ADVANCED TECHNOLOGY

A DISCUSSION ON QAM SNARE SENSITIVITY

HOW PROCESSING GAIN DELIVERS BEST SENSITIVITY IN THE CATEGORY

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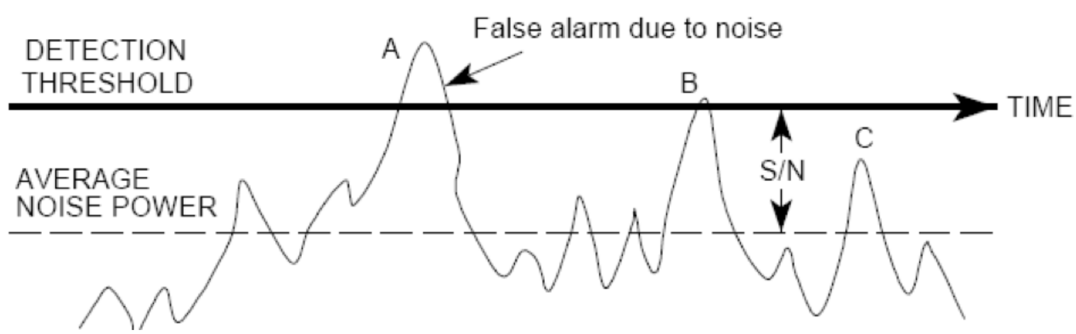
OVERVIEW

This paper describes the sensitivity achievable with the QAM Snare cross correlation detector. We'll first present some background terms and definitions, and then provide the mathematical calculation of theoretical sensitivity. We then show how real world results match the calculated theoretical results. Lastly, we'll discuss the input signal operating range.

SENSITIVITY DEFINITIONS

The sensitivity of the QAM Snare leakage receiver is defined as the minimum QAM input signal level (in dBm or dBmV) required to detect peaks of the cross-correlation function at the output of the correlation processor, with some fixed minimum signal-to-noise ratio (typically +5...+15 dB) sufficient such that false alarms are not recorded.

The diagram below illustrates the required S/N – a detector threshold needs to be selected higher than that shown below in order to avoid false alarms.



The level of the QAM signal is defined as level of CW carrier at the output of a QAM modulator when the QAM modulation is OFF (a similar technique as is employed for measuring QAM signal levels in the cable industry). This also means that the sensitivity of QAM Snare receiver is defined over the full frequency band of the QAM signal (6 MHz for NTSC).

The signal-to-noise ratio at the output of cross-correlation receiver depends upon:

A) Cumulative noise level at the input of receiver (Gaussian noise, plus all interference noise in the QAM signal frequency band);

B) The processing gain of the cross-correlation processor.

The processing gain of the cross-correlation receiver depends upon the accumulation time for the coherent accumulator (integrator). Therefore, the sensitivity of QAM Snare also depends upon this accumulation time. Possible values for accumulation time are presented from a few milliseconds to a hundred, depending upon the leakage-sampling rate (typical sampling rate is 1 per second). This processing gain is what enables QAM Snare to have the greatest sensitivity in the category.

THEORETICAL CALCULATION OF SENSITIVITY FOR GAUSSIAN NOISE

The sensitivity S_{in} (dBm) of the cross-correlation receiver is defined as follows:

$$S_{in}\ (dBm) = NF\ (dB) + KTB\ (dBm) + E_b/N_o\ (dB) - G\ (dB)$$

Where:

NF = total noise factor of receiver before cross-correlation processor, in dB;

KTB = input thermal noise power, dBm;

Where:

K = Boltzmann's constant = 1.381×10^{-23} W/Hz/K,

T = 290°K at room temperature and

B is the bandwidth of the receiver in Hz (B = 6 MHz for QAM Snare);

E_b/N_o is the signal-to-noise ratio before the detector and after the cross-correlator, in dB;

G is the processing gain of the QAM Snare cross-correlation processor, in dB.

The processing gain of the cross-correlation processor is defined as $G = 10 \text{ Log } (B \times T_o)$, where T_o is the accumulation time (the duration of the QAM signal used for calculation of the cross-correlation function). For an accumulation time of $T_o = 10$ ms (10×10^{-3} seconds), the processing gain is defined as

$$G = 10 \text{ Log } (6 \times 10^6 \text{ Hz} \times 10^{-3} \text{sec}) = 47.78 \text{ dB}.$$

Assume that the noise factor of receiver is NF = 6 dB (a typical value), the thermal noise power for room temperature (T = 290°K) is KTB = – 106.2 dBm and accumulation time $T_o = 10$ ms (10×10^{-3} seconds) and signal-to-noise ratio (SNR) $E_b/N_o = 15$ dB, then the sensitivity of QAM Snare is defined as follows:

$$S_{in} \text{ (dBm)} = 6 \text{ dB} - 106.2 \text{ dBm} + 15 \text{ dB} - 47.78 \text{ dB} = -132.98 \text{ dBm } (-86 \text{ dBmV}).$$

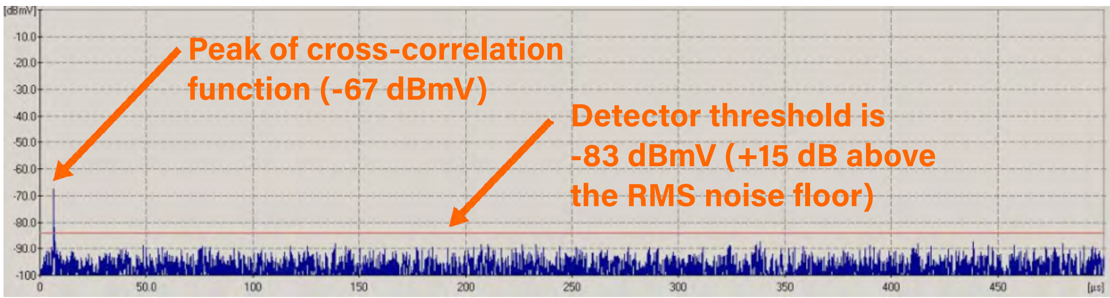
The sensitivity data for different combination of SNR and accumulation times are shown in the following table.

/ QAM SNARE SENSITIVITY, dBm / dBmV

SNR / dB	Accumulation Time, ms			
	1	10	50	100
3	-35/ -88	-145/ 98	-152/ -105	-155/ -108
5	-133/ -186	-143/ -96	-150/ -103	-150/ -106
10	-128/ -81	-138/ -91	-145/ -98	-148/ -101
15	-123/ -76	-133/ -86	-140/ -93	-143/ -96

FIELD RESULTS AND IMPLEMENTATION

The plot below is an actual output response of a QAM Snare device in the field. The accumulation time was selected as 10 ms.



As illustrated in the correlator response, the measured sensitivity of QAM Snare is –83 dBmV for a selected SNR = 15 dB. This closely tracks the theoretical value of –86 dB. Additionally, from looking at the detector threshold and how high above the noise floor it is, it is obvious that the SNR threshold may be reduced to 6 – 10 dB without significant changes in the possibility of false alarms, which has been implemented in production units. Accumulation time of 10ms has also been implemented in drive-out and field units, which provides appropriate and best in class sensitivity for these devices.

Other applications such as that realized in QAM Snare Small Cell certification products require greater sensitivity and therefore are engineered to utilize significantly longer accumulation times for increased processing gain – in order to achieve the required performance.

SIGNAL LEVEL DETECTION RANGE

The minimum signal level (sensitivity) as shown above depends upon selected parameters of the correlation processor and SNR. The typical value is around 80 to 90 dBmV.

The maximum signal level at the input of QAM Snare is 0 dBmV. This level depends upon the dynamic range of the down-converter and the AGC. QAM Snare will still indicate presence of leaks under conditions of signals more powerful than 0 dBmV, but measured results of the signal level will not be correct due to overloading of the receiver.

This signal level range should be completely adequate for the types of leaks expected from digital channels in a cable network. For example, accounting for the antenna factor, to overload the receiver the field strength would need to be +23dBmV or 4400 μV/m at 550MHz – an unlikely scenario.

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