# PERCEPTUAL EFFECTS OF REDUCED NONLINEAR MICROPHONE DISTORTION

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## ABSTRACT

During the development of the acoustic impedance matching Model A microphone extensive subjective trials were undertaken in parallel to the measurement related testing. These trials were designed to offer a subjective perspective on the audibility of the large order reduction of nonlinear distortion.

In the course of correlating objective measurement results & subjective trials a strong link between the two fields of testing was observed and is investigated.

## 1. INTRODUCTION

When we measure the nonlinear distortion behaviour of the microphone, we do so over the bandwidth of the working range, using the technique known as difference frequency analysis.

This technique allows us to measure the non-harmonic component of nonlinear distortion with a relatively simple & reliable test, and allows us to indicate the general nonlinearity of the microphone at any given sound pressure level & frequency range.

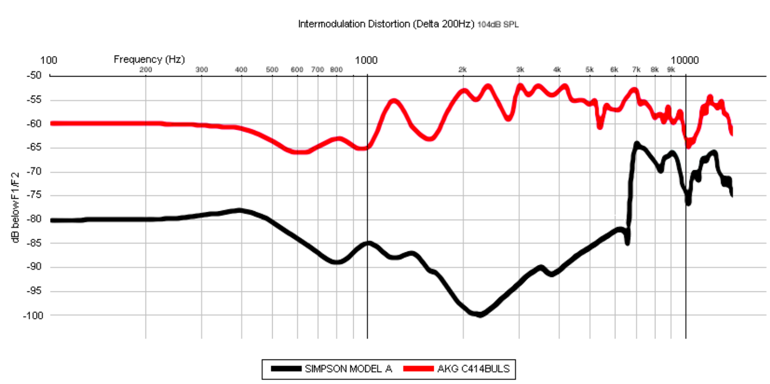
Due to the nature of the nonlinear distortion, we are able to measure at a given sound pressure level and extrapolate the results reliably to other sound pressure levels.

This means that we can, for example, measure the microphone at 100dB SPL and reliably predict that the distortion level will rise/fall proportionally to the rise/fall in measurement SPL.

For example, if at 100dB SPL the microphone has measured distortion at -70dB, it will have predictable distortion at -20dB for 150dB SPL.

This allows us to view the nonlinear behaviour of the microphone over its working range and easily predict the distortion level for any specific acoustic output in acoustic music.

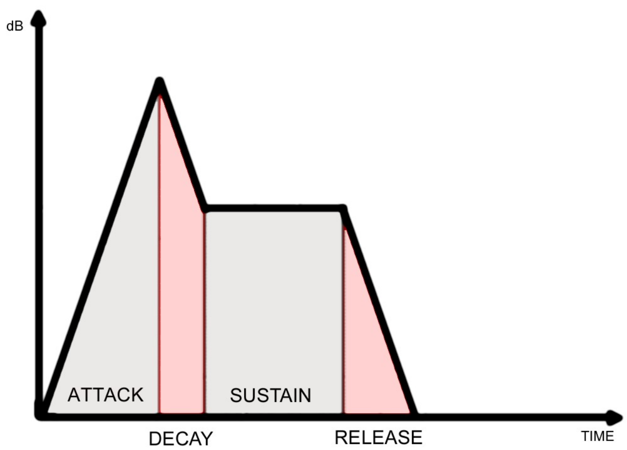
Figure 1. Comparative distortion levels



# 2. PERCEPTION OF SOUND

For the purpose of investigating the potential practical effects of nonlinear microphone distortion on the recording of acoustic music, it is necessary to consider the composition of musical notes played on an acoustic instrument.

Figure 2. Typical sound envelope




The time-domain description of a sound is often broken down into the stages of *attack, decay, sustain & release.*

This is known as the ‘ envelope’ of a sound.

## *Attack & decay*

The attack component of a sound generally contains identifying signature components, which are not necessarily harmonically related to the musical tone being played and are more often related to the percussive action of sounding a note on a given instrument.

It is largely this uniquely identifying attack component of the sound envelope that allows us to recognise musical instruments, spatial locations & other physical properties of a sound.

## *Sustain & release*

The sustain/release component of a sound contains the musical tones (fundamental & harmonic overtones) which represent the musical content of the sound.

In the case of sustained energy instruments such as violin or voice, this sustain section can last an indefinite amount of time.

However, in the case of percussion instruments such as piano, the sustain section effectively does not exist and the release phase immediately begins as the note decays after attack.

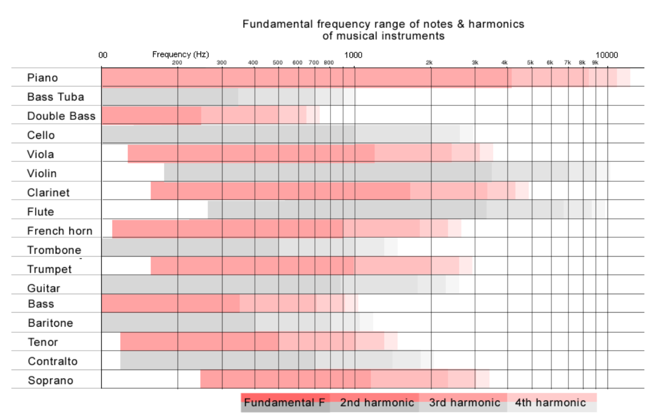
## The musical scale

Musical notes in the western scale have fundamental frequencies from around 20Hz to around 4-5kHz (see fig. 3).

This means that for any particular musical note, musical instruments generally have the most significant steady state (sustain/release) output at the fundamental frequency (f) and falling output at the harmonic overtones of the fundamental frequency (2f, 3f, 4f,…*n*f).

However, while the most significant steady state output of the musical note of a given instrument is predominantly that of the fundamental frequency & its harmonic overtones, in peak terms it is the ‘attack’ of the note (see fig. 2) which commonly reaches the highest amplitude.

Figure 3. Fundamental frequency ranges available to acoustic instruments



# Time & frequency domain perception

For the purposes of this discussion, the perception of sound is divided into two critical parts: *time-domain & frequency-domain.*

In sound quality terms, for reasons mentioned above, we are most interested in the perception of the attack (time-domain) & sustain/release (frequency domain) portions of the sound and how these might be affected by nonlinear microphone distortion.

## *Time domain*

In psychoacoustics it is well understood that the greater part of *time-based* human auditory perception is based on the *attack* portion of a waveform.

This information describes the physical & localisation properties of the sound source (*wooden, metallic, big, small, near, far, left, right, etc)*.

The attack portion of the sound is also responsible for the basic sense of dynamics.

## *Frequency domain*

Musical pitch/tonal perception is known to be a *frequency-based* perception – contained & perceived in the *sustain/release* stage – where the perception of tonality & pitch of music itself is based on the perception of specific frequency tones & their harmonic overtones.

It is also well known that perception of musical harmony (minor/major, etc) is based on harmonic relationships between the frequencies (& harmonic overtones) of the musical notes in question.

## *Perception of rhythm*

The perception of rhythm is a critical part of the perception of music.

By definition, rhythm or ‘feel’ or ‘swing’ consists not only of timing but of *accent*, which information is predominantly contained within the attack portion of the sound envelope.

Since accent is directly a function of amplitude, we see a direct link between perception of rhythm and nonlinear microphone distortion.

In other words, since nonlinearity acts to compress sound, it must also act to affect/reduce rhythmical content & perception of the music.

# Expectations

Given the two different mechanisms of perception, we can expect the effects of nonlinear microphone distortion to be perceived in two separate ways.

In the attack portion, we can expect amplitude nonlinearity to affect the perception of clarity, timbre, rhythm, dynamics, etc.

In the perception of musical tonality, we can expect nonlinear distortion to be perceived as the presence of unpleasant atonal (non-harmonic) out-of-key or sharp/flat components.

# 3. HYPOTHESIS

According to the above descriptions, it is expected that a reduction in nonlinear distortion will be perceived according to the two separate perception mechanisms.

It is expected that improvements in time-based perception (attack) will be seen – fundamental improvements in clarity, rhythm, dynamics, timbre, etc.

It is also expected that improvements in frequency-based perception will be seen – fundamental improvements in musical tonality, pitch, etc.

# 4. SUBJECTIVE TESTING

Throughout the course of development of the Model A microphone, we have worked with an international panel of experienced subjective listeners. These listeners were not paid or in any way related to Simpson Microphones and their subjective impressions were recorded as impartial.

Over a 2 year period, subjective impressions of various Model A specimen recordings were collected.

In later cases, direct comparisons were made to well known microphones and the results were further analysed.

Given that in the critical 'speech range' (1-4kHz) the Model A acoustic impedance matching microphone offers approximately a 40dB reduction in nonlinear distortion over the average condenser microphone - a level of distortion with which most listeners are intimately & intuitively familiar by experience - a striking difference was expected to be observed.

# 5. RESULTS

## *Commonly observed descriptive adjectives*

In the subjective evaluation of the Model A microphone performance, we observed several common descriptive adjectives, used to describe the sound quality improvements related to reduction in nonlinear distortion.

In order to usefully correlate the subjective findings, descriptive adjectives were grouped according to whether the perception related to time-based perception (attack) or frequency-based perception (musical tonality).

## Time-based (attack) perception

The most common (statistically significant) adjectives used to describe the improvement in linearity of the Model A microphone were as follows:

- *'better dynamics'*
- *'better clarity'*
- *'more realistic timbre'*
- *'cleaner sounding'*
- *'better spatial representation'*
- *'uncompressed'*
- *'sounds more free'*
- *'more natural sounding'*
- *'better rhythmical feel'*
- *'better swing'*

## Frequency-based (musical tonality) perception

The most common adjectives were:

- *'sweeter tone'*
- *'no sharp or flat notes'*
- *'cleaner sound'*
- *'more musical sounding'*
- *'more melodic'*

## Miscellaneous comments

Other less easily defined commonly observed descriptive adjectives appeared to be a combination of the two perceptive categories, such as:

- *'more engaging'*
- *'more alive'*
- *'less fatiguing'*
- *'more relaxing'*
- *'more primitive'*

## Limitations

In any subjective listening trial there is an element of expectation bias. This is unavoidable in tests of this sort and should be considered in the interpretation of the results.

It should also be noted that it is not possible to extract the perceptual effects of the improved spectral-masking behaviour of the Model A microphone, which alone can account for a large improvement in clarity & depth perception.

To this end, positive subjective comments regarding 'depth' were specifically omitted from this discussion.

However, since the polar response of the microphone in effect constitutes a reduction in linear (polar) distortion, the investigation was not considered to be compromised significantly.

# 6. CONCLUSIONS

Generally, it was empirically found that the improvements in microphone linearity were both significantly audible & welcome.

Interestingly, although it was expected that the reproduction system (loudspeakers/headphones) would have a great impact on the subjective impressions, the overall trends indicate otherwise.

It was observed that the common positive subjective impressions were independent of reproduction system and independent of listening level.

This perhaps indicates that the nature of constructive (nonlinear), cumulative distortion allows such linearity improvements to be significantly noticeable despite the nonlinearity of the reproduction system itself.

In the course of the subjective listening trials, there were also a small number of listeners who were unable to detect significant improvement in some or all of the subjective categories.

Some listeners were able to detect improvements in musical tonality, but not dynamics. Other listeners were able to detect improvements in dynamics but not musical tonality.

Some listeners were able to simply detect the 'reduction of distortion', which they did not quantify in the above descriptive terms.

Other listeners described the reduction of distortion as a reduction of music related 'dirt' or 'noise'.

It is hypothesised that these particular limitations of perception are related to listening system & listening level.

In any case, the tests were taken as part of the microphone development process, useful simply as indicative of audibility, rather than as objective proof.

Further research & more controlled trials will be necessary to properly objectify the measurements and direct further development.

## Acknowledgements

*Thank you to everybody who took part in our subjective listening trials.*

*Your time & assistance were of great help to us in the development of the microphone.*