AM NOISE: THE QC STANDARD FOR FM BROADCAST

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By Joel Bump

PART 1

It has been slightly more than 16 years since I first published a series of detailed technical articles in RW on the subject of AM noise in FM transmission systems. Over the years, a number of engineers I knew in the Southern California area have retired or moved on to other markets and positions. More solid state transmitters are in service and AM noise has been routinely monitored and controlled in hundreds of stations improving service areas and reception quality. Yet demands on FM transmission system bandwidth persist and questions often are asked about proper coupling methods for AM noise monitoring in both new installations and existing transmitter plant upgrades.

AM NOISE DEFINED

A simple definition of AM noise is: unwanted amplitude modulation of an FM carrier. There are two types of AM Noise, synchronous and asynchronous. Asynchronous noise consists of amplitude modulation unrelated to the FM modulation of the carrier, typically caused by power supply hum or vibration. Unless there is a serious problem with the transmitter, asynchronous AM is far less significant than synchronous AM. Unwanted AM modulation produced by normal FM carrier modulation from baseband audio and all subcarriers is synchronous AM, sometimes referred to as incidental AM. Consistent control of synchronous AM noise can result in improved audio clarity, better stereo separation, lower crosstalk into subcarriers and extended service area.

EFFECTS OF UNCONTROLLED AM NOISE

FM receivers ultimately are required to produce analog output signals. This is accomplished by converting the frequency swing of the incoming carrier to amplitude values that feed the receiver output or are further decoded to produce stereo audio outputs. Receiver designs seek to minimize the effect of carrier amplitude variations during this process, but received RF levels in weak signal areas or in mobile receivers vary drastically over short distances. When the received signal instantaneously drops below a certain threshold in the radio, the received amplitude variations are directly detected and combined with the baseband audio. The result is audible noise in the stereo audio, reduced separation, poor subcarrier performance and a reduction in the station’s effective “solid” service area.

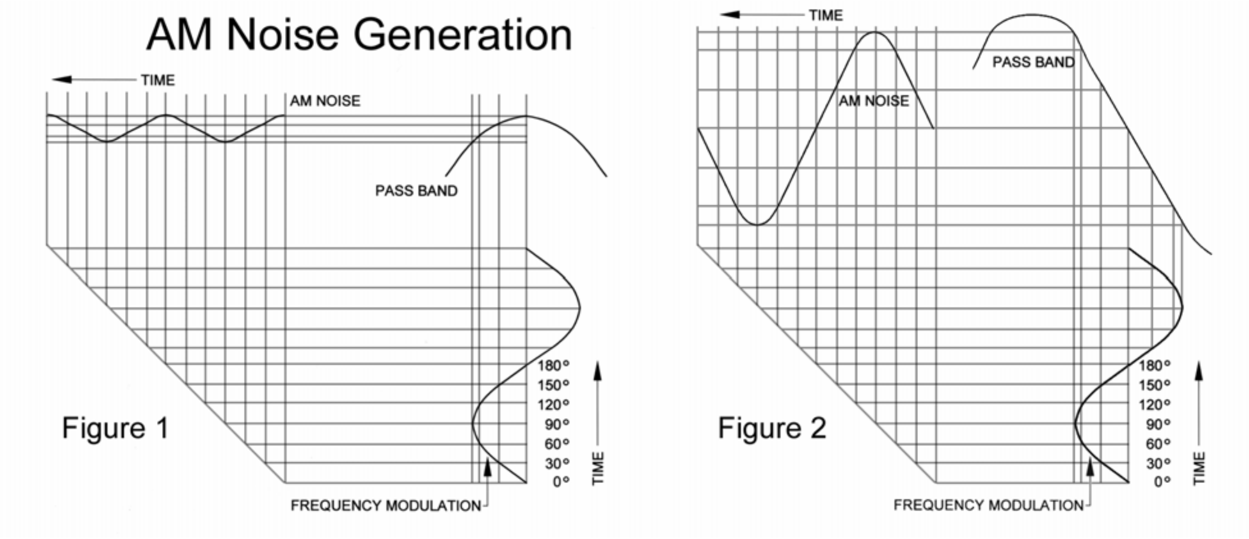
SOURCES OF AMPLITUDE VARIATIONS AT THE RECEIVER

Amplitude variations that can be detected by the receiver may result from multipath distortion of the carrier. At the relatively high frequencies in the FM band, transmitted signals reflect off many surfaces, from hills to buildings to power lines. When a direct and a reflected signal reaches the receiving antenna at the same time, they will add or subtract resulting in significant variations in level. I have measured multipath variations as great as 30 dB over distances of 50 feet.

Amplitude variations from AM noise are also inherent in the actual transmitted carrier. AM noise produces an effect similar to multipath at the receiver in weaker signal areas. Large and often important portions of a station’s coverage area may be located in these regions. AM noise in the transmitted signal tends to significantly multiply the effects of multipath. A moderate level of AM noise together with moderate, otherwise unobjectionable, multipath can produce highly objectionable noise in many receivers. This effective reduction in coverage area can be substantially controlled by insuring that low AM noise is being transmitted at all times.

HOW SYNCHRONOUS AM NOISE IS PRODUCED

Synchronous AM noise results from tuned circuits. Coupling between rf amplification stages in a transmitter, tuned output circuits, low pass filters, antenna tuning and even transmission line bullets contribute to AM noise. Ideally, all power is transferred equally across the frequency deviations of the transmission system. In practice, however, sideband attenuation is never perfectly equal and many system elements vary with time and temperature.

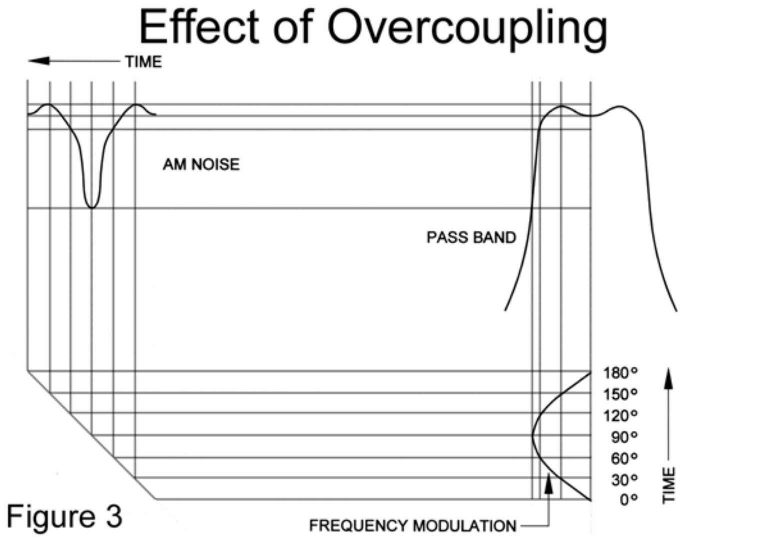


These graphs show the AM Noise waveform and relative amplitude produced as a result of modulation. The FREQUENCY MODULATION waveform drives the carrier above and below the center frequency. The PASS BAND of the transmission system at each frequency produces variations in the carrier amplitude producing AM NOISE. ***Time is indicated in 30 degree increments relative to the modulation frequency. The vertical lines drawn from the modulation waveform represent instantaneous carrier frequencies above and below the station's assigned carrier frequency. The intersection of the instantaneous frequency with the pass band slope is carried to the left side of the graph where the resulting AM noise is plotted against the same time increments.***

The fundamental production of synchronous AM noise is shown in Figure 1. As the FM carrier frequency shifts with modulation, shown as a sine wave, the pass band slopes produce a direct variation in the carrier amplitude. These variations are defined as AM noise. Because the pass band is symmetrical, amplitude variations result from both the higher and lower frequency slopes. The resulting AM is twice the frequency of the FM modulation.

If the center of the pass band is shifted below the center frequency, the resulting AM will be the same frequency as the FM modulation. As seen in Figure 2, the amplitude of the AM noise also increases as the tuning shifts off center.

These diagrams visually indicate how AM noise is produced. Multiple amplification and tuning stages are designed to maintain the flattest pass band and widest bandwidth. Interstage coupling, however, results in actual pass bands that are less uniform than in these basic examples. Coupling may be increased to produce flatter response over a broader range of frequencies while simultaneously producing steeper skirts.



The pass band in Figure 3 results from some inter-stage overcoupling and is more nearly representative of a multistage transmission system. This example only shows one-half cycle of modulation applied to the carrier, yet the resulting AM noise is now four times the modulation frequency. The waveform of the AM noise does not exhibit uniform positive and negative amplitudes but it does produce four AM cycles for each FM cycle applied to the carrier. This graph clearly shows the effect of the skirts on the amplitude of the AM noise. If the pass band in Figure 3 was slightly wider, the same frequency deviation would produce a significantly lower AM peak amplitude.

Figure 4. AM Noise with overcoupled pass band

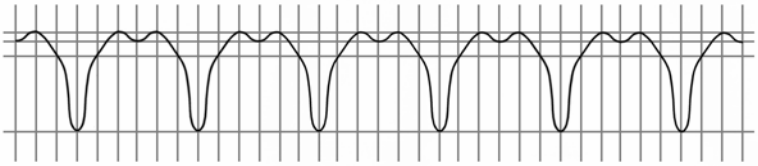


Figure 4 shows the AM noise produced by the pass band from Figure 3. This waveform exhibits a high peak excursion relative to the corresponding RMS voltage. It is particularly important to note the ratio of RMS to peak energy in the AM component. It is the peak AM that is subject to detection in the receiver. If the slope of the pass band skirts in Figures 3 and 4 was tightened, the peak AM excursion would become narrower while still producing the same objectionable amplitude at the receiver.

The sine wave modulation used in these examples clarifies the generation of AM noise and its relationship to the system pass band. The nature of program audio and subcarrier modulation consists of narrower waveforms containing even less RMS energy while still producing the same peak amplitudes.

The second and final installment of this series will examine sampling methods, planning for AM noise measuring, typical waveforms and practical considerations.

PART 2

Making accurate measurements and monitoring the AM noise levels at all critical times are essential to optimum FM transmission system performance. Part one of this series explored the theory of AM noise generation and the effects it has on receivers. In this final installment we will examine typical waveforms and practical considerations for planning successful AM noise monitoring.

WHERE AM NOISE SHOULD BE MEASURED

The best measurement would include the effects of every bandwidth limiting factor in the transmission system. Ideally, AM noise should be measured at the output of the transmitting antenna without the effects of any external reflections. Since that is not practical, the optimum sample is immediately prior to the transmission line feeding the antenna. It is imperative that the sample be taken from a directional sample of the forward carrier wave. The sample should be as close to the antenna in the signal path as possible. It should be after the harmonic filter and after any other notch filters or coaxial switches. The location of the monitoring sample is very important and can be useful in verifying the mechanical integrity of the plumbing prior to the sample. In addition to verifying transmitter performance, I have found AM noise readings to be instrumental in identifying burned bullets in rigid line or RF switches before they became off-air critical.

Many older transmitters and some line sections provide monitor outputs that are capacitively coupled to the carrier. Such samples must be avoided for AM noise measurements because they contain harmonic and reflected components that produce erroneous AM. When unwanted signals combine with the forward signal, spurious AM is produced that would cause the engineer to mistune the transmitter, degrading rather than improving performance. Certain sampling slugs that fit line section ports are capacitive as evidenced by a coupling adjustment screw adjacent to the output jack. These samplers must not be used for AM noise.

SAMPLING RF CARRIERS FOR AM NOISE MEASUREMENT

A transmission line section with an available sampling port is normally installed just prior to the transmission line. A directional sampling slug is used for proper AM noise measurement. The slug should be oriented toward the forward carrier wave and the AM measurement detector must be connected directly to the output of the slug. Two characteristics of the slug are most important. First, it must have sufficient RF output level to produce linear detection over the wide dynamic range to be measured. Second, it must have sufficient 50 Ohm internal load dissipation to deliver its output continuously into a 50 Ohm detector load. Some common sampling slugs do not meet these requirements. Available samplers meeting the requirements are listed at: rdlnet.com/pdf/Data_Sheets/acm-3.pdf

The AM noise levels being measured in a properly operating facility can be as low as 70 dB below the carrier level. Clearly, if the sample is to be accurate, it cannot contain any spurious material. For that reason, the detector must be directly connected to the sample. If the detector is connected to the sampler using a coaxial cable, even minor reflections in that cable will produce serious errors in the detected AM. The output from an AM detector contains dc plus detected amplitude modulation with a bandwidth less than 100 kHz, therefore standard coax can carry the detector output a long distance to the monitor without any compromise in the reading accuracy. Modulation monitors connected to a sample using coaxial cable cannot be expected to produce meaningful synchronous AM readings.

IMPORTANCE OF SETTING UP AN ACCURATE SAMPLE

It may seem that I am over stressing the importance of an accurate sample position and level. It is imperative to plan sampling and detection properly because an inaccurate sample can prompt severe mistuning of the transmitter and yield incorrect overall indicated levels of AM noise. When the sample is established properly, it can be relied on for real-time monitoring of transmission system integrity for many years.

The linearity of the detection circuit is equally as important as the RF sample. The optimum detector employs full wave carrier rectification with LC filtering to produce an AM level that can be calibrated against the detected carrier level. The RDL DCF-100MB detector used with the ACM-1, ACM-2 and ACM-3 AM Noise Monitors relies on this method. Engineers have used half-wave diode rectifiers and suitable filter capacitors to produce samples that can be used as a relative tuning indicator when a quantitative value of AM is not desired.

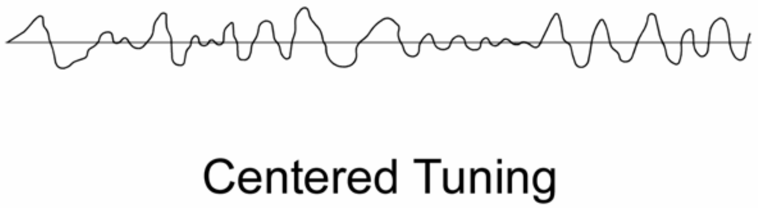
HOW LITTLE IS ENOUGH?

Each station may establish its own threshold for maximum AM noise based on terrain, multipath in critical coverage areas and transmitter capabilities. In general, simply tuning for minimum AM without taking a calibrated reading can result in actual levels from -25 dB to -50 dB or better. Readings of -40 may be acceptable if there is minimal multipath in critical listening areas and no subcarriers are in use. The same value may be unacceptable in a competitive market with moderate to severe terrain or other reflection producing obstructions. Most systems can attain a sustained level of at least -50 dB with good maintenance. Levels of -55 dB or better will produce optimum station performance in any environment.

It is best if the station can constantly monitor the level, allowing a predetermined threshold to trigger an alarm. Changes in the bandwidth caused by any source such as tube aging, variations in power service voltages, temperature, and transmission line or switch heating, can alert the station of impending maintenance before the station's service area or subcarrier performance is noticeably affected. In selecting the proper threshold, it is normal to allow for a variation of 5 dB or more during each broadcast day.

Monitoring is always desired though not always possible or practical. Today's monitoring system costs are within most expense budgets, but some facilities prefer periodic measurements by engineering staff. Other sites share common antennas with combiners that can not sufficiently reject neighboring carriers to allow constant monitoring. At such sites, AM noise should be checked individually on each transmitter during a coordinated maintenance period. That period can also be used to check the antenna's effect by measuring and logging the AM noise on a *reflected* carrier sample. The low amplitude of the reflected signal should require a more sensitive sampling slug. Such a maintenance check is equally beneficial to stations that do not share a common antenna.

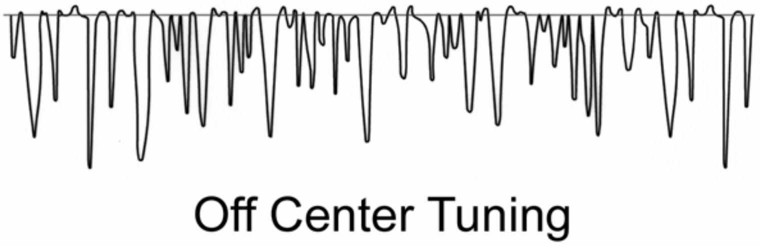
Figure 1. AM Noise with centered pass band



PROPERLY TUNED AND OPERATING PASS BANDS

When a transmitter and associated components are properly tuned and operating, a waveform similar to Figure 1 will be produced by a detector or at the output of an AM noise monitor. With this display of centered tuning and a measured AM level of -55 dB or better, the station is assured of optimum performance.

Figure 2. AM Noise with offset pass band



Good performance may also be possible with a pass band that is not perfectly centered, provided the measured AM level is sufficiently low. Frequently, offset pass bands as indicated in Figure 2 produce excessive AM noise levels.

QUALIFYING AND INTERPRETING THE READINGS

If an AM noise measurement method is being used that does not produce a calibrated level, care must be exercised in qualifying the results. An important characteristic to understand is that typically as AM noise becomes worse, the peak content increases while the RMS energy remains the same or decreases. Therefore, metering that produces RMS or averaged results will become more inaccurate as AM noise increases. Receiver performance, however, will degrade as peak AM increases. This makes it critical to monitor the *peak* AM excursions.

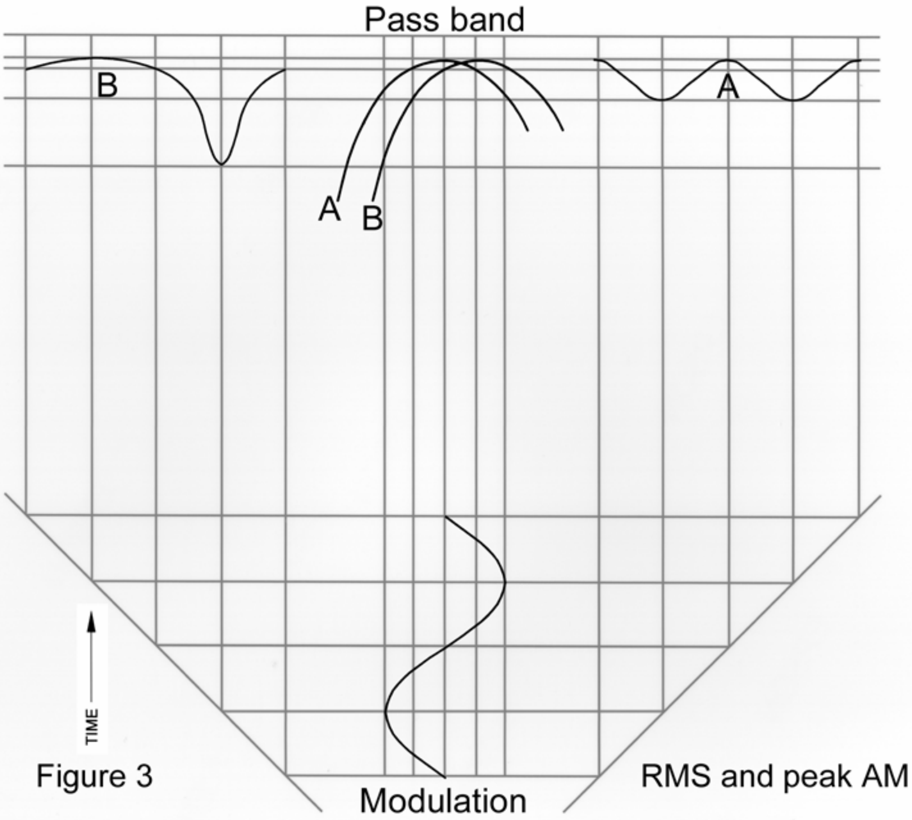


Figure 3

Figure 3 details the problem. If the peak value of AM indicated by pass band A was measured at -39 dB, an RMS meter would indicate the same waveform at a level of -45 dB. If the pass band was then tuned for an RMS null, waveform B would result in an RMS reading of -46 dB. However, the peak value produced from pass band B would actually be -32 dB. Nulling the RMS reading would result in an actual performance degradation in AM noise from -39 dB to -32 dB!

Similarly, if a common diode was used as an RF rectifier, equally erroneous results can easily be produced. A 1N4148 fed with 10 V p-p at 100 MHz with 10% applied AM modulation will produce a dc/ac ratio of -20 dB, which is an accurate indication of AM. The same diode fed the same signal at 4 V p-p would result in a reading of -17.9 dB, while with a carrier sample of 1 V p-p it produces a reading of -9.8 dB. This is an error of more than 50%. Accurate, repeatable AM noise measurements are improved through the use of low capacitance high frequency diodes.

BENEFITS OF MONITORING AND CONTROLLING AM NOISE

Nearly any anomaly in the performance of the transmitter and associated plumbing has an immediate and measurable effect on AM noise. When the accurate AM level is monitored continuously against a threshold standard, the station can be assured of proper performance. Control of AM noise optimizes subcarrier operation and any broadcast services relying on signals in the upper spectrum of the baseband. Stereo separation relies on the 38 kHz subcarrier, and is materially worsened by increased AM levels.

Proper sampling and monitoring of AM noise levels produces coverage consistency, maximum service radius, improved stereo separation and satisfied subcarrier tenants. It provides the final “QC” for the station’s carrier signal, program content excepted.

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Article available in .pdf format at: www.rdlnet.com/acm-3.htm

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