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tech tips

Understanding and Using "On-Channel Tests" C/N and HUM

INTRODUCTION

C/N (carrier to noise ratio) and HUM are signal quality tests that relate to the picture being delivered to the customer. Poor HUM or C/N will quickly be spotted by customers since the "interference" will typically affect all channels. C/N or carrier to noise ratio is the difference in level between the RF carrier and the Noise in the system over the 4 MHz bandwidth of the video Information.

Poor C/N performance will produce "snow" in the picture. The visible threshold is approximately 39 dB C/N. A "professional viewer" will notice even higher ratios, but 39 to 40 dB easily satisfies the common viewer. The adjacent figures 1 and 2 illustrate a 34 dB C/N ratio compared to a > 45 dB C/N. A poor C/N

Figure 1: 34 dB C/N

Figure 2: > 45 dB C/N

can be caused by many sources in the CATV system. Any component which passes the RF signals could effect either the signal level or the noise content and therefore affect the C/N ratio.

Noise is originated at the headend and in the 1st amplifier of the system and can never be reduced, only increased as the signals are processed and distributed through the system. Even a 75 ohm termination generates noise caused by the electrons colliding within the material forming the termination. This low level signal is amplified along with our desired signals. The amplifier's Noise Figure is also added to the input noise level. These levels will be discussed later. Components such as splitters and cable which can develop higher than normal losses can degrade the systems C/N performance. Likewise active components can generate excessive noise which can add to the signal's noise content and increase the overall C/N.

HUM is the unwanted low frequency AM distortion of the video signal. This distortion includes all AM distortion below 400 Hz. This distortion may be incurred on the baseband video signal at the headend prior to the modulator or, as is more often the case, the AM modulation caused by power supply induced amplitude modulation in the system trunk and distribution amplifiers. Strictly speaking HUM is any low frequency AM distortion which is summed with the video signal causing picture degradation. HUM results in picture distortion as is illustrated in figure 3. The HUM bars will roll vertically through the picture as the HUM signal varies in phase relation to the vertical interval. 60 Hz and 120 Hz HUM are the most common AM distortions. These added to the composite video signal will typically produce one or two black bars whose intensity is proportional to the amplitude of the AM HUM distortion.

Figure 3: 5% HUM

HUM may be caused by several different types of problems in the CATV system. These are: unwanted AM modulation in the video processing equipment or modulator; power supply ripple in the system amplifiers caused by low line voltage, low power supply settings, overloaded power supplies or failing components in the DC power supply; or by corroded connections in the RF network acting like a mixer diode.

These different types of HUM can be isolated by testing and by the location of the HUM problem. HUM present at the headend as well as the rest of the system, must be generated at the This will also be characteristic of a particular channel. HUM present only in the downstream section of one leg or downstream from sections of the system powered by a common power supply is caused by a bad DC supply or low line voltage to that power supply. In the DC supply 120 Hz hum usually indicates low line voltage, a wrong voltage setting or a failing filter capacitor, while 60 Hz HUM will typically indicate a blown diode. 60 Hz HUM can also be generated when corrosion at a loose connector forms a diode junction from the oxidized aluminum and copper sulfates in the corrosion. This diode junction will act like a mixer, modulating the RF signals with the 60 Hz signal from the 60 V square wave power supply signal. Once a HUM problem is identified the SL750's VOM can be used to troubleshoot the AC and DC power supplies to isolate the source The 60 V AC line voltage can be measured directly through the RF input connector AC or DC voltages can be measured using the external voltage probes

C/N and HUM MEASUREMENTS

C/N and HUM are actually two of the easiest signal quality measurements that can be made on an operating system. Since these measurements can be made at almost any point in the system, they should be part of your standard practice. Measurement of only the signal level will only tell half the story Signal levels could be perfect and yet poor signals could be delivered to the customers.

AGC and ASC operation can correct for a bad amplifier or excessive passive losses to restore the signal level after just a few amplifiers, however, severe degradation to C/N can occur.

HUM caused by low line voltage, low power supply setting or failing DC supply components can often be detected through HUM measurements before the HUM is viewable on the customer's TV. This is especially true of a failing capacitor in the DC supply since excessive leakage causes ripple in the DC supply before the capacitor totally fails. Since HUM will typically run 1.5 to 2.0% and is not visible to the customer until it reaches 4.0 to 5.0%. making regular measurements will let you locate most HUM problems before they are noticed by any viewer.

Measuring C/N is not quite as simple as measuring the two levels with your signal level meter or spectrum analyzer and subtracting the difference. C/N is defined as the ratio of the RMS of the peak modulated RF carrier to the average power of the noise in a 4 MHz bandwidth. Note that we are comparing the RMS of peak of the carrier to the average of the noise. Also note, the noise is "measured" in a 4 MHz bandwidth.

When we measure the level of the RF carrier our normal instruments are calibrated to properly make this measurement, however, the noise measurement is much different. Our instrument will not have a 4 MHz bandwidth - certainly not a perfect 4 MHz even if we tried to build one. Thus we will have to address the bandwidth with a compensation factor. The following formula can be applied to correct the bandwidth limitations of our instrument:

$$CF_{BW} = 10 \text{ Log } (BW_1/BW_2),$$

where,
CF_{BW} = Correction factor
BW_1 = Desired measurement BW
BW_2 = Actual measurement BW

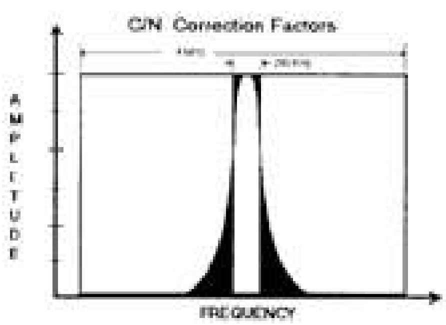

Figure 4: B W Compensation

In addition, since the formula assumes a perfect IF shape factor an additional correction factor must be used to correct our actual IF shape factor. to an ideal shape factor as illustrated in figure 5.

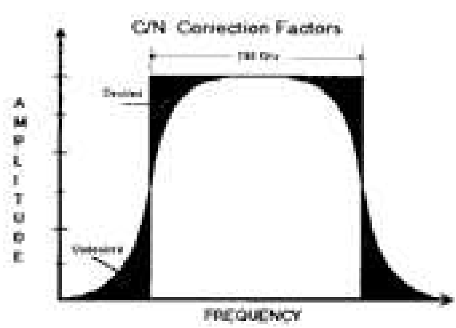

Figure 5: IF Shape Factor Correction

If the lower lobes contain more energy than the missing portion from the ideal square topped response, the compensation factor will be negative and subtracted from the total correction factor If the missing top portion contains more energy (area under the curve). then the actual readings will be too low and the correction factor will add to the noise reading.

$$CF_T = CF_{BW} + CF_{SF}$$

where
CF_T = Total correction factor
CF_{BW} = Bandwidth correction factor
CF_{SF}= Shape factor correction factor

One other correction must be made to our measurement if we use the same detector to measure the peak carrier and the noise level. If we use a peak detector to measure the noise. then. the average noise level will be approximately 3 dB lower than the peak:

$$V_C = 20 \text{ Log } (V_1/V_2)$$

V_C = 20 Log (ratio of RMS of peak to average)
V_C = 20 Log (.707 * 1 / .5)
V_C = 20 Log 1.414 = 3 dB

While the shape factor and peak vs. average correction factors can be calculated from data sheet information and some basic testing of the Instrument, the most accurate method to determine the total correction factor is though an empirical experiment. Results of such an experiment should be available from the instrument's manufacturer, or have been included in any automated noise measurement procedure.

The FCC instituted new rules in '92 which require the C/N ratio to be 40 dB as of '93. and 43 dB in '95. This measurement must be made at. or equivalent to. the customer's terminal. Since the nominal signal level will be 0 to +10 dBmV, a pre-amplifier will usually be required to make a C/N measurement, because the uncorrected noise measurement will equal the carrier level minus the C/N ratio minus the correction factor.

$$V_N = V_C - V_{C/N} - C_{FT}$$

where,

V_N = Uncorrected noise measurement
V_C = Carrier level
V_{CN} = C/N ratio
C_{FT} = Total correction factor

If we assume a 0 dBmV carrier level and a minimum C/N ratio of 40 dB then,

V_N = 0 dBmV - 40 dBmV - 10 dB
= -50 dBmV

Thus. we need sufficient sensitivity to measure the uncorrected noise at an anticipated level of -50 dBmV or lower. A pre-amp is required to gain the additional sensitivity.

The C/N ratio can be predicted at any point in the system At the headend, the C/N ratio at the modulator will be very near the thermal noise floor. The passive devices following the modulator do not add to the noise in the system Passives will have the same loss effect on the noise that they have on the RF signals. Amplifiers. however will add to the noise and therefore reduce the C/N ratio.

The thermal noise floor is ~ -59 dBmV (4 MHz bandwidth) in a 75 ohm system This is therefore the lowest possible noise level. As we amplify signals on the system we will also amplify the noise, thus the output of our first amp will increase the noise level as well as the signal levels by it's gain. The amplifier will also add it's own internal noise to the system. This is called the amplifiers' Noise Figure. Thus we can predict the noise level at any part of the system. The noise level at the output of the first amplifier will be:

$$V_N = -59 \text{ dBmV} + V_G + V_{NF}$$

where,
V_N = Uncorrected noise measurement
V_G = Gain of the amplifier
V_{NF} = Noise figure of the amplifier

If the noise figure is 8 dB and the gain of the amplifier is 22 dB, then the noise level will be:

V_N = -59 dBmV + 22 + 8 =
-29 dBmV (corrected)

The C/N ratio will then be the difference from the corrected noise level to the carrier level. Typical trunk amplrfier output levels would be, +30 dBmV, thus providing a 59 dB C/N.

The C/N can also be predicted at any other point in the cascade of amplifiers. For similar amplifiers we can use the following formula:

$$C/N = C/N_1 - 10 \text{ Log } N$$

where.
C/N = The C/N ratio
C/N_1= The C/N ratio at the first amplifier
N= The number of amplifiers in cascade

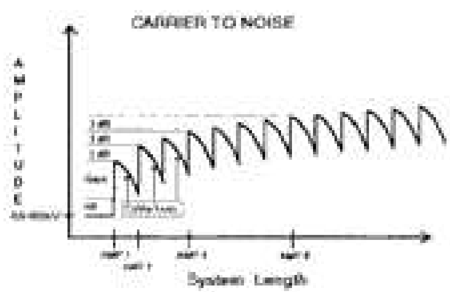

Figure 6: C/N

Note that this equation will yield the C/N ratio and that every time we double the cascade the C/N ratio degrades by 3 dB. This should make predicting the approximate C/N ratio easy at any point in the system.

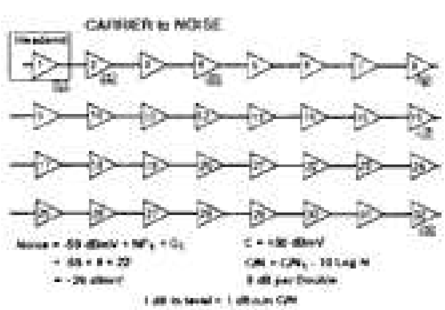

Figure 7: C/N Predictions

The typical test method for measuring C/N is to measure the carrier level and note the reading. Secondly, the noise level must be measured Whether using a signal level meter or a spectrum analyzer, the manufacturer will provide a similar test procedure for measuring the noise floor. Some of these procedures include automated functions which may include the correction factors which we have discussed. In general. the correction factor will vary from instrument to instrument depending on the resolution bandwidth and the type of detector utilized. Refer to the specific instructions of the manufacturer when making noise measurements to get the required correction factors or to see if they are built in to a special noise measurement routine. With any instrument, one common requirement is to tune the instrument so that only the noise is measured without interference from carriers on the system. beats on the system or beats produced by the measurement instrument. The measurement instrument will need 60 dB of rejection at all carrier frequencies, in reference to the frequency of the noise measurement. for a 40 dB C/N ratio if the correction factor is 10 dB and a margin of 10 dB of the measurement to other signals is desired (1 dB accuracy). This can be difficult to find in the CATV spectrum if all channels are in use. Typical methods include tuning below channel 2, tuning to an unused midband channel, or shutting off the modulation on one channel during the test. No matter which method is used, the rejection of the other signals will have to be 10 dB greater than the uncorrected noise measurement as depicted in figure 8.

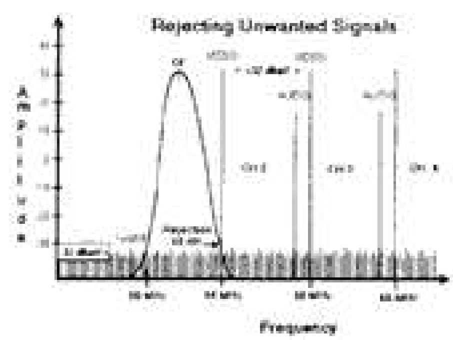

Figure 8: Rejecting Unwanted Signals

In making HUM measurements, we want to measure the low frequency AM distortion of a video carrier. This is easiest done as a post detection measurement. That is, a measurement after detecting the video information. The best approach to measuring HUM is to pay careful attention to the definition of HUM. HUM is simply the ratio of the peak to peak amplitude of the unwanted AM modulation to the peak of the video signal. See figure 9.

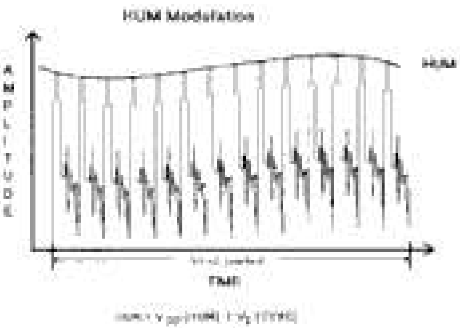

Figure 9: HUM Measurement

HUM = V_{PP} / V_P

where,
V_{PP} = Peak to peak AM distortion
V_P = Peak of the video signal

Note that HUM is not the same as %AM modulation, but approximately 1/2 the %AM. Measuring the video signal level at the maximum level of the video signal and comparing that level with the amount of variation in successive measurements will provide very accurate HUM measurements. The problem with this technique is that you can not distinguish between the wanted and the unwanted low frequency AM modulation unless the measurement is made on an unmodulated carrier. except with an FFT analyzer, which is very expensive, complex to use, and not meant for field operation.

The FCC's '92 rules require the HUM to be less than 2.5% at the customer's terminal. This is an easy specification to meet. HUM will typically run 1.5 to 2.0% on a properly operating system.

Readings higher than 1.5 to 2.0% will indicate that a problem exists, which can easily be isolated to the component or module causing the problem. HUM is not like C/N or other distortions, in that it is not built up through the cascade. Since HUM is typically the result of low power supply voltage or a failing component in the AC or DC supplies, the problem occurs at the point of that failure and remains relatively constant through the remainder of the cascade.

HUM is typically measured by de-modulating the test carrier and comparing the peak level of the demodulated signal with the low frequency AM "riding" on that signal. See figure 10 for a basic block diagram. This is done by first using a standard video detector to measure the baseband peak signal level, then AC coupling a low pass filter to the video detector, peak to peak detecting the low frequency signal and adding a calibrated high gain amplifier to provide a measurable DC component signal. The difficulty lies in measuring the very low level AC low frequency signal. This method provides good measurement results. but has one key drawback - a CW test signal must be placed on the system for the measurement.

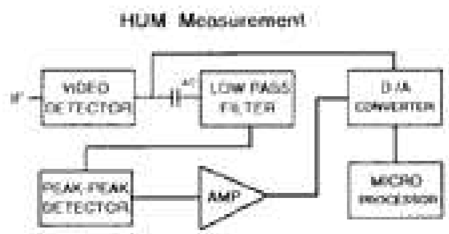

Figure 10: HUM Measurement Black Diagram

LIVE "ON-CHANNEL" TESTS

Testing without interference to the system's operation and without adding additional test signals should always be our priority. Interference to the picture quality is the reason that we test the system. Having the tests interfere with system operation is somewhat contrary to our objective.

Adding carriers to perform our tests utilizes valuable spectrum that could better be used for revenue purposes. Single test carriers do not require much spectrum, but also provide only limited test data. The solution to these problems is simply to develop a test method and instruments which will perform these measurements on an active system without adding test carriers. The goal would be to make the tests on all of the live video carriers on the system. This would also provide us with the capability to test the C/N and HUM on all of our channels. HUM and C/N problems that occur at the headend in processors, modulators, receivers or strip amps can be tested if the tests can be performed on live carriers. The SL750 is the only signal level meter which will make these patented on channel tests.

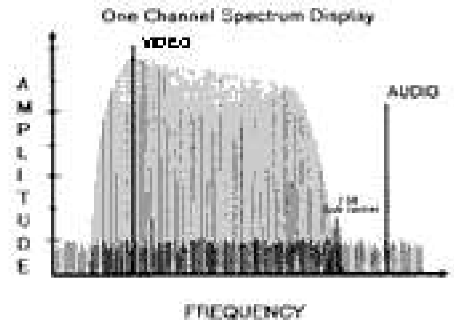

Figure 11: Spectrum Display

While signal level meters and spectrum analyzers measure signal levels across the frequency spectrum. no attention is paid to the timing of those measurements. If we were to analyze a channels spectrum over time we will find that the energy from the modulation process is dispersed in the spectrum from ~ -.75 to +3.5 MHz around the carrier. This typical vestigial sideband modulation is shown in figure 11.

Measurements can be made in the time domain of the video signal. If we break time down into small increments and take snapshots of the energy dispersed in the channels' spectrum, we would be able to break each horizontal line down into a discreet pattern associated with that line of video in the picture. Similarly we could look at the time increment during the VBI (vertical blanking interval). During the VBI the equalizing and sync pulses are present, however the video is blanked or at the blacker than black level. This time increment during the VBI when the sync is at It's peak level will produce a spectrum display that would contain the video carrier and the sync sidebands at 15,734 Hz. The key being that the balance of the spectrum will be empty durrng this short period of time. Obviously, if our instrument could measure the noise floor between the video and audio carriers during this time period there would be no signal interfering with the measurement, and we would not have to turn the modulation off or tune to an unused frequency.

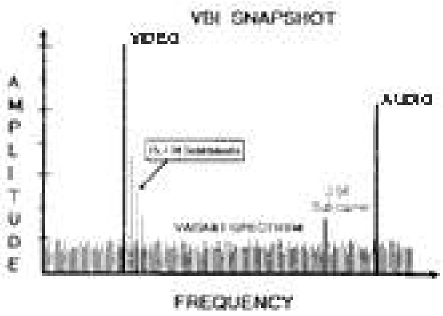

Figure 12: Spectrum Display During VBI

Similarly, if our HUM measurement could be timed so that each measurement is made on the peak of the horizontal sync pulse during the vertical blanking interval, the wanted low frequency modulation can be distinguished from the unwanted AM distortion. Making successive measurements gated to correspond to the sync pulses allows us to measure the deviation from the expected signal and thus determine the HUM content in a live video signal.

Measurements made by these patented techniques are done in a similar manner to the manual or automated testing techniques used by other manufacturers except for the gated timing, which allows the measurement to be made "in channel" during a time increment when no "interference" is present. Measurements of this type will exactly duplicate the results used by the other methods for "off channel" testing.

C/N tests will correlate to the standard off channel tests or the method requiring the modulation to be removed. Discrepancies in measurements between methods will only occur when there is a real C/N problem specific to a particular channel.

HUM tests will correlate to the other methods of testing since the method IS identical except for the gated timing of the measurements.

The Sencore SL750A and SL750M provide these on channel capabilities as well as off channel capabilities that will allow comparison between other instruments. Either the "on-channel" or "off-channel" C/N technique may be selected from the front panel controls. The SL750 automatically accommodates the "off-channel" HUM test technique when no modulation is present on the test carrrer.

In the "on-channel" C/N measurement the SL750 will automatically tune 2.7 MHz above the video carrier and trigger its' measurement circuitry during the horizontal sync pulses of the VBI so that the C/N measurement can be made on a live video carrier. The appropriate noise measurement correction factors are factored into the measurement by the micro-processor and the C/N ratio is displayed digitally.

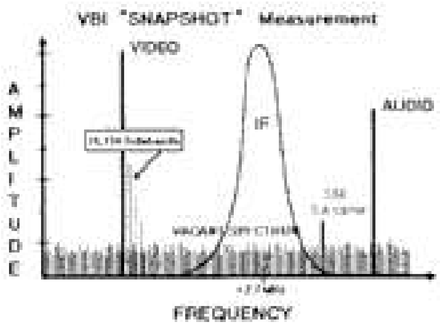

Figure 13: C/N On-Channel

In the "off-channel" mode, the measurement is made without the gating circuits. The carrier level is measured, the noise is measured at the programmed frequency, and the correction factors are applied such that the C/N ratio is displayed on the LCD.

HUM can be measured "on-channel" or "off-channel". The SL750 will detect the presence of video and switch modes automatically. In the "on-channel" mode the gating is controlled by the video's sync, while in the "off-channel" mode the gate is controlled by the instrument's microprocessor.

AVOIDING ERRORS

As with all measurements, care must be taken in making these measurements. Although a great deal has been done to automate many measurements, there are always pitfalls available to cause erroneous readings. The best method to avoid these pitfalls is to thoroughly understand the measurement procedure, the technique employed by your instrument and as much of the criteria about the signals on the system as possible.

To avoid errors in making the C/N measurement we must be concerned about accurately making two measurements: the carrrer level and the noise level. Possrble sources of error in measuring the carrier depend heavily on the ability of the Instrument to measure the carrier level accurately whether it is a CW carrier (unmodulated), a standard video carrier or a scrambled channel carrrer (& type of scrambling).

CW carriers are typically the easiest to measure since they are the simplest. Most signal level meters respond equally well to a CW and a standard video modulated signal. Small differences of .5 dB should be expected with most meters. In using a spectrum analyzer the measurement should be straight forward. The only pitfall is to avoid scan loss. To avoid scan loss, slow the sweep rate until the maximum amplitude is achieved.

Since video modulated carrier measurement is the primary function of a signal level meter, it's accuracy should be the best on a modulated carrrer. In utilizing a spectrum analyzer, care should be taken to avoid scan loss, not only of the RF but of the sync peaks. A different resolution bandwidth and sweep rate will be required for measuring the noise than for measuring the carrier level.

Modern scrambling has complicated the measurement of carrier levels. The correct level reading for a scrambled channel is the level which would be present if the scrambling were turned off. Some meters are capable of reading the correct level and some others will read 4 to 6 dB low and may "drift around" in their reading according to the scene of the picture. Consult the manufacturer for the effectiveness of any particular instrument on your specific type of scrambling. Since the SL750 has a gated measurement capability, all scrambling techniques which do not change the level of the horizontal sync pulses during the VBI will provide the correct level measurement on the SL750. Most popular scrambling techniques do not affect the VBI sync pulses. Again, with a spectrum analyzer use the maximum resolution bandwidth and slowest sweep speed reasonably possible, but be sure you have maintained sufficient selectivity.

As noted previously. measuring the noise level is much more complex than measuring the carrier level and therefore requires greater care to insure an accurate measurement.

The primary concern when making the noise measurement is to be sure that the instrument is tuned to the noise Most other aspects of the measurement are automated, however, the tuning is often left to the operator. except on the "on channel" test by the SL750s. When tuning to the noise with a meter or a spectrum analyzer, the major concern is the selectivity of the instrument. In order to get a good noise measurement the Instrument must reject the other signals on the system. Note that a narrower resolution bandwidth or IF bandwidth is a trade off. While improvrng the selectivity it also raises the correction factor requiring greater sensitivity for the same C/N ratio. When in the "on-channel" mode the SL750 will reject the video and audio carriers by more than 60 dB.

The instrument used to make the noise measurement must have a noise figure or noise floor which is 10 dB below the noise level which you are measuring (for < 1 dB error). A pre-amp can be used in front of the instrument if additional sensitivity is required. If you do this, be sure that the pre-amp noise figure is significantly below the noise level you are measuring and that the pre-amp will handle the signal load without distortion.

When measuring the noise, another source of error can be beats generated by 2nd or 3rd order distortion; not only in the system, but in the instrument itself. When using a meter, tuning for the minimum noise level or listening for the clear noise are the easiest methods to avoid beats. When using a spectrum analyzer you must distinguish between the noise and the beats appearance Newer automated test techniques actually make this more difficult If you have difficulty avoiding the beats, a preselectron filter on the Instrument RF input is required Since the SL750 makes a gated measurement at 2.7 MHz above the video carrier. no beat or distortion is commonly found at this frequency during the measurement time frame

Caution must be taken when making C/N measurements on a positive trapped system with the SL750, since, the "interfering carrier" is placed between the video and audio carriers. On this type system the C/N is best done with the interfering carrier turned off or measured using the off channel technique.

HUM only has a few possible sources of error. Since this is a baseband measurement, few RF phenomena can affect the measurement. Keep in mind that measurements can only be made on a CW carrier with most instruments. The SL750 will make accurate measurements on any video modulated carrier or any CW carrier. With all instruments the key is to be sure you are tuned to the peak of the carrier to avoid any FM to AM conversion in the instrument, producing drastically erroneous readings.

SUMMARY

Although the SL750 is the most sophisticated instrument and avoids many of the possible sources of error and automates the measurement process, there is no substitution for care and knowledge about the specific system under test

As technology increases, system complexity and regulations burden the technical staff. The only solution is more sophisticated test equipment, that does more, faster and at the same time is easier to use. The "on-channel" tests represent such advances. Testing "on-channel" greatly simplifies the engineers task and increases his ability to thoroughly test the system without the paradox of shutting off channels or inserting test carriers.

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