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TRANSMITTING AUTONOMOUS UNDERWATER ACOUSTIC RECORDER - SHELF-07

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This paper describes the technical characteristics of an autonomous underwater acoustic recorder designed and fabricated by POI for extended (up to 1 month) acoustic measurements over the frequency range from 1-15000 Hz at a fixed location on the sea floor. The recorder can be equipped with a radio-telemetry unit capable of transmitting acoustic data in the frequency range from 10-5000 Hz to a land or marine receiver if real-time monitoring is required. Different generations of the recorder have been successfully deployed at the borders of the Piltun feeding area from 2005-2007 for real-time monitoring of the sound produced by the installation of the PA-B platform and pipe-laying operation.

In 2002 an acoustic group from POI participating in an acoustic monitoring program on the NE Sakhalin shelf [1] was requested to design and manufacture a number of autonomous underwater acoustic recorders (AUAR) that could be used for acoustic studies, including real-time monitoring, in and around the traditional feeding areas of the western gray whale population (WGW) [2]. This population is listed as endangered in the Red Book of the Russian Federation and is classified as critically endangered by the IUCN. The NE Sakhalin shelf is characterized by complicated hydrodynamics with tidal current velocities reaching 2 m/s and water depths of between 10-20 m at most of the monitoring locations, acoustic measurements may therefore be strongly influenced by the retrograde motion of water particles in surface waves and swell. One of the requirements was that acoustic data must be able to be continuously recorded for 16 or more days over a frequency range of 1-15000 Hz; and must be capable of transmitting part of the data to a land or marine receiving station by radio in real time. Existing autonomous acoustic buoys [3, 4] could not meet these specifications and POI decided to design a transmit autonomous underwater acoustic recorder that was adaptable to the real time monitoring requirements and satisfied the technical specifications. A single PC/104 board computer with an integrated 16-bit ADC was used for recording the acoustic data. This type of computer is commonly used in critical embedded applications for control and data collection in a wide range of operational conditions and enables the operation of the AUAR to be flexibly programmed to fulfill the goals of the monitoring program. Six first generation AUARs were deployed on the Sakhalin shelf in 2003. In 2005 four buoys deployed at the edge of the Piltun feeding area [2] were additionally equipped with radio transmitters [6] for real-time acoustic monitoring of industrial activities [5]. In 2006 five transmit AUARs (T-AUAR) were successfully used for further real-time monitoring in the same area.

This paper discusses the latest generation of T-AUAR the Shelf-07. The POI team employed the experience they had accumulated during acoustic studies on the Sakhalin shelf using autonomous units deployed in relatively shallow water (10-50 m) areas with strong tidal currents. Figure 1(a) illustrates the deployment of the T-AUAR, the schematic for the Shelf-07 T-AUAR is given in Figure 1(b). The unit records acoustic signals in the frequency range from 1-15000 Hz with a potential dynamic range of 96 dB and transmits acoustic data with a frequency range of 10-5000 Hz over a radio channel.

The T-AUAR container is titanium and is tested for deployments at depths of up to 50 m. Three sealed gel batteries with a capacity of 115 Ah provide 18 days of continuous recording with transmission, and 30 days without transmission. The weight of the unit in air is ~145 kg. A hydrophone with an associated pre-amplifier fabricated and calibrated at VNIIFTRI was used to convert acoustic pressure into voltage. Figure 1(a) shows that the hydrophone is fixed inside a pyramidal frame with rubber bands and is placed at a distance of 15 m from the T-AUAR container.

The normalized frequency response of the T-AUAR analog circuits $K(f)$ and the hydrophone $M(f)$ has a low frequency roll off to prevent low frequency acoustic components and flow noise from overloading the system. These responses are used for calculating the total frequency response of the AUAR, the inverse of which is later applied to the recorded data to correct it to absolute values of

acoustic pressure in the frequency range from 1-15000 Hz. The hydrophone output is connected via cable to a scale amplifier whose amplification coefficient can be set to 1, 2, 10 and 40.

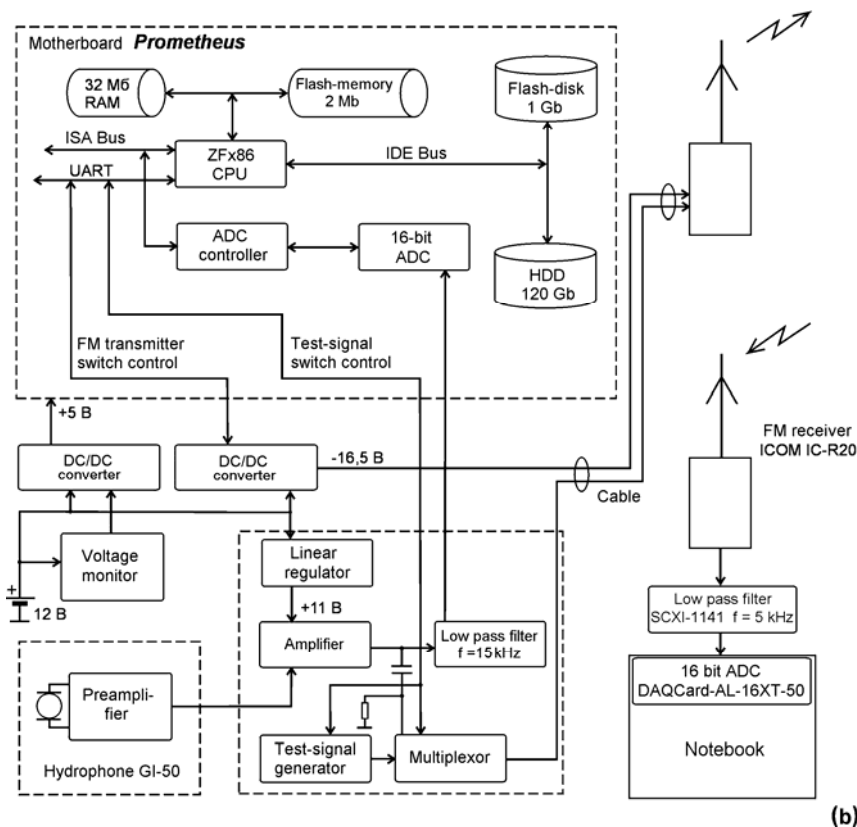
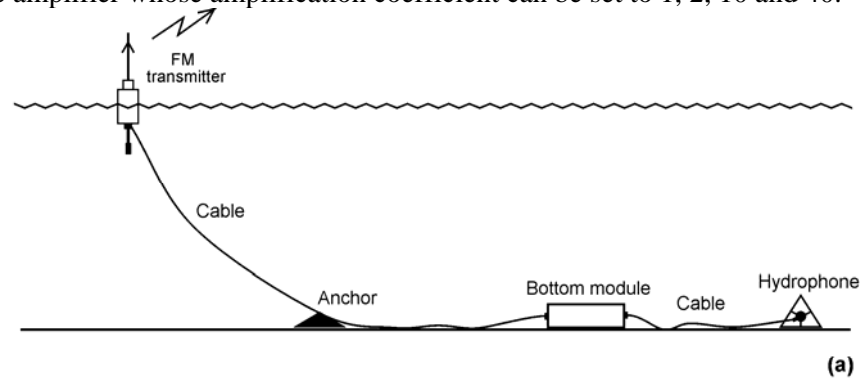


Figure 1 (a) - Deployment of the *Shelf-07* AUAR at sea (b) - Schematic of the T-AUAR and additional land receiving station

The signal then passes through an 8th order low-cut filter with a low cut frequency of 15 Hz and digitized. In parallel it passes through a low-cut RC-filter (-6 dB/octave) and is input to the FM modulator of a VHF transmitter.

The T-AUAR has two analog channels, one records data on an internal disk and the other transmits data over a radio channel. The latter has a low frequency correction to prevent overload of the radio telemetry channel as FM modulation gives a dynamic range of less than 45 dB.

The surface radio unit (Figure 1(a)) is connected to the seafloor container with a four-wire cable, the cable is shielded with a steel and copper mesh and has a PVC coating. It is used to send to the surface unit both power from a DC/DC converter controlled by the onboard computer and signals from the output of the radio-channel switching circuit. Experience demonstrates that a combination of the high gain directional antenna installed at 35 m elevation (Piltun lighthouse) and the 1-1.5 W transmit power output at the buoy, gives a stable reception at a distance of 23 km. ICOM IC-R20 radio receivers were used for receiving and decoding the radio-telemetry signals.

A dummy hydrophone with a capacitance, equal to that of the hydrophone used for the acoustic data collection was connected to the input of the scale amplifier for system noise and dynamic range measurements of the T-AUAR. The measurements illustrated that for a scale amplification coefficient of 40, direct (disk) recording system noise is limited by the internal noise of the hydrophone preamplifier and at frequencies above 70 Hz is below 30 dB re 1 $\mu\text{Pa}^2/\text{Hz}$. The dynamic range of the direct (disk) and radio-telemetry channels is dependent on the ratio between the test signal and its harmonics and is ~ 80 dB and ~ 35 dB respectively.

The practical dynamic range of an analog radio-telemetry channel is limited by the internal noise of the channel, stable test signals were therefore used for the estimation of the dynamic range of the Shelf-07 (Figure 2(a)). A test signal can be input into the transmitter for 3 minutes under a preset schedule. Spectral analysis of the test signal received at the Piltun receiving station (Figure 2(a)) enables the practical dynamic range and the radio noise level in the radio channel at different frequencies to be estimated. Figure 2 shows the power spectral density level for the test signal and the acoustic noise received at Piltun lighthouse from a T-AUAR deployed 16 km away from it.

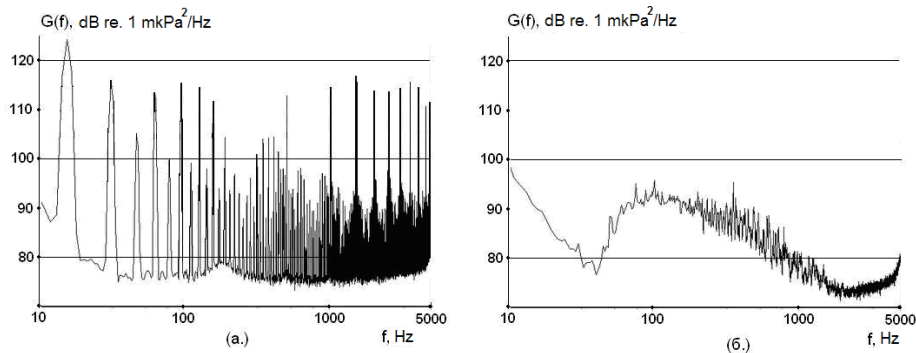


Figure 2 (a) Power spectral density level of the test signal; (b) acoustic noise received at Piltun lighthouse from a T-AUAR deployed 16 km away from it.

The Recording system of the T-AUAR is based on the *Prometheus* single board PC/104 computer manufactured by Diamond Systems Corporation. Figure 1(b) gives a schematic of the system architecture which includes a 486-DX2-100 CPU, 32 MB RAM, an IDE controller on an internal PCI bus, analog and digital I/O and 2 MB solid-state memory. A data controller manages an 8-channel 16-bit ADC with a maximum sampling rate of 100 kHz. A 160 GB hard drive serves as the main storage media. To reduce power consumption and eliminate electromagnetic interference and mechanical noise from the rotating hard drive a 1GB flash disk is used as a buffer.

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REFERENCES

1. A.N. Rutenko. Results of a study of industrial noise on the Sakhalin shelf in the gray whale summer feeding area // *Acoustics of the ocean // Presentations at the 9th Brekhovskiy conference, 2002*, pp. 459-462
2. O.U. Tyurneva. Seasonal movements of gray whales between the feeding areas on the NE Sakhalin shelf // *Marine Mammals of Holarctic // Proceedings of the conference, 2006*, pp 530-535
3. Trokhan, Konovalov. Autonomous hydro-acoustic measuring devices. Results and future developments // *Problems and methodology of acoustic measurements, 2003*, pp 72-80.
4. Trokhan et. al. Applications of autonomous systems for measuring the acoustic fields of marine objects in stationary measuring systems // *Problems and methodology of acoustic measurements, 2004*, pp. 61-65
5. Rutenko, Racca. Organization and results of acoustic monitoring during installation of the LUN-A and PA-B concrete gravity bases on Sakhalin shelf // *Acoustic of the ocean // Presentations at the 11th Brekhovskiy conference, 2006*, pp. 353-356.
6. Borisov, Rutenko. Autonomous hydro-acoustic buoy for environmental monitoring on the Sakhalin shelf // *Acoustics of the ocean // Presentations at the 11th Brekhovskiy conference, 2006*, 305-308.