ON THE EFFECTS OF RECEIVER BANDWIDTH
ON THE PERFORMANCE OF AVALANCHE BEACONS

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ABSTRACT: Contrary to transmitter frequency tolerance, the receiver bandwidth is not standardized for avalanche beacons. Some transmitters even transmit outside the specified tolerance range. This may give raise to compatibility problems.

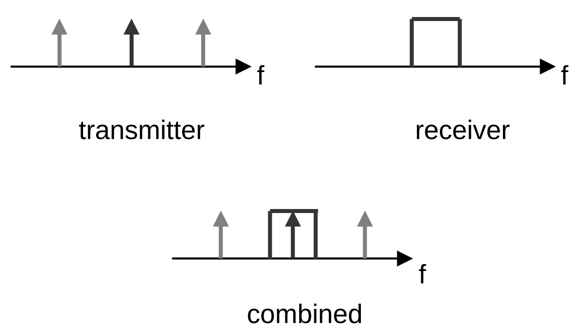
If the receiver bandwidth is widened to accommodate even out-of-band transmitters, receiver performance will be degraded. If the receiver bandwidth is made too narrow, this causes unpleasant audible effects and renders proper digital signal evaluation impossible. Simulation results for various settings are presented in audible and display format. They indicate that the optimum bandwidth for achieving long range is less than what would be required for good performance against transmitters that operate at the limits of the frequency tolerance. This can be mitigated by making the receiver adaptive to the transmitter's frequency.

Receiver bandwidth should be optimized for best performance in terms of range. Out-of-spec transmitters should be replaced.

KEYWORDS: Avalanche beacons, Receiver Bandwidth, Frequency Tolerance, Standards.

1. INTRODUCTION

The transmitter frequency of avalanche beacons is subject to some tolerances due to quartz crystal material constants, manufacturing and temperature. The receiver bandwidth is determined by some kind of filter(s), mostly quartz crystal filters for analog receivers and digital filters implemented by means of a DSP (Digital Signal Processor) for digital receivers. It defines a window for the (transmitter) frequencies that may be recognized by the receiver.



Signals from transmitters that are outside this window will not be recognized. This causes a compatibility problem, since it will be impossible to locate such transmitters when performing a beacon search (Edgerly and Hereford, 2004; Meier, 2005).

The current EN 300718 standard defines a tolerance range of 457'000 Hz ± 80 Hz for the

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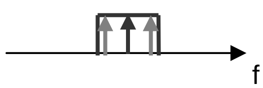
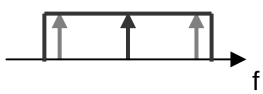
transmitter frequency. It does not specify a receiver bandwidth. While most products' transmitter frequencies are well within the range as defined by the standard, some of them, in particular vintage devices, do not meet the specification (Sivadière, 2001).

The receivers of many products use a quartz crystal filter. Those filters exhibit bandwidths ranging from ± 50 Hz to ± 300 Hz. Digital receivers may use some signal processing to achieve similar or even better performance.

There are two options to mitigate the compatibility problem: Restricting the transmitter frequency tolerance or widening the receiver bandwidth:



restricted transmitter tolerance

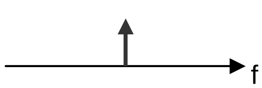


wide receiver bandwidth

A restriction of the transmitter frequency tolerance to ± 50 Hz can be achieved at no extra cost by proper quartz crystal selection and oscillator circuit design. Widening the receiver filters affects the SNR (Signal to Noise Ratio), which is the most important parameter for receiver performance.

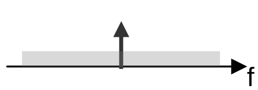
2. RECEIVER PERFORMANCE

In addition to the strong signal from some transmitter, the receiver always sees a certain amount of noise:



signal

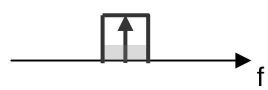
noise



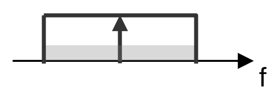
receiver input

The noise power density is more or less flat over the entire frequency range, but there may also be some peaks from specific sources. There are multiple sources of noise: Radiation from nearby electronic devices that is coupled into the antennas, radiation from the on board digital electronics that is coupled into the antennas, crosstalk between digital and analog signals on the printed circuit and noise caused by receiver circuits etc.

The SNR is defined as the ratio of the signal power to the noise power as seen by the receiver. The higher the SNR is, the better is the performance of the receiver. In graphic terms, the signal power is equal to the surface of the transmitter signal peak. The noise power is equal to the surface of the noise signal as passed through the filter. When the filter bandwidth is changed, the signal power remains constant, whereas the noise power increases or decreases. The wider the filter, the more noise power is received in addition to the wanted signal from some transmitter. The narrower the filter, the more of the noise power falls out of consideration when evaluating the received signal.



high SNR

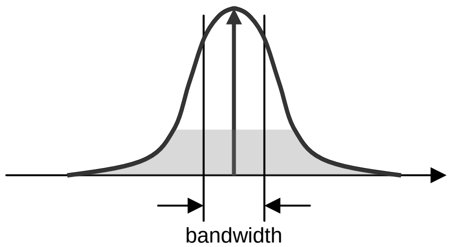


low SNR

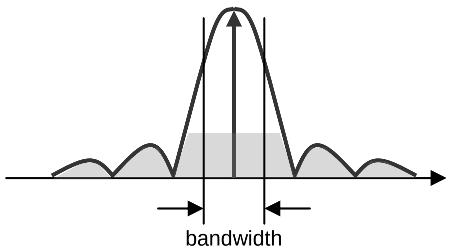
3. REAL FILTERS

Real filters never exhibit a perfect rectangular ("box car") characteristic. By some laws of physics, perfect filters would cause an infinite rise time to the signal in the time domain. Depending on the implementation, the filter characteristic will rather be similar to a bell shape (quartz crystal filters) or to a sin(x)/x shape (digital filters). Filter band limits are usually defined by means of the – 3 dB points of the transfer function. dBs are a logarithmic measure of magnitude ratio, and -3 dB is equivalent to 0.707 times the peak value. So a real filter will not cut off completely a signal that is outside the specified band, but still pass some of a signal, although with increasing attenuation.

A filter attenuation of 3 dB causes a reduction in receiver range of about 10%. A filter attenuation of 6 dB (0.500) reduces the range by about 25%. So, with real filters, the there is no abrupt range reduction at the band limits.



quartz filter

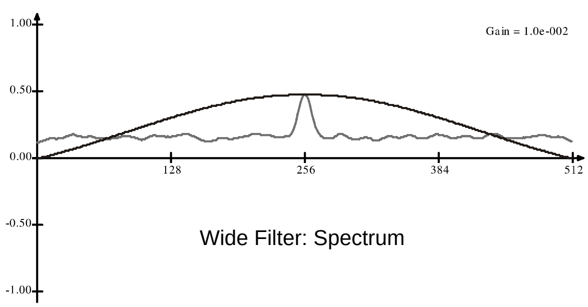


digital filter

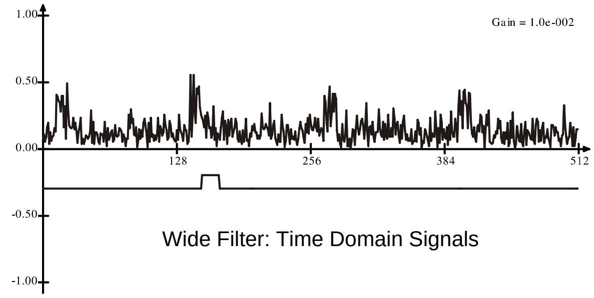
3. SIMULATION EXAMPLES

We have simulated receivers with different bandwidth options:

For the first option, we chose a wide filter that would provide almost no attenuation to signals from transmitters that operate near the frequency tolerance limit. As a consequence, the audible signal is corrupted by noise, and the digital receiver performance is deteriorated.

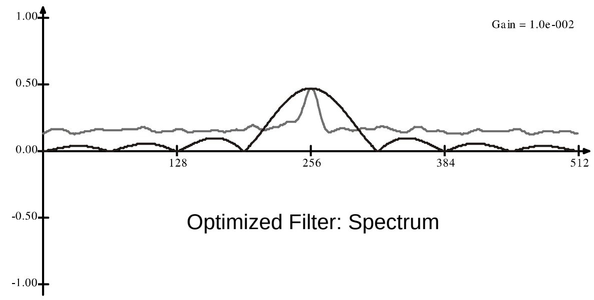


Wide Filter: Spectrum

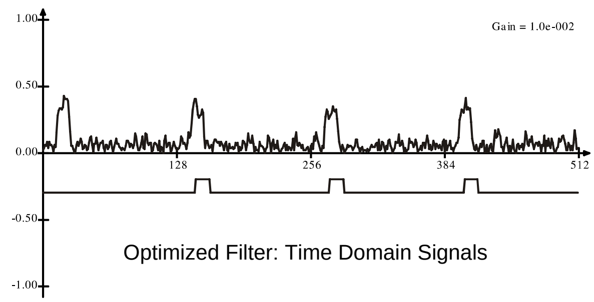


Wide Filter: Time Domain Signals

For the second option, we chose a filter which is optimized for best range and best analog signal. Its characteristic is similar to today's widespread quartz crystal filters. Unfortunately, such a filter will attenuate signals from transmitters that are operating at the limit of today's specification very much.

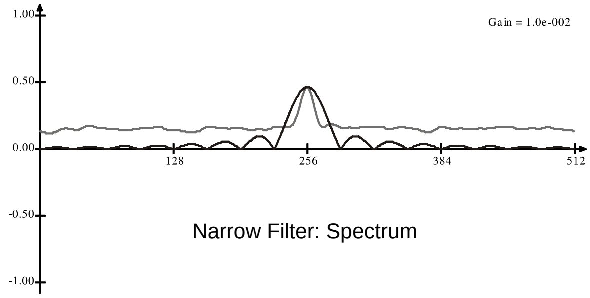


Optimized Filter: Spectrum

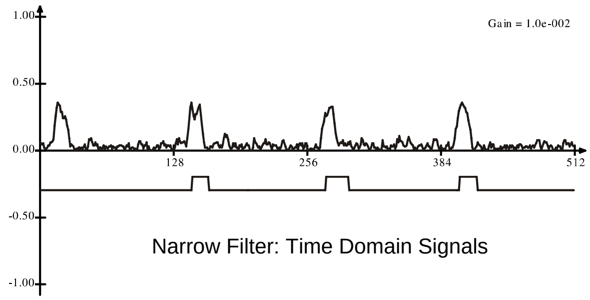


Optimized Filter: Time Domain Signals

As a last option, we have chosen a very narrow filter that, as the above theory states, should provide the best performance. But alas, this is not the case. Because the filter is so narrow, the remaining noise resembles a real transmitter signal very much. It turns out that it becomes more difficult to pick the real signal out of the noise background by hearing.



Narrow Filter: Spectrum

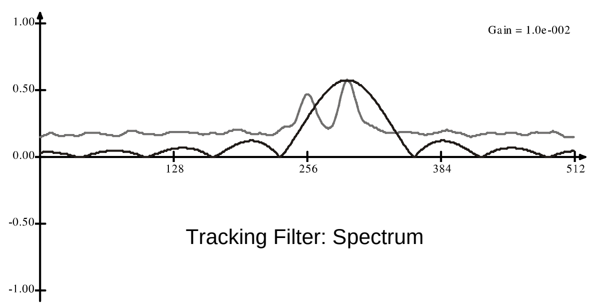


Narrow Filter: Time Domain Signals

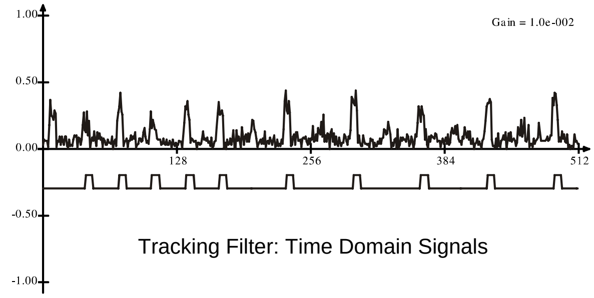
Also, the impulse rise time is now much longer because of the reduced filter bandwidth. It is not possible any more to properly characterize an impulse because of the time limit imposed by the 70 ms minimum pulse duration as specified in EN 300 718.

4. OUTLOOK

In order to take advantage of an optimized filter without loosing the capability to capture transmitters which operate at the limits of their frequency tolerance, new receiver structures are needed. One option is to introduce an adaptive receiver system that tracks the transmitter by positioning the center frequency of the filter at the transmitter's frequency. When such a receiver is used in multiple burial situations, a nearby transmitter may overrule a remote transmitter operating at a significantly different frequency. This is the price to be paid for the improved performance in terms of range.



Tracking Filter: Spectrum



Tracking Filter: Time Domain Signals

In the future, the use of DSP technology may facilitate the introduction of receiver structures with multiple instances of narrowband receivers that each focus on one transmitter in a multiple burial situation. When the standard is going to be revised, such receivers should also be accommodated.

5. CONCLUSIONS

Receiver bandwidth should be optimized for best performance and not for accommodating out-of-spec transmitters. The users of such transmitters should be encouraged to replace their devices.

A future revision of the EN 300718 standard should also include a specification for receiver bandwidth. A concise definition has been proposed in Meier (2005). The specification should also provide for new receiver systems that have become available through DSP technology.

REFERENCES:

Edgerly, B. and Hereford, J, 2004. Obsolescence and Analog Avalanche Transceivers: Ensuring Downward Compatibility. The Avalanche Review, Vol. 23, No. 2, December 2004

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Sound files with the audio signals pertaining to the examples can be downloaded from http://www.girsberger-elektronik.ch for playback on any PC with a sound card.