Present status and development trend of Acoustic releaser

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Abstract. Acoustics releaser plays an important role in the recovery of marine surveying system. This paper analyses and introduces present situation of the acoustics releaser in our country. Finally, main technology development direction and strategy of localization are put forward in the paper. The paper mainly includes research status quo outside and in China as well as key technical problems in design of underwater acoustic releasers.

1. Introduction
Acoustic releasers have seen wide adoption in maritime engineering and military missions. In the field of maritime monitoring and engineering, different types of acoustic releasers have been employed in such devices as raised maritime surveying systems, underwater transponders, and subsurface buoys; in military missions, acoustic releasers are required in construction of sea test ranges, and they are indispensable modules in underwater communication networks and underwater network centric warfare (NCW). The acoustic releasers partially decide whether the investments worth millions of dollars into the maritime surveying devices and experiment data can be recovered or not. Nonetheless, China is now still a net importer of acoustic releasers. As reverse globalization gains momentum and global superpowers initiate technology blockades against China, it is a pressing mission to develop highly-reliable acoustic releasers of independent intellectual property rights.

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2. Research status quo outside China

Western countries have a head start on China in research of acoustic releasers and hence play a world-leading role in this field. Many a company is capable of designing and manufacturing acoustic releasers, with cut-throat competition in the market. Traditional acoustic releaser manufacturers like iXblue in France, Benthos in America, Sonardyne in Britain, NGK in Japan and InterOcean in America, have produced a range of acoustic releasers of stable performance. The last twenty decades have seen the rise of acoustic system developers who have produced more unique underwater releasers, such as Edgetech in America, AppliedAcoustic Engineering in Britain, and ORE offshore in America [1].

iXblue is a well-known acoustic device developer in France, and its Oceano-series underwater acoustic releasers, thanks to their reliable performance, have won recognition from the users and have achieved sales over 150,000 sets globally. The R5 releaser, iXblue’s latest model, is made of stainless steel, adopts the duplex working mode, with a release load of 2,500 kg, a depth rating of 6,000 m, and a communication range of 10,000 m. It uses the 8-bit FSK 2-state command coding system, featuring low power consumption, the positive drive-off release mechanism, and an underwater operating life up to 30 months. The 2500T-model releaser can work at a depth of 12,000 m, with a safe load of 2,500 kg, and an underwater operating life up to 36 months.

Edgetech’s acoustic releaser works at a frequency between 7 and 20 kHz; the hadal model has a working depth of 6,000 m, an effective load of 5,500 kg, and the BACS coding system, and the battery can last 9 years/5,000,000 responses after being charged once. The PORT model of acoustic releaser that has a working depth of 3,500 m adopts the motor-driven rotatory positive push-off release mechanism, while the 8242 model adopts a spring driven, motor actuated release mechanism. The equipped deck unit can display the tilt state, which solves the problem that there is no feedback of the attitude of the release when the instrument capsule is deluged. Besides, sending false release commands will untie the safety rope that used to tie the underwater instrument capsule to the ship, and the capsule that cannot return onto the water surface by dint of its buoyance force is likely to sink into the sea. The equipped deck unit will reduce this risk[2].
The acoustic releasers developed by Applied Acoustic Engineering (AAE) can be matched with its Easytrack ultra-short baseline locating (USBL) system, and is compatible with USBL systems developed by other manufacturers. Besides, its internal frequency and release recognition signals can be changed on site. The most commendable upside of AAE’s releaser is its cost efficiency: a deck unit matched with different beacons can serve as both a locating system and a release system. AAE’s release system has a working depth of merely 2,000 m, a small working load, and the maximum load of the 559P release beacon is merely 200 kg. Nonetheless, due to its unique design, it has low power consumption, and the 559 model can last 18 months underwater and provide 2,500,000 responses.

Figure 3. AAE acoustic releaser

Benthos in America is a world-leading manufacturer of oceanographic devices. The acoustic releasers it produces work at a range principally within 7 and 15 kHz, adopt the high-torque motor-driven release mechanism, have a maximum release load of 5,000 kg with an operating life of two years. The water surface unit cannot only boost or stop the releaser and receive feedback movement information, but also survey distance information remotely, with a slant range up to 10 km.

Some acoustic releasers developed by Sonadyne adopt the motor-actuated mechanism, some adopt the spring-assisted release mechanism (which resemble the iXblue’s oceanographic models), some others adopt the active separation release mechanism. The Sonadyne releasers have a working depth of 6,000 m, and an operating life ranging from two to three years.

3. Research status quo in China

Acoustic releasers developed by Chinese organizations cannot match their western counterparts in terms of such technical indicators as reliability, motor servo separation, sensitivity and underwater operating life. Many a Chinese organization has invested much in development of acoustic releasers, including the 710th Research Institute of China Shipbuilding Industry Corporation (CSIC) and Harbin Engineering University funded by the National 863 Project, and National Ocean Technology Center that keeps introducing and absorbing advanced technologies and is funded by the National 863 Project. Other organizations like The Institute of Oceanology, Chinese Academy of Sciences, and the 715th Research Institute of CSIC, Nanjing University, Xiamen University, and some emerging acoustic measurement device manufacturers have made much research effort into this field.

In 2007, to solve the problem of separation between the underwater instrument platforms and the anchor in deep water, the 710th Research Institute of CSIC developed a model of timed pneumatic separation releasers that could work at a depth of 1,000 m. The workflow of this releaser is as follows. First, the ignitor is started by the pneumatic timed circuit, the high-pressure gas generated from which pushes the connecting pin to unlock the device, and thereby separate the mooring mine and the anchor. It can work at a depth of 1,000 m and lasts a maximum of 30 days underwater. Later, the 710th Research Institute probed further, employed the bandwidth coding technology and developed a releaser that can work at a depth of 4,000 m underwater and in dual-release mechanisms – timed
release mechanism and acoustic communication remote-control release mechanism, staying in a timed state for a maximum of one year.

In the sub-project “development of highly-reliable acoustic releasers” of the National 863 Project, Harbin Engineering University developed a releaser that adopts the electrochemical fusing release mechanism. In this project, the research team principally probed into acoustic communication, and around 2010, published several papers on acoustic communication, which laid a theoretical foundation for acoustic communication of underwater releasers, large-scale hadal acoustic releasers in particular.

By introducing and absorbing advanced technologies, National Ocean Technology Center has laid a methodological and technical basis for development of acoustic releasers. It has developed some approved models of releasers. In late September 2017, in the project “demonstration of application of deep- and open-sea surveying devices”, the Center developed a release that can be deployed 4,000 m under the sea surface, perform communication and release over ten thousand meters for six months, and match global alternatives in performance, as proved in comparative tests.

Industrialized companies have been on the rise in these years. Scientists devoted to developing advanced Chinese equipment have founded a bunch of high-tech firms, trying to promote development of acoustic products by dint of their professional expertise. For instance, E-sound Corporation in Jiaxing, Haiying Group based in Wuxi, and Ruisheng Group in Hangzhou have dabbled into development of acoustic releasers.

The eART transponder-releaser developed by Jiaxin E-sound can serve as an acoustic beacon, perform range finding, depth surveying, position measurement, and release under heavy loads; it also has the function of multi-target long-baseline positioning.

![Figure 4. E-sound’s eART medium-frequency responder-releaser](image)

The specifications of the eART medium-frequency responder-releaser are as follows:

- Working frequency: 18 Hz - 35 Hz.
- Maximum working depth: 1,000 m.
- Working range: 3,000 m.
- Maximum release load (heavy-type): 500 kg.
- Stand-by time: 6 months.
- Depth surveying accuracy: ±1%FS.

Hangzhou Ruisheng Oceanographic Instrument Development Group consisting of 715 experts has developed the SFQ-1 releaser. This releaser can work at a depth of 10-1,000 m underwater, stay underwater for 90 days, with a maximum load of 1,500 kg, and a working range of 3,000 m. This model, however, is not yet available on the market.

Though some Chinese releaser models have been approved and are ready for production, they can still not match the advanced releasers developed by western countries in terms of the working depth, response distance, operating life, and reliability. Specifically, Chinese acoustic releasers suffer such defects as low reliability, inconvenient operation, poor workmanship, and poor durability. Another depressing fact is that most Chinese acoustic releasers are mere copies of foreign ones, without traces of innovation.
4. Key technical problems in design of underwater acoustic releasers

Acoustic releasers often need to work underwater for one to two years before sending a command to be recovered. Thus, reliability after long-term stand-by is a key indicator to the performance of the acoustic releaser. There are two causes for failure of acoustic releasers[3]:

1. Damages or failures of the hardware of the underwater unit. The underwater unit, deployed under the sea for long, is subject to erosion by the seawater and high pressure, which will damage the water tightness of the unit cavity and lead the internal circuits to disfunction. As the unit needs to stay underwater for long, the overused batteries are likely to cause shortage of voltage to boost the electrode of the release execution component, and the release action will end up in failure. Besides, once the releaser is deployed, the release hook is under a heavy load state; under extreme conditions like strong erosion and high pressure, impacts from undercurrents and attachment by maritime creatures are likely to cause damages or failures of the release hook [4].

2. Damages or failures of the communication module. The communication module is responsible for communication between the above-water units and the underwater units. It encodes and sends the commands from the emitting terminal, and decodes information into valid commands at the receiver terminal. A proper acoustic communication decoding scheme, which is employed to reduce the error rate and realize stable and reliable communication, is the basis to ensure stable performance of the releaser.

It is not hard to see that the reliability of the releaser relies on the pressure-resistant underwater transducer [5], the release component, the low-power circuit, and the acoustic remote-control command decoding technology. Problems in any of these parts are likely to cause failure in recovering the releaser [6].

4.1. Modulator-demodulator (modem) technique of acoustic communication

Earlier acoustic communication adopts the modem technique, but the modulator system often fails to address the distortion problem caused by acoustic communication channel fading, which limits the improvement of the system. The digital demodulator, however, cannot only improve the reliability of data transmission by the error correction coding technique, but make up for the channel distortions caused by the multipath effect and the Doppler shift [7]. In terms of the features of acoustic communication channel, the demodulators can be divided into two categories. The first is the frequency shift keying (FSK) demodulator. FSK demodulator has strong resistance against multi-path jamming and strong adaptability to delays and frequency shifts of the acoustic communication channel. Nonetheless, its bandwidth efficiency and communication speed of single modules are low, and it has high requirements for the signal-to-noise ratio (SNR). The other category of demodulator is the phase shift keying (PSK) demodulator, which features high bandwidth efficiency, low requirements for the SNR, a low bit error rate, strong resistance against inter-symbol interferences, as well as resistance against bandwidth shifts and multi-path interferences.

Take Benthos’ 865-A model of acoustic releaser for example. The commands sent by the 865-A releaser are 2FSK signals with a length of 6 s, are filled with two carrier frequencies. Its decoding scheme has strong resistance against multi-path interferences with a high detection rate and a low false alarm probability, boasting good resistance against bandwidth noises [8].

The FSK encoder used by the 710th Research Institute of CSIC employs sequences of good correlations to modulate coded communication. Based on theoretical analysis and experiments, the bandwidth encoding scheme is adopted [9].

The team at Harbin Engineering University uses the PSK demodulator and the zero correlation zone (ZCZ) sequence to meet the high standards for interference resistance and reliability, confidentiality and security, and multi-user accessibility. Through water-tank experiments, they have confirmed the capacity of the demodulator for big data transmission [10].

In acoustic communication, the reliability and transmission rate of acoustic signals are subject to influences of such factors as long delays of the communication channel, limited available bandwidths, serious time-varying multi-path interferences, strong Doppler shifts, sea thermocline, ambient noises
in the sea [11]. Most mature acoustic releasers developed by western countries combine the FSK demodulation technique with spread-spectrum technique, some use the brief assessment of cognition in schizophrenia (BACS) encoding and decoding technique (Edgetech, for instance), and some Chinese organizations focus on the PSK demodulation technique [12]. It is still too early to tell which modem technique is better. Extensive research is required to optimize single techniques and combine multiple techniques to realize stable communication in the complex environment in the sea [13]. Much research effort is needed to solve these fundamental problems.

4.2. Reliable release component

In terms of the release mechanism [14], most international releasers adopt the release mechanism that relies on the motor-driven stretch and rotation of the lock pin; some adopt the separation release mechanisms such as the start-separation release mechanism and line-combustion separation mechanism (such as the pneumatic release mechanism used by Japan’s NGK releasers). The motor release execution component principally uses the load mechanical amplification structure and the parallel execution structure. The driving motor is a direct-current motor equipped with a decelerator, featuring a high deceleration rate and a high torque; the stopper of the release execution component can detect whether the release is normal or not; the load mechanical amplifier can provide different loads; the parallel execution component can work in two ways — relying on the stretch or the rotation of the lock pin, to improve the reliability of high-release devices in deep sea. When one set of devices is releasing, the other set is locked tight [15].

Though the working principles of the release mechanism are known, the whole release process remains largely unknown. Prof. Chang of Ocean University of China performed kinetic modelling on the release process of the releaser and obtained the movement parameters and working trajectories of different components in the releaser through kinetic analysis. Through simulations, it was found that when the motor-actuated rotation-style active push-off bearing release mechanism is executed, tangible collisions occur between the latch and the load hook [16].

Lin Hang and some other research fellows from Hangzhou Applied Acoustic Research Institute have built a finite-element model for the motive seal structure of acoustic releasers, and under an external pressure at a depth of 2,500 m, simulated and calculated the Von-mises stress and contact pressure of the O-shaped motive seal ring, and performed experiments to optimize the compressibility of the O-shaped seal ring, which laid a theoretical foundation for optimizing the sealing performance of the releaser [17].

4.3. Other issues related to the releaser

One issue that deserves attention is the design of high-pressure resistant underwater transducers. Designing the pressure-resistant transducer for deep-sea acoustic releasers is more challenging than designing that of neritic releasers. Though most Chinese deep-water transducers adopt the overflow mode, Chinese manufacturers still have a long way to go to catch up with their global rivals in terms of the performance and appearance of the transducers. The Chinese transducers cannot realize full sealing, require overflow by opening pores, and cannot achieve stable performance at different depths of water.

Another issue is the design of stable, reliable and low-power circuits [18]. Most Chinese releasers can stay under water for half a year, while western releasers with batteries of the same capacities can stay underwater for two years or longer and provide more than ten thousand responses. Western acoustic releasers adopt the two-level power supply system supported by the micro-power on-duty circuits and large-power circuits. The circuits include the power source management circuit, the on-duty decoding circuit, the transponder circuit, and the release control circuit. The power source management circuit is responsible for power supply and cut-off; the low-power on-duty decoding circuit is always in the working state, while other circuits fulfill tasks as per the commands from the deck unit above the water; and when the tasks are fulfilled, the system repeats the cycle and returns to
the low-power on duty state [19]. Design of releaser circuits is still at the stage of function implementation, while function optimization is yet to be realized.

Aside from these issues, more in-depth studies should be made to other issues like the design of the sound signal emitter of the host computer [20], the selection and processing of erosion-resistant materials, refined design of the components of the releaser, and development of high-capacity batteries suitable for air-tight space.

5. Prospect and Conclusion
It has been 15 years since the National 863 Project was started in 2006. During these 15 years, Chinese acoustic releasers have developed from neritic releasers that work at a depth of 1,000 m to deep-sea models operable at a depth of 4,000 m, and these models have passed tests in the sea. Studies on acoustic releasers have shifted from overall design and function realization to more specific fields such as manufacturing techniques of acoustic transducers, optimization of acoustic communication decoding techniques, and mechanical analysis of release execution components. Technological progress has provided solutions to some problems in development and application of acoustic releasers. For instance, Chinese acoustic releasers have high power consumption than the global alternatives, but as the lithium battery development technologies advance, Chinese acoustic releasers can stay underwater much longer than before.

Moreover, in the two years after the conclusion of the National 863 Project in 2010, many papers were published on acoustic releasers, but since 2013, there have been few related papers which were published. As research institutions provided specific funds to studies on acoustic releasers, the number of research papers in this regard saw a surge; when the project was concluded, however, there were hardly any technical advancements or innovations, and researchers showed no motives to engage in relevant studies. Some researchers have both theoretical and technological expertise, but rely on national funds in research attempts and find no way to translate their expertise into commercial benefits. As a result, it turns out to be a slow process to industrialize the development and manufacturing of acoustic releasers. Therefore, we suggest that the national funded research projects be dominated by enterprises, and the enterprises provide the fund to specific research teams. In this way, the research cost can be reduced and standard production can be realized. Indeed, a strict responsibility system should be established.

When promoting the application of acoustic releasers in China, we should consider not only the security issues. As analysis above shows, aside from the pneumatic timed releaser developed by the 710th Research Institute that has considered security, other acoustic releasers are still in the initial stage of development, and their security is far behind that of imported releasers.

With the fast economic growth, we suggest that insurance companies provide insurances for application of China-made equipment. When domestic devices are applied to practical systems, the government can invest in insurance of these devices on insurance companies, to encourage users to use these devices and solve their concerns. Surely, to this end, we should first promote technical progress. For example, the contact function can be introduced to the releaser to allow users collect data in real time and avoid failures in data collection when the recovery of the device is not attainable.

The article mainly includes research status quo outside and in China as well as key technical problems in design of underwater acoustic releaser. Key technical problems includes Modulator-demodulator (modem) technique of acoustic communication, Reliable release component and Other issues related to the releaser. Finally, main technology development direction and strategy of localization are put forward in this paper.

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