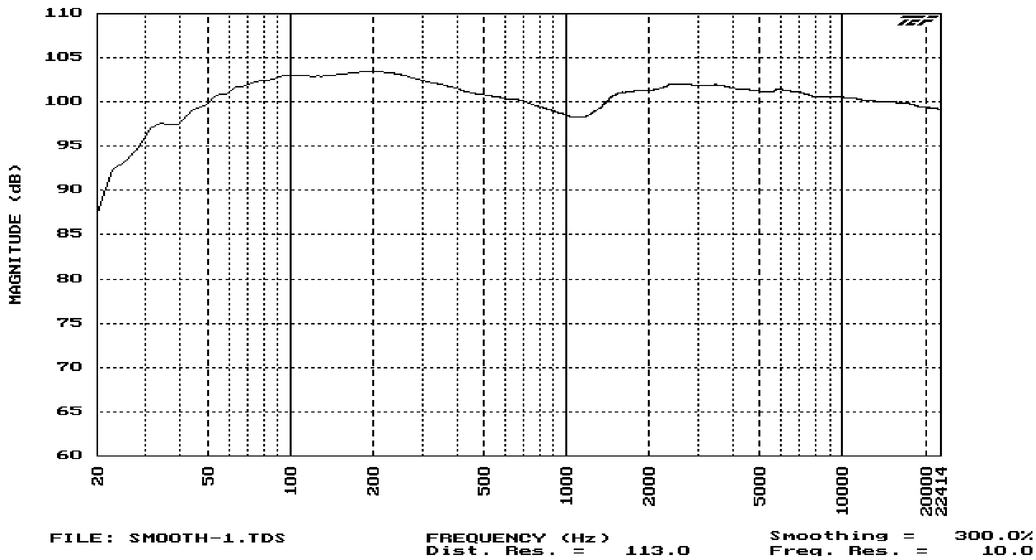

Figure 7. 300% (3 Octave) Smoothing

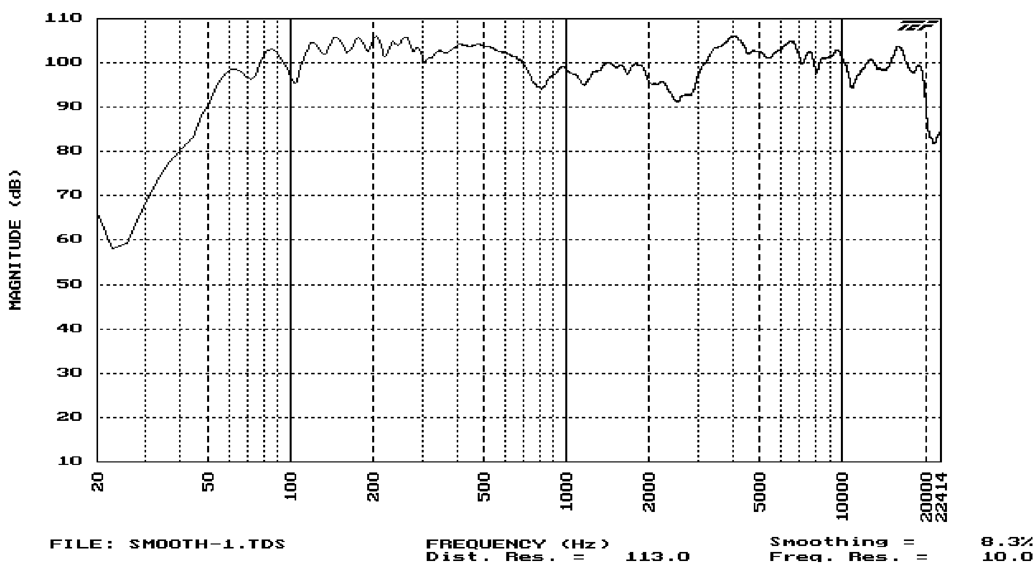

Figure 8. 60dB per decade

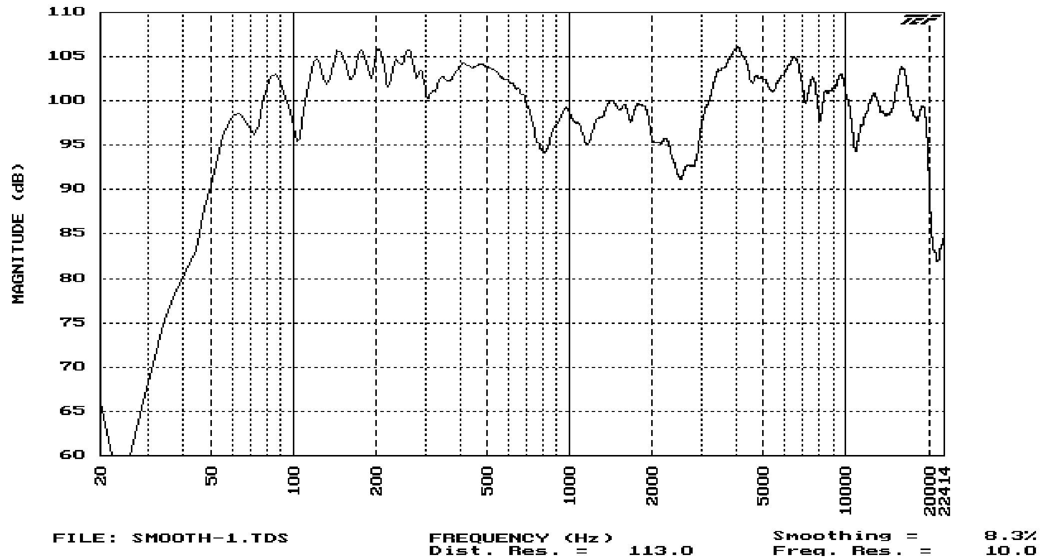

Figure 9. 30dB per decade

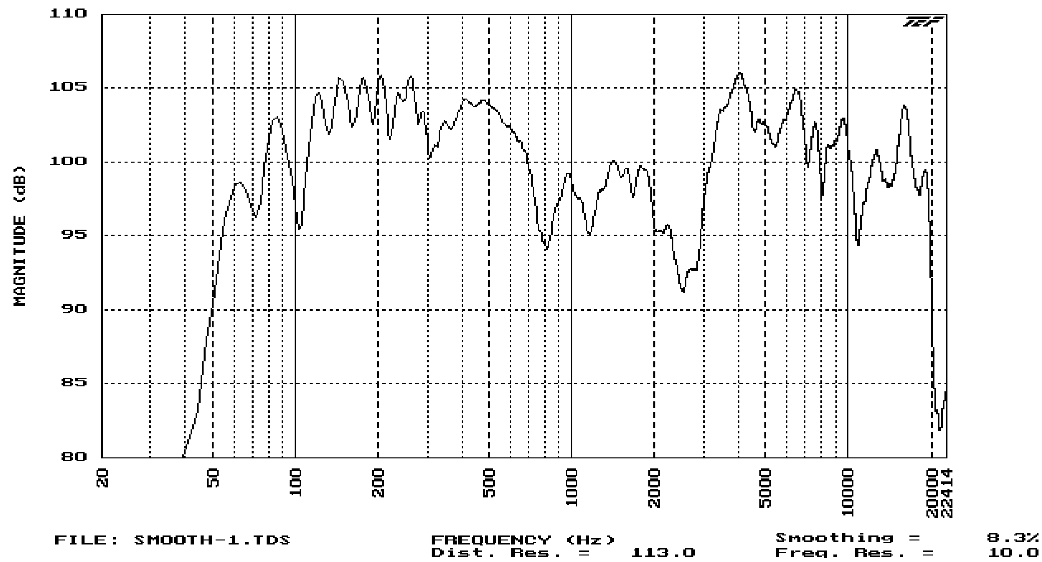

Figure 10. 18dB per decade

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