Military Headsets Safety in numbers

RACAL ACOUSTICS

Part of the INVISIO Group

Background

Part 1 of this whitepaper described the potential hearing damage caused by excess low frequency noise, which is particularly prevalent when soldiers are mounted in military vehicles. It explained why the use of Single Number Ratings (SNR) when specifying military headsets did not fully account for this risk. Part 2 explains why standard passive “over the ear” hearing protection may be insufficient to fully protect military vehicle crew, how Active Noise Reduction (ANR) improves the protection provided and why digital ANR is the best solution for whole life equipment cycles. It also highlights the extreme risk of hearing damage if the user removes their hearing protection, even for a short period.

How does over the ear (circumaural) hearing protection work?

Passive over the ear (circumaural) hearing protection essentially creates a barrier to noise. The trapped air (occluded volume), absorbent materials within the earcup together with a good seal to the head from a soft ear cushion, provides the overall protection. For analysis and design, it can be represented as an electro-acoustic model as shown in Figure 1, taken from MIL STD 1474 [1].

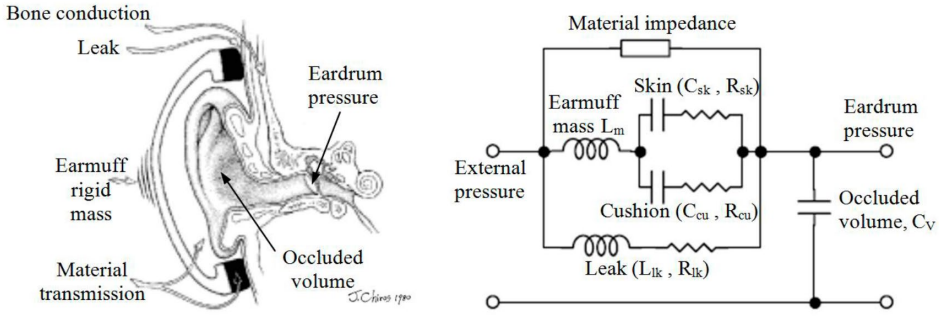

Figure 1 How over the ear protection works.

There is an acoustic frequency dependency due to the equivalent inductive properties (ear-muff mass and leak components) and capacitive properties (skin, cushion and occluded volume) which means circumaural headsets tend to have better attenuation at higher frequencies, typically above 1000 Hz. But we already know that low frequencies tend to dominate the noise profile when

mounted in military vehicles. Therefore, many military situations require more hearing protection than a purely passive over the ear solution can deliver, and consequently, since the early to mid-1990s there has been a widespread adoption of Active Noise Reduction technology.

Analogue Active Noise Reduction (ANR)

ANR is achieved using microphones internal to the headset that detect the noise environment, then electronics invert the signal to create an equal and opposite sound wave within the headset. ANR is ideally suited to enclosed spaces like an earcup and the opposing wave effectively filters out the unwanted sound as shown in Figure 2 below. The external noise is not fully cancelled, but the output to the ear is significantly reduced in the all-important low frequency portion of the spectrum.

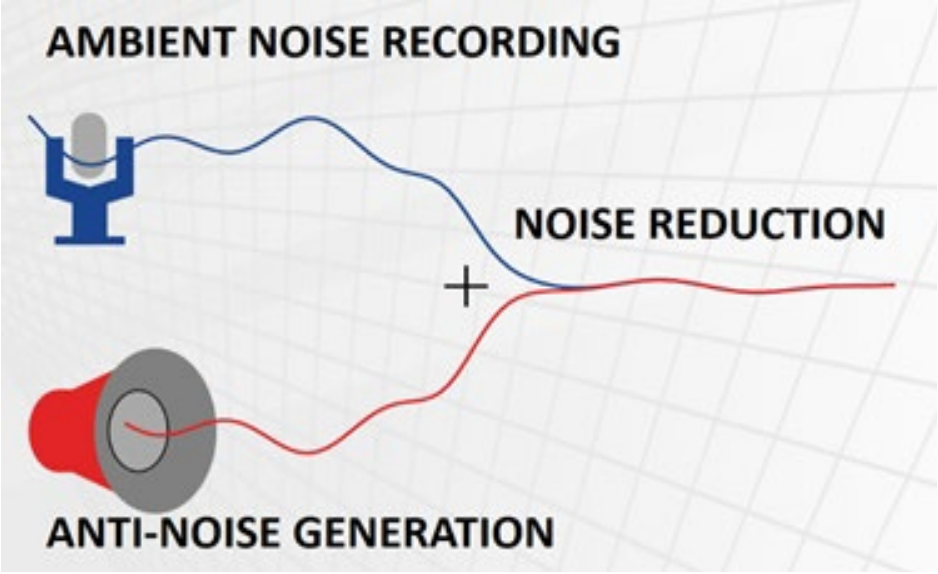

Figure 2 How active noise reduction works

ANR can be achieved through analogue filters, which are optimised by choice of components for a given headset design and source noise characteristics. In addition to reducing damaging noise exposure, ANR also improves speech intelligibility, which is of critical benefit to the military user. However, there is a potential down-side to analogue ANR. In the mid-frequency range ANR does not necessarily improve the SNR value and in some cases, can make it worse!

Figure 3 shows 1/3 octave-band data for a headset tested on an artificial head implemented using traditional analogue filters. The normal circumaural passive attenuation (in blue) is generally better at higher frequencies above 1000 Hz and ANR (in red) increases the protection provided at lower frequencies in the range 40 – 500Hz, which is the desired effect.

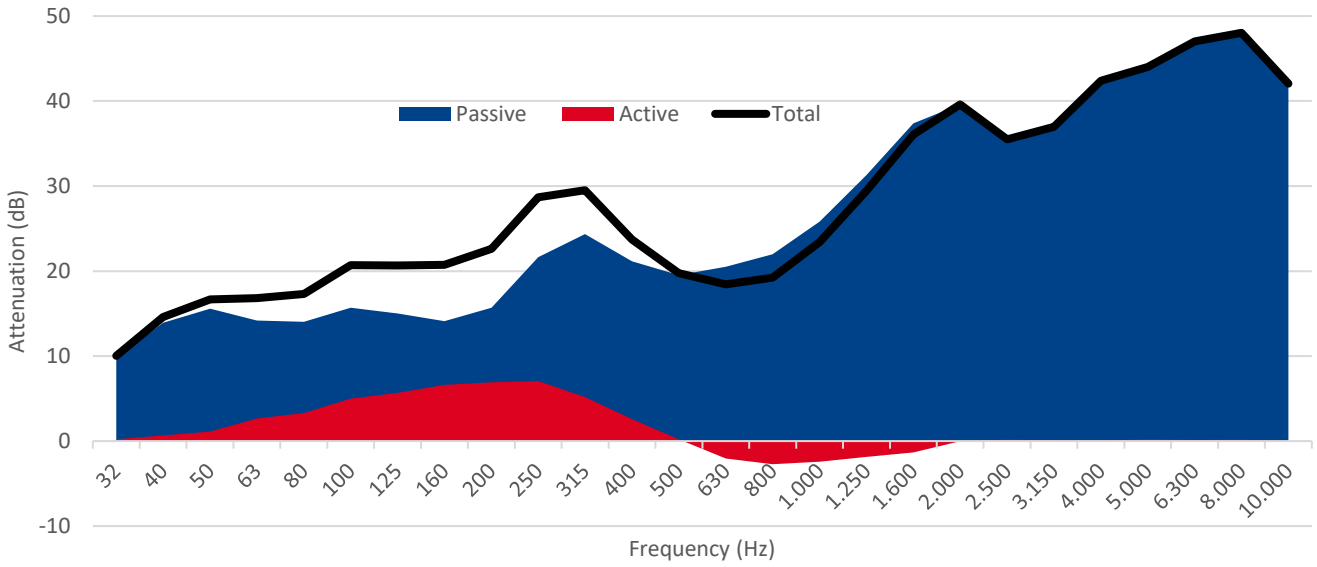

Figure 3 The negative impact of analogue active noise reduction on overall SNR Value

However, at the mid-range 630 to 1600 Hz the ANR actually reduces the overall attenuation performance (represented by the black line); albeit by just a few dBs. In this instance, the estimated SNR value would be lowered from 26.2 to 25.6 dB, which may be undesirable, even though there is improved low frequency protection.

Digital Active Noise Reduction (ANR)

There are multiple benefits of using digital ANR over analogue. Digital ANR filters generally achieve greater attenuation and a wider frequency bandwidth than their analogue counterparts, but they can still exhibit the same adverse effect in the mid-range of frequencies. This effect can be mitigated by changing the attenuation characteristics of the ANR functionality, but with digital ANR this is achieved by 'tweaks' to embedded software (rather than a hardware circuit re-design), where the peak centre frequency can be 'shifted', in this case from 250 Hz in Figure 3 to 315 Hz as shown in Figure 4.

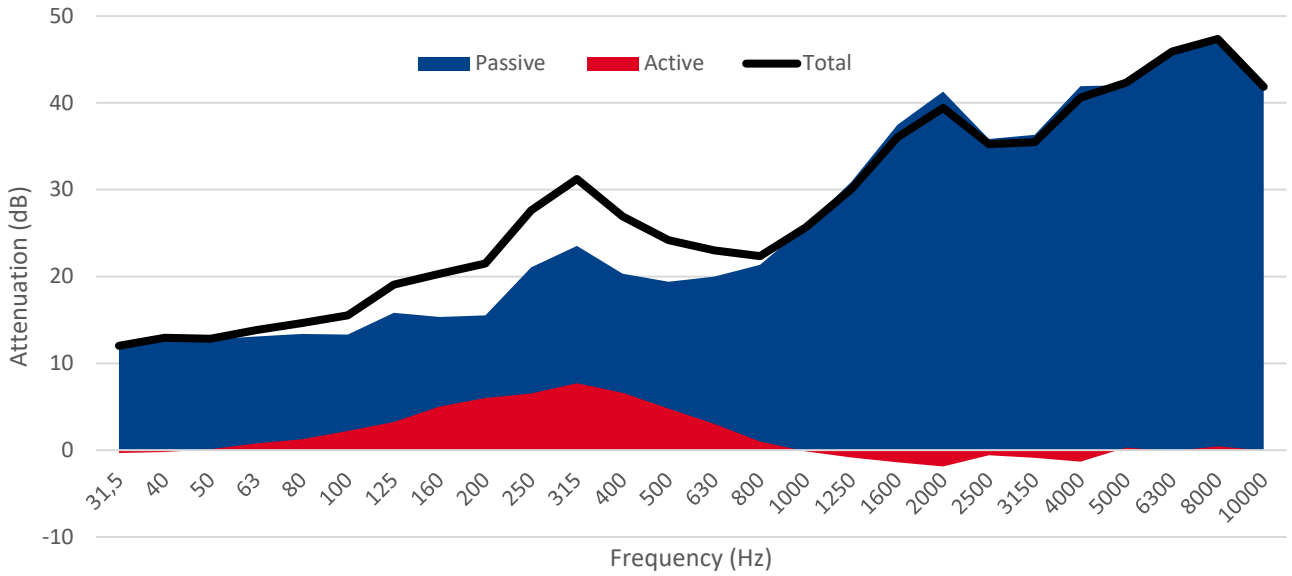

Figure 4 Improved SNR value using Digital ANR and shifting Peak Centre Frequency

This has the effect of minimising the adverse negative effects of ANR, as well as improving the SNR value from 25.6 to 28.6 dB; a full 3 dB increase.

In acoustics, 3 dB is a 'special number' because it represents a doubling (or halving) of noise energy which in this case means a reduced noise dose (a combination of noise level and time) and consequently a lower risk of noise induced hearing loss. Alternatively, the wearer could extend the mission life and still maintain the same noise dose.

It is now possible to add the digital ANR capability (from Figure 4) to the performance data used for Headset B referenced in Part 1 of this whitepaper, again using the HSE calculator H-M-L method[2] and Viking military vehicle noise data[3].

Hearing protector			**Workplace noise**				
Make/Model:			*Location / Machine:*				
HML values			Weighted level		Potected noise level at the ear	HSE recommended value for the likely noise level at the ear	**Protection rating**
H	**M**	**L**	L_A	L_C	$(L'_A = L_A - PNR)$	$(L'_A + 4)$	
dB	dB	dB	dB(A)	dB(C)	dB(A)	dB(A)	
33	23	17	94	107	79	**83**	*Acceptable*

Figure 5 Headset B performance data using H-M-L method

As a reminder, using passive only performance yielded 83 dB(A) at the ear (see Figure 5), which is a very acceptable result, but by adding digital ANR capability, it can be seen from Figure 6, that while the H-value is marginally

reduced and the M-value is slightly improved, the L-value is significantly improved from 17 to 22 dB.

Hearing protector			Workplace noise				
Make/Model:			*Location / Machine:*				
HML values			Weighted level		Potected noise level at the ear	HSE recommended value for the likely noise level at the ear	Protection rating
H	M	L	L_A	L_C	$(L'_A = L_A - PNR)$	$(L'_A + 4)$	
dB	dB	dB	dB(A)	dB(C)	dB(A)	dB(A)	
32	24	22	94	107	73	77	*Good*

Figure 6 Headset B Performance with Digital ANR

This represents a reduction of noise at the ear from 83 to 77 dB which is more than two halvings in noise energy. Clearly this is of significant benefit to the user in terms of direct hearing protection, but also increases the potential for significantly increased mission life before attaining the same noise dose. The need for longer mission profiles is increasingly being driven by the demands of agile, asymmetric warfare, and maintaining good hearing is pivotal to maintaining situational awareness.

Benefits of Going Digital

In addition to clear benefits of digital ANR, there are several other benefits of digital that are relevant to the military environment:

- **Technology insertion.** A digital platform can be upgraded throughout its lifetime reducing the whole life cost of ownership.
- **Multiple vehicle profiles.** These can be stored so that the same headset can be deployed across the entire fleet of wheeled and tracked vehicles. In addition, sensing its local noise environment, the headset could self-optimise during the vehicle's own lifecycle as its noise profile changes with time due to wear and tear.
- **3-D Sound.** This allows the virtual placement of sound sources anywhere in three-dimensional space, including behind, above or below the listener. The position could relate to a colleagues' physical position i.e., a commander to a driver or gunner to squad members relative positions and when dismounted it dramatically improves speech intelligibility and reduces cognitive load.
- **USB Connectivity.** Analogue connections are rapidly disappearing on COTS products e.g., Apple iPhone, because direct digital to digital connections provide the best audio quality. In addition, this universal format (power & data) means that it can be plugged directly into a PC for training purposes, battlefield tablet or computer, or the intercoms and radios of the future.
- **Situational Awareness.** The talk through (aka hear through) of the past only provided telephone quality. Today it has a wider frequency response, and

not only has a simple volume control but can also be optimised for a given mission profile. Improved detection, recognition, identification and localisation lead to better lethality and survivability.

- **Built in test.** Built in test on power up can also run a full system test to check that the headset is working correctly, preventing mission critical failure. This feature can also reduce the logistic burden by prompting preventative maintenance. The internal check can also detect age hardened or damaged ear cushions or a weakened headband which reduces hearing protection, alerting the user to take action.

Effect of Removing a Headset in Noise.

When operating in a noisy environment, there is one universal truth for any hearing protection to be effective… it must be worn **all** the time. Figure 7 compares three levels of hearing protection (SNR 30, 20 & 10 dB) and shows the rapid reduction in protection when not worn.

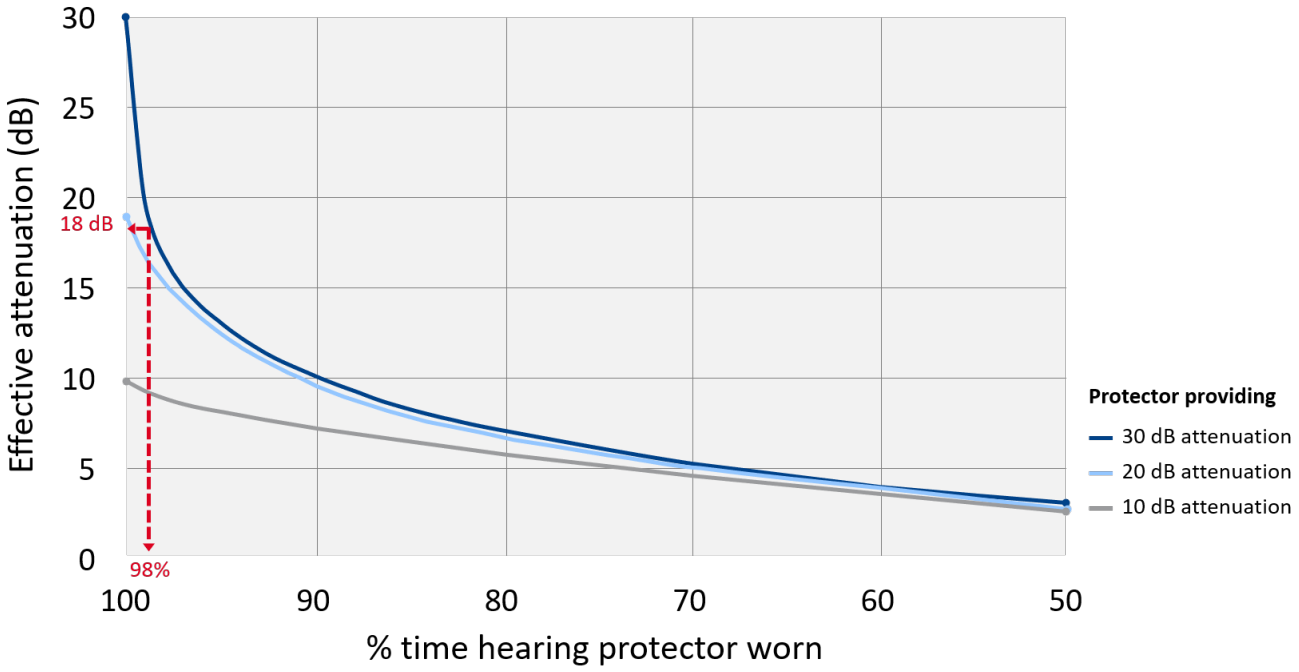

Figure 7 The impact of removing hearing protection.

It can be seen from Figure 7 that if the user removes the 30 dB protector for just 2% of the time (one minute in every hour when in a noisy environment), its protection is nearly halved and all hearing protection has virtually no benefit whatsoever if only worn 50% of the time. It is for this reason, that Racal Acoustics place significant emphasis on user comfort to reduce the risk of users feeling the need to remove their protection.

Finally, to ensure a headset retains its noise attenuating properties, it must be kept in good condition; ear cushions and head/neckband need to be inspected and maintained to ensure good fit, there are no noise leaks and thus maintains optimum performance.

Conclusion

Standard passive circumaural hearing protection does not fully protect military personnel from the low frequency hazard posed by vehicles when in a mounted role. The addition of active noise reduction (ANR) is advantageous for mitigating the low frequency risk and digital ANR in particular can be modified through software to improve the overall performance of hearing. A digital implementation not only improves ANR performance but also includes other benefits including the capability for technology insertions and reduced whole life costs. All hearing protection only works effectively if worn 100% of the time.

Look Forward

Part 3 will investigate the nuances of the dismounted role, the specifics of protecting users from impulse noise rather than continuous noise and how military headsets need to differ to cope with the extreme challenges of this environment.

Related Links and Resources

1. MIL-STD-1474E DEPARTMENT OF DEFENSE DESIGN CRITERIA STANDARD: NOISE LIMITS (15-APR-2015)
2. HSE - Noise: Exposure Calculator
3. G.S. Paddan and M.L.L. McIlraith, *Noise and vibration measurements in a Viking military vehicle,* Defence Technology, https://doi.org/10.1016/j.dt.2020.09.021
4. Military Headsets: Safety in Numbers Part 1 | Racal Acoustics

Racal Acoustics Ltd- - part of the INVISIO Group
Racal Acoustics provide situational awareness, hearing protection and communication solutions. Our products are customised specifically for end-user applications and offer exceptional situational awareness, hearing protection in a range of noise environments, and deliver reliable, versatile audio communications while maintaining the highest levels of user safety and comfort. Sales are made via our UK facility and sales office in the US, as well as a global network of partners.

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