Analysis and Countermeasure of Positioning Sound Source Interference of a Certain Mining Vehicle with Large Depth

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Abstract. The acoustic positioning of seabed mining vehicle is directly related to the acoustic positioning of mining vehicle. This paper analyzes the interference of multi-path interference and background noise of seabed mining vehicle and the influence of other factors on the acoustic positioning of mining vehicle. A through signal source frequency coding method and a new type of underwater acoustic positioning signal system, which can effectively reduce the receiver to the location of sound source high quality requirements, simple filter processing, can put forward the noise influence, in addition, new type of underwater acoustic positioning signal system can enhance the anti-interference ability of the mining vehicle acoustic positioning.

1. Introduction
The acoustic interference analysis of underwater harvester is the basic work of Marine mining engineering. The main purpose of the project is to provide theoretical data for the acoustic positioning system of the mining vehicle. The mining vehicle works at the sea bottom. The determination of underwater working position can only depend on acoustic positioning. In the process of mining vehicle operation, strong noise will be generated and received by the receiver together with the locating sound source. The closer the receiver is to the locating sound source, the greater the noise interference effect will be.

The interference of the acoustic positioning system includes the mother ship on the water surface [1], mining vehicle, multi-path interference of seawater and noise of Marine environment [2]. First of all, through the noise analysis of the ship equipment, the noise spectrum [3] is generally concentrated under 1kHz, and it has attenuated a lot from 10kHz to 30kHz, so the working frequency (12kHz~25kHz) of the transducer of receiver and sound source has been successfully avoided. The noise of Marine environment [4] is around 55kHz, and the transponder communication of this system has no impact, so it is not necessary to consider. Both of these interferences are at specific frequency points, and the noise source of mining vehicle [5] acoustic system can be avoided to eliminate the influence. Background interference of mining vehicle operation and multi-path interference of seawater are the main sources of noise. The corresponding method to eliminate or reduce the interference can effectively improve the efficiency and quality of Marine engineering operations.
2. Multipath disturbance analysis

The multipath interference formed by sea surface reflection mainly comes from the acoustic reflection of sea surface and the secondary reflection of sea surface after reflection from sea bottom. The characteristics of sea surface acoustic reflection are random, and the emission signal source is equal to the incident Angle and reflection Angle of sea surface. Therefore, the position formula (1) to (3) of the reflection point can be established.

\[ M_1 = \frac{(D - H) \times L}{(D - H) + (D - h)} \]
\[ M_2 = \frac{(D - H) \times L^3 + (D^2 - D) \times L^2 + [(H - 2) \times D^2 + H \times D] \times L}{L^2 + (2D - H) \times L} \]
\[ M_3 = \frac{D \times H \times L + (D - H) \times L^2}{(D + L) + (D - H)} \]

Where, \( M_1 \) is the horizontal distance from the sea surface reflection point to the mining vehicle; \( M_2 \) is the horizontal distance from the surface reflectance point to the mining vehicle; \( M_3 \) is the horizontal distance from the seabed reflection point to the mining vehicle. \( D \) is the depth of sea water; \( H \) is the height of mining car; \( H \) is the height of the underwater receiver; \( L \) is the horizontal distance between the mining vehicle and the underwater receiver.

By formula (1), (2), (3) to identify the position of reflection point, transponder with temperature and depth of the sensor measured underwater depth of temperature \( T \) (°C) and \( P \) (atmospheric pressure) value, according to the empirical formula for sound velocity (4) the value of the sea the sound velocity \( C \).

\[ C = 1450 + 4.21 \times T - 0.037 \times T^2 + 1.14 \times (S - 35) + 0.175 \times P \]

Known receiver height \( h \) and mining height \( h \), according to the law of trigonometric function, can determine the reflection point to the mining vehicle's straight line distance \( r_2 \), \( r_1 \) transponder to the reflection point of the straight line distance, transponder to mining vehicle linear distance \( r_0 \), transponder distance to the bottom of the sea a reflection point \( r_3 \), a reflection point to the surface of the sea twice the distance of the reflection point \( r_4 \), submarine secondary reflection point to the mining vehicle distance \( r_5 \), sound source after reflection delays by formula (5) and (6) to calculate.

\[ T_{\text{delay1}} = \left[ (r_1 + r_2) - r_3 \right] \times C \]
\[ T_{\text{delay2}} = \left[ (r_1 + r_3 + r_4) - r_5 \right] \times C \]

Where, \( T_{\text{delay1}} \) is the time delay time of the signal received by the mining vehicle after the sound source is reflected by the sea surface; \( T_{\text{delay2}} \) is the time delay time of the signal received by the mining vehicle after the sound source is reflected once on the sea floor to the sea surface.
The acoustic transmission path of the mining vehicle is larger than that of the direct sea surface reflection. Therefore, only multipath interference of direct reflection path simulation is needed. It is assumed that the horizontal distance $L$ from the mining truck to the receiver is equal to 1,000 meters, the installation height of the signal source of the mining truck is equal to 3 meters, and the height $H$ of the base array is equal to 1 meter. The relationship between the distance (depth) from the signal source of the mining truck to the water surface corresponds to the delay of the underwater sound channel, as shown in fig.2. As can be seen from the figure, as the ocean depth increases, the delay deviation between the direct water acoustic signal and the reflected water acoustic signal becomes larger and larger.

### Multipath interference analysis

Ocean the multipath interference is mainly produced by the surface and bottom reflection, this section will focus on the bottom of the sea of multipath interference, as shown in figure 3, the bottom of the sea there are three kinds of multipath interference path, one is direct be received after the bottom reflection interference, is two kinds of sound source after the sea after a reflection to the bottom of the sea be accepted after the second reflection interference, a third is sound source after the seabed sediment of a reflection, then through the interference of surface reflection. The third type of transmission path is far away and has no effect on acoustic positioning. Therefore, the position formula of three reflection points can be established:
\[ M_4 = \frac{H \times L}{H + h} \]  

\[ M_5 = \frac{2L \times D^2 - D \times H \times h}{2D^2 + (h - H) \times D} \]  

\[ M_6 = \frac{L \times D^2 - H \times L \times h}{2D^2 + (h - H) \times D} \]  

Where: \( M_4 \) is the horizontal distance from the seabed reflection point to the acquisition disturbance device; \( M_5 \) is the horizontal distance from the sea surface refection point to the acquisition disturbance device; \( M_6 \) is the horizontal distance from the seabed reflection point to the acquisition disturbance device.

\[ \text{Surface of the sea} \quad M_5 \quad \text{Bottom of the sea} \]

\[ \text{Transponder} \quad \text{Mining vehicle} \]

\[ \text{Z} \quad \text{X} \quad \text{Y} \]

\[ \text{Figure 3. Submarine multipath interference schematic} \]

Determine the position of the reflection point \( M_4, M_5, M_6 \) through triangle formula to calculate a solution: the seabed reflection point to the linear distance acquisition disturbance device \( r_6 \), transponder to bottom reflection point linear distance \( r_7 \), disturbance device, the transponder to the acquisition of linear distance \( r_0 \), the transponder to the bottom of the sea a reflection point distance \( r_10 \), a reflection point to the surface of the sea, the second reflection point \( r_8 \), the distance to the surface of the second reflection point to the distance the \( r_8 \) acquisition disturbance device, according to the formula (1) and (11) to calculate two kinds of reflection path delay time.

\[ T_{\text{delay,3}} = [(r_6 + r_7) - r_8] \times C \]  

\[ T_{\text{delay,4}} = [(r_6 + r_0 + r_{10}) - r_8] \times C \]  

Where: delay time of \( T_{\text{delay,3}} \) direct seabed reflection; Delay time of secondary reflection after primary reflection of \( T_{\text{delay,4}} \) seabed.
Figure 4. Simulation of delayed deviation between direct and submarine reflected acoustic signals

The distance of the underwater acoustic signal from the sea floor to the sea surface is much greater than that of the direct receiver. When the water depth is 6000m, the journey after the secondary reflection of the sea surface is more than 2x6000m. After the loss of acoustic intensity transmission, it has become relatively weak. The receiver can only receive weak interference signals, which has no effect on the signal processing in the later stage. As shown in figure 4 for the bottom reflection and direct sound signal delay deviation between the simulation, assuming that the height of the acquisition disturbance device is 3 meters, the height of the transponder is 1 m, the nearer the transponder acquisition disturbance device, signal source to the receiver of the direct wave and the greater the distance deviation of after bottom reflection of sound waves, such as mining vehicle to the transponder horizontal distance \( L \) is equal to 5 meters, difference of 1.02 meters, the deviation of 1.52 ms delay, horizontal distance increases to 100 meters, the corresponding delay deviation of 0.08 ms. Therefore, the acoustic communication system needs to have strong anti-interference ability, otherwise, the positioning system will not work properly.

4. Background noise analysis of mining trucks
Due to the cost and necessity, the background noise of the mining truck was tested only in the shallow water field. Under the 8 test conditions in table 1, the power spectrum of the running noise of the harvester was measured as shown in figure 5 to 12. "D =" represents the distance from the collector to the standard hydrophone; "2 motor /2 pump" represents hydraulic motor motor and suction pump; "Stop/advance" represents the movement of the collector; The "standard listening (-203db)" represents the noise spectrum measured by the standard hydrophone, and the sensitivity is -203dB; The "measuring hydrophone" represents the resonant noise of the collector.

Figure 5. Condition 1  
Figure 6. Condition 2  
Figure 7. Condition 3
**Table 1. List of test conditions**

| Number | Test | Gain | Running state |
|--------|------|------|---------------|
| Conditions 1 | 25m | 50 | Start the motor, stop, and mark -203db |
| Conditions 2 | 25m | 50 | Start motor, start 2 pumps, stop, standard listen -203dB |
| Conditions 3 | 25m | 50 | Start motor, start 2 pumps, stop, standard listen -203dB |
| Conditions 4 | 25m | 200 | Start motor, start 4 pumps, stop, standard listen -203dB |
| Conditions 5 | 25m | 200 | Start motor, start 4 pumps, forward, standard listen -203dB |
| Conditions 6 | 20m | 500 | Start motor, start 4 pumps, forward, standard listen -203dB |
| Conditions 7 | 25m | 500 | Start motor, start 4 pumps, forward, standard listen -203dB |
| Conditions 8 | 10m | 500 | Start motor, start 4 pumps, stop, standard listen -203dB |

Test results show that the set of harvesters in running noise and has no obvious change under different working conditions (error is about 3 dB), you can see from the graph, the collector machine noise has an obvious characteristics: 22.3kHz, 42.5kHz and 47kHz frequency of three point exist strong advantage, with the "test condition A = 200, d = 25m add 4, 2 motor pump start-up, forward, standard - 203 dB" power spectrum diagram calculation:

According to the sonar equation, set the spectral intensity of mining car noise as $SL$, then:

$$SL = 20\log_{10} \frac{25 + (-203)}{200} + 20\log_{10} 200 = -50$$

$SL = 135dB$

The maximum spectral level reaches 135dB.

It can be seen that the noise intensity of the harvester is very strong and the spectrum distribution is wide. The noise intensity exceeds the positioning signal intensity of the mining truck end. If no measures are taken, the acoustic system will not work properly. There is strong colored background noise during the operation of the harvester, and the noise has strong line spectrum at some frequency points. The overall frequency band of the noise is relatively wide, and it is likely to drown the locating
sound source signal, so that the receiver cannot normally receive the underwater sound signal of the submarine transponder. In addition, under different working conditions, signal amplification factor, distance and other parameters, the noise changes will not be too large, which means it is impossible to change the noise characteristics by changing the working state and mode of the harvester to meet the requirements of the positioning system.

5. Anti-interference measures
The communication interference of large depth acoustic receiver mainly comes from the radiation noise of harvester and reflection noise of multi-path interference of sea water. These two kinds of noise interference cannot be avoided or weakened. Only by optimizing and improving the anti-interference ability of acoustic system itself can the reliability of the system be improved. There are two methods to eliminate the influence of noise on the work of the system. Firstly, the processing methods of the acoustic signals received by the receiver transducer, such as fixed amplification, bandpass filtering, time gain control (TVGC), width and amplitude discrimination and digital filtering are adopted. In addition, there are ways to get around the source, such as changing the underwater sound coding method emitted by the signal source and the new communication transmission system.

(1) Frequency coding
So-called frequency coding, that is, using the frequency of different element random combination represents a specific information, this kind of coding way has not repetitive, multiplicity of interference on the time of the direct signal broadening signal is still with the effective signal coding sequence of the same, therefore, this approach can greatly improve the performance of multiplicity resistant effect.

As shown in figure 13, synchronous to the signal, signal launch underwater acoustic communication signal \((f_0 f_1 f_2)\), and start receiving underwater acoustic signal receiver, after a period of time delay, the receiver receives the effective \((f_0 f_1 f_2)\), will also receive the multiplicity interference of underwater acoustic signal \((f_0 f_1 f_2)\), after analysis of the signal processing, the instruction information obtained has uniqueness, acoustic system not receiving the wrong instruction and produce false action.

(2) Communication and transmission system
Communication and transmission system is the core of acoustic system, which belongs to the data transmission carrier of acoustic system. As shown in figure 14, the schematic diagram of communication system is implemented as follows:

Step 1. After the signal source is in effect at the falling edge of synchronization signal, it immediately issues the instruction code \(S_1\) of underwater sound signal;

Step 2. After each transponder \(X\) has passed \(T_X\) time, it receives signal instruction code \(S_1\). After delay of \(T_\Delta\), the first transponder signal \(A_{1X}\) is sent.
Step 3. After the next synchronous signal is lowered, each transponder $X$ will immediately send a second transponder $A_{2X}$.

Step 4, a receiver to receive signals instruction code $S1 \ A_{1X}$, several groups of first response signal and a second response signal after $A_{2X}$ available source and receiver to the transponder signal transmission time $X \ T_X$ and $T_{XF}$, therefore a distance information can be set for the transponder $X$ to source $l_X$ and distance between receiver and transponder $X \ l_{XF}$, can calculate the coordinate point target and receiver.

![Communication transmission schematic diagram](image)

**Figure 14.** Communication transmission schematic diagram

The communication transmission system in strict accordance with the synchronous signal transmitting, solved the polling response caused by time delay, at the same time, delay time $T_X$ is included in the transponder two response time ($T_0-T_X-\Delta$), acoustic transmission paths, identity, thus can reduce the influence of different sound velocity gradient on the positioning accuracy.

6. Conclusion

The acoustic interference of mining vehicles not only affects the reliability of the equipment, but also reduces the efficiency of engineering operation and even damages the equipment. In order to achieve both efficiency and quality, it is necessary to fully consider the interference between equipment in advance.

Solution to the interference is first find the interference source, this paper focus on the surface of the sea multipath interference and mining vehicle running noise were analyzed, and the understanding of jamming signal intensity and frequency distribution, which can effectively eliminate the influence of interference frequency coding method and positioning communication transmission system, the prototype test of late has the vital significance.

Acknowledgments

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