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EDITORIAL

Brief Notes on Non-Lethal Acoustic Weapon

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1 Introduction

Non-lethal weapons are mainly used to disperse illegal demonstrations and street riots without inflicting serious physical injuries on the law violators. The development of non-lethal weapons complies with the civilized standards aimed to protect the law-abiding population from violent crowds with no casualties and injuries. It is noteworthy that tasers and pepper sprays are already in widespread use for personal self-defense. Thunder and lightning are the simplest natural examples of non-lethal and lethal weapon. Thunders sound frightening but they do not kill, lightnings can kill.

The rioting street crowds may significantly outnumber the team of law enforcement officers. This makes difficult to identify and neutralize the hiding militants which smash stores, set fire to cars, and beat up those who condemn their actions. Using non-lethal weapons, the law forces can safely disperse the more peaceful protesters. The militants, deprived of their human shield, can be neutralized with minor risk to the other participants.

Traditional non-lethal weapons usually include fire hoses, tear gas, and (for the militants throwing Molotov cocktails or cobblestones) shock grenades and rubber bullets. Reeking liquid sprays or sticky gels has been also developed for this application, but such methods require bulky equipment and pose similar risks to the law enforcement officers.

Powerful speakers, radiating unpleasant acoustical noise into a crowd of violators, seem to become a more suitable type of non-lethal weapon. There are many publications on acoustic weapons, including my paper published in the Sound and Vibration magazine in 2004. This paper is written as editorial, a brief review without equations and experimental data.

2 The Biblical Trumpets of Jericho

According to the Bible, Moses had finally brought his people to the Promised Land near Jericho, a fortress with high walls. Before Moses died, he had nominated Joshua, a brave and gifted military leader, to be his successor. It took Joshua seven days to subdue the fortress. In the end of this siege "the people shouted with a great shout, and the wall fell down flat." However, even the Bible does not exactly state that the walls were destroyed just by the "great shout." There might have been at least two natural reasons. For seven days the attention of Jericho's defenders was occupied by the noisy procession of Joshua's army around the city, so they might not have heard Joshua's sappers secretly undermining the city's walls.

A horizontal earthquake could also have destroyed the ancient walls made of clay rather than of stone (such structures are not much stable under shear stresses).

Archaeological excavations revealed that Jericho, which is considered the oldest city in the human history, was destroyed, and rebuilt at least eight times. One of such events occurred at the turn of the

fourteenth and thirteenth centuries BC. The chances are that it happened during the siege of Jericho by the troops of Joshua.

3 Infrasound As Acoustic Weapon

Infrasound, sound waves with frequencies below 20 Hz, is not audibly perceived but can be annoying or even hazardous to humans because: (1) it can adversely affect internal organs, (2) it can excite the Helmholtz resonances of air in dwellings.

French scientist Vladimir Gavreau tried to design an infrasound acoustic weapon after he and his assistants had been accidentally exposed to infrasound waves. They often experienced bouts of nausea during working hours. The cause of this unpleasant condition was found. An improperly installed powerful fan produced intense infrasound, which was further amplified by the acoustic resonance in the giant Helmholtz resonator formed by the laboratory room with a partly open window. The most common analogue of such a resonator is a bottle with an open neck. In the described case, the role of the bottle neck was played by the open window. Closing or, conversely, opening the window even wider, Gavreau reduced or accordingly increased the Helmholtz resonance frequency. When it was sufficiently shifted away from the frequency of the infrasound emitted by the fan, the resonance disappeared.

Thus, Gavreau decided that he had discovered a new kind of weapon, and began to develop its prototypes: special pipes, horns, and whistles. Those instruments were large (at least 1–2 meters long and wide), otherwise the emitted infrasound was weak. When they were turned on, Gavreau and his assistants felt pain in the heart, lungs, and stomach, as well as muscle spasms. Similar experiments by other researchers have shown that such effects exist but they are less significant.

The infrasound radiators do not seem to be optimal for use by law officers against street rioters, because at very low frequencies the wavelength of sound is too big (for instance, 68 m at a frequency of 5 Hz) compared to the size of typical sound emitters in use. Therefore, a typical infrasound generator works much similar to the ideal monopole which radiates sound equally in all directions. Such a non-directional acoustic weapon would equally assault both street rioters and law officers. Peaceful residents would not be safe in their houses too because infrasound can pass through walls and windows with little attenuation.

4 Effects of Audible Sound on Humans

Loud audible noise can be very annoying for human ears and causes pain starting with a sound pressure level of 140 dB. For comparison, the sound pressure level of a normal conversation is about 60 dB.

Here, sound stability and frequency spectrum are also important. Intermittent sounds, where the ‘loud’ and ‘quiet’ intervals alternate, are more unpleasant than steady sounds. This can be illustrated by means of a visual analogy. Imagine that you are in a room lighted by an electric bulb and compare two different situations: (1) the bulb is on constantly, (2) the bulb is frequently turned on and off. Certainly, the second situation is more annoying.

From the frequency spectrum viewpoint, broadband noise bothers people less than tonal or narrowband noise. The most unpleasant is the buzzing tonal noise with a frequency of 700 Hz, which fits the upper frequency limit of the sound produced by mosquitoes.

However, the most frightening are low-frequency audible sounds, which in human mind are associated with global natural disasters or roar of dangerous beasts. But some high-frequency sounds (for example, the hissing of a snake) also make us worry.

5 Ultrasonic Emitters

Ultrasound (sound waves with a frequency above 20,000 Hz) of high intensity can cut soft tissues. However, (1) ultrasonic waves quickly attenuate in air with distance because of sound energy dissipation

which notably grows with frequency, (2) their "frightening" effect is insignificant, since they are not audible by people.

Special ultrasound emitters are designed and utilized to repel vermin and wild animals from people, crops, and livestock. But the effectiveness of such methods is still not obvious. In particular, various studies found that while creatures like mice and cockroaches hear this noise, they also soon learn to ignore it. Dogs may react but wolves and bears are less sensitive to the ultrasonic repellents.

6 Long Range Acoustic Device (LRAD)

In acoustics, a beat is an interference pattern between two sound waves of slightly different frequencies. It is audibly perceived as the signal, amplitude-modulated at a rate which is equal to the difference of those frequencies (often mentioned as the audible beat frequency). For example, two interfering acoustic waves with frequencies 1000 and 1005 Hz can produce a pulsating signal with the audible beat frequency of 5 Hz. Beat is commonly heard by people as a high-frequency tone with the periodically changing amplitude. Sometimes people can hear it nearby double (twin) window fans. However, some people can perceive such a beat like combination of sound and infrasound.

This idea can be considered like the basis for the development of the long-range 'infrasound gun' since the divergence of high-frequency waves to the sides with the distance is much less significant than in the case of infrasound waves. Certainly, ultrasonic waves are not suitable for this application because of the rapid attenuation of ultrasound in the air.

Currently, the most famous of the loudspeakers used as acoustic weapons is LRAD (Long Range Acoustic Device). According to the data published on Internet, it can produce pulsating tone signals with frequencies 2000–4000 Hz (like the screech of a home smoke detector), but much more powerful (up to 140 dB at 300 m). The information on the audible beat frequency is not mentioned. The sound that comes from an LRAD is highly directional.

This device was originally designed to protect warships from suicide bombers masquerading as fishers or peaceful traders who swam in booby-trapped boats close to the side to commit sabotage. In order not to immediately use lethal weapons, systems such as LRAD were installed on military and some merchant ships. There is a case when armed Somali pirates tried to seize an American merchant ship but retreated after the sailors directed the included LRAD at them.

However, it looks like LRAD devices are rarely applied by police to disperse street demonstrators because the related safety issues are still in question.

7 Soaring Drones with Noisy Loudspeakers

Drones with loudspeakers can serve as effective acoustic weapons making loud and unpleasant noises (in particular, intermittent roaring or buzzing sounds). A drone can approach a rebellious crowd, hovering at a height of 50–100 m. Here, (1) the drone operator is not exposed to noise and (2) the geometric divergence of the emitted sound beam can be a favorable factor because the loud sound zone becomes wider, covering the entire crowd. On the other hand, peaceful residents would be safe in their houses since well audible sounds (in particular, the most annoying tone with a frequency of 700 Hz) are notably reduced in power while passing through walls and closed windows.

8 Shock (Stun) Grenades

These weapons produce bright flashes of light and loud pulses of noise. Therefore, the use of shock grenades to disperse crowds with many women and children is commonly avoided by police. However, shock grenades can be effective against aggressive "demonstrators" whose actions pose a real threat to the police and other citizens.