Compatibility of Avalanche Transceivers

Story by Felix Meier

In their recent story published in the Avalanche Review, Edgerly and Hereford propose some actions to be taken to improve on the compatibility among avalanche transceivers. Most of their general conclusions are appropriate, but some important details require a clarification. In particular, new standard requirements should not lead to inferior performance.

INTRODUCTION

The issue of transmitter frequency tolerance and receiver bandwidth has been around for quite some time, at least since the publication of the ANENA report on transceiver tests [2]. It is generally agreed that the current standard EN 300 718 should be improved by specifying a receiver filter bandwidth, and this will definitely be an issue in the next overhaul of the standard.

TRANSMIT FREQUENCY

The requirement for transmit frequency tolerance has been set to ± 100 Hz since the appearance of the first standards on avalanche beacons (ÖNORM S 4120, 1984 and DIN 32944, 1986). This requirement can not be met by using ceramic resonators, but with X cut crystals it is possible. So any beacon using such resonators would not conform to the standard. Almost all older beacons with poor quality resonators should be phased out by now.

Excessive frequency offset or drift for transmit oscillators are due to

- poor crystal quality
- improper crystal type selection (cut type)
- inadequate quality control (incoming parts inspection)
- improper design (circuits around crystal, minimizing mechanical shock to crystal)

All these effects can be controlled through careful design and production. Crystal ageing is almost negligible, and the sensitivity to shock can be reduced by proper mechanical design. Those criteria apply to both analog and digital beacons. Good designs result in a frequency deviation of less than ± 50 Hz from the nominal 457.000 kHz over the entire temperature range.

AT cut crystals exhibit a better performance against temperature changes than X cut crystals, but the AT cut is not available for frequencies as low as 457 kHz. If an AT cut crystal is used, it will resonate at a higher frequency, which must then be divided to yield a frequency of 457 kHz. However, frequency divider circuits can produce strong interference at frequencies which are used by portable radios. If a ski patroller is using a transceiver with such a frequency divider together with a portable radio, you will get complaints about some nasty noise on the radio.

Being aware of the compatibility issue as stated in [1] and of the limits imposed by technology, some participants in the creation of the current EN 300 718 voted for an even more stringent frequency tolerance requirement of ± 50 Hz, but the committee finally compromised on ± 80 Hz in 2001.

Beacons not conforming to the ± 100 Hz requirement should therefore be replaced, and newer beacons (later than 2001) should not be put on the market unless they meet the ± 80 Hz requirement.

RECEIVER BANDWIDTH

As stated by [1], narrow bandwidth helps to increase receive range. The detection capability of a receiver is limited by the ratio of the signal power received to the noise power received, shortly the signal to noise ratio. Noise is always around; it is a feature of Mother Nature.

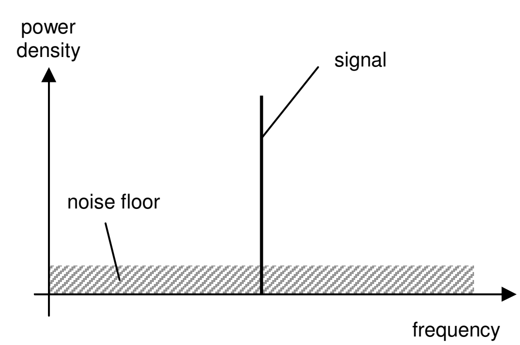

Figure 1

The signal to noise ratio as seen by the receiver is equal to the ratio of the signal surface to the noise floor surface in figure 1. The purpose of a receiver filter is to minimize the noise floor surface by limiting the frequency range where it is significant to the receiver:

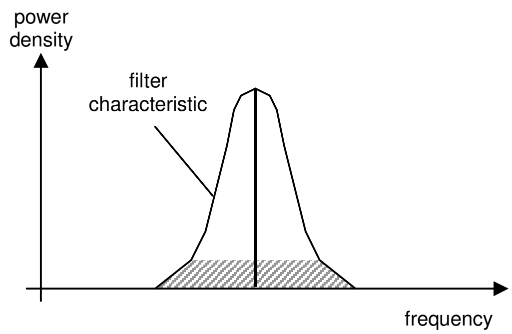

Figure 2

As can easily be seen from figure 2, using a narrow band filter is a good means for reducing the noise power seen by the receiver, thus increasing the signal to noise ratio. This is why crystal filters have been in use for more than 30 years in some receivers, which is a long time before the appearance of digital beacons.

The bell shape of the characteristic is typical for all kinds of crystal filters.

The more a transmitter frequency is offset from the center frequency, the more its signal is attenuated when it enters the receiver:

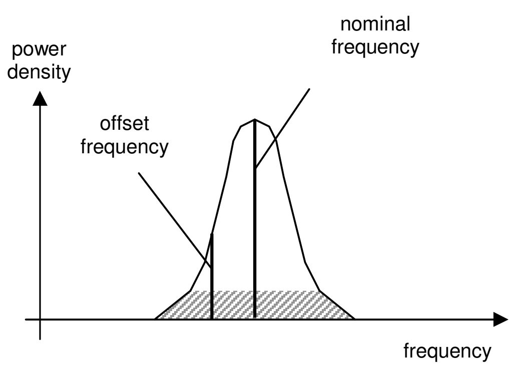

Figure 3

If the width of the bell shape is extended in order to produce less attenuation on the offset transmitter's signal, this also widens the noise floor area, thus reducing receiver performance or, in other words, receiver range:

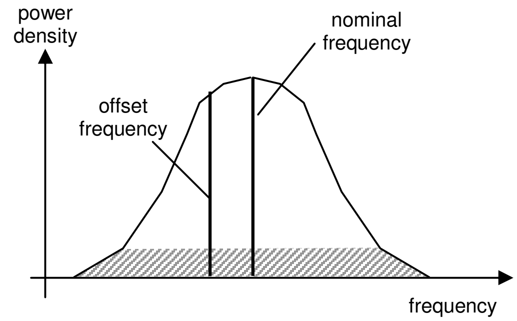

Figure 4

Standardizing on such a wider filter would force manufacturers to build beacons with inferior performance. This does not serve the user community well.

An obvious question would be why manufactures do not use a filter with a rectangular characteristic to minimize the noise power as seen by the receiver and still provide no attenuation to offset transmitters:

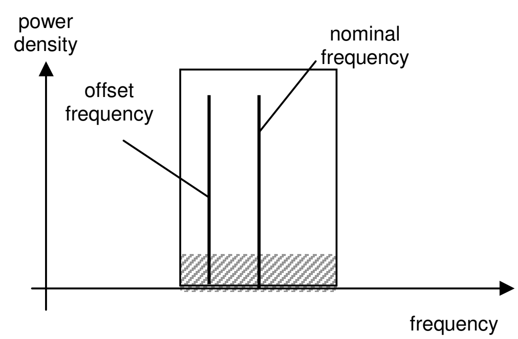

Figure 5

Unfortunately, the laws of nature prohibit the implementation of such an ideal filter, so we must live with a compromise such as the bell shaped filter curve shown in figures 2, 3 and 4.

A closer approximation to the ideal filter shape than provided by a single crystal filter can be obtained by means of a combination of a crystal filter and a Digital Signal Processor (DSP). The tradeoff between bandwidth and receiver range still exists with this approach. The drawbacks of this approach are an increase in the bill of materials as well as an increase in power consumption. Also, the performance is disastrous with transmitters that are outside the filter pass band. The bell shaped filter has the advantage of graceful performance degradation when used against offset transmitters. One manufacturer has selected the DSP approach. This is the reason why the sample D5 in figure 3 of [1] achieves zero range.

Receiver sensitivity is specified in terms of the maximum magnetic field strength required to produce a noticeable signal to the user. The unit of measurement is Nanoampères per Meter, or nA/m for short. This signal may be either a distinct audible tone or a change in some visual indication. The current requirement is a sensitivity of 80 nA/m at 457.000 kHz ± 0 Hz. A higher numeric value for the maximum field strength thus implies a lower sensitivity:

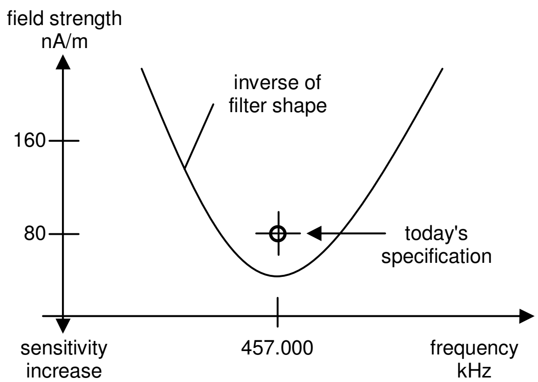

Figure 6

Upon the next revision of the EN 300 718 standard, a specification for receiver bandwidth should be introduced. A reasonable specification would be that the sensitivity of the receiver at 457 kHz ± 100 Hz be no more than + 6 dB relative to the sensitivity required at 457.000 kHz (dB is a logarithmic unit of measure for the ratio between two signals, 6 dB are equivalent to a ratio of 2 for field strength):

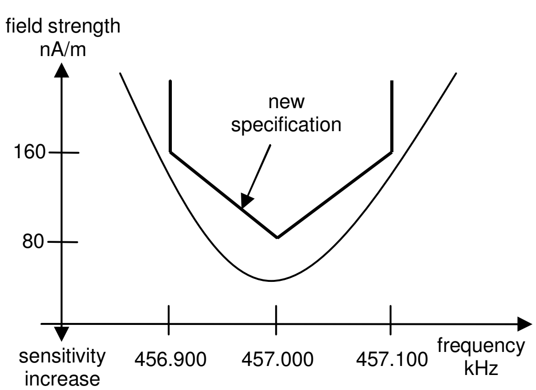

Figure 7

At the edges of the pass band, the sensitivity would thus have to be 160 nA/m at most. This requirement enforces a minimum receiver bandwidth and thus a minimum of compatibility among transceivers.

Electromagnetic field theory says that range is proportional to the inverse of the 3rd root of a change in field strength for this kind of application (operating in the near field). Doubling the maximum field strength is thus equivalent to a -2 dB or about 20% reduction in range. At the edges of the band, i. e. at 457.000 kHz ± 100 Hz, the range thus still is about 80% of the range against a transmitter operating at 457.000 kHz. Most transmitters operate within ± 30 Hz of the nominal carrier frequency. In that band, the reduction in range would be even smaller (about 7%).

CONCLUSIONS

Transmitter frequency tolerance requirements can easily be met by proper design and manufacturing. Rather than standardizing on inferior receiver performance, we should try to eliminate the beacons that are not conforming to the standard.

- Receiver bandwidth should be specified in a modified version of EN 300 718. We propose to settle on a specification of + 6 dB at 457 kHz ± 100 Hz for the maximum field strength to produce a noticeable signal.
- The receiver bandwidth should not be extended from the values currently in use, because this would mean standardizing on inferior performance.
- The issue of transmitter frequency offset is not limited to analog transceivers; it covers digital transceivers as well.
- Users should be encouraged to have their beacons checked and replaced if necessary.

REFERENCES:

[1] Edgerly, Bruce and Hereford, John; "Obsolescence and Analog Avalanche Transceivers: Ensuring Downward Compatibility"; Avalanche Review, Vol. 23, No. 2, December 2004

[2] Sivardière. François; "Transceiver Tests: Laboratory Measurements"; Neige et Avalanches, ANENA, March 2001.

Felix Meier is a consultant in electronics and software engineering. He has participated in all avalanche beacon standard groups since 1982. He was involved in the development of the Mammut Barryvox beacon. You can reach him at felix.meier@smile.ch.