OBSOLESCENCE AND ANALOG AVALANCHE TRANSCEIVERS: ENSURING DOWNWARD COMPATIBILITY

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Keywords: Avalanche transceivers, frequency drift, receiver bandwidth, downward compatibility

Abstract: Between the new international standards adopted in 2001 and the aging of the world's fleet of analog avalanche transceivers, the time is approaching when older analog transceivers will need to be retired. As beacon manufacturers worldwide convert to digital technology, downward compatibility with aging analog beacons is gaining in importance. Transmit frequency precision and tight receiver tolerances aid in digital beacon performance. But transmit frequency "drift" is characteristic of aged and traumatized analog units; many no longer meet the new international standards. Our research indicates that many of the recently introduced digital transceivers don't reliably detect older units transmitting outside the standards—or even new units whose frequency has been altered by physical abuse. To ensure downward compatibility and decrease risk, an international standard should be created for receiver bandwidth. Users should strongly consider receiver bandwidth when selecting new transceiver fleets. Those with analog fleets should institutionalize a regular inspection program with the manufacturer—and eventual replacement of that fleet with units containing high-quality crystal transmitters and wide receiver bandwidth.

1. BACKGROUND

In 2001, the French avalanche research institute, ANENA (Association Nationale pour l'Étude de la Neige et des Avalanches), published a report detailing the results of comprehensive laboratory tests on avalanche transceivers. The report revealed that under the existing European standard for avalanche beacons, ETS 300 718, one widely used brand of analog transceiver (A1) was having difficulty meeting the requirements for transmit frequency at cold temperatures. Under the new standard (EN 300 718), which took effect in April 2001, the report concluded, that brand would consistently fail to meet the new standard and that the company should be seriously concerned about the transmit performance of its product (Sivardière, 2001). This phenomenon, when the transmit frequency is significantly off the target frequency of 457 kHz, is often referred to as "frequency drift."

The findings were relevant not only because the new European standard was more stringent, therefore jeopardizing the conformity of this transceiver brand, but because several other new models of transceivers were being introduced at the time. The report suggested that several of these newer transceivers could experience compromised receive performance when used in conjunction with the older "drifted" transmitters.

With over 300,000 of the above transmitters in use, and yet another generation of new transceivers coming into the market in 2003-04, the authors determined that another round of testing was necessary to determine the downward compatibility of these new models with the aging analog fleet. In 2004, Backcountry Access and Rescue Technology commissioned an independent testing lab, Apex Wireless, to perform the testing. The objective was to determine the receiver bandwidth of this newest generation of avalanche beacons and the compatibility of these new digital units with drifted or traumatized transmitters, specifically the one identified by ANENA.

2. TRANSMIT FREQUENCY

Since 1997, the worldwide standard for transmit frequency in avalanche transceivers has been 457,000 Hz (cycles per second), or 457 kHz. The tolerance allowed under this standard was tightened in 2001 from 457,000 +/- 100 Hz to 457,000 +/- 80 Hz.

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The change in this standard was the result of better components that were becoming available and the growing acceptance of digital technology in the marketplace. In the past, many analog beacons used ceramic reference oscillators to create the 457 kHz signal. These ceramic oscillators, while inexpensive, are often unreliable in producing a signal meeting the tolerance specification. They are also very susceptible to frequency drift caused by such factors as time, temperature and trauma. Consequently, manufacturers routinely recommended that users send their beacons back to the manufacturer for periodic inspection and recalibration.

The new generation of beacons generally use higher quality, higher cost oscillators made of quartz crystal. This material has proven to be more reliable in transmitting within the specifications and much less susceptible to frequency drift due to aging, cold temperatures and abuse—factors historically known to affect ceramic oscillators.

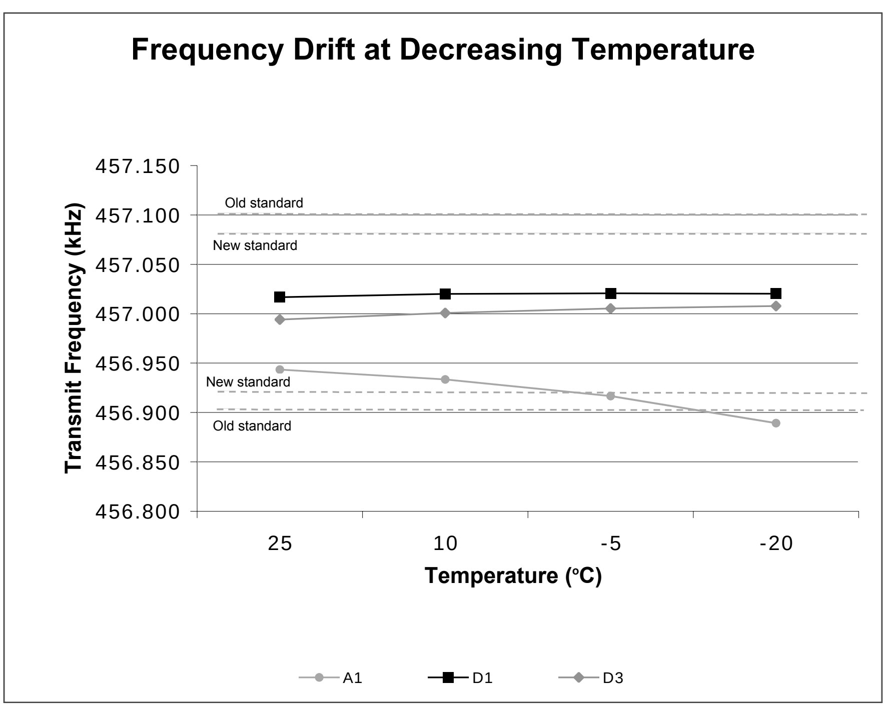
Fig. 1 summarizes the ANENA results and graphically illustrates the effect of temperature on the transmit frequency of transceiver A1 and two newer digital models with high-quality crystal oscillators (D1, D3). The data indicates that beacon A1 not only has a very wide initial tolerance—it isn't centered on the 457 kHz target—but drifts significantly with a decrease in temperature, often outside the industry standard. The ANENA study only tested for the temperature effects of frequency drift; only new transceivers were used in the study. It did not test for the effects of age or trauma, which can have equally significant effects on transmit frequency, but are difficult to simulate under controlled conditions. In fact, the effects of any of these three factors can be cumulative on the beacon's performance, the worst possible combination being an older (ceramic-based) transmitter being used in cold conditions. Trauma, moreover, can be the result of thermal shock (extreme temperature changes) and/or physical abuse.

To determine the effects of time and trauma, the authors collected an assortment of used beacons and hired Apex Wireless to test their transmit frequency (at room temperature). The poorest transmitter in this sample was later used to determine "worst-case" compatibility with narrow-bandwidth receivers.

3. RECEIVER BANDWIDTH

Receiver bandwidth is a measure of a receiving beacon's sensitivity to the transmit frequency it is receiving from another beacon. Wide bandwidth means the receiver can accommodate a wider range of frequencies.

Figure 1



Narrow bandwidth means it is less compatible with drifted transmitters and will experience significantly compromised performance. This can be in the form of reduced (or nonexistent) receive range or in widely inconsistent readings.

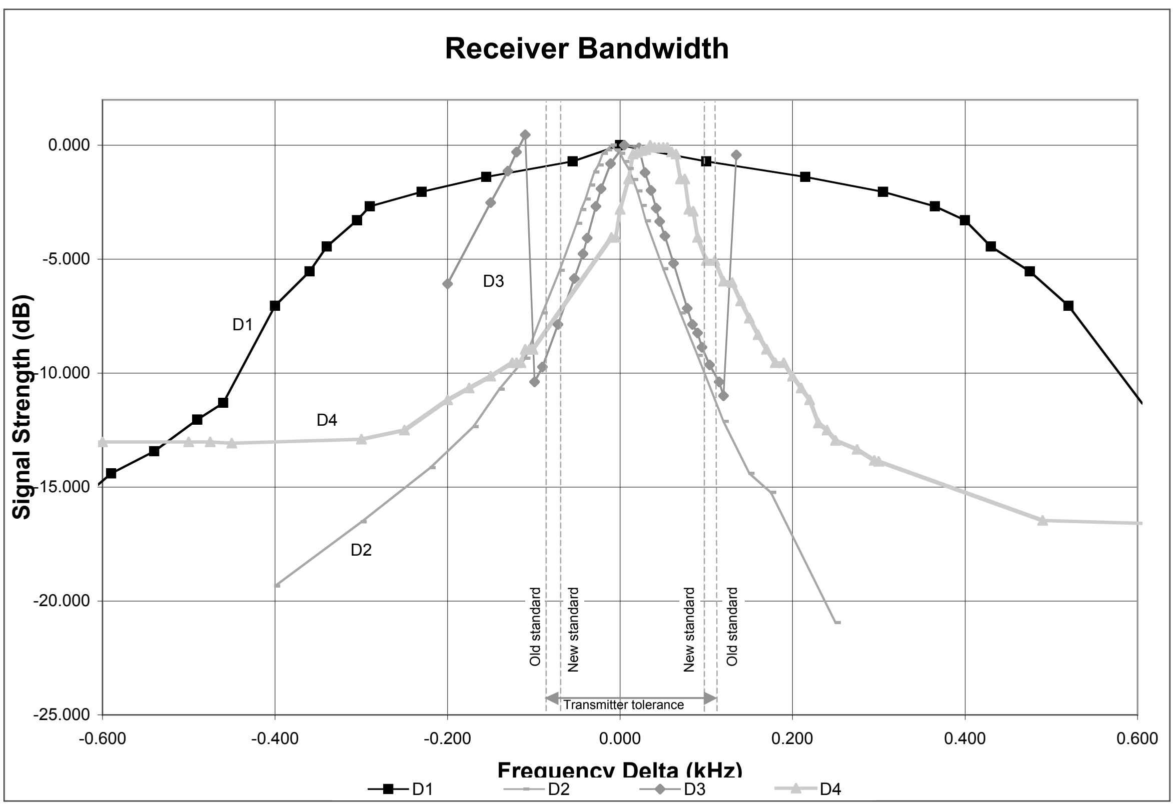
A beacon's receiver bandwidth is mainly influenced by the type of filter in the critical processing point (typically in the Intermediate Frequency, or IF, stage). This filter is defined by its center frequency and "steepness." In the avalanche beacon application, it is important for the center frequency to be at exactly 457 kHz. The steepness of the filter determines how well the filter attenuates other noise outside the receiver's bandwidth. If the filter is shaped like a brick rather than a bell, for instance, there is serious potential that it won't "see" the transmitter if it is transmitting poorly, or that it might provide readings erratic enough that they are counterproductive to the search effort.

Bandwidth is measured by the difference in frequency (in relation to the center frequency) that creates a specific decrease in sensitivity of the receiver (measured in decibels, or dB). For example, a receiver bandwidth of 200 Hz means that at plus or minus 100 Hz from the targeted center frequency of 457,000 Hz, the receiver experiences a decrease in sensitivity of 3 dB, also referred to as the "half-power point."

One way to mitigate this decreased range is to provide audible feedback through use of a supplemental analog output to a speaker. This takes advantage of the high sensitivity of the human ear. However, in many instances, this audible signal can be so weak that it is indistinguishable from background noise. A decrease of 6-10 dB generally means the aural sensitivity is cut in half. Research indicates that a weak audible signal can actually be counterproductive in transceiver searches, especially among recreational users (Atkins, 1998).

There is no specific requirement in EN 300 718 regarding receiver bandwidth. However, as the ANENA report states, the standards imply that all receivers should be equally sensitive to transmit frequencies that fall inside the transmit frequency specification of 457 kHz +/- 100 Hz. (Transceiver D1, it points out, is the only one that achieves this goal). This goal is further clarified in a recent report by Dostie (2004): "To

Figure 2



properly receive this signal one would expect that the receive bandwidth would equal or exceed the transmit tolerance range…"

Figure 2 illustrates the center frequency, receiver bandwidth and steepness of the filters used in several of the newer digital transceivers, measured by Apex Wireless. As stated in the ANENA report, transceiver D1 has the widest receiver bandwidth and the most gradual filter steepness, making it the least sensitive to frequency drift and better able to reliably detect poor signals from damaged transmitters. D2, D3, and D4 show much narrower bandwidths and significantly steeper filters.

D5 showed widely varying inconsistencies the farther away the transmitter drifted from the center frequency, indicating multiple signals despite the existence of only one. As a result, Apex could not determine its bandwidth:

> "No complete determination of the bandwidth and center frequency of [transceiver D5] was possible. Outside this range [456.845 to 457.128 kHz], [transceiver D5] detects multiple signals, in multiple directions, at multiple distances, with the display jumping around so much that it is impossible to track any consistent linear pattern." (Johnson, 2004)

This detection and display of multiple signals in the presence of one drifted signal could be related to the statement in the owner's manual for transceiver D5, regarding incompatibilities with older analog devices:

> "In case of multiple burials involving older analogue devices, faults may at worst occur which impair the efficiency of the digital signal separation. In such cases, you may find for a short time that more signals are displayed than actually exist." (Seidel Electronik, 2003)

4. DOWNWARD COMPATIBILITY

The data from both Apex Wireless and ANENA suggest that compatibility is an issue when narrow-bandwidth receivers are used in conjunction with drifted transmitters. While these newer receivers have bandwidths wide enough to receive signals transmitting within the industry standard, it has been shown that lower quality transmitters don't transmit within this standard. When these units are transmitting outside the industry standard, the narrow-bandwidth receivers can experience significantly decreased range, inconsistent readings, and the erratic detection of multiple signals.
The question then is how far outside the existing transmit frequency standard can a transmitter drift before performance is compromised to the point of unacceptable risk? At what point are older and abused beacons no longer compatible with the newer, more popular digital beacons?

This is difficult to determine, as it is unknown what percentage of the existing beacon fleet is transmitting outside industry specifications. And while analyzing the temperature effects on transmit frequency in the laboratory is straightforward, analyzing the effects of time and trauma are not—and can only be analyzed empirically.

With this objective, the authors collected a sample of ten used A1 transceivers from various professional ski patrol and guiding organizations, then hired Apex Wireless to perform transmit frequency tests on them, at room temperature. The variation in transmit frequencies was substantial: from –90 Hz to +423 Hz.

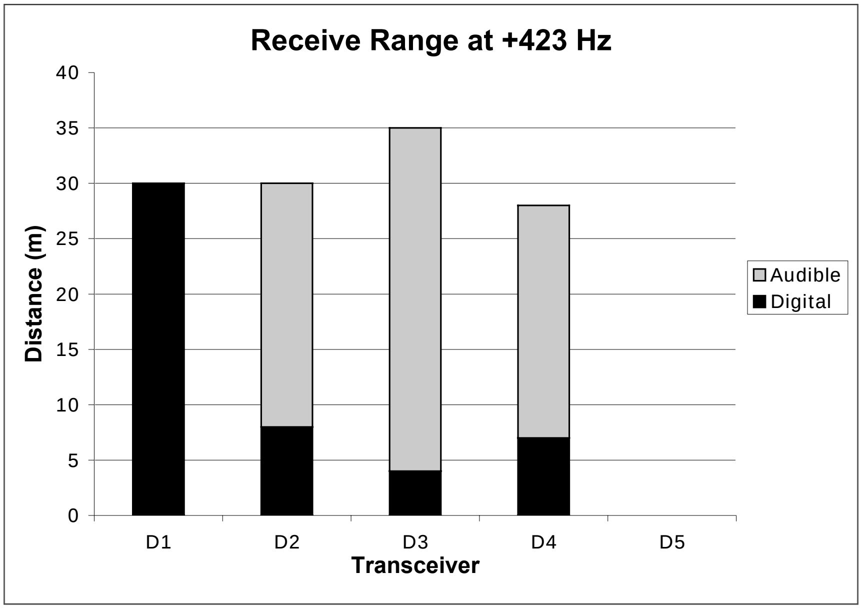
The authors then performed field tests with the poorest transmitter to determine its effect on receive range. These were done with the +457 Hz transmitter oriented in-line with the receiving units, all with full batteries.

The field results showed a significant difference in range between the receiving beacons: from 35 to 0 meters (Fig. 3). Transceiver D1 showed reliable distance readings and insignificant loss of receive range. Transceiver D5 detected no signal at all. The hybrid analog/digital units (D2, D3, D4) showed decreased range and erratic readings, making them difficult to use for pinpointing.

5. CONCLUSION

In the recent development of modern transceiver technology, there has been a direct tradeoff between ease-of-use and receive range. Easy-to-use digital beacons provide less receive range than analog beacons because the microprocessor must filter out extraneous electromagnetic noise before showing the user

Figure 3



LEGEND

A1: Ortovox F1 Focus
D1: Tracker DTS
D2: Ortovox M2
D3: Mammut Barryvox
D4: Ortovox X1
D5: Pieps DSP

clear distance and directional information. Despite this tradeoff, all major beacon manufacturers are focusing their design efforts on increasing ease-of-use instead of range, as ease-of-use is where the market has shown the most interest.

To mitigate this tradeoff, manufacturers have taken several approaches: a) add analog/audible capabilities outside the beacon's digital range; b) narrow receiver bandwidth and increase filter steepness, decreasing the amount of noise the receiver must analyze to determine distance and directional information; and c) a combination of the above. The first approach, adding analog capabilities, has proven to increase complexity and decrease ease-of-use for the majority of users. The second approach, narrowing bandwidth, has proven to decrease compatibility and increase erratic readings. The third approach combines the adverse effects of the first two. Advances in programming could result in future development of a longer range, wide-bandwidth digital transceiver.

While today's new beacons have adequate bandwidth to accommodate the effects of poor initial tolerance and temperature-induced drift on transmit frequency, some cannot accommodate the cumulative effects of time and trauma, two factors that will continue to exacerbate frequency drift problems with the aging of the world's analog beacon fleet.

To ensure downward compatibility, an international standard should be created for receiver bandwidth. It should require equal sensitivity to signals within both the old and the new European standard on transmit frequency. It should also require the reliable detection of signals transmitting significantly outside this tolerance.

Users should strongly consider receiver bandwidth when selecting new transceiver fleets. Those with analog fleets should institutionalize a regular inspection program with the manufacturer—and eventual replacement of that fleet with units containing high-quality crystal transmitters and wide receiver bandwidth.

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