Analyzing the Signal Quality of NTSC and ATSC Television RF Signals

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*T*here's a new kid on the block! I'm talking about the new television transmitters in your area broadcasting HDTV (high definition television) RF signals.

These new TV-RF signals are much different than the NTSC – RF signals broadcast by TV stations over the past 60 years. Likewise, testing these new digital RF-TV signals to insure proper receiver decoding without dropout or complete loss of reception are entirely different.

This article briefly looks at the differences between the NTSC TV-RF signals and the new HDTV – RF signals. It further shows how each can be analyzed for signal quality using the Sencore SLM1453.

Figure 1 – Analyze NTSC TV-RF and HDTV signals using Sencore's SLM1453 Signal Level Meter.
For more information click on http://www.sencore.com/products/SLM1453.htm

Traditional Analog NTSC TV-RF Signal

Quick review of the current analog NTSC TV broadcast channel.

Let's start with a quick review of the current analog NTSC TV broadcast channel. The NTSC TV channel consists of two independent analog RF carriers. The carriers are contained in a 6 MHz channel bandwidth. A video carrier is amplitude modulated and has an assigned frequency that positions it 1.25 MHz above the bottom edge of the assigned 6 MHz TV channel bandwidth. A separate and independent audio carrier is frequency modulated and is positioned 4.5MHz above the video carrier in the 6 MHz TV channel bandwidth.

Sideband signal energy is created above and below the video carrier as it is amplitude modulated with the composite video signal. The sideband signal energy below the carrier is limited to 1.25 MHz by the transmitter's vestigial sideband filter. Sideband energy above the video carrier extends to 4.2 MHz, and includes sync, luminance and chroma signals. The strongest sideband signal energy is contained near the video carrier. (See Figure 2)

The audio RF carrier is frequency modulated by the audio signal causing the frequency to deviate above and below its resting frequency +/- 25 kHz. FM audio sidebands are contained in a 200 kHz bandwidth of the carrier frequency. Again, the strongest sideband energy is near the carrier.

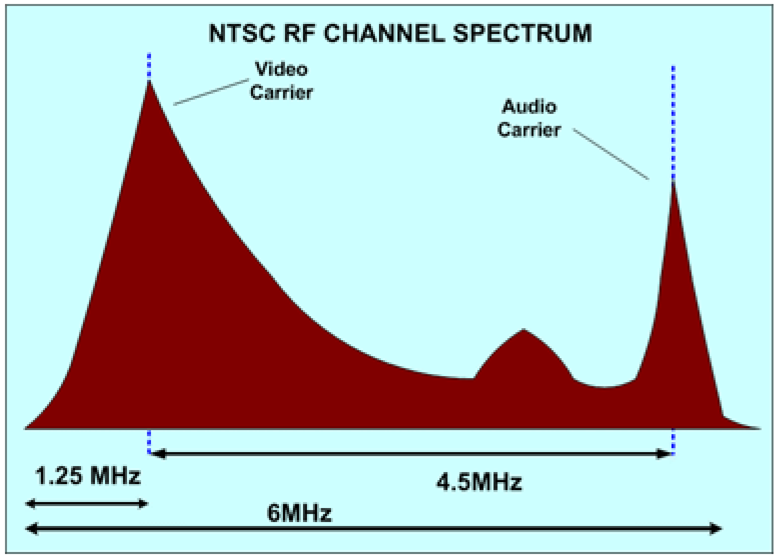


Figure 2 – A 6 MHz NTSC TV channel has separate video and audio RF carriers. Signal energy is strongest near the carriers.

Measuring NTSC Video & Audio RF Carrier Levels

The level or signal strength of the video carrier in the NTSC signal directly relates to signal quality and how good the picture looks on a television display. A video carrier level of 0 dBmV (1mV @ 75 ohms) or higher represents a good video carrier level resulting in good, noise-free pictures. Video carrier levels less than 0 dBmV will begin to produce grainy or noisy pictures.

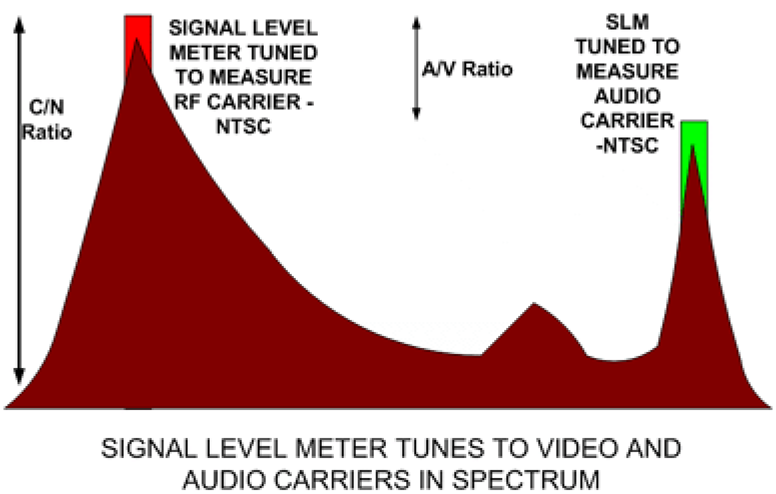


Figure 3 – An NTSC channel level is made by alternately tuning the video and audio carriers and sampling a 250 kHz bandpass. The video level and A/V ratio are measured and simultaneously displayed.

In the NTSC signal transmission, the audio RF carrier is normally reduced in dBmV level compared to the video carrier. Good practice in a cable system is to reduce the audio carrier level by 13-15 dB compared to the video carrier. This is commonly known as the A/V ratio and is expressed as a difference between two dBmV levels simply in dB. Off-air NTSC signals reduce the transmit power of the audio carrier compared to the video carrier, resulting in A/V measurements typically ranging from 8-15 dB. Modern signal level meters, such as the Sencore SLM1453, can alternately measure the level of both carriers and display the video and A/V ratio simultaneously.

Measuring C/N Ratio

An additional measurement used to analyze an NTSC – RF signal is a carrier-to-noise ratio measurement. Noise exists with the NTSC signal when received by an antenna and is also present on a cable system. To prevent noisy pictures on a TV receiver the noise must be very weak in level (dBmV) compared to the level of the signal (dBmV). The difference between the video carrier level and noise level is the Carrier/Noise ratio, and like the A/V ratio, is expressed in dB. C/N ratios near or above 40 dB generally provide acceptable noise-free TV viewing.

The Sencore SLM1453 provides a signal level measurement, A/V ratio measurement and C/N measurement on any NTSC-RF channel. The measurement results are simultaneously shown on the display. (See Figure 4). In addition, a speaker monitors the audio carrier so you can hear the program audio material.

Figure 4 – The Sencore SLM1453 measures and displays the video level dBmV, A/V ratio dB and C/N ratio dB of an analog NTSC TV signal.

New terrestrial HDTV signal is based on a digital signal scheme developed by ATSC (Advanced Television System Committee).

New Digital HDTV TV-RF Signal

The new terrestrial or off-air HDTV signal is based on a digital signal scheme developed by the ATSC (Advanced Television System Committee). With recommendations made by the ATSC, the FCC (Federal Communications Commission) adopted a signal using an 8 level vestigial sideband modulation scheme known as "8VSB" as a standard for HDTV. The terrestrial HDTV signal is commonly referred to as "ATSC" or "8VSB."

Like its NTSC predecessor, a digital broadcast TV signal must be contained in a 6 MHz bandwidth for transmission. However, in this 6 MHz channel bandwidth, several video and corresponding audio programs can be multiplexed and encoded before being modulated onto an RF carrier. The RF carrier itself is greatly reduced in power or level before the signal is transmitted, leaving no carrier in which to measure signal level.

Unlike the NTSC spectrum, the modulation techniques used to produce a digital TV RF signal result in a near even distribution of signal energy across a 5.38 MHz bandwidth. The digital signal is converted and centered within any of the FCC allocated 6 MHz off-air TV channel number assignments and the channel frequency band. The majority of the FCC assignments are in the UHF (ultra-high frequency) band from 470 to 800 MHz.

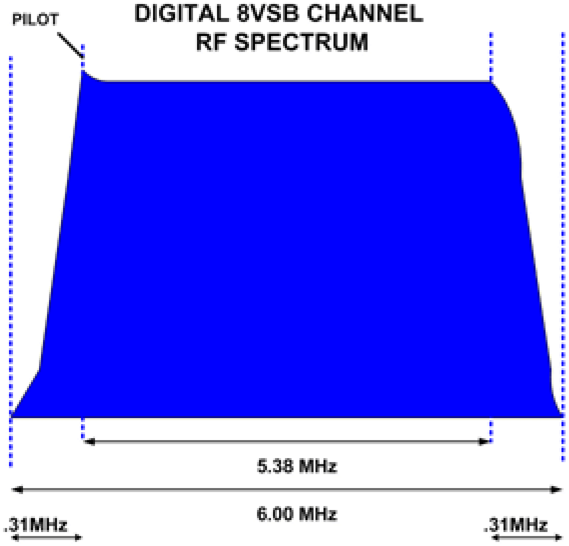


Figure 5 – A digital TV signal has near even signal energy across a 5.4MHz bandwidth centered within the 6MHz channel designation.

In theory, a digital TV signal should have near equal sideband energy across the 5.38 MHz band output from the transmit antenna, and when picked-up by the receive antenna. In reality, because of phase distortions, multi-path reception, impedance mismatches and other distortions, the flatness of the signal energy across the 5.38 MHz bandwidth may peak and dip. These level variations across the band pose a challenge to signal level measurements.

Measuring Digital HDTV TV-RF Signal Level

The digital TV channel has no RF carriers to measure for signal level. In theory, the sideband signal energy is distributed evenly across the digital channel's 5.38 MHz band. If this signal energy was flat across the band, a signal level meter's IF bandpass could be sampled anywhere in the 5.38 MHz digital channel band to obtain an accurate level indication.

Unfortunately, digital TV channel signal power can become uneven across the channel band. If a signal level meter was sampled in only one 250 kHz band, such as the center of the channel, an error in the relative signal level would result. For an accurate signal level indication of a digital channel, the signal level meter must take multiple signal measurements across the channel band and then average the readings. The result is an accurate indication of the average or overall signal power in the channel band.

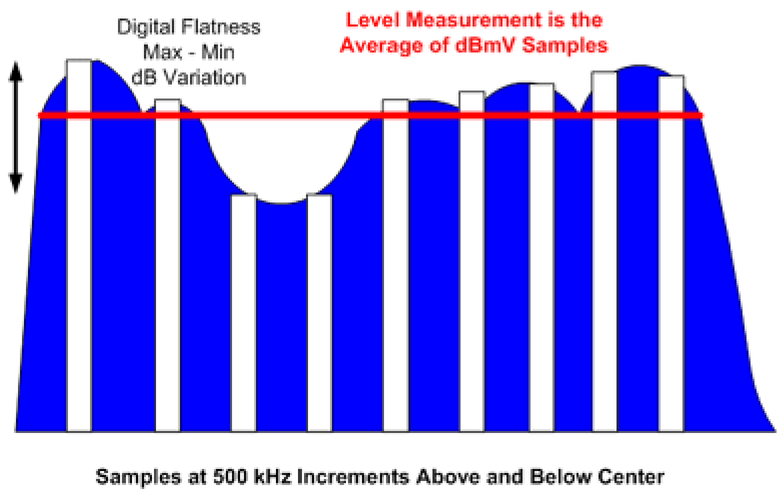


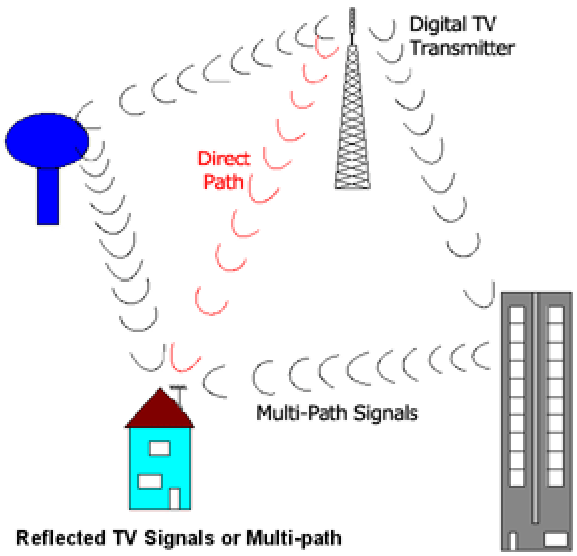
Figure 6 – A digital channel level is made by tuning the meter through the channel band and performing multiple level measurements, which are averaged to derive an accurate level dBmV measurement.

The Sencore SLM1453 can be used to accurately measure the signal level of a digital TV channel. The signal level meter automatically tunes through the channel band taking multiple measurements. The measurements are averaged to determine the level which is displayed by the meter.

Typically the more signal level, the more dependable is the digital TV channel reception. Proper receiver decoding is possible with signal levels below 0 dBmV. Receivers may be able to receive and decode digital signals down to -25 dBmV. However, for a good window of decoding to prevent a loss of reception, keep the signal level greater than -20 dBmV. ***Note:*** *The "M" indicator shown in the LEVEL/POWER readout indicates a level measurement in dB**m**V.*

Measuring Digital TV Flatness

In addition to a level measurement of a digital TV signal, a flatness reading is calculated and displayed by the SLM1453. A flatness reading indicates the difference between the maximum (peak) and minimum (valley) signal levels of all the level samples taken during the digital channel measurement. The flatness measurement is continually updated as the meter continues to sample levels across the channel band.



The closer you can get to a perfectly flat signal power across the digital band, the better. The flatness measurement gauges the presence of multi-path signal pickup by the antenna. Multi-path signals reach the antenna by a route other than directly from the transmit antenna to the receive antenna. The slight time delays and strength of the multi-path signals cause a variation in the level of the RF signal energy across the 6 MHz band.

Figure 7 - Multi-paths are signals reaching the antenna by way of an indirect route. Multi-path degrades the flatness of the signal energy in the 6 MHz channel band.

The more severe the multi-path signal pickup, the more difficulty the digital receiver will have in decoding the digital signal. Flatness variations of 1-3 dB are normal in most reception locations under ideal reception conditions. Multi-path worsens the flatness to 5 dB or greater and can vary with the increasing or decreasing reception and multi-path conditions. This can be seen and monitored with meter updates. For best digital signal antenna reception, orient the antenna for the most level in dBmV and lowest flatness dB reading.

Surprisingly, digital decoders can tolerate some flatness variations ranging from 4-10 dB but flatness readings about 5 dB are more likely to cause brief loss of signal decoding which can result in picture breakup. High multi-path, which is indicated by high flatness readings, is a common cause of intermittent reception or picture breakup.

Measuring Digital TV C/N

The carrier-to-noise ratio test indicates the difference in power in dB between the TV digital channel power and the noise in the frequency spectrum near the channel. A larger value indicates a stronger signal or less noise.

Carrier-to-Noise ratios over 20 dB are good for digital channel reception.

Unlike NTSC analog TV which requires C/N ratios of 40 dB or more, C/N ratios over 20 dB are good for digital channel reception. C/N ratios decreasing and approaching 15 dB can intermittently begin to cause digital decoding difficulties and signal dropout. C/N ratios of 15dB or less cannot be properly decoded by the receiver, resulting in loss of reception.

In most cases, a decreasing C/N ratio is a result of reduced signal reception levels below -20dBmV or severe multi-path indicated by a high Flatness measurement on the SLM1453.

Measuring Digital TV EMULATED b BER

The Emulated b BER measurement provides a bit-error-rate indication. This bit-error-rate readout is an indication of how many digital bit errors are estimated to occur each second when the decoder in the receiver attempts to read the digital data that represents the picture and audio program information.

Ideally, one error in 10 billion data bits is desirable. This is expressed as 1×10^{-10}. The BER measurement is expressed as a number with a negative exponent to the power of 10. (See Figure 8).

Reduced signal level, multi-path or other interferences may reduce the BER considerably. The SLM1453 indicates Emulated BER measurements of $<10^{-8}$ when the bit errors are insignificant and will not cause reception difficulties. Emulated BER values less than this can begin to effect reception. Typically emulated BER values of 1×10^{-6} or better can still be decoded properly. Values less than this (Example 1×10^{-5}) can cause occasional signal dropouts. Worsening values (Example 1×10^{-4}) eventually cause a complete loss of reception.

BER: Bit – Error – Rate

$$\text{BER} = \frac{\text{Number of Errors}}{\text{Bit rate}} \qquad \frac{30}{270 \times 10^{6}} \qquad \text{BER} = 1.1 \times 10^{-7}$$

Example: 30 bit errors in 270 Mbps (Million bits per second) results in BER of 1.1×10^{-7}

Figure 8 – Bit-error-rate (BER) is a measurement or estimation of how many bit errors will result when the receiver decodes the digital data stream.

A Digital Signal Quality Analysis Readout

The digital quality test indicates the overall quality of the digital signal and indicates pass (pas), marginal (mar), or fail (fai). The quality is determined by an algorithm analysis of the digital channel measurements including the Level, Flatness, BER, and C/N ratio tests.

For consistent decoding and reception, the quality test should show a “pas” reading. A fail or marginal readout indicates the digital signal reception is not as good as it needs to be for consistent decoding by the receiver. A fail indication generally results in a complete loss of reception and output from the receiver or severely interrupted reception.

A marginal readout typically causes occasional signal dropout where the picture would breakup. Occasionally, the signal reception, or picture, may disappear until the decoder in the receiver can get an improved signal to decode. Any of these conditions would be displeasing to the TV viewer, so the signal reception requires improvement. Improving antenna signal reception typically involves one or more of the following:

1. Better antenna (more gain, more elements)
2. Better antenna location (more height, another location)
3. More directional antenna (reject side/back multi-path)
4. Makeup for cable or down-lead losses (preamplifier)

Look at the measurements provided by the SLM1453 to determine why the signal is not adequate. A weak signal level indicates the need to improve reception of the digital TV signal. A good level with a high flatness measurement indicates the need to reduce multi-path reception. A more directional antenna or multiple directional antennas aimed at each transmitter may be required.

Figure 9 – The SLM1453 measures the digital TV signal level, flatness, C/N ratio, Bit-error-rate BER and provides a total quality analysis indicating pass, marginal or fail.

In most cases reduced C/N or Emulated BER values can be tied back to weak level or poor flatness. However, a good level and flatness measurements, but a reduced Emulated BER may be an indication of an interfering signal getting into the channel bandwidth. You may need to investigate possible sources of interference such as a distance NTSC TV signal near or on the HDTV channel or a strong local FM broadcast station.

The Sencore SLM1453 analyzes all TV terrestrial broadcast and cable TV signals to insure quality TV reception. If you have questions or would like additional information, please call 1-800-SENCORE.

For more information click on http://www.sencore.com/products/SLM1453.htm