Big Noise in Baghdad

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Is it a loud hailer… or is it a non-lethal weapon? Only experience will give the answer, but American forces in Iraq are to be equipped with a noisy piece of equipment known as a Long Range Acoustic Device (LRAD). One use is to give instructions from a safe distance to crowds, vehicles, shipping or anything else which may be a potential danger. However, the LRAD also packs a punch as a generator of loud and unpleasant sounds. Flick a switch and change from voice messages to a built in generator, giving an ear-splitting and piercingly unpleasant output, designed to make you wish you were well out of its beam. The LRAD is a development from a new form of highly directional loudspeaker, HSS (HyperSonic Sound), from the American Technology Corporation (www.atcsd.com)

BACKGROUND

Some of the impetus for LRAD development came from the small boat attack in October 2000 on the destroyer USS Cole, which was damaged when at harbour in the Yemen and 17 lives lost. This showed the need for a hailing device which could be used at a safe standoff distance.

A big problem in using sound in loud hailing is sending it in the direction you require, without sideways spill. Considering a restricted speech range from 300Hz to 3000Hz, the lowest frequencies have a wavelength of more than a meter, so that a reflector to give good directivity will be several meters diameter. The LRAD overcomes this by using a short wavelength ultrasonic carrier, modulated by speech or other signal.

The modulated, highly directional, ultrasonic beam carries the audio information, which is recovered automatically by self demodulation in the non-linear properties of air. Of course, very high ultrasonic levels are required to drive hard into the non-linear region, as the demodulation is not very efficient.

NON-LINEAR PROPAGATION IN AIR

The concepts on which the systems are based originated in underwater acoustics[1,2]. A simple non-linear system follows a square law response. Then if two signals, f_1 and f_2 are transmitted together, a squared component $(\sin 2\pi f_1 t + \sin 2\pi f_2 t)^2$ is produced, in addition to the original signals. Expanding the square gives terms including $2\sin 2\pi f_1 . \sin 2\pi f_2$, which transforms into

$$\cos[2\pi\ (f_1 - f_2)]t - \cos[2\pi (f_1 + f_2)]t$$

showing the presence of sum and difference components. If the original frequencies are 40kHz and 41kHz, the difference frequency is 1kHz, an audible signal.

When the transmitted signal is amplitude modulated, say with speech, there is a whole range of sum and difference components, in which the difference components are the audible speech signal. Thus, self demodulation occurs due to the non-linearity, producing audible sound.

As a result of transmitting an amplitude modulated ultrasonic signal, where the modulation carries audio information, is to recover this information along the ultrasonic beam, a highly directional audio frequency beam is obtained from a system which is only of the size necessary to produce a directional ultrasonic beam. The ultrasonic beam is absorbed in the air

STOLEN INSULATION MONEY?

A new $862 million plan to expand Minneapolis-St. Paul and International airport has drawn outraged cries from those living near the airport. City Council member Scott Benson said that the plan to add 46 more gates, a new concourse, an outdoor people-mover, a 400-room hotel and more to the airport just two months after the Metropolitan Airports Commission (MAC) and Northwest in effect claimed the cupboard was bare for noise insulation, is an outrage. “They basically wanted to steal all of this money they had promised for [noise] insulation and use it to expand the airport for Northwest,” he said. “Not for competition, not for the betterment of air travel in Minnesota, not to save consumers’ money, but to fortify Northwest’s hub here in Minnesota and give them more monopoly profits.” In July, the MAC voted to cut by almost three-quarters a plan that would have fully insulated homes in the 63–64 DNL (day-night level) sound contour near the airport and given those in the 60–62 DNL free central air conditioning. Instead, the MAC approved a sliding-free subsidy for both groups to buy central air. No other sound insulation was included. The city claims the MAC agreed to fully insulate homes out to 60 DNL in 1996; the MAC denies this and said its plan goes beyond federal requirements.

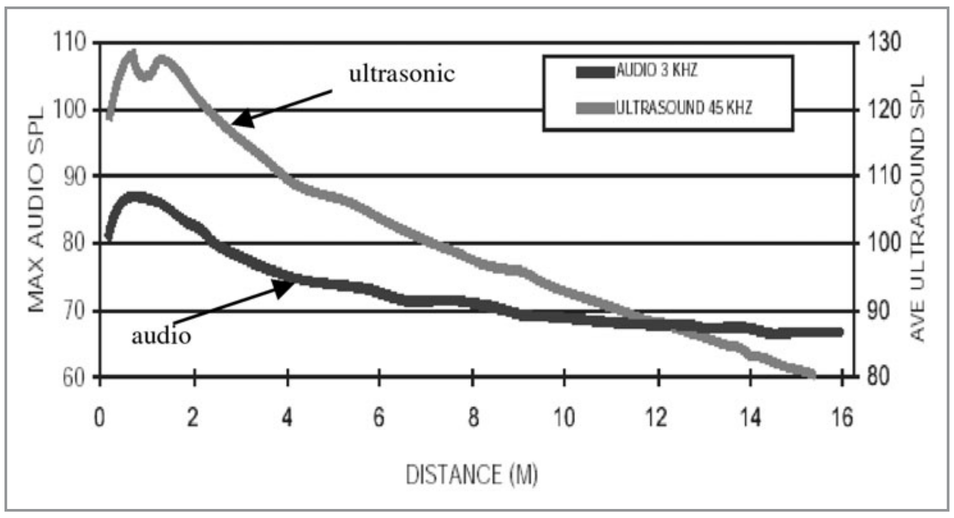

Figure 1. Ultrasonic and audio signals for a HSS loudspeaker. Ultrasonic frequency 45kHz. Right hand vertical scale. Audio frequency 3kHz. Left hand vertical scale (Information from American Technology Corporation)

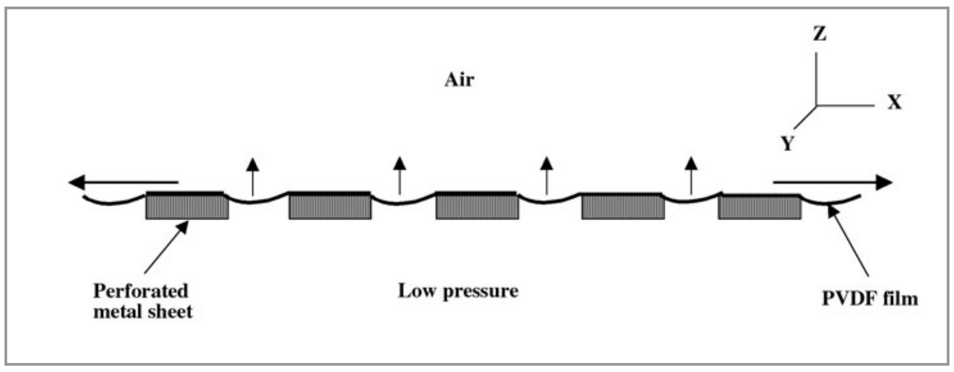

Figure 2. Operation of HSS transducer. As the film stretches and contracts under the applied voltage in the X and Y directions, it also moves in the Z direction

far more rapidly than the recovered information which it carries. For example, the attenuation at 45kHz is about 1500dB per kilometre

Figure 1 illustrates the production of 3kHz sound in a HyperSonic Sound loudspeaker, designed for commercial and domestic use. At the maximum levels, the audio frequency is about 40dB below that of the ultrasound, indicating the inefficient conversion. The ultrasound decays more rapidly than the audio signal, so that the crossover in levels is at about 12m from the source. When the ultrasonic level is low, conversion of the audio signal ceases, but the existing audio continues to propagate with relatively low dispersion. For example, the beam corresponding to 3kHz in Figure 1 is about 1.5m wide at the crossover distance.

There are problems to be solved in the reproduction. It can be shown that the audio output rises as the square of frequency, leading to 12dB/octave rise[3]. This requires a similar fall off in the output of the transducer, either by pre-filtering of the input or by transducer design. It has also been shown that distortion is reduced by using single sideband modulation.

THE TRANSDUCER

The ultrasonic transducer must have

sufficient bandwidth to transmit the carrier and audio modulation. However, the required pre-filtering fall off of 12dB/octave means that it is difficult to generate a level response down to very low audio frequencies. There are 10 octaves in the full audio range, so that the level difference required between a carrier of 40kHz and the upper sideband of 60kHz is 120dB. This is not easy to achieve but, if the lower audio limit is 500Hz, the equalisation requirement is halved.

The transducer is based on a large number of small elements, positioned over a relatively large area, in order to give a highly collimated beam. Early versions used small bimorph piezoelectric elements, but these have been replaced with thin film piezo elements based on polyvinylidene difluoride (PVDF). The film, which is about 25 micron thick, metallized on both sides and very low mass, works by expanding and contracting in its plane (x-y directions) when voltages are applied. Significant motion at right angles to the plane (z direction) is obtained only if the film is distended in the z-direction. Then x-y contractions and expansions then lead to z direction changes. One way of achieving this is by stretching the film over a perforated plate on an airtight box and reducing the pressure behind the film, so that the film distends into the perforations. The diameter of the perforation is chosen to resonate the film at the carrier frequency, whilst the depth of the box is may also be chosen to resonate at this frequency. Figure 2 shows how the film operates and Figure 3 is a complete HSS unit.

THE LRAD

This is a rugged device, less than a meter in diameter and about 125mm thick, as shown in Figure 4. Its maximum sustained audio frequency tone level at 1m is 146dB, with bursts up to 151dB. For voice use, the level at 1m is about 120dB but, because of the directed beam, the fall off with distance is low, so that at 275m the level is as high as 105dB. The warning level is even higher. When used over water, the range is up to 500m.

Current development is through a million dollar contract, in order to supply a field device which can defuse potentially dangerous situations by sending instructions and information from a distance. And if the instructions are ignored, the switch can be flicked to the behaviour-influencing warning tone. Of course, if the object of the beam copies the LRAD operator and wears hearing protection, the effectiveness is reduced.

Figure 3. HSS loudspeaker with protective grid

Figure 4. The operator side of the LRAD

There are suggestions for civilian applications of the LRAD. These include shore to ship communications and general law enforcement. An early application may be to increase security in large area installations, where the LRAD can be coupled with a video camera and activated remotely.

Careless operation of the LRAD could lead to hearing loss in nearby unprotected persons. In this sense, it has the ability to cause non-lethal injury.

APPLICATIONS FOR HYPERSONIC SOUND

American Technology Corporation is confident of a wide range of applications for its commercial HSS loudspeaker. In addition to domestic use there is potential for:

Communication over large sites
Localised advertising in supermarkets and shopping centres

Communicating information in a museum or gallery

Localised sound in vehicles, enabling passengers listen to different music etc

Noise cancellation over defined locations – and many similar ones.

The HSS loudspeaker is said to be the only really new development in sound reproduction hardware since the cone loudspeaker came on the market in the 1920s. It is an interesting example of how developments in one area of acoustics – non linear propagation in underwater acoustics – may gradually find application in another area. There may be others, just waiting to be exploited.

REFERENCES

1 H. O. Berktay, "Possible exploitation of non-linear acoustics in underwater transmitting applications", J Sound. Vib 2(4), 435–461, (1965)

2 P. J. Westervelt, "Parametric acoustic array", J Acous. Soc Am. 35 (4) 535 – 537

3 M.Yoneama and J. Fujimoto, "The audio spotlight: An application of non-linear interaction of sound waves to a new type of loudspeaker design", J. Acoust. Soc Am. 73(5), 1532–1536, 1983

noise notes

GUN CLUBS

A homeowners group in New Hampshire is seeking to declare unconstitutional recent legislation exempting shooting ranges from liability and prosecution from noise complaints. Twenty-three members of Residents Defending Their Homes say the measure, passed in May, violates their legal recourse against a local gun club. The Lone Pine Hunters Club began in Nashua in 1913 and moved to Hollis in 1966. In 1998, the residents group brought its concerns to local boards. The residents said the club never received permission to use its 118 acres as a shooting range, and should therefore submit to a site-plan review involving noise and environmental studies. In 2003, the state Supreme Court ruled that the club would have to submit to a site-plan review. But in May, the state passed the bill exempting Lone Pine from noise liability. An old version of the law said that gun clubs were exempt from noise ordinances as long as they complied with the laws in place at the time the club's construction was approved. Now, the law says clubs are exempt from noise ordinances as long as they comply with the noise laws that were in place when they were established, constructed or began operations: in this case, the laws of 1913 – virtually none. The law "plainly favors" the gun club "to the detriment of the neighboring landowners and the larger community," the residents' petition said.