A STANDARD FREQUENCY FOR AVALANCHE BEACONS - WHAT'S GOING ON IN EUROPE [1]

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Currently, two different frequencies are in use in Europe for avalanche beacons. After an in-depth presentation of the selection criteria and the performance of both frequencies against them, a brief analysis of the current state of standardisation efforts in Europe documents the strong tendency to converge to 457 kc.

DIRECT VS. ORGANIZED RESCUE

Time is probably the single most critical factor for the successful rescue of avalanche victims. Therefore, direct rescue ("Kameradenrettung") by people from the affected party, which eliminates all the time lost in alarming a rescue organization and bringing men and equipment to the place of the accident, provides the highest chances of saving victims (see figure 1 and table 1), (Föhn 1985). The only means known today for an efficient direct rescue are avalanche beacons consisting of a transmitter and a receiver, **and** small shovels. This is why most efforts have been concentrated on the promotion of beacons. Any other devices for locating victims, which require bringing into place special search equipment, are seriously handicapped (what do you do in case of heavy fog ?) and no better than the traditional means from the age before electronics : a well trained dog.

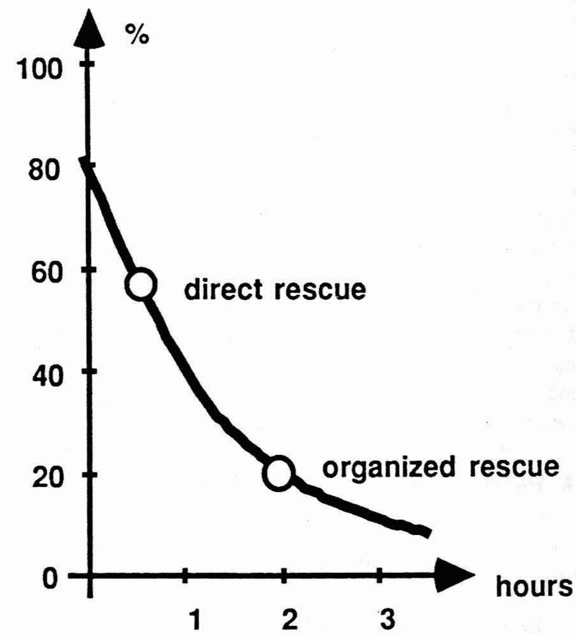

Figure 1 Probability of survival in an avalanche

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Table 1. Time elapsed between avalanche accident and uncovering of victim (in minutes). Sources : Swiss Federal Institute for Snow and Avalanche Research, Swiss Air Rescue, personal experience of author.

	direct rescue			organized rescue		
	min.	max.	mean	min.	max.	mean
alarming	0	0	0	10	120	65
transportation	0	0	0	10	40	25
locating	10	30	20	10	20	15
digging	10	20	15	10	10	10
total	20	50	**35**	40	190	**115**

A GLIMPSE AT HISTORY

Since the introduction in Europe of the first avalanche beacons in 1968 these devices have found widespread use throughout the Alps. However, in the early seventies two different frequencies came into use, namely 2.275 kc and 457 kc. This has given raise to a serious safety problem : Would anyone like being buried in an avalanche, his transmitter operating at one frequency and the rescue squad receiving at the other one ? Definitely not ! This situation has led to the development of devices operating at both frequencies simultaneously, with the inherent disadvantages of higher cost and battery consumption. Pushed by consumer demand and by the International Commission for Alpine Rescue (ICAR), a standardisation effort has been launched, which we all hope will solve this problem in the future.

SELECTING A FREQUENCY

Besides the other criteria for practical and reliable avalanche beacons the choice of frequency is the most important item for standardisation. The selected frequency should

- provide reasonable protection from interference from other electronic equipment
- permit operation in the near field, where the strength of the magnetic field decreases with $1/r^3$, which leads to an easily perceivable change in received signal intensity within the search range
- allow for sufficient amplification of the received signal without any risk of antenna feedback oscillations and without squeezing component performance (and tolerances) to extreme limits
- not suffer from considerable attenuation by any kind of snow
- permit the use of both loudspeakers and earphones for electroacoustic transducers
- not require many and/or expensive components and circuits for the implementation of transceivers

In 1984, the major European manufacturers of avalanche beacons met to evaluate one of the two frequencies currently in use for long term recommendations and finally opted for 457 kc for the following reasons :

- There is no international frequency allocation for frequencies below 8 kc. Therefore, no protection can be expected for 2.275 kc from the authorities, although the commission of the European PTT's (CEPT) recommends both frequencies (CEPT 1983). Wristwatches with stepper motors do interfere with the 2.275 kc receivers and may deceive untrained users. Around 457 kc, the last World Administrative Radio Conference (WARC-79) of the International Telecommunication Union (ITU), a specialized agency of the United Nations, allocated frequencies to the following services (ITU 1982) :

Region 1 (Europe, Africa, USSR, China):

435-495 kc primary: MaritimeMobile
secondary: Aeronautical Radionavigation

Regions 2 and 3 (North and South America, Asia, Pacific):

415 - 495 kc Maritime Mobile

Currently, there is only one known beacon for aeronautical radionavigation interfering to some extent with avalanche beacons locally: Gleichenberg near Graz at 449 kc.
Avalanche beacons are a newcomer in the struggle for reserved frequencies. Therefore, we cannot expect full protection and freedom from interference, and both frequencies are considered about equal in this respect.

- The higher order components of the magnetic field strength contain factors of $(l/2\pi r)^2$ and $(l/2\pi r)^3$ where l is the wavelength and r the distance from the transmitter. At about $l/2\pi r = 1$ their influence on total field strength starts diminishing rapidly. This is considered the limit of the near field. At 457 kc, r then equals to 105 meters, which is still above the practical range for beacons. At 2.275 kc, the near field extends to more than 20'000 m.

- The electroacoustic transducer, be it a loudspeaker or an earphone, acts as an antenna and radiates electromagnetic energy at the frequency of the audible signal. This energy is coupled into the receiver's antenna. Care must be taken so this will not result in a condition sufficient for self - oscillation of the receiver which would render it useless. At an operating frequency of 2.275 kc, even a frequency translation within the audible range will not provide for a sufficient margin to avoid oscillation. This is the most serious disadvantage of 2.275 kc beacons. It imposes severe limits on the sensitivity of the receiver and consequently on the search range.
For 457 kc receivers, the incoming signal is mixed with a locally generated signal of 457 +- ~2 kc to produce an audible tone. The frequency separation provided by this mixing process is ample to allow for feedback loop disruption by appropriate filtering. Since feedback is not critical any more, the receiver amplification can be made larger and component variations, in particular their stability over the operating temperature range, may be considerably larger.
The wider range obtainable with beacons using 457 kc only has been verified by extensive field measurements (Stuber 1984). Compared to beacons operating at both frequencies, the 457 kc beacons achieved more than the double the range for a signal plus noise to noise ratio of 6 dB at the terminals of the electroaccoustic transducer. These results were confirmed by field tests in Austria and Switzerland carried out by the ICAR, where the 457 kc beacons achieved a range of about 80 m. The same field tests also proved that the reduction of the primary search time is roughly inversely proportional to the range extension.
In the case of multiple victims being buried under an avalanche, the potential confusion can easily be avoided by reducing the volume of the audible tone.
Furthermore, there is a considerable difference in antenna efficiency at the two frequencies : assuming comparable antenna geometries and dimensions, the efficiency of an antenna increases proportionally to the third power of the radiated frequency. Some of this advantage of the higher frequencies is offset by parasitic losses, but an antenna may still be made more efficient for 457 kc than for 2.275 kc, since dimensions can not be chosen arbitrarily large for obvious reasons.

- For wet snow, the attenuation is about $2x10^{-2}$ dB/m at 2.275 kc and $1x10^{-1}$ dB/m at 457 kc (AUTOPHON 1984). The difference is not negligible, but its effect is, considering real situations : Let the depth of snow be 50 meters : Then the attenuation at 457 kc is 5 dB, which is still small compared to the beacon's capabilities.

- Operating at 2.275 kc excludes using a built-in magnetic loudspeaker as an electroaccoustic transducer, its coil being to close to the antenna to eliminate feedback problems. All beacons using this frequency or both of the frequencies therefore must rely on an earphone. The question of whether a loudspeaker or an earphone is more practical is still debated among users. But imagine stumbling over an avalanche in stormy weather and that ..... connection cord constantly getting tangled up with your clothes, so the earpiece gets pulled out again and again ! And what about a torn cord because you tried to catch the falling beacon by the earpiece ?

- The reliable processing of 457 kc signals requires the use of crystals for frequency stability. Actually, two of them are required, one for the transmitter oscillator and for use as a filter in the receiver and another one for the receiver local oscillator. 2.275 kc beacons can do without crystals. This leads to a slightly higher component cost for 457 kc.

THE CURRENT STATUS OF STANDARDISATION

Germany

The German standard DIN 32 924 has come into effect on May 1st, 1986 (DIN 1986). Because of legal complications, it was not possible to standardize 457 kc beacons immediately, as many members of the standard commitee would have liked to do. Instead, for a transition period of about five years, beacons operating on both frequencies have been standardized. The standard mentions, however, that after 1989 457 kc beacons shall be standardized as a long term solution for single frequency devices.

Austria

The Austrian standard S 4120 has been effective since October 1st, 1984 (ÖNORM 1984). It covers beacons using both frequencies simultaneously and beacons using 2.275 kc only. On June 5, 1986, the Austrian standard committee decided to revise the standard and adjust it to the German standard for the promotion of a long-term 457 kc solution. A new version of the standard excluding the 2.275 kc only beacons and mentioning the trend towards 457 kc will be discussed in November 1986.

In both countries, the working groups decided against a standardisation of beacons that permit the physical separation of the transmitter from the receiver, arguing that this separation would seriously affect the use of beacons for direct rescue. The cost advantage in carrying a transmitter only was not considered a valid argument for this approach, given the substantial reduction in chances of survival.

Switzerland

Switzerland does not have a standards organization of its own. The Swiss army originally triggered the development and production of 457 kc beacons, which also have become a de facto standard for civilian use in this country.

France and Italy

There are no known standardisation efforts at this time in Italy. After tests performed by the "Fédération Française de Ski ", the French will convene again in October and there is an strong tendency to go for 457 kc. Both countries have explicitly permitted the use of 457 kc beacons.

ICAR

On September 27, 1986, the International Commission for Alpine Rescue decided to recommend standardisation on 457 kc after 1990.

CONCLUSION

The frequency problem has plagued Europe for fifteen years. Today's strong tendency to settle on 457 kc promises an end to this struggle. However, some more years will go by before we all will be using single frequency beacons.

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