Signal to Noise and Interference Effects
H.R. Walker
5/20/04

Ultra Narrow Band Modulation employs a phase detector, which is also responsive to amplitude levels if they are large enough. Typical of the phase detectors is the XOR gate, such as the 74AC86. This device has zero output if the incoming signals are in phase, and a shift to the maximum rail voltage if they are opposite in phase.

Figure 1 shows the XOR gate used with an established phase reference. If the incoming signal is not in phase with the reference, the output is +5 Volts. If the signal is in phase with the reference, the output is 0 Volts. If the signal is at 90 degrees relative to the reference, the output is 2.5 volts. For any phase angle between 0 and 180 degrees, the level is directly proportional. For example, 45 degrees will have an output level of 1.25 volts and a 135 degree angle will have an output level of 3.75 Volts.

Phase reversal keying and missing cycle keying of Ultra narrow band signals have a full 5 volt output swing. Phase shift keying (90 degree shifts) will have a 2.5 volt peak output.

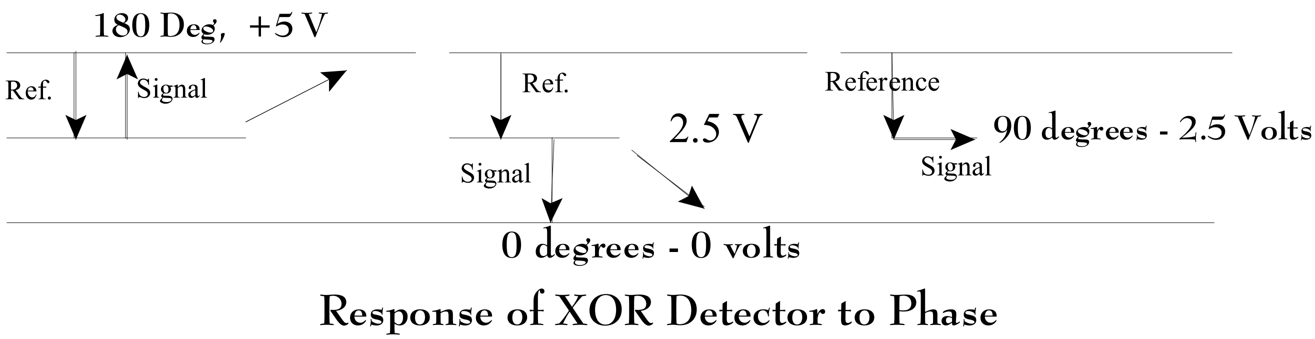
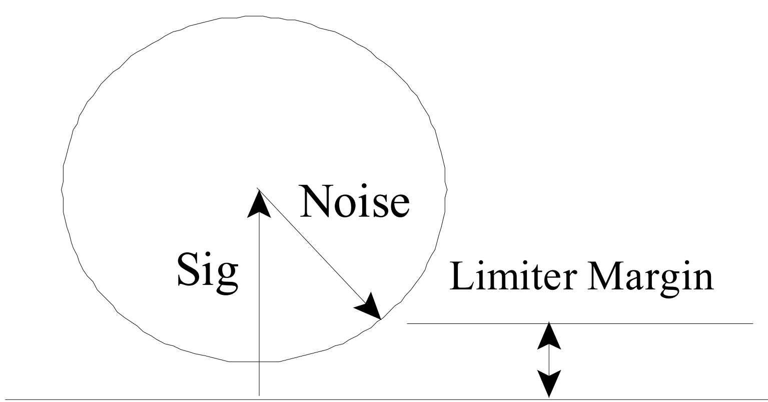


Figure 1.

For purposes of analysis, it will be assumed the reference is stable and white noise or other interference will only influence the signal.

A wide range limiter is essential if the XOR gate is to have reliable input levels for the signal and reference.
Figure 2 shows the vector sum of the signal plus noise. The resultant must not be allowed to be



zero (signal and noise are equal, or, signal greater than noise.). Assume the limiter has a 70 dB dynamic range, then it is theoretically possible (though not probable) that the limiter margin will accept a signal to noise ratio where the noise is within 1/1000 the level of the signal (1.000 V olts signal and .999 noise.). The greatest hazard is that the noise will exceed the signal. Even if the noise equals the signal level, as seen in Fig. 3, the maximum phase shift error is 45 degrees. This would of course cause a voltage rise and fall from the XOR gate that is added or subtracted from the peak to peak values. Experimentally, it was found that an interfering voltage within 2dB of the desired signal will not cause trouble in the detector. Voltage clipping the XOR detector output will enable a level to be found that almost ignores a 45 degree noise shift.

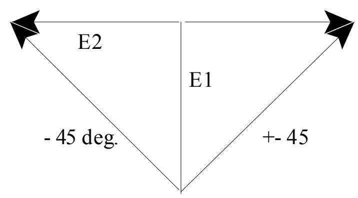


Fig.3.

A more serious matter is the noise bandwidth relative to the filter bandwidth.

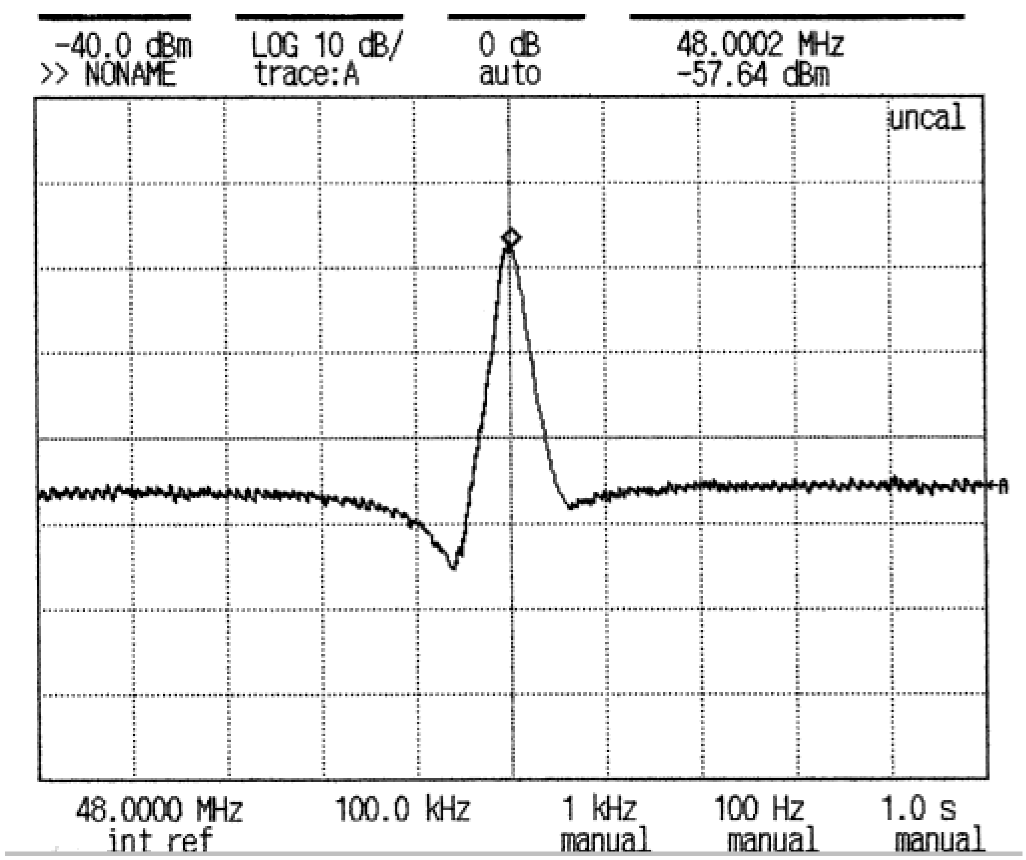


Fig. 4.

Figure 4 shows a typical narrow bandpass zero group delay filter with 2 poles. The 3 dB bandwidth at the peak is about 1 kHz., but note the shoulders which are approximately 30 dB lower than the peak. These shoulders extend from 0Hz to infinity. All of the AWGN in that bandwidth is a very large amount of power, while the AWGN in the 1kHz bandwidth is relatively weak.

Some means must be used to reduce the zero to infinity power. In superheterodyne receivers, this is done with a bandpass filter in the RF stages, which is broader than the narrower band IF filter.

Inserting values for E_b/η :

$$SNR = (\sin m)^2 \left(\frac{BitRate}{Bandwidth} \right) \left(\frac{E_b}{\eta} \right) = (\sin m)^2 \left(\frac{BitRate}{Bandwidth} \right) \left(\frac{\frac{SignalPower}{BitRate}}{\frac{NoisePower}{Bandwidth}} \right)$$

Canceling terms:

$$SNR = (\sin m)^2 \left(\frac{SignalPower}{NoisePower} \right) \qquad m = \beta \quad = \text{+- 90 or +-45 degrees.}$$

SNR = C/N for +-90 degree or missing cycle modulation.

Noise power/ Bandwidth is the major concern. There are two noise sources to contend with. Source 1 is the noise and bandwidth associated with the ultra narrow band filter and source 2 is the noise source that comes in from the shoulders. The noise portion of the equation becomes:

$(\text{Noise Power/BW})_1 + (\text{Noise Power/BW})_2$

$(\text{Noise Power/BW})_2$ must be kept small, that is - less than $(NP)_1$. Assume there is pre- filter that is less than 1 MHz wide and the shoulders are -30dB down. $(\text{Attenuation x Noise Power/BW})_2$ is the factor that must now be used.

The NP1 bandwidth is 1 kHz, so the NP2 bandwidth could be 30 dB (1,000 times) wider. Noise power is proportional to bandwidth, so the pre filter could be 1 MHz wide at the 3 dB points. To allow a margin of safety, 6 dB is arbitrarily subtracted so the bandwidth allowable is only 250 kHz.

Zero group delay pre-filters with bandwidths this narrow are available. If used, the lowest (best) C/N is available. This has been measured to be better than for BPSK where SNR = C/N, but the noise bandwidth is many times greater for BPSK than it is for MSB ultra narrow band methods.

Unless a pre-filter is used, C/N and SNR measurements will be falsely too high.

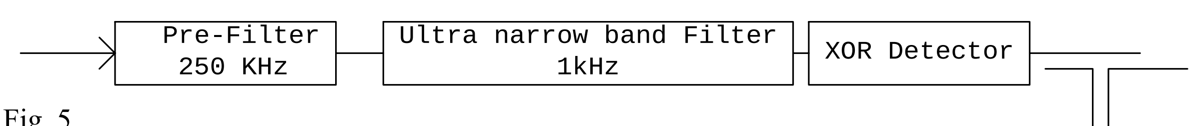


Fig. 5.
MSB Fitering and Detection for Best SNR

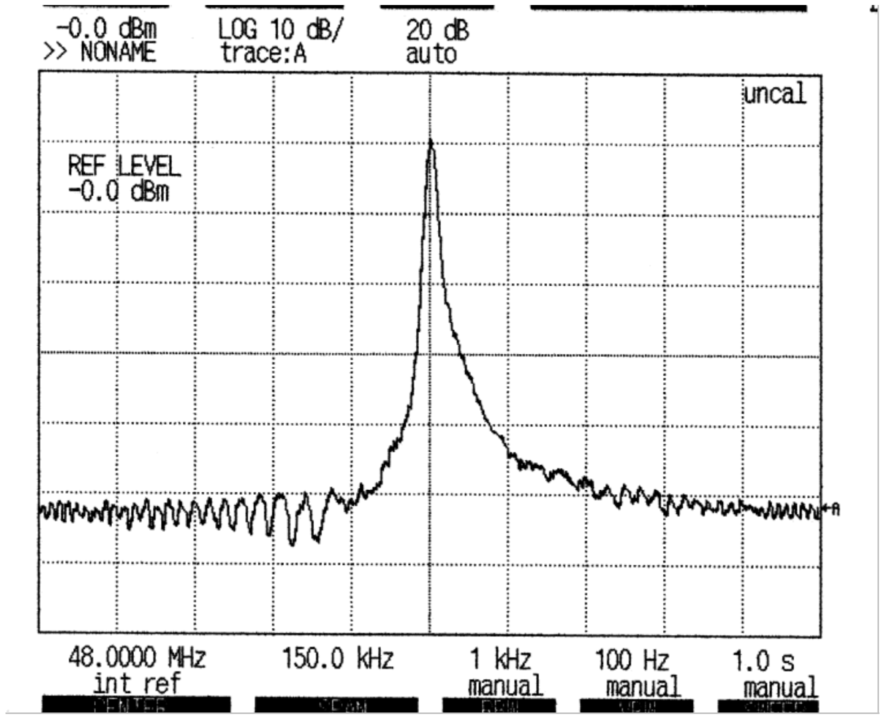


Fig. 6. Swept bandpass of 3 pole Ultra Narrow Band Filter. Shoulders are more than 50 dB down to remove adjacent channels.

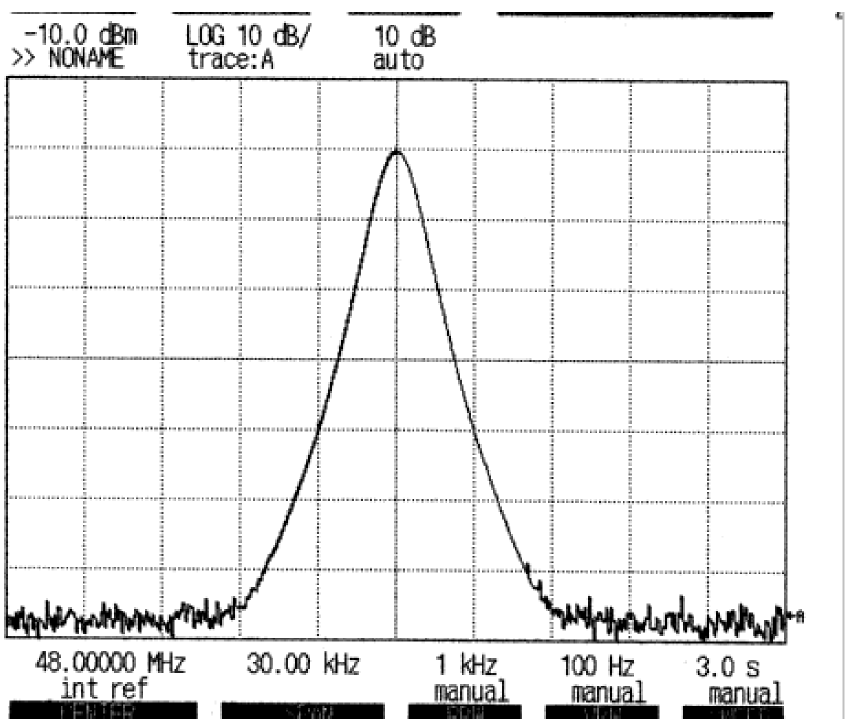


Figure 7. Level of MSB signal used for test.

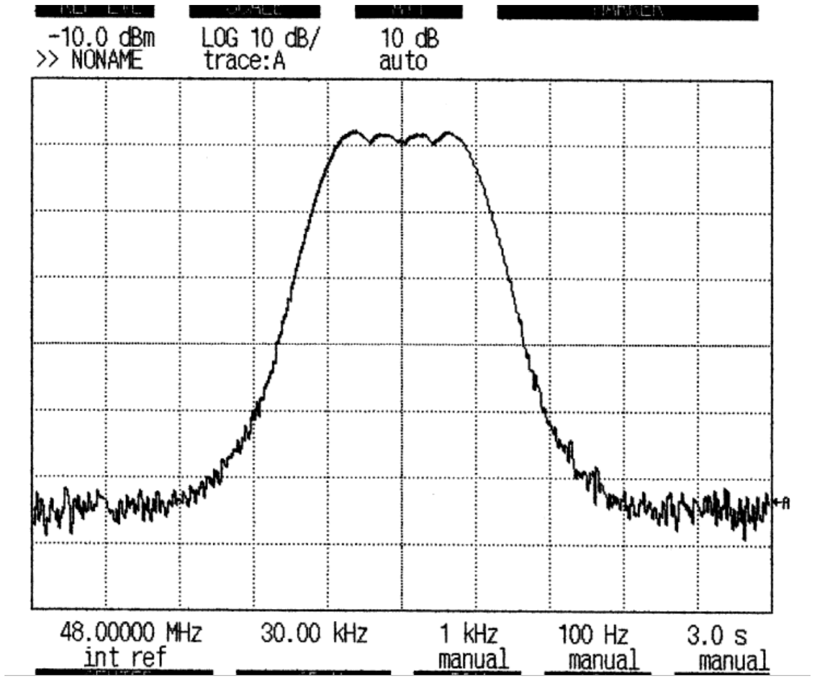


Figure 8. Interfering Signal. FM with +-2.7 kHz deviation. 400 Hz tone. Note that this is at or slightly above the level of Fig. 2.

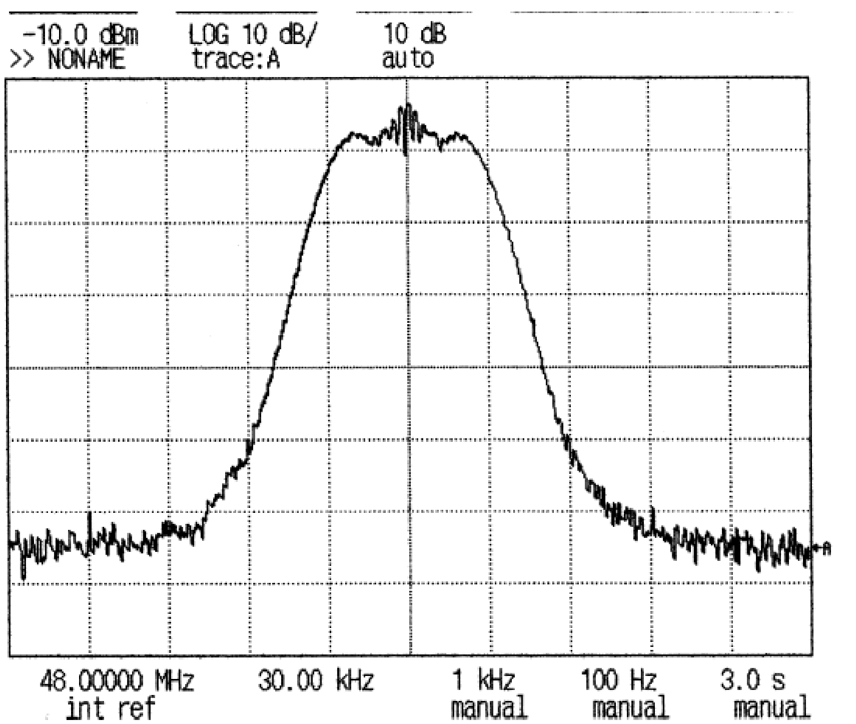


Figure 9. Signal plus interference at the Ultra Narrow Band Filter input. At this level (approximately 0 dB) interference just becomes noticeable in the detected output. This is 7-10 dB better than for AM or FM.

Using a CW interferor, the signal begins to show errors at 1dB C/N - ON channel.

The filter will reject adjacent channel interference until the signal level on the shoulders after filtering is within 6 dB of the desired signal level. For example: The shoulders are -50 dB. An adjacent channel 46 dB stronger that the desired channel will be rejected. Signals at the same level as the desired signal are obviously rejected unless they are too numerous and too close for the pre-filter to reject some of them.