Development of Ultrasonic Multiple Access Method by the M-sequence code

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1. Introduction
The sensory processing in the robot is always disturbed by the ubiquitous presence of noises. Robots using active sonar sensing systems for tasks of location and echolocation face this problem severely because of the presence of signals from neighboring conspecifics (robots). In the presence of conspecifics, the plural robots need to employ an ultrasonic multiple access method (UMAM) to avoid masking of the other users’ signals.

In this paper we propose and investigate a new UMAM against the conspecific interference, which adaptively identifies the time-varying ultrasonic transmission characteristics of individual robots in the plural robots system. Since the UMAM can regenerate the replicas of the undesired robots’ signals in the robot by using known M-sequences of every user, it is possible to eliminate conspecific interference by subtracting the replicas from the received signal. Therefore, the UMAM makes it easy to detect the direction and distance using an active sonar system, and may increase application fields of the robots.

2. UMAM Processing
The different M-sequences(C) are assigned to individual sonar systems, and the received signal includes all multiplexed ultrasonic signals, the desired signal and the undesired signal. The important informations for ultrasonic transmission, the traveling time and the impulse response(h) of the ultrasonic pulses, cannot be obtained from such multiplexed signals with accuracy. In this method, the nth received signal $Z_n$ can be presented in the next form

$$Z_n = h_{n,n} + \sum_{n=1}^{m,n \neq m} h_{m,n} + N$$

where

$$h_{m,n} = h_m \otimes h_n,$$

$$\theta_{m,n} = C_m \otimes C_n.$$  

In Eq. 1, the first term of the right-hand side indicates the desired ultrasonic signal, the second term, the other jamming ultrasonic signals, third term, the noise component(N).

Figure 1 shows the processing of the proposed 1th UMAM system. The UMAM consists of three steps, estimation, cancellation and demodulation. In the first step, the correlator with $C_x$, the demodulation, the preset threshold and the spreading generate the replica of a preliminary jamming interference results $\hat{h} m, n \hat{\theta} m, n$. In order to estimate all the jamming interference, the correlators for all the other $C_n$ (n = 2,3,···,m), where the number is m – 1, are prepared. The correlator has two outputs. One is used to demodulate the amplitude information. The other is directly lead to the spreading. And using the preset threshold, the jamming interference position (consist of the travel time and the impulse response h) is obtained. In the second step, the signal is spread by the same M-sequences $C_n$. Outputs from all the spreadings are added. The result is used to cancel the jamming interference. In the final step, after estimation and cancelation, the signal is despread again by the correlator with desired M-sequence($C_1$) and demodulate the amplitude information. In this processing, depending on the preset value of the threshold, the error probability of estimation would change.

3. Experiment
Four broadband tweeters are used as the ultrasonic transmitting source (approximately 40 kHz, $f_0$), and a 1/4-inch electrostatic condenser microphone is used as the receiver. The received signals are digitally recorded on a 16-bit PCI board. The received signals are sampled at 156 kHz (4$f_0$). The four selected degree-7
M-sequence codes, M203, M211, M217 and M247, are applied in the four tweeters.

4. Results

Figs. 2, 3 show the despread signals with the conventional method and with the UMAM processing respectively. Each signal (M-sequence ultrasonic pulse) was transmitted to the receiver in turn with given delay times, $\delta t \approx 0.38$ ms (60 sampling points). Each transmitted signal was overlapping and interfering each other. From Figs. 2, 3, it is noted that the SN ratio was improved by the UMAM processing. Even if there might be errors in the estimation step depending on the preset threshold, the major of jamming interference could be abated in the cancellation step. Therefore, the proposed UMAM processing can improve the SN ratio in comparison with a conventional method and, even when four systems are simultaneously operating.

5. Conclusion

We proposed a new UMAM processing and evaluated its effect in the case of four systems simultaneous operation. And from the experimental results the UMAM was shown to be useful in the simultaneous control of plural systems. However, the effect of the UMAM processing would be depending on the preset threshold level in the estimation step. Hereafter, we will continue to study for such issues in future.

Reference