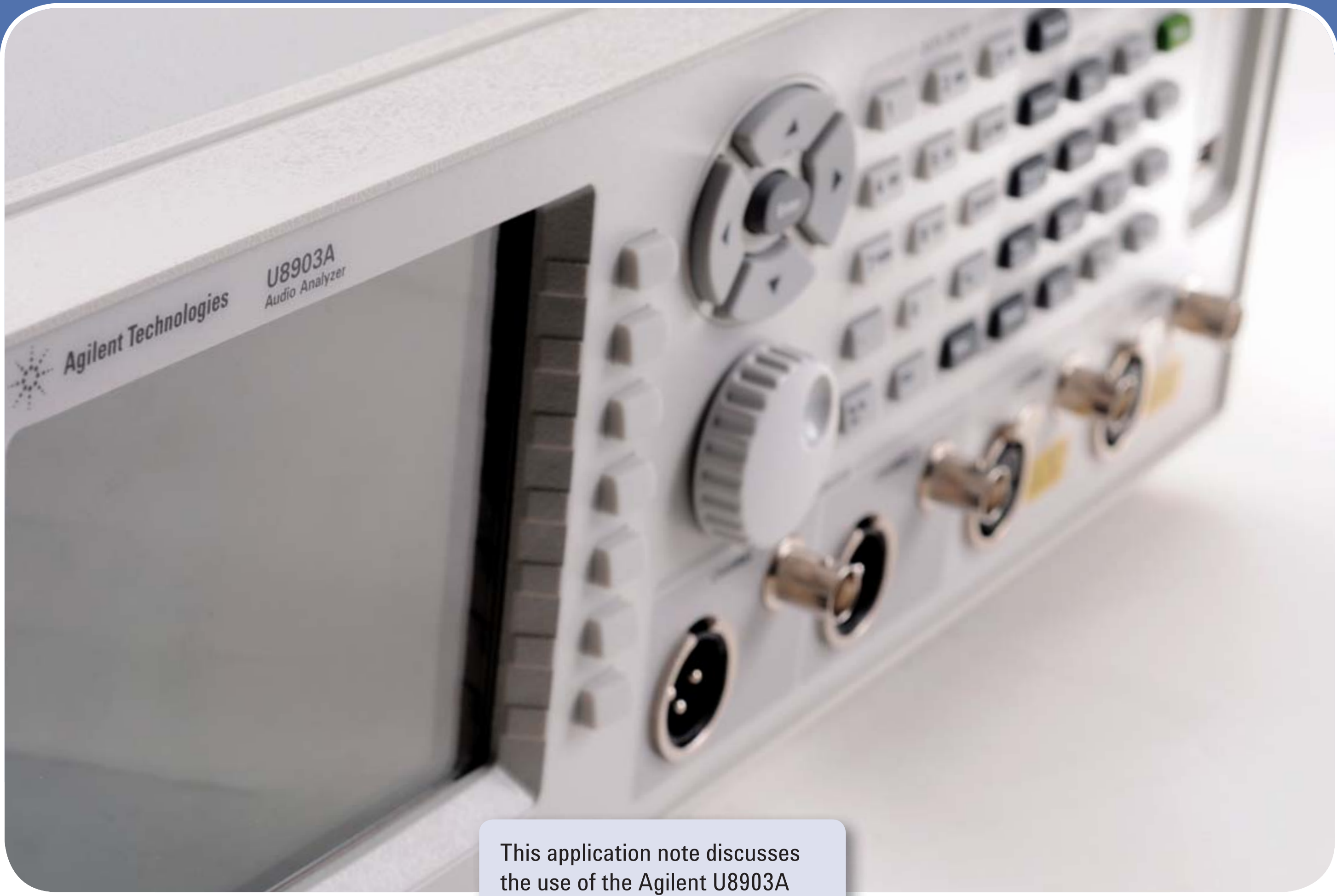
SINAD Measurements Using the Agilent U8903A Audio Analyzer

Application Note



This application note discusses the use of the Agilent U8903A Audio Analyzer in characterizing radio receiver sensitivity by means of measuring SINAD. An overview of the measurement is given and potential differences in results between the modern U8903A and older generation instruments like the 8903B are discussed.

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SINAD

SINAD is an acronym for SIgnal, Noise And Distortion. It is an audio quality value that is typically used to specify the RF sensitivity of radio receivers. The ratio is usually expressed in dB and is calculated as per the equation:

$$SINAD = 20Log\left(\frac{\text{rms value of signal, noise, and distortion}}{\text{rms value of noise and distortion}}\right)$$

There are other forms of this equation, depending on the exact form the values take. For example, if the values are powers then the equation would use 10Log. On the other hand, if the values are already in dB then the two components are simply subtracted. A higher SINAD value indicates higher quality audio.

Measuring SINAD

The classic block diagram of a SINAD measurement is shown in Figure 1. An RF signal of appropriate frequency is applied to the receiver under test. This RF signal is generally modulated with a 1-kHz tone. On the top path, the audio signal from the receiver is passed straight through to the level measurement block which measures the combined level of the signal, noise and any distortion.

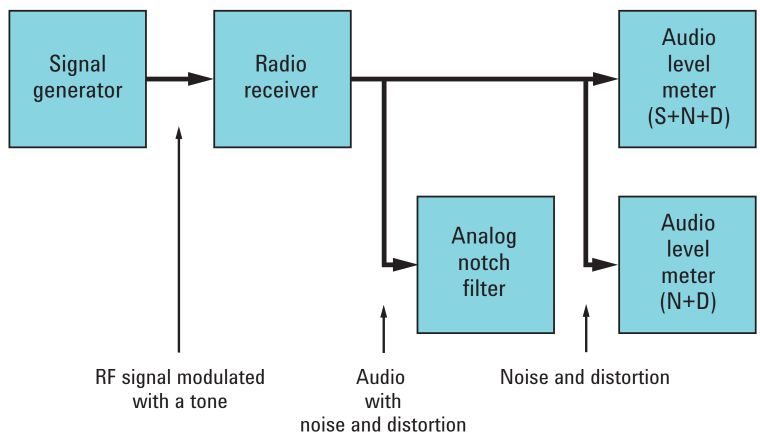

Figure 1. Typical block diagram of a SINAD measurement

In the lower path, the audio signal from the receiver is applied to a notch filter whose purpose is to remove the signal but leave any noise or distortion components for measurement. The two measurements are then used in the above equation to compute SINAD. Modern instruments tend to make more use of digital techniques. The audio signal is sampled as early as possible and the computation is performed in DSP as per the block diagram in Figure 2.

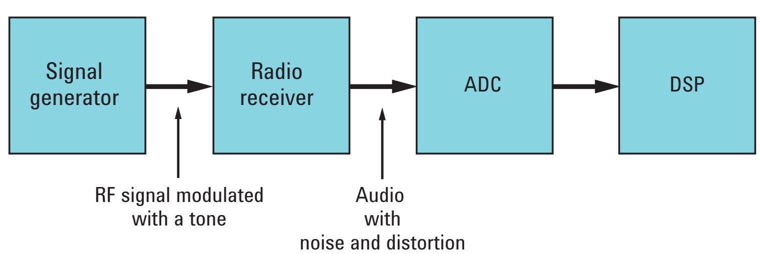

Figure 2. Block diagram showing the sampling of an audio signal and computation in DSP

These modern techniques offer increased accuracy and repeatability in many respects, which will be discussed further throughout this application note.

Receiver Sensitivity

This is the minimum RF level specification of a radio receiver. The task is to find the minimum RF level which results in a particular SINAD level. This level is generally 12 dB for a communications receiver and 23 dB (mono) or 26 dB (stereo) for a broadcast receiver such as a car radio or Hi-Fi tuner.

At first it may seem a little strange that an audio quantity is used to quantify the RF performance of a radio receiver, however, this is quite logical once the subject is explored. The basic receiver block diagram shown in Figure 3 will be used to describe how the two quantities are related.

Let's start at the right hand side of the diagram where we have the audio detector. This block has the job of extracting the audio signal from the IF carrier. From a measurement point of view, it converts an IF Signal/Noise Ratio into an Audio SINAD Ratio. The block will, of course, have imperfections of its own that will be ignored for the purposes of this example.

When considering a 2-way communications radio, the general minimum standard for SINAD is 12 dB. This amounts to audio distortion of 25%, which is the minimum deemed intelligible. The detector will require a particular IF S/N Ratio in order to provide this 12 dB SINAD. The particular value of S/N required will depend very much on the detector employed.

For this example we will assume we have an analog detector of some description and that it requires 10 dB S/N to give 12 dB SINAD.

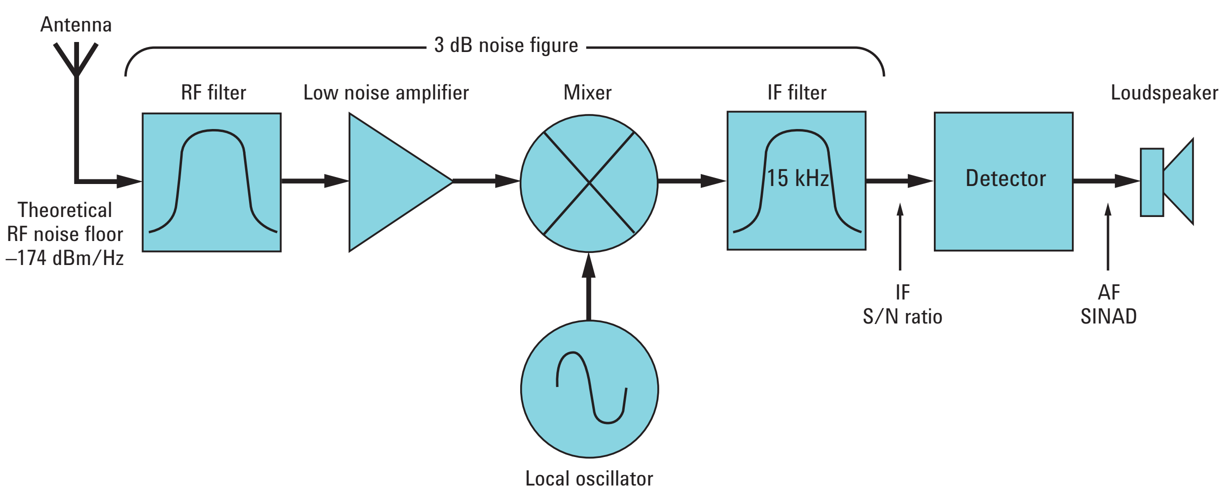

Figure 3. Basic receiver block diagram

In order to calculate the expected receiver sensitivity we need to know three other parameters:

1. The bandwidth of the signal being applied to the detector as defined by the IF Filter. In this case,15 kHz is chosen since this is a typical value in a communications receiver.
2. The noise figure of the receiver, which is defined as the noise added by the receiver circuitry and is primarily defined by the input filtering and Low Noise Amplifier (LNA).
3. The theoretical noise floor at the input of the receiver, which is defined by the impedance. For a 50-Ω system this parameter is well documented as –174 dBm/Hz.

The receiver sensitivity is then calculated as follows:

Noise Floor +Noise Figure + Bandwidth + S/N at Detector
= –174 + 3 + 10Log(15k) + 10= –119.24 dBm

For 12 dB SINAD, this receiver requires a minimum of –119 dBm RF signal at its antenna.

From the above example it is clear that the only variable available as a design parameter is the Noise Figure of the receiver. To this end, the input amplifier and filter are very critical areas of design in any receiver.

We should also note that the sensitivity calculated here will only be realizable with a signal generator connected to the receiver. In the real world environment where an antenna is used, background noise will affect performance.

Measuring SINAD using U8903A

The U8903A is the ideal modern instrument for making SINAD measurements. Figure 4 shows the general measurement setup. In this case, the modulation signal is applied from the U8903A. Another common arrangement is where the signal generator provides its own modulation, assuming it has such a feature. This simplifies the measurement setup slightly.

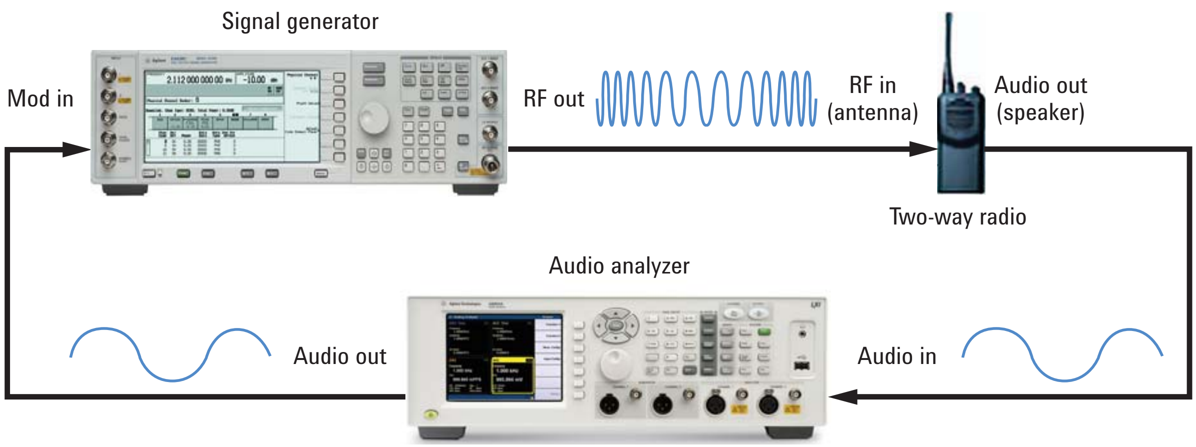

Figure 4. General SINAD measurement setup

The signal generator is set to the desired RF frequency and level. The deviation (FM) or modulation depth (AM) of the modulating tone is set to an appropriate level. The audio output level of the receiver is then set as required and connected to the audio analyzer, either by direct connection or an appropriate acoustic coupler.

Making the measurement is simply a case of selecting SINAD under the Analyzer menu as shown in Figure 5.

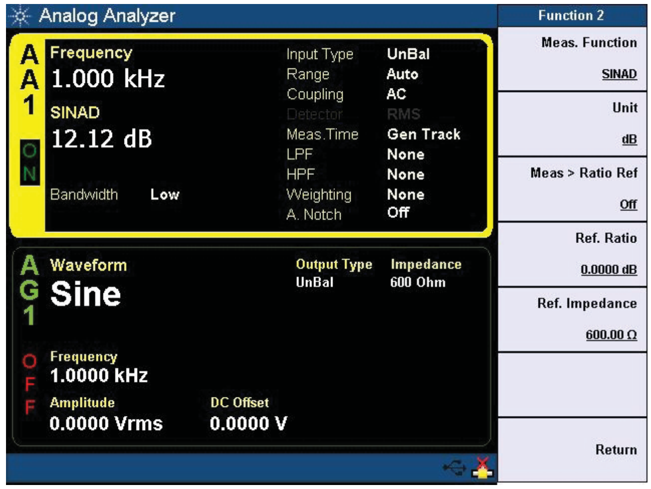

Figure 5. The U8903A Analyzer menu

A SINAD level which deviates from what is expected indicates that something is wrong, but gives no indication as to what the problem might be. Investigation of the RF path and audio sections of the receiver would then follow to diagnose the actual cause of failure.

The U8903A offers several variables that the user can control within the SINAD measurement.

Fundamental Frequency

The fundamental frequency is generally detected automatically as part of the SINAD measurement. However, this can be problematic when there are other high level tones in the spectrum such as might be the case when doing a blocking test. The fundamental frequency can be set to track the generator. It is also possible to force the analyzer to use a fixed frequency.

Filtering

SINAD measurements should be made within a specified bandwidth. The radio receiver itself may well define this bandwidth, but the bandwidth settings of the measurement instrument should also be considered. U8903A has an array of built in filters, as well as the ability to import custom filter files.

Averaging

Measuring the SINAD limit on any receiver is an inherently noisy measurement. The limiting amplifiers in the receiver will no longer be limiting completely and so the high gain in the system will act on any small changes in level.

Lower SINAD readings from a radio receiver (like 12 dB) can therefore, benefit from some averaging. The plot in Figure 6 shows the difference in the distribution for 1000 measurements with no averaging and 5 averages.

Note that the result with no averages is not a less accurate result; on the contrary, it is more indicative of the variations in the noise levels.

As the SINAD value increases, the requirement for averaging reduces since the measurement becomes inherently more stable.

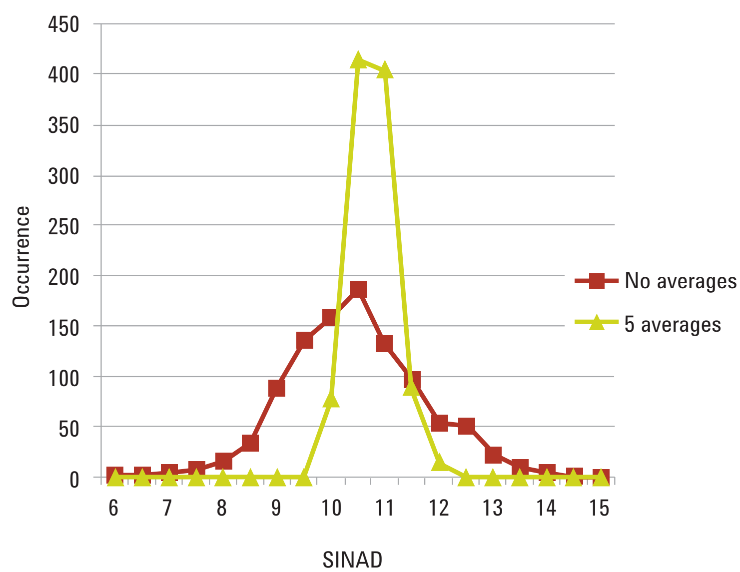

Figure 6. SINAD plot showing the difference in the distribution for 1000 measurements with no averaging and 5 averages

Applying averaging in the U8903A is very straightforward as can be seen from the menu in Figure 7.

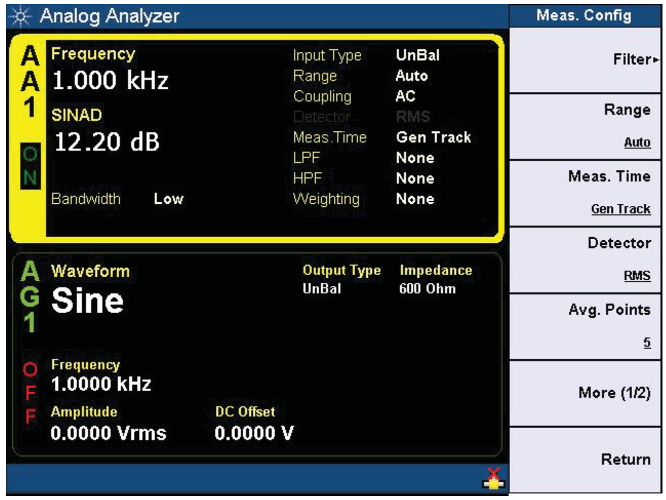

Figure 7. Averaging in the U8903A

Notch Filter

The notch filter which is used to remove the fundamental tone must be deep enough to ensure that the tone is not passed into the noise and distortion quantity of the measurement, but narrow enough to ensure that the distortion and noise components are passed on. Two options are available, digital notch and an 8903B analog notch emulator. While the digital notch (default) provides the ultimate in accuracy, there may be situations where the 8903B notch emulator is of interest. The reasons for this will be fully discussed in the next section.

Detector Type

U8903A offers a number of different measurement detectors. For SINAD measurement, however, it is important that only the RMS detector be employed. This will be automatically selected when making a SINAD measurement. The RMS detector is required to ensure that the measurement result is independent of signal type (e.g., sine, noise, pulse, etc.).

Comparing U8903A SINAD Results with 8903B

In certain circumstances when comparing U8903A with the legacy 8903B, users may observe that the 8903B gives a better SINAD reading. Differences can be as much as 1 dB and this can be disconcerting when the reasons for the differences are not fully understood.

In general, both of these instruments employ the same measurement techniques but the technologies and implementations are very different. This is not surprising given the three decades that separate these two generations of instruments.

Modern instruments of any description are much more digital in nature since we try to digitize the input signal as early as possible, thereby avoiding any difficult manipulation of the signal in the analog domain. This is certainly true of the U8903A, where all filtering and measurements are implemented in DSP, which simplifies the analog nature of the instrument a great deal. This also offers increased performance in many areas.

When making a SINAD or THD measurement, one of the main tasks is to remove the fundamental frequency component from the spectrum. This is really very easy with modern instruments, where the algorithm simply looks at the FFT (Fast Fourier Transform) and subtracts the peak value from the spectrum. In effect, this gives an extremely high Q notch filter which removes the fundamental signal and does not affect any adjacent frequency components.

By contrast, previous generation instruments did not have this facility. The technology simply wasn't available and so the hard work had to be done in the analog domain. The 8903B employed a tuneable analog notch filter to remove the fundamental frequency component in measurements where this is a requirement. This circuitry is non trivial and performs very well, but its Q is limited by the analog circuitry. In many measurement cases, this has very little impact. Particular cases can, however, present a measurement inaccuracy since the filter will also attenuate some spectrum adjacent to the fundamental signal.

To illustrate situations where measurement differences become apparent, let's look at an example. Assume we want to characterize a 2-way communications type radio and measure the sensitivity at the standard 12 dB SINAD. In this example, we will assume that the radio has 3 kHz audio bandwidth from 400 Hz to 3.4 kHz. We will also assume that the fundamental frequency component is 1 kHz 1vRMS (0 dBv).

The frequency spectrum is shown in the Figure 8.

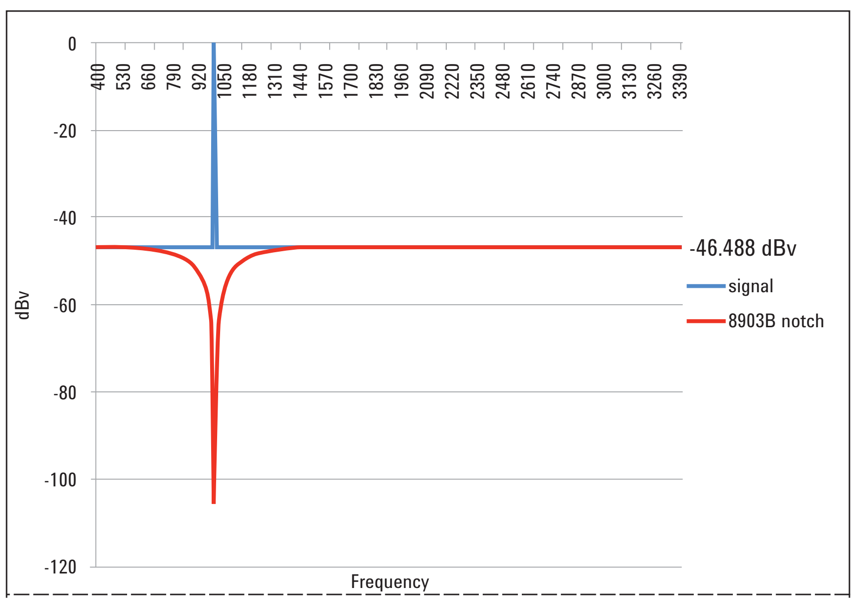

Figure 8. Frequency spectrum for a 2-way communications type radio example

Here we see the main signal in blue at 0 dBv and the noise floor at –46.488 dBv. There are no distortion components present since these are below the noise floor.

If we integrate over the whole spectrum we get:

Signal + Noise + Distortion = 0.283 dBv

Subtracting the 0 dBv fundamental component we get:
Noise +Distortion = –11.717 dBv

SINAD = 0.283 + 11.717 dB = ***12 dB***

This is the result that can be achieved by modern DSP techniques, which remove the fundamental and no adjacent frequency components.

The graph in Figure 8 also shows the 8903B notch filter response at 1 kHz. Here we can see that this filter will attenuate frequency components adjacent to the fundamental. The difference in noise level is the area between the red line and the flat blue line.

With this filter in place the results are:

Signal + Noise + Distortion = 0.283 dBv (same as before)
Noise + Distortion = –12.431 dBv

SINAD = 0.283 + 12.431 dB = ***12.714 dB***

Here we see that since the filter is removing a chunk of the noise floor the result is apparently 0.7 dB better!

The situation can be exacerbated if the audio spectrum from the radio under test is not flat. The graph in Figure 9 shows a 10 dB downward slope over the 3 kHz band.

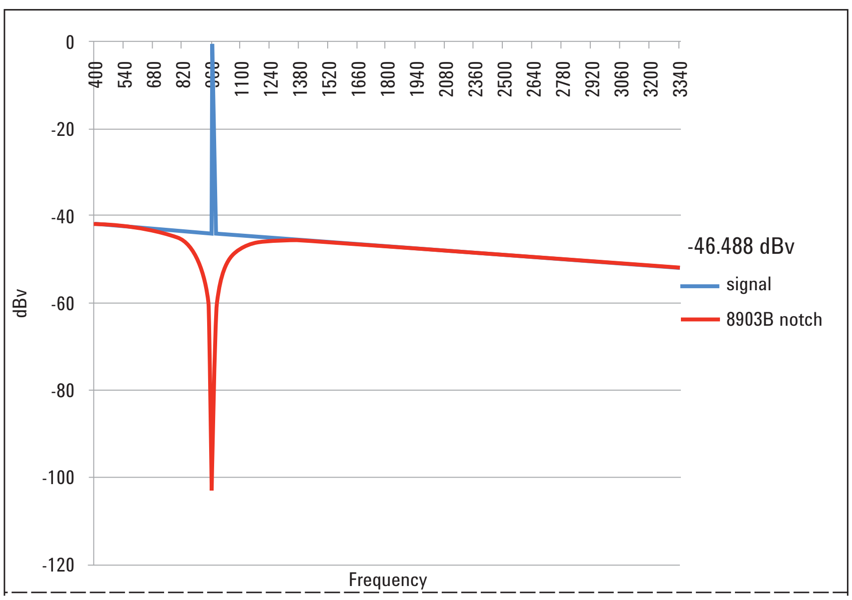

Figure 9. Graph showing a 10 dB downward slope over the 3 kHz band

The situation is worse here because the notch filter is acting on the higher level portion of the spectrum and therefore, removes proportionately more noise than the previous example. The difference in SINAD results between the analog and digital techniques is 1 dB in this case.

This type of sloping frequency response is actually closer to the normal situation in a communications type receiver, since the audio filters within the receiver concentrate on the important part of the voice spectrum (around 1 kHz). Filter specifications are usually based on those developed for early telephone systems. The two most common filters are the C-MESSAGE for use in North America and the CCITT filter. The frequency response of these two filters is shown in Figure 10. From our example, these different frequency responses will clearly result in different SINAD values.

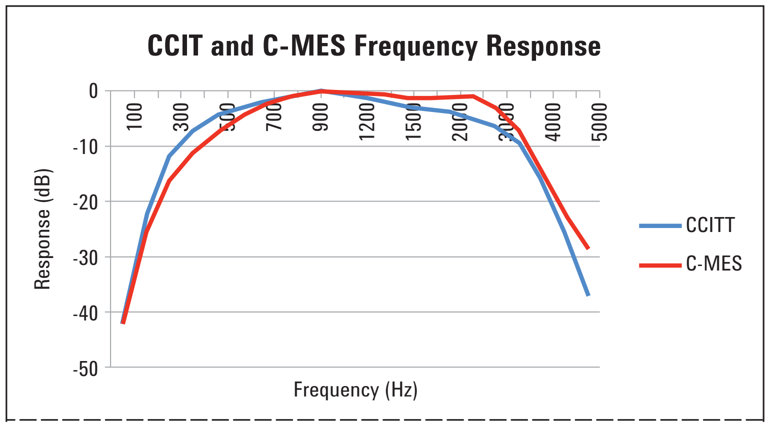

Figure 10. The frequency response of the C-MESSAGE and CCITT filters

The actual value of SINAD may also have an effect on the difference in results between the two instruments.

Referring to Figure 11, we can see that as the SINAD increases the shaped noise floor area decreases in amplitude. This means that any lower level broadband noise from the device comes into play more apparently. The small reduction is spectral power due to the notch filter then begins to have less of an effect since we are removing a small portion from a bigger overall number. This effect shows why it’s important to set and specify the overall bandwidth of the audio analyzer within any SINAD measurement.

The theory here also tells us that as the bandwidth of any test device is increased, any measurement differences between analog and digital notch implementations will diminish.

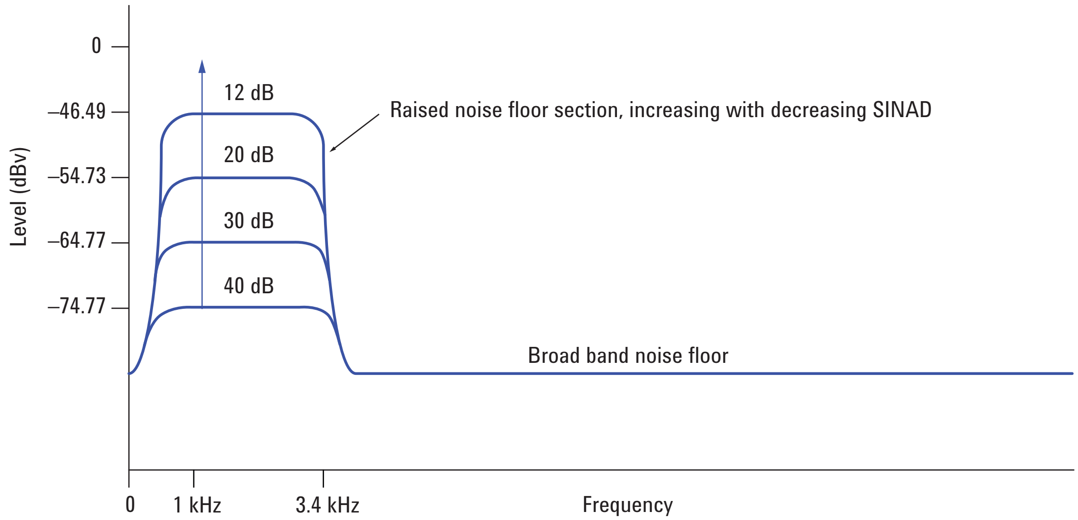

Figure 11. SINAD increases as the shaped noise floor area decreases in amplitude

It is clear from these examples and theory that the U8903A with its high Q digital notch will provide the most accurate result in all measurement cases. The 8903B however, has been around for a long time and some users of the new U8903A may want to emulate the results of the older instrument for their particular DUT.

For this reason, the U8903A provides a selectable analog notch filter emulator in the SINAD measurement Config menu. Selecting this will shape the noise floor as per the 8903B notch filter.

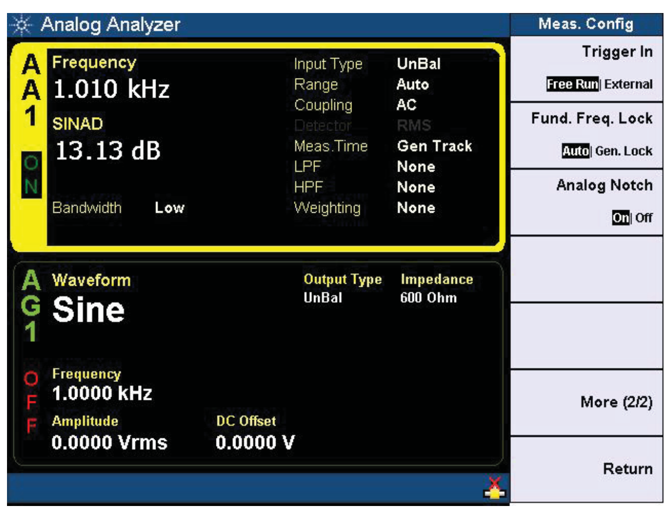

Figure 12. Selecting the analog notch option

An alternative method of allowing the two instruments to correlate more closely in measurements where there is an inherent understandable difference is to use the offset feature. We know that for a given measurement situation, the two instruments will be different by a fixed amount. The offset feature subtracts the difference and can be used if the user wishes to emulate the results of other older generation instruments.

Other SINAD Measurements

As well as being used for receiver sensitivity measurements, SINAD can be used for characterizing several other receiver specifications.

Ultimate SINAD

This is the SINAD under ideal reception conditions, typically in excess of 40 dB.

Adjacent Channel Rejection

A radio receiver must have the ability to reject strong signals in channels adjacent to the channel of interest; it must be 'selective.' This is a function of the filters employed in the receiver.

To make this measurement, the reference sensitivity is measured and then the RF level is increased by 3 dB. Next, a second source (interferer) is introduced to the adjacent channel. This source will generally be modulated by a 400 Hz tone. Lastly, the RF level of the interferer is raised until the SINAD reaches the same value as was present under the reference sensitivity test.

The ratio of the interferer to the wanted signal is defined as the Adjacent Channel Rejection.

Receiver Intermodulation

A radio receiver must have the ability to reject high-level interfering signals that combine to form a third-order intermodulation product at the receiver input frequency. This is a function of the receiver filters and linearity of the front-end circuitry.

This figure is determined by setting the input RF signal 3 dB above the reference sensitivity. Two interfering signals are then applied, one of which contains a 400 Hz modulating tone. These two interfering signals should be equal in value and increased until the SINAD degrades to the reference value.

The ratio of the interferer levels to the wanted signal is defined as the Third-Order Intermodulation specification.

Receiver Blocking

This is very similar to the Adjacent Channel Rejection test, the difference being that the interfering signal is far away from the input signal. An extensive search of different frequencies must be carried out to identify troublesome areas. Typical areas of focus might be any Image frequency or IF frequency that is used in the receiver.

Summary

SINAD is a measurement used to characterise radio receiver sensitivity, it can however be used to define various other specifications discussed in this note.

In particular situations it is possible to see different results when comparing previous generation instruments with the latest offerings on the market. The mechanisms behind these measurement differences have been discussed.

In all situations Agilent's U8903A is the ideal modern instrument for making accurate SINAD measurements.

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