If one does not begin with a right attitude,
there is little hope for a right ending.
— Kung Fu Meditation

From audio consumer perspective the only valid test signal for measuring audio quality is real-life music signal. The signal that audio equipment is designed for. The signal that makes possible the comparison of objective measurements with subjective evaluations. Exactly degradation of this signal is the only cause of all perceived differences in sound. Measurement and research of a signal degradation in relation to corresponding sound degradation is the basis of the proposed audio metric – *df-metric*.

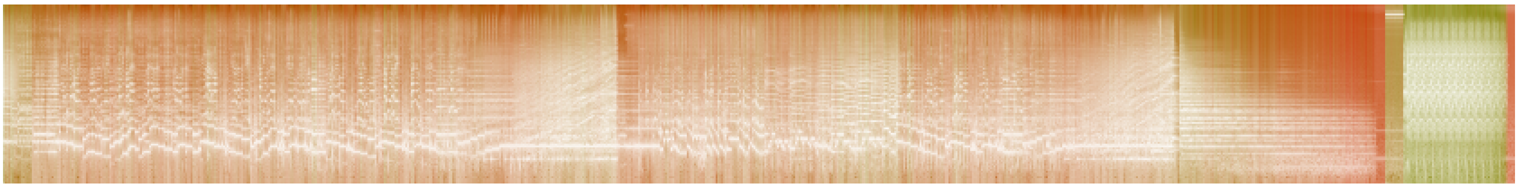
Single audio parameter
The metric has one and the only measurable parameter - *Difference Level (Df, dB)*, which measures difference between waveforms of two signals, input and output of some device under test (DUT) [1]. Specially designed time warping algorithm removes linear pitch and phase shifts of output signal with any predefined accuracy. The algorithm finds such linear pitch and phase transformation of output signal, that the latter has maximum correlation with input signal. This maximum correlation *Rmax* determines the value of *Df* :

$$Df\ [dB] = 10lg(1-|Rmax|)$$

In other words *Df* parameter measures the difference between *canonical waveforms*. The time warping operation is deterministic and produces repetitive results for any signals. So, *Df* values are all-objective measurements. They can be computed with arbitrary time windows: 50ms, 400ms, 3000ms, ... For visualization purposes the scale of *Df* values is associated with the color scale:

Isoluminant color scale [2], which helps to color-code *Df* values.

A sequence of *Df* values, computed for some DUT and test signal, shows degradation of the signal as it varies with time. A visual representation of such sequences is called *diffrogram* [3]. For convenience diffrogram is combined with spectrogram:



Diffrogram (400ms) showing degradation of the test signal (A Day in the Life - The Beatles) in the DUT (HTC Desire C). Different parts of the signal are distorted to different levels.

Multiple test signals
Having only one measurable parameter, df-metric allows unlimited number of test signals, including real-life music signals. Their levels of degradation can be compared with each other. Audio researcher can design any waveform and measure the level of its degradation in some DUT. Performance of any DUT can be examined in great detail using elaborated set of test signals. This new dimension of audio research and experimentation is unreachable with classic audio metric, which is mostly Sine-based. It should be noted that df-metric has exact analog of THD+N parameter - *Df* with Sine signal. For a listener it is almost useless audio measurement.

Artifact signature
As sequence of *Df* values, computed with various music material, shows in detail how the test signal was distorted in a DUT, such sequence can be considered as signal artifact signature of the DUT. Df-metric tells apart two types of artifact signatures:

- sound artifact signature or just *sound signature*, which is revealed by listening a device
- signal artifact signature or just *artifact signature*, which is revealed by measurements

Devices that have similar *artifact signatures* distort musical signal in a similar way. This results in similar listening experience for these devices. They sound similar or ... they have similar *sound signatures*. So, these two types of signatures are interrelated. Also similarity of artifact signatures in most cases indicates similarity of software/hardware audio solutions used.

Artifact signatures can be compared with each other by means of cluster analysis. The early research (not finished yet [4]) shows that for DUTs with close artifact signatures their df-measurements correlate well to their perceived quality estimations. This relation holds for any type of DUTs - analog, digital, psychoacoustic processing ... Thanks to the relation some audio research "magic" is possible:

- reusing of results of already finished listening tests for grading new similar DUTs
- amplification of artifacts (SARTAMP [5]) for DUTs with small impairments; in case of such amplification listening tests of less strict design can be performed

Use cases
- objective audio measurements of portable players - http://soundexpert.org/portable-players
- objective audio measurements of Bluetooth audio codecs - http://soundexpert.org/articles/-/blogs/audio-quality-of-sbc-xq-bluetooth-audio-codec
- SE listening tests of high bitrate codecs (128+ kbit/s) use SARTAMP technology since 2005 - http://soundexpert.org/encoders

How to measure
Df-measurements have good and predictable correlation with perceived sound quality and we can research this relation even further. Finally, we have better instrument for audio quality measurements. Now we can be more productive in R&D of new, perfectly sounding audio products.

1. In most cases it suffices to have high quality digital audio recorder to start df-measurements - http://soundexpert.org/portable-players#how2measure
2. All *Df* values are computed from such recordings with this Matlab code - http://soundexpert.org/articles/-/blogs/visualization-of-distortion#part3

If you need further assistance, feel free to contact me for cooperation. Questions, comments and objections are also welcomed.

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