Document Cover Sheet

Project Number			
Document Title	PN-SDNR distortion measurements on devices with AMR codecs		
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Abstract

Some mobile handsets using codecs such AMR fail the PN-SDNR distortion test in ANSI/TIA-5050. The purpose of this document is to analyze why this happens and propose substituting PN-SDR.

1. Background

The distortion test method in ANSI/TIA-5050 is Pulsed Noise Signal-To-Distortion-Ratio (PN-SDNR). The test method is described in that standard, but it originated from IEEE Std 269-2019. The method was first introduced in IEEE Std 269-2010.

Testing distortion in mobile phones is difficult because most of the codecs used are nonlinear in some or all of the following ways:

1. The codecs are “tuned” to real speech. They may transmit other signals under some conditions, but the output may be distorted. This behavior can often be overcome, at least to some extent, by using speech conditioning signals inserted immediately before the distortion test signal.
2. There is no stable phase relationship between the input and output of the codec. The consequence is that noncoherent distortion* cannot be measured. Noncoherent distortion is otherwise an excellent way to measure distortion using real speech. (*uses the coherence function in 2-channel FFT analysis.)
3. Many codecs disperse the signal content by spreading it out to adjacent frequencies. A sine wave at the codec input might become a narrowband noise at the output. A 1/3rd octave band of noise might become a much wider distribution.
4. Many codecs are not completely stable. When tests are repeated the results may be similar, but not the same.

2. The PN-SDNR method

The PN-SDNR test method uses a 1/3rd octave band of noise as the stimulus. When analyzed, the result is typically as shown in Figure 1.

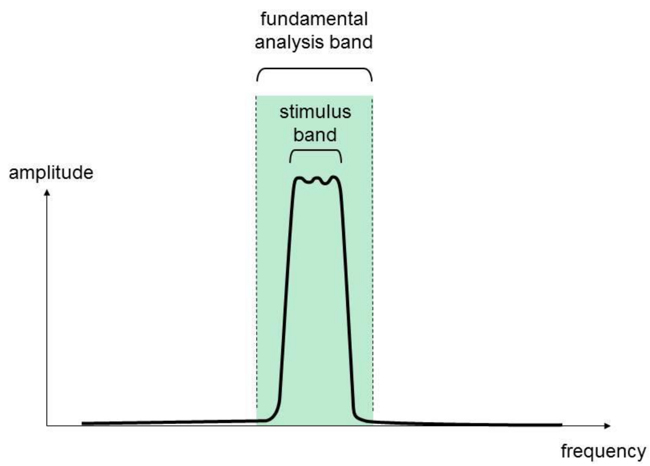


Figure 1*

A typical response from DUTs without aggressive codecs (e.g. most USB devices) shown in Figure 2

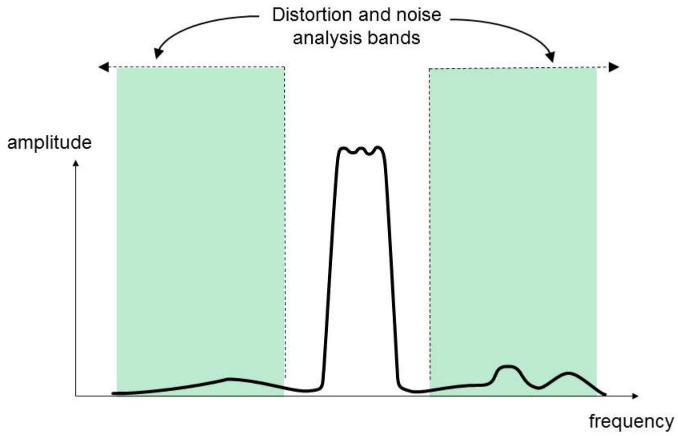


Figure 2*

3. The problem

When mobile phones with AMR and some other codecs are tested, the response from the DUT looks more like the actual measurement shown in Figure 3 .

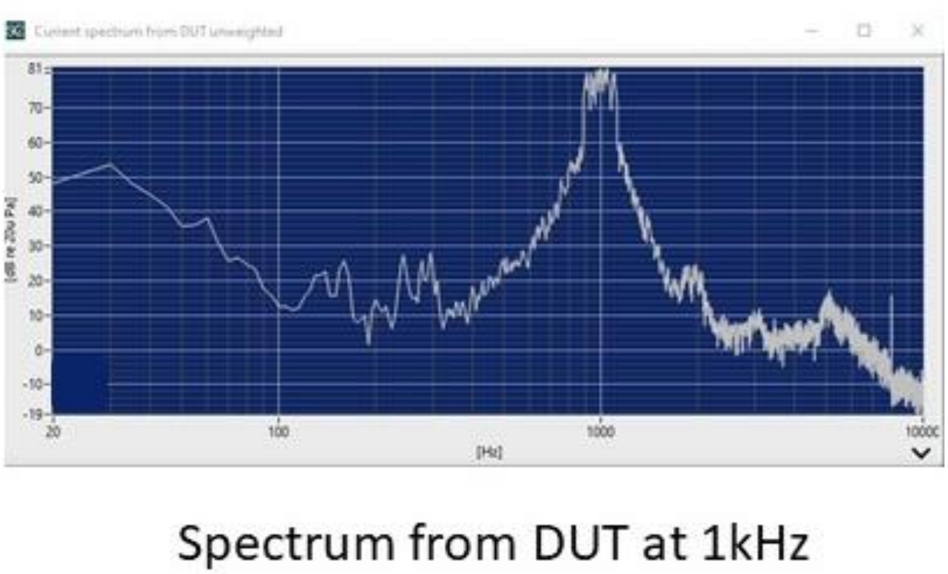
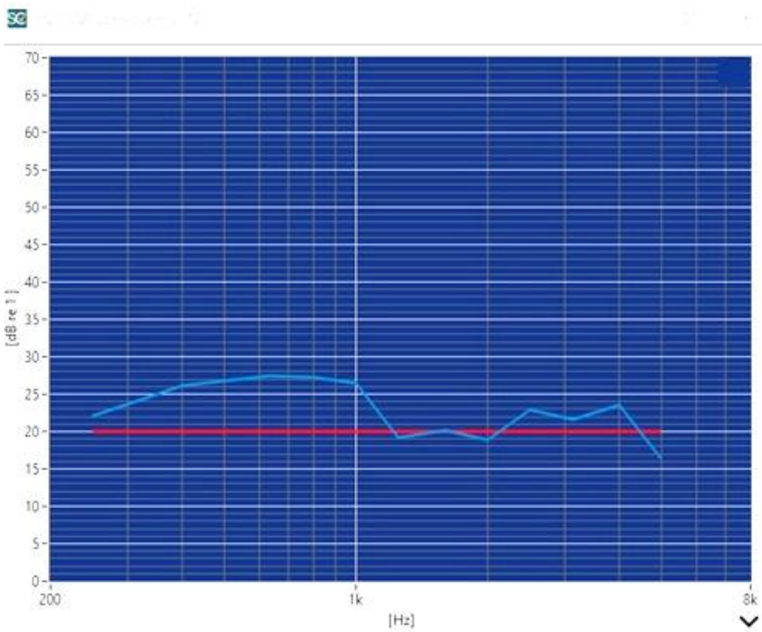


Figure 3**

When the above measurement is completed, the result fails the TIA-5050 tolerance, mostly above 1kHz. Figure 4 (Note: A signal to distortion ratio of 20dB is equivalent to 10%.)



PN-SDNR (completed test)

Figure 4**

The analysis window for the PN-SDNR test is shown superimposed on the 1kHz measurement in Figure 5. The spectrum around the stimulus band has been spread, due to the codec (red lines). Since anything inside the analysis window (yellow) is counted as distortion, the distortion amount will be large, even if there is no significant distortion from the audio amplifier and receiver transducer. (Note: The black line shows the A-weighting that is applied to the distortion spectrum before the total level is measured.)

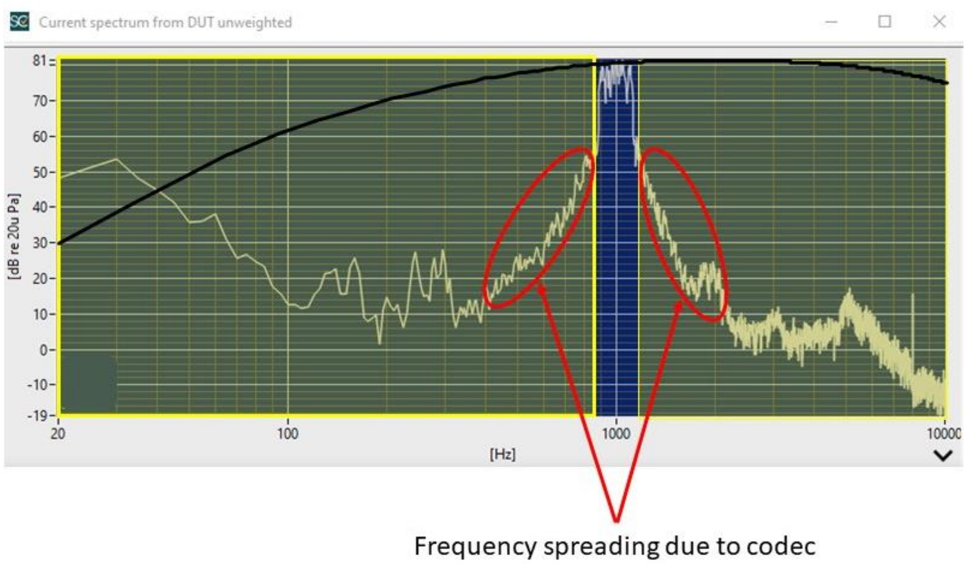


Figure 5**

4. The cause

To further analyze the source of this behavior, it is helpful to consider the receive audio path in a typical mobile phone Figure 6. The codec output is the beginning of the signal chain. Any distortion further downstream is added to an already distorted signal.

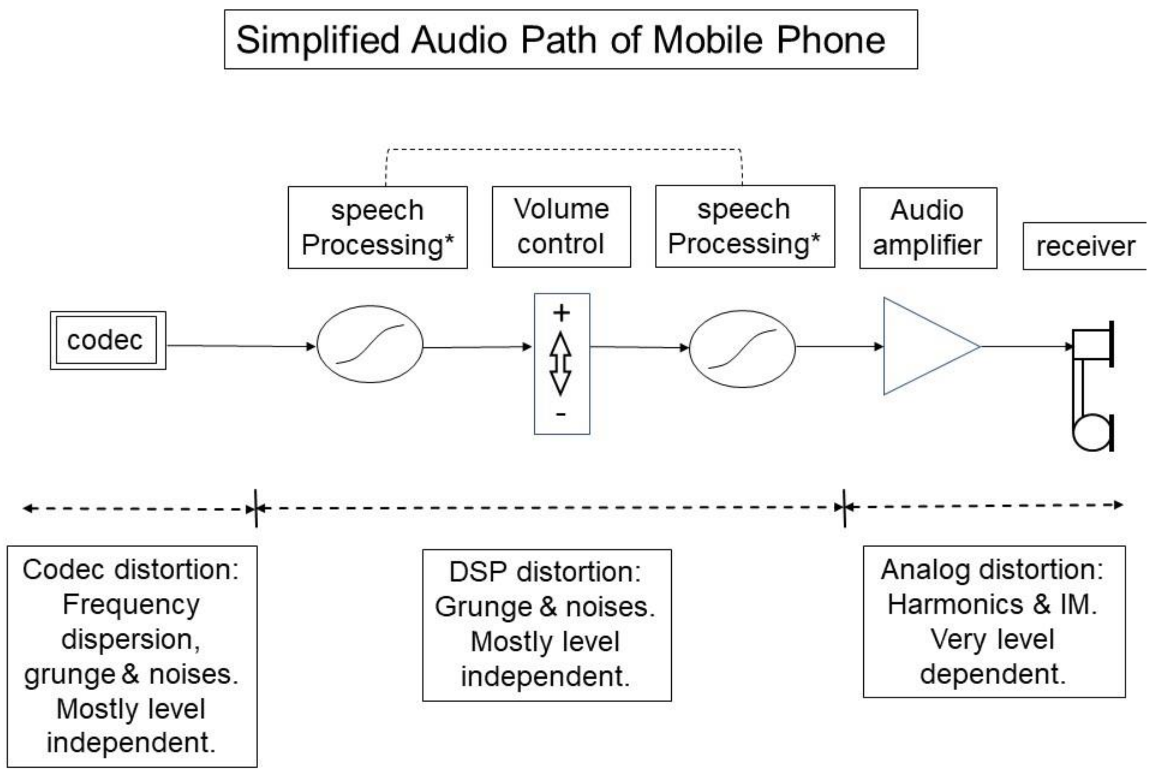


Figure 6

5. Proposed solution

Distortion and/or clipping in the amplifier and receiver parts of the audio chain almost always produces 2^{nd} and 3^{rd} harmonic distortion. The 2^{nd} and 3^{rd} harmonic parts of the distortion spectrum are located well above the fundamental, where the codec spreading occurs. (Figure 7)

Analyzing the 2^{nd} and 3^{rd} harmonics is described in IEEE Std 269-2019, but it is not now included in TIA-5050.

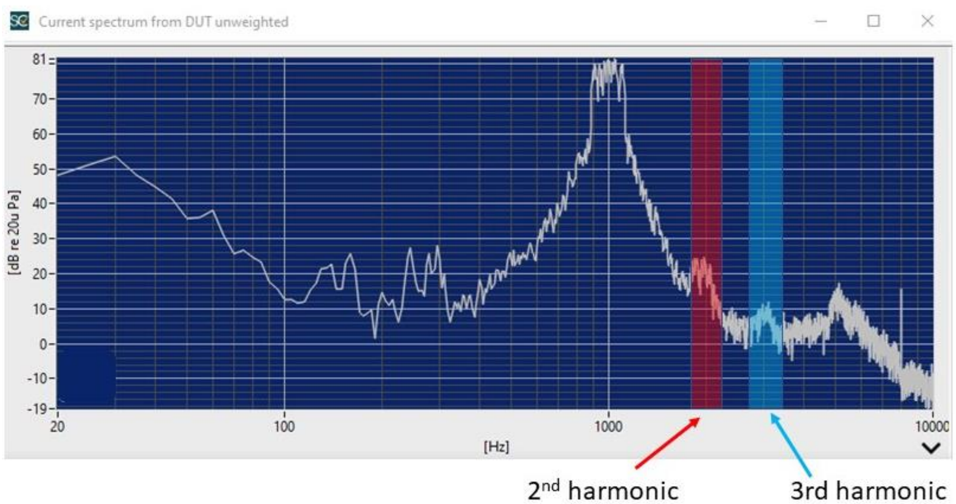
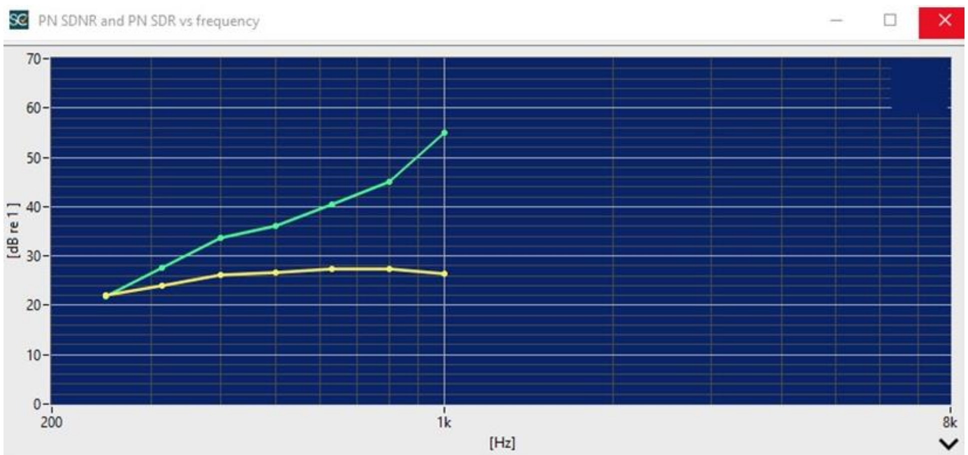


Figure 7**

The measurement example shown here has been made with an implementation of PN-SNDR that also includes signal-to-distortion ratio (PN-SDR) as shown in Figure 8.

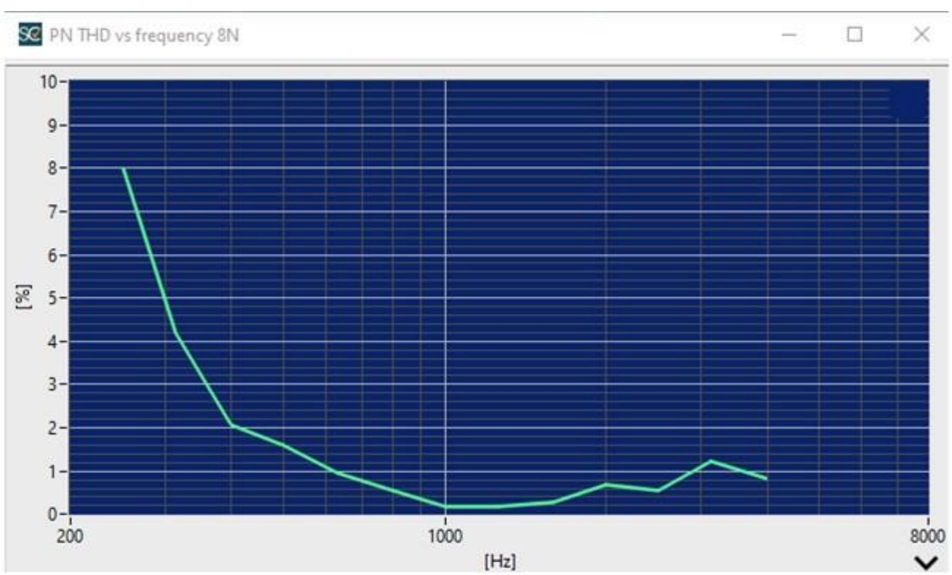
If there is no serious audio overload, the PN-SDR is usually much greater than PN-SDNR over most of the frequency range. (The most common exception is at low frequencies, where the response of the receiver rolls off.)



Yellow = PN-SDNR
Green = PN-SDR

Figure 8**

2nd and 3rd harmonic distortion are plotted in percent (%) in Figure 9.



PN-SDR expressed as percent (completed test)

Figure 9**

6. Summary

A more direct test of audio overload would be to use PN-SDR (2^{nd} & 3^{rd} harmonics expressed as a ratio) in place pf PN-SDNR.

In the implementation shown here, PN-SDR is already included. All that remains is to define another tolerance mask. Based on other work, a ratio of 26dB might be a good place to start. This corresponds to 5% distortion, which most casual listeners usually do not find objectionable. The tolerance would need to be relaxed below about 400 Hz, because poor low frequency response amplifies the harmonics relative to the fundamental. The final tolerance would need to be confirmed by lab measurements on several representative devices.

*Note: Figures marked * are excerpted from IEEE Std 269-2019. Figures marked ** are lab measurements provided by Element Materials Technology. The DUT is a mobile phone operating in wideband mode using an AMR codec.*