Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7703606

INTERFERENCE SUPPRESSION OF UNDERWATER ACOUSTIC MULTI-INPUT MULTI-OUTPUT SYSTEM BY TIME REVERSAL TECHNOLOGY

Kanne Naveen and Dr. Amol Kumbhare
Department of Electronics & Communication Engineering, Dr. A. P. J. Abdul Kalam University, Indore (M. P.) India -452010
Corresponding author Email: kanne.naveen@gmail.com

Abstract: Through the analysis of inter-code interference and concentric interference in Time Inverter (TRM) MIMO system, the application potential of TRM technology in underwater acoustic MIMO system is discussed. A common TRM MIMO system interference composition expression is obtained, and the interference of TRM MIMO system is calculated for the typical shallow seawater channel, and the relationship between the interference suppression ability of TRM technology to MIMO system itself and the parameters such as the formation structure, channel structure and transmission signal form is studied. Comparing the calculation results of the letter-stem ratio with the results of the signal-stem ratio in the outdoor wireless channel TRM MIMO, and with more abundant multi-paths in the underwater acoustic channels with a smaller attenuation coefficient, TRM can obtain better spatial focus, so that the trunk in the underwater acoustic TRMMIMO channel is larger than in the outdoor wireless channels. It can be concluded that the inhibition ability of TRM technology to interference with underwater acoustic MIMO system mainly depends on the richness of multi-path, the number of condones of receiving, burst spacing and time reversal.
Keywords: OFDM; bidirectional multi-relay; power distribution; subcarrier pairing.

1. INTRODUCTION

Time reversal, also known as phase conjugation in the frequency domain, is based on the spatial reciprocity and time symmetry of the wave equation in a static medium. It has good spatial focus and pulse in strong reverberation environment compression characteristics. The spatial focus of time reversal means that it can refocus the incident sound field after time reversal at the position of the original probe signal in a medium no matter how complicated the space propagation is. In high-speed underwater acoustic communication, the time spreading effect of the channel will bring serious inter-symbol interference, so many underwater acoustic communication researchers are interested in time reversal technology. They have done a lot of theory and research on the space-time focusing and statistical stability of time reversal in the underwater acoustic channel, as well as the performance comparison with other equalization technologies in the SISO (single-input-single-output) underwater acoustic communication system. Experimental work [1～10]. In addition, the limited bandwidth and abundant multipath propagation of underwater acoustic channels make MIMO technology have great application potential in increasing the rate of underwater acoustic communication. The spatial focus of time reversal technology is multiple channels with different spatial positions in the MIMO system. Simultaneous communication provides the possibility, which can greatly reduce the calculation amount of space-time signal processing. The combination of time reversal and

MIMO technology has the following advantages: 1) the spatial focus of time reversal suppresses co-channel interference in the MIMO system; 2) the temporal focus of time reversal suppresses inter-symbol interference;

3) Compared with the traditional channel equalization technology, the time reversal technology requires a very low amount of calculation and is easy to implement. In [11], a coherent MIMO time reversal communication experiment was carried out, which verified the possibility of simultaneous communication of 2 to 3 channels at different depths through time reversal technology in a shallow sea with a depth of 110m and a distance of 9km. The document [[12] uses outdoor measurement data to study the feasibility of time reversal technology applied to 8×4 radio MIMO systems, through channel RMS (root mean square) delay expansion and instantaneous signal-to-interference ratio (expressed by RSI) The ability of time reversal technology to suppress inter-symbol interference and co-channel interference is studied. The main purpose of this paper is to discuss the potential of applying time reversal technology in underwater acoustic MIMO channels. First, analyze the interference composition of the general TRM MIMO system itself, and then study the performance and performance of the TRM MIMO system in a typical shallow sea acoustic channel. Some important system parameters such as the relationship between the number of receiving and transmitting array elements, the distance between array elements, communication distance, and system bandwidth. The dynamic effect of the ocean is not considered here, and it is considered that the channel forward propagation and the time-reversed backward propagation are quasi-static.

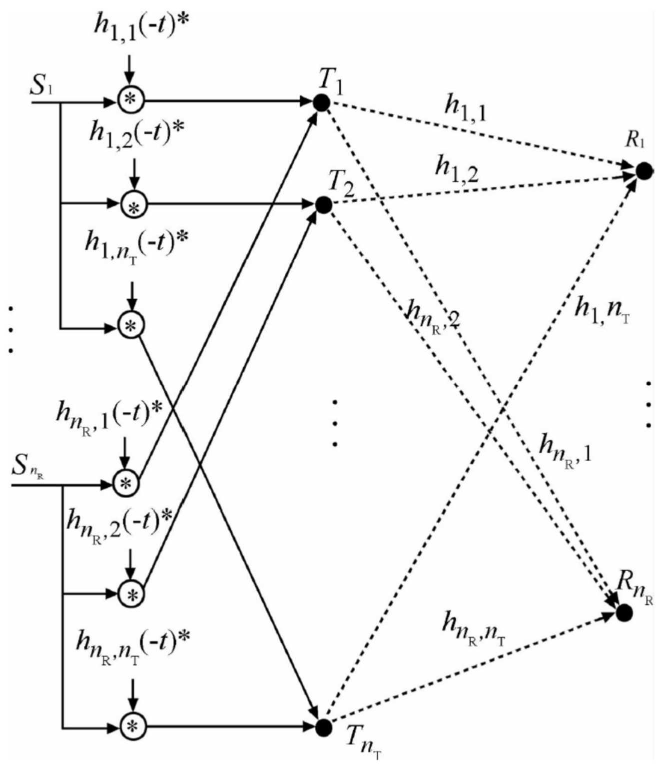


Figure 1: Performance analysis of time reversal MIMO communication system

2. Performance Analysis of Time Reversal MIMO System

2.1 System Components

For active and passive time-reversal underwater acoustic communication systems, their performance can be analyzed by the system structure shown in Figure 1. Where $\{S_1, \dots, S_{n_R}\}$ are n_R sources, $\{T_1 \dots T_{n_T}\}$ are n_T transmitting elements, $\{R_1, \dots, R_{n_R}\}$ are n_R receiving elements, $h_{j,i}$ are the i-th The channel response between the $i(i = 1{:}\, n_T)$ transmitting element and the $j(j = 1{:}\, n_R)$ receiving element. It is assumed here that the number of transmitting array elements n_T is equal to the number of time reversal array n_{TR} elements, and the number of receiving array elements n_R is equal to the number of communication channels n_{CH}.

2.2 General time reversal MIMO system interference composition

Corresponding to the time reversal MIMO communication system shown in Figure 1, the signal $r_j(t)$ of the j-th receiving element can be expressed as

$$r_j(t) = \sum_n S_{jn} H_{j,j}(t - nT) + \sum_{m=1, m\neq j}^{n_R} \sum_n S_{mn} H_{j,m}(t - nT) + n_j(t) \qquad (1)$$

where, S_n is the transmitted information sequence, T is the width of the symbol, $H_{j,i}(t)$ is the channel response between the i-th source si and the j-th receiving element, and n_j is the j-th receiving element Additive noise, in order to analyze the relationship between the performance of the time reversal MIMO system and the array and channel parameters, the influence of additive noise is not considered. Sampling $r_j(t)$ at time $t = kT$ can be obtained

$$r_j(kT) = S_{jk} H_{j,j}(0) + \underbrace{\sum_{n\neq k} S_{jn} H_{j,j}((k - n)T)}_{ISI} + \underbrace{\sum_{m=1, m\neq j}^{n_K} \sum_n S_{mn} H_{j,m}((k - n)T)}_{CI} \qquad (2)$$

Due to the spatial focusing of the time reversal technology, the signal r_j of the j-th receiving array element is mainly composed of the signal of the j-th transmitting source S_j. Therefore, the signal of the j-th receiving array element can be used as the signal for the j-th transmitting element. The basis for the source to make a decision, so that the total interference can be expressed as

$$I = \frac{1}{H_{j,j}(0)} \left(\sum_n S_{j,n} H_{j,j}(nT) + \sum_{m=1, m\neq j}^{n_R} \sum_n S_{mn} H_{j,m}(nT) \right) \qquad (3)$$

It can be seen that the interference to the sampled value of the j-th receiving array element at time k consists of two parts, one part comes from the sampled value of the same source S_j at time $n \neq k$, which is called inter-symbol interference (ISI) , the other part comes from the sourceS_i $(j \neq i)$, which is called co-channel interference. When the number of communication channels is 1, there is only inter-symbol interference. When the number of communication channels is greater than 1, the interference in each channel is calculated separately and the average value is taken. Assuming that the sequence $\{S_n\}$ is not correlated, the source S_i and S_j $(i \neq j)$ are not correlated with each other and have the same transmit power,$E[S_n^2] = \sigma_s^2$, then

$$E[I^2] = \frac{1}{|H_{j,j}(0)|^2}\left(\sum_{n\neq 0}\left|H_{j,j}(nT)\right|^2 + \sum_{m=1,m\neq j}^{n_R}\sum_n\left|H_{j,m}(nT)\right|^2\right)\sigma_s^2 \quad (4)$$

Consider the baseband transmission system, then

$$H_{j,i}(t) = \sum_{k=1}^{n_T} g(t)\otimes h_{j,k}(-t)^*\otimes h_{i,k}(t) \quad (5)$$

where, $g(t)$ is the baseband signal, and the raised cosine pulse is selected in this article. It can be seen from equations (4) and (5) that in a time-reversed MIMO system, the ability to suppress interference depends on the number of time-reversed array elements n_{TR}, the number of simultaneous communication channels n_{CH}, and the number of baseband signals Bandwidth BW, and channel response h. Both pulse broadening and sidelobe leakage will cause inter-symbol interference. For discrete multipath channels, assuming that the amplitude of each multipath is a_i and the delay is τ_i, the channel response can be expressed as

$$h(t) = \sum_i a_i\delta(t-\tau_i) \quad (6)$$

After a single element time reversal

$$h(t)\otimes h(-t)^* = \sum_i a_i\delta(t-\tau_i)\sum_j a_j^*\delta(t+\tau_j)$$
$$= \sum_i|a_i|^2\,\delta(t) + \sum_{i,i\neq j}\sum_j a_i a_j \times \delta\left(t-\tau_i+\tau_j\right) \quad (7)$$

2.3 Performance Analysis of Underwater Acoustic Time Reversal MIMO System

The following discusses the performance of time-reversal MIMO technology in a typical shallow water acoustic channel. Using the virtual source theory [13,14], in the underwater acoustic channel, the channel response between the i-th transmitting element and the j-th receiving element can be written as

$$h_{j,i}(w) = \sum_{n=0}^{\infty}(-1)^n\left\{\left[R_B\left(\theta_{n_1}^{j,i}\right)\right]^n\frac{e^{imkR_{n_1}^{j,i}}}{R_{n_1}^{j,i}} + \left[R_B\left(\theta_{n_2}^{j,i}\right)\right]^{n+1}\frac{e^{imkR_{n_2}^{j,i}}}{R_{n_2}^{j,i}} - \left[R_B\left(\theta_{n_3}^{j,i}\right)\right]^n\frac{e^{imkR_{n_3}^{j,i}}}{R_{n_3}^{j,i}} - \left[R_B\left(\theta_{n_4}^{j,i}\right)\right]^{n+1}\frac{e^{imkR_{n_4}^{j,i}}}{R_{n_4}^{j,i}}\right\} \quad (8)$$

where, $k = w/c$ is the wave number, here we assume a constant speed of sound, $c = 1500m/s$, $R_{n_1}, R_{n_2}, R_{n_3}, R_{n_4}$, the expression can refer to literature [13], and write it in the form of time domain

$$h_{j,i}(t) = \sum_{n=0}^{\infty}(-1)^n \left\{ \left[R_B\left(\theta_{n_1}^{j,i}\right)\right]^n \frac{\delta\left(t-\frac{R_{n_1}^{j,i}}{c}\right)}{R_{n_1}^{j,i}} + \left[R_B\left(\theta_{n_2}^{j,i}\right)\right]^{n+1} \frac{\delta\left(t-\frac{R_{n_2}^{j,i}}{c}\right)}{R_{n_2}^{j,i}} - \left[R_B\left(\theta_{n_3}^{j,i}\right)\right]^n \frac{\delta\left(t-\frac{R_{n_3}^{j,i}}{c}\right)}{R_{n_3}^{j,i}} - \left[R_B\left(\theta_{n_4}^{j,i}\right)\right]^{n+1} \frac{\delta\left(t-\frac{R_{n_4}^{j,i}}{c}\right)}{R_{n_4}^{j,i}} \right\} \quad (9)$$

TABLE 1: RELATIONSHIP BETWEEN R_{SI} AND THE NUMBER OF MULTIPATHS

$(z_{t_0} = 6m, z_{r_0} = 6m, d_t = 4m, d_r = 4m, n_{TR} = 10, n_{CH} = 4, D_W = 60m, r_{r_0} = 1km)$

$(a) v = 0$

Number of Multipaths	2	4	6	8	10	12	14	16	18	20
R_{SI}/dB	11.79	17.132	21.930	24.927	26.266	28.637	30.995	32.403	33.388	35.753
(b) $v = 5$										
Number of Multipaths	2	4	6	8	10	12	14	16	18	20
R_{SI}/dB	16.800	26.707	26.487	26.328	26.418	26.176	26.908	26.11	26.216	26.685

The bottom reflection coefficient can generally be assumed to be exponential decay $R_B(\theta) = e^{-v\theta}$, where$\theta$ Is the glancing angle of the sound ray relative to the bottom. Using equations (4), (5), (7), and (9), some numerical calculations are carried out on the interference suppression capability of the underwater acoustic time reversal MIMO system.

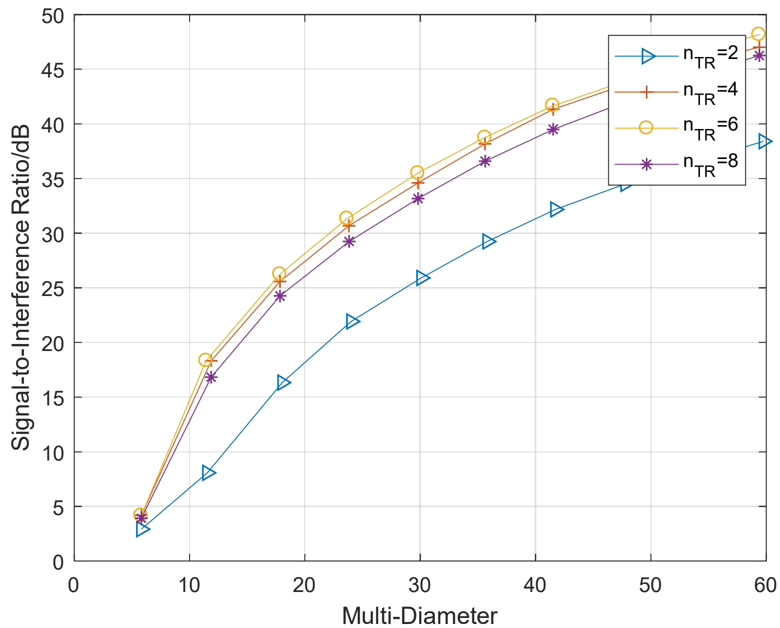
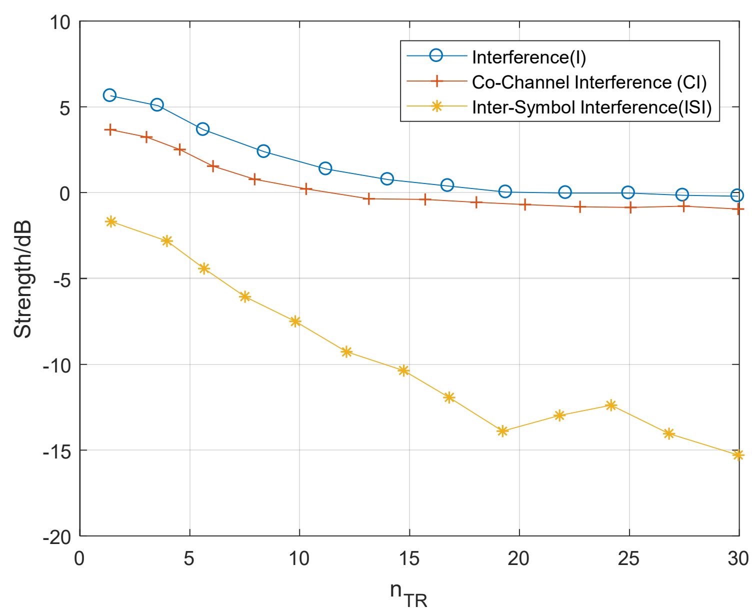


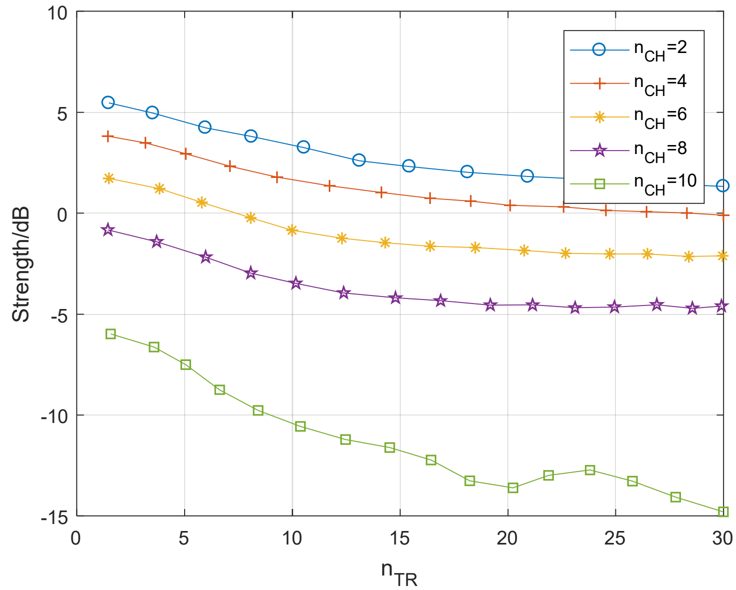
FIGURE 2: Relationship between the signal-to-interference ratio and the number of time reversal array elements with $v = 0$ ($z_{t_0} = 6m, z_{r_0} = 6m, r_{t_0} = 0, n_R = 4, d_t = 4m, d_r = 4m, D_w = 60m, r_{r_0} = 4km$)

3. NUMERICAL CALCULATION RESULTS AND BRIEF ANALYSIS

3.1 Signal-to-Interference Ratio



(a) Two receiving elements



(B) Multi-Receiving Array Element

FIGURE 3: Relationship between interference and the number of time-reversal array elements ($B_W = 6kHz, z_{t_o} = 6m, r_{t_0} = 0, \alpha = 0, d_t = 4m, d_r = 4m, D_w = 60m, R = 9km, v = 6, T = 0.125ms, n_M = 30$)

First, in order to have some perceptual understanding of the time compression and spatial focus of the time reversal technology, the channel impulse response after time reversal is described in Figure 2. In formula (5), when $g(t) = \delta(t)$, the time-reversed channel impulse response can be obtained. Take the MIMO system as an example, the two cases where the seabed attenuation is 0 ($v = 0$) and not 0 ($v = 5$) (take the multipath number 40) are respectively described. It can be seen from Figure 2 that when $v = 0$ and $v = 5$, the channel response $H_{1,1}$ between the first source and the first receiving element is close to$\delta(t)$, indicating that the time reversal technology has a very It has a good time compression effect, and has a higher peak signal-to-interference ratio compared with $H_{1,2}$ (R_{SI} at $v = 0$ and $v = 5$ are 33.0179 dB and 31.4932 dB, respectively), so the reception of the MIMO system is reversed in time At the end, the signal of the first receiving element can be regarded as the basis for making a judgment on the first source.

Since R_{SI} is closely related to the number of multipaths in the channel, in order to compare with the results in [12], the R_{SI} of the TRM MIMO system with 8 transmitting elements and 2 receiving elements is calculated, and v 0 When and $v = 5$, the calculation results of R_{SI} under different number of multipaths are listed in Table 1. It can be seen from Table 1 that with the increase of the number of multipaths, the co-channel interference suppression ability of the time reversal system gradually increases, but the growth trend is slightly different for the case of no attenuation and attenuation on the seabed. It can be seen from Table 1(a) that for the seabed without attenuation, as the number of multipaths increases, RSI will always increase. This is because the attenuation of each multipath by the seabed is 0. After multiple seabed reflections, there is still no energy loss; for the attenuated seabed, in Table 1(b), as the number of multipaths increases, R_{SI} will gradually become saturated. When the number of multipaths is greater than 20, R_{SI} will remain basically unchanged. This is because the seabed has reflection losses. When the sound rays are reflected from the seabed for many times, the energy gradually attenuates, and these attenuations are related to their glancing angles relative to the seabed. The greater the glancing angle, the greater the attenuation, so it contributes to interference suppression. The sound rays with a small glancing angle are the main ones. In literature [12], when 8 time-reversed array elements, 2 receiving array elements, and a distance of 300m, R_{SI} is 18dB, which is equivalent to the case where the number of multipaths is 8 in Table 1(a). Considering the situation in Table 1(b), the number of multipaths is less than 8. In addition, in the calculation in Table 1, the distance between the two receiving array elements is 2m, and in the literature [12] when the receiving array element spacing is 2m, the R_{SI} is 15.6dB, so it can be considered that the attenuation on the seabed is small. The shallow water acoustic channel has more multipaths than outdoor wireless channels, so that better interference suppression capabilities can be obtained in the time reversal MIMO system. In addition, since the number of time-reversed array elements also has an important impact on R_{SI}, the relationship between R_{SI} and TRM array elements under different multipath numbers is depicted in Figure 3. It can be seen from Figure 3 that when the seabed is when the attenuation is 0, the R_{SI} increases with the increase of the number of multipaths, and a higher R_{SI} can be obtained without a lot of array elements. When the attenuation of the seafloor is not 0, increasing the number of array elements will obtain a higher R_{SI}.

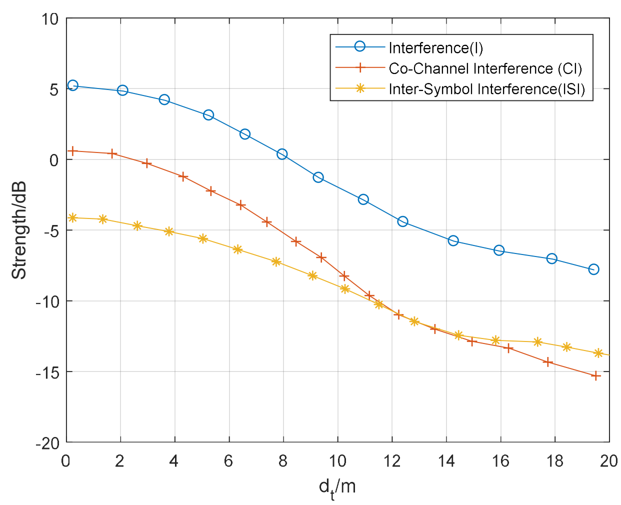


FIGURE 4:.Relationship between interference and the distance between transmitting array elements ($B_W = 6kHz, n_{TR} = 4, n_{CH} = 4, \alpha = 0, d_r = 4m, D_W = 60m, T = 0.255ms, z_{t_0} = 6m, z_{r_0} = 6m, R = 10km, v = 6, n_M = 30$)

3.2 Numerical calculation results of interference in time reversal MIMO system

From equations (4), (5), (7), and (9), it can be seen that the ability to suppress interference in a time-reversed MIMO system depends on some parameters related to the transmitting and receiving arrays, such as transmitting, number, spacing and direction of the receiving array elements, the distance between the receiving and receiving arrays; channel-related parameters such as water depth and bottom reflection coefficient; signal-related parameters such as bandwidth (symbol width), raised cosine roll-off coefficient, etc., these parameters The influence of the interference suppression capability in the time-reversed MIMO system is studied separately. Parameter meaning, n_{TR} is the number of time reversal array elements, n_T is the number of transmitting array elements, n_{CH} is the number of communication channels, n_R is the number of receiving array elements (here $n_{TR} = n_T, n_{CH} = n_R$), n_M multipath number, d_t Transmitting array element spacing, d_r Receiving array element spacing, D water depth, R communication distance, z_{t_0} Depth of the first transmitting array element, z_{r_0} Depth of the first receiving array element, BW signal bandwidth, T symbol width, raised cosine roll-off coefficient, for the raised cosine signal $BW = \frac{1+\alpha}{2T}$.

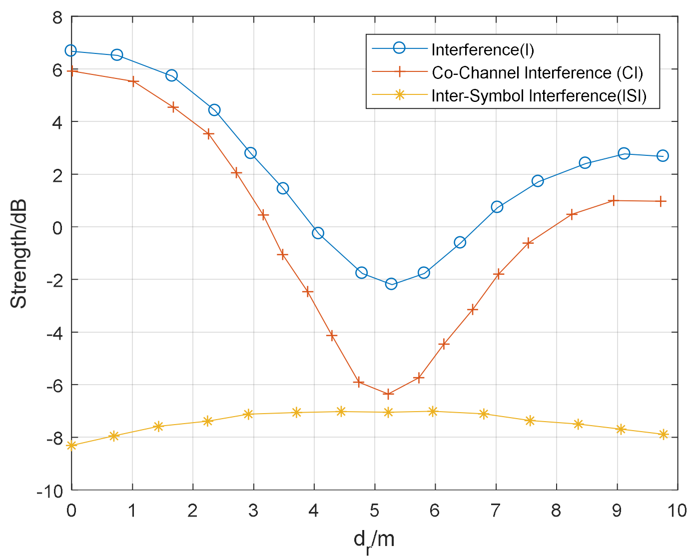


FIGURE 5: Relationship between interference and receiving array element spacing ($B_W = 6kHz, r_{t_0} = 2m, n_{TR} = 4, n_{CH} = 3, \alpha = 0, d_t = 4m, D_W = 60m, T = 0.255ms, z_{t_0} = 6m, z_{r_0} = 6m, R = 10km, v = 6, n_M = 30$)

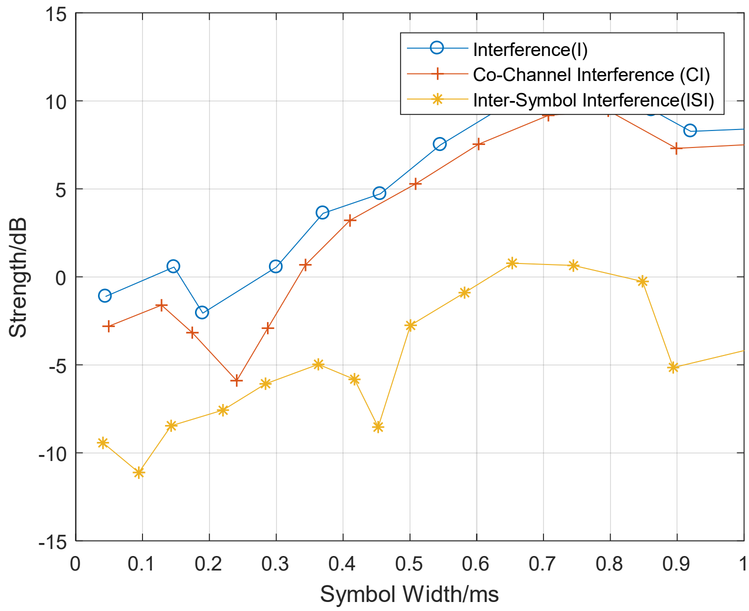


FIGURE 6: Relationship between interference and code width ($n_M = 30, n_{CH} = 4, n_{TR} = 4, v = 6, z_{t_0} = 6m, z_{r_0} = 6m, r_{t_0} = 1m, \alpha = 1, d_t = 4m, d_r = 4m, D_W = 60m, R = 10km$)

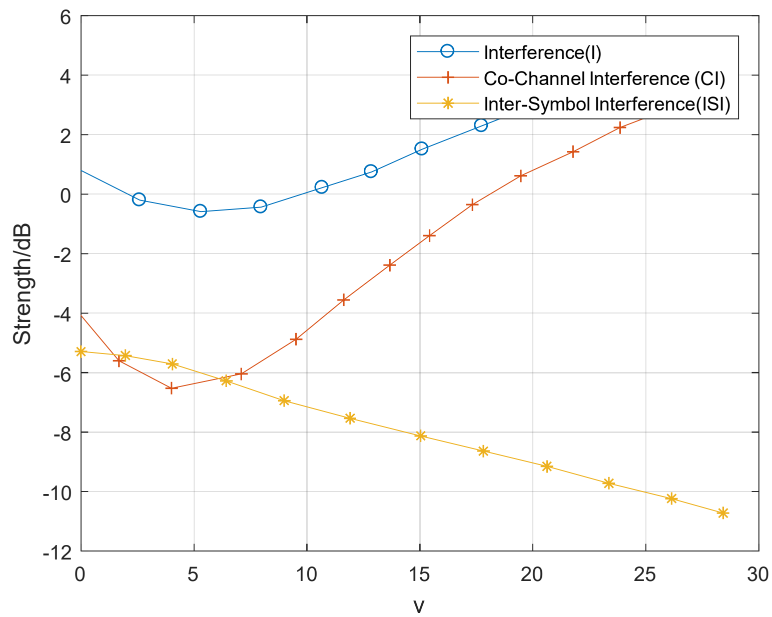


FIGURE 7: Relationship between interference and the attenuation coefficient of the seabed ($r_{t_0} = 1m, n_{TR} = 4, n_{CH} = 4, \alpha = 2, d_t = 4m, d_r = 4m, T = 0.225ms, z_{r_0} = 6m, R = 10km, D_W = 60, n_M = 20$)

3.3 Brief analysis of numerical results

In Figure 3(a), when the number of communication channels is 2, the influence of the number of time-reversed array elements on the interference suppression capability of the TRM MIMO system is described. It can be seen from Figure 3 that both inter-symbol interference and co-channel interference decrease with the increase of the number of time-reversed array elements, but the number of time-reversed array elements has a greater impact on ISI. When the number increases from 1 to 20, ISI will drop by about 10dB, CI will drop by about 4dB, and when the number of elements is greater than 10, CI has basically remained unchanged. In addition, it can be seen from Figure 4 that as the number of time-reversed array elements increases, the contribution of ISI to the total system interference I gradually decreases. The interference of the time-reversed MIMO system mainly comes from co-channel interference. In Figure 3(b), when the number of communication channels is different, the total interference I in the time-reversed MIMO system changes with the number of time-reversed array elements. From Figure 3(b), it can be seen that the total interference I will be Decrease with the increase of the number of time reversal array elements, and increase with the increase of the number of communication channels. When the number of communication channels is 1, increasing the number of time reversal array elements from 1 to 20 can reduce the total interference by about 10dB , And when the number of communication channels is 5, the total interference can only be reduced by about 3dB, so we can see that as the number of communication channels increases, the co-channel interference will increase significantly. Although the time reversal can interfere with the same channel Suppress, but there will still be a certain amount of co-channel interference when the number of communication channels is large.

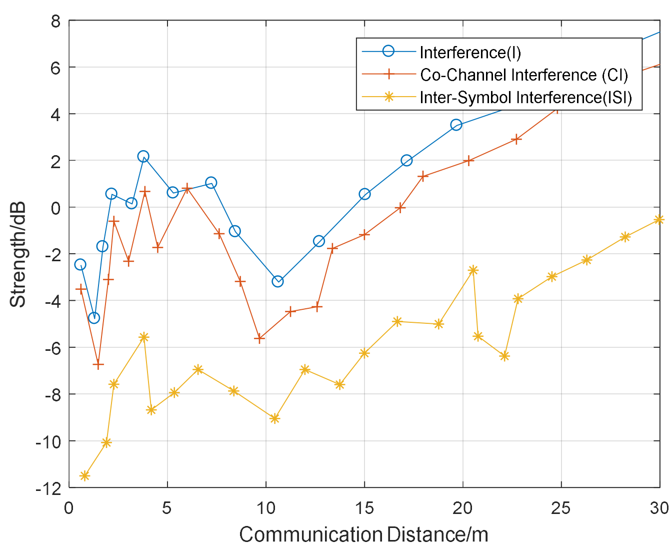
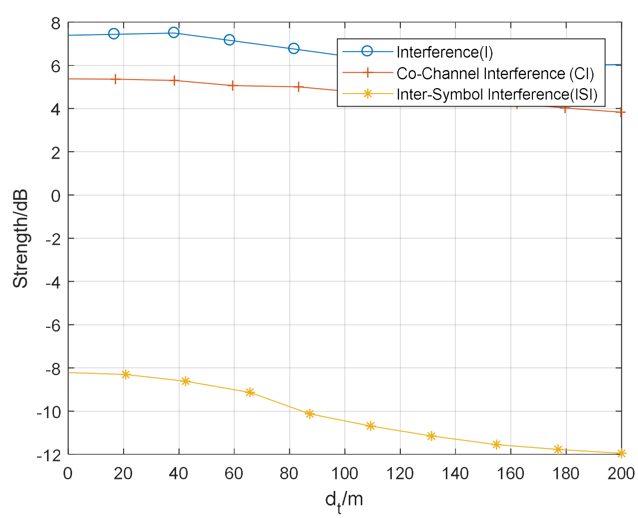


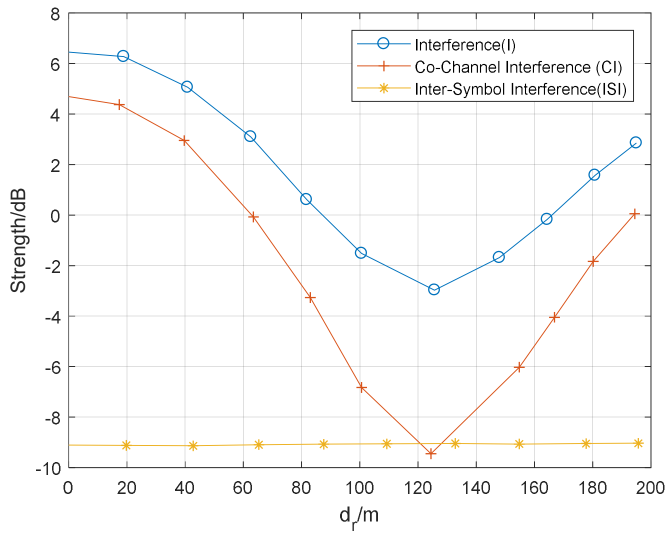
FIGURE 8: Relationship between interference and communication distance ($r_{t_0} = 1m, \alpha = 1, d_t = 4m, d_r = 4m, n_{TR} = 4, n_{CH} = 4, D_W = 60m, z_{t_0} = 6m, z_{r_0} = 6m, T = 0.225ms, v = 6, n_M = 20$)

In Figure 4 and Figure 5, the total interference, inter-symbol interference and co-channel interference in the MIMO system with the number of time-reversed array elements being 3 and the number of communication channels being 2 are calculated respectively with the changes in the distance between the transmitting and receiving array elements. . It can be seen from Figure 4 that both ISI and CI decrease with the increase of the array element spacing at the transmitting end. When the array element spacing is large enough, the reduction of ISI and CI will reach saturation. In the case of the calculation parameters in Figure 4 , When $d_t > 4m$, the change of ISI and CI is very small. It can be seen from Figure 6 that CI decreases with the increase of the receiving array element spacing. When the receiving array element spacing $d_r > 3m$, the decrease of CI becomes very slow. In addition, it can be seen from Figures 4 and 5, that the increase in the distance between the transmitting and receiving elements will reduce the CI, but their impact on CI is slightly different, and the receiving element spacing has a greater impact on CI. , When the receiving array elements are close to each other, it will cause a lot of co-channel interference, and as the distance between the receiving array elements increases, the CI will drop rapidly. This is related to the spatial focusing ability of the time reversal system. Stronger, the faster the co-channel interference decreases as the distance between the receiving array elements increases.

In Figure 6, the impact of the symbol width T on the interference suppression capability of the TRM MIMO system is described. It can be seen from Figure 6 that CI and ISI will increase as the symbol width increases. In the TRM MIMO system, the interference suppression capability will be enhanced as the signal bandwidth increases. Figures 7 and 8 respectively describe the relationship between the TRM MIMO system's own interference and the seabed attenuation coefficient and communication distance. It can be seen from Figure 7 that as the seabed attenuation coefficient increases, the inter-symbol interference will gradually decrease, and the co-channel interference will first decrease slightly and then gradually increase. When the seabed attenuation is large, the total interference of the system will be dominated by the co-channel interference. When $v = 0$, the attenuation of the seabed is zero. At this time, the interference suppression ability of the time reversal MIMO system is the strongest. As the seabed attenuation increases, the interference will increase. The seabed attenuation has an aperture shadow effect, which will cause time reversal. The effective aperture of the array is reduced. However, when $v > 10$, the increase in system interference has tended to be saturated. It can be seen from Figure 8 that as the communication distance increases, CI and ISI increase slightly. This is because as the distance increases, the effective multipath number in the channel will gradually decrease, so the vertical sum of the time reversal system, horizontal spatial focusing ability decreases as the distance increases.



(a)



(b)

FIGURE 9: Relationship between interference and array element spacing (horizontal transmitting and receiving array)($B_W = 5kHz, n_{TR} = 4, n_{CH} = 2, \alpha = 0, D_w = 60m, z_{t_0} = 30m, z_{r_0} = 30m, R = 10km, v = 6$)

Figures 3 to 8 consider the case where both the transmitting and receiving arrays are vertical arrays. In order to compare with the horizontal receiving and transmitting arrays, in Figure 9, the variation of the interference with the distance between the receiving and transmitting array elements is taken as an example. Describes the interference suppression capability of the time-reversal MIMO system when the transceivers are both horizontal arrays. It can be seen from Figure 9 that for the horizontal transceiver array, to achieve the same interference suppression capability as the vertical transceiver array, a larger array element spacing is required. For example, a horizontal array is used at the transmitting and receiving ends at the same time, and the element spacing must be 30-40m. The interference suppression capability with a vertical array spacing of 2 to 3 m is due to the fact that the spatial variability of the shallow water acoustic channel in the vertical direction is much greater than that in the horizontal direction, so the spatial resolution of the channel after the time reversal in the vertical direction will be Much greater than the spatial resolution in the horizontal direction.

4. CONCLUSION

This article first analyzes the interference composition of the TRM MIMO system itself, and then uses the virtual source model to calculate and briefly analyze the changes of the interference with the channel parameters, array parameters and signal parameters by taking the shallow sea horizontal channel as an example. The following conclusions can be drawn :

1) By calculating the SIR of the time-reversed MIMO system in a typical shallow sea channel and comparing it with the results of the SIR in the outdoor wireless channel, it

can be seen that the shallow sea channel with lower seabed attenuation has more abundant than outdoor wireless channels Therefore, the time reversal system can obtain better spatial focusing performance and co-channel interference suppression.

2) Increasing the number of time reversal array elements can enhance the interference suppression capability of the time reversal MIMO system. With the increase in multipath richness, the number of time reversal array elements required to achieve the same interference suppression capability gradually decreases. When the number of channels is large, increasing the number of time reversal array elements can also reduce the total interference of the MIMO system, but there will still be some residual co-channel interference, which needs to be solved by other technologies.
3) Increasing the distance between the receiving and transmitting array elements will significantly enhance the interference suppression capability in the time-reversed MIMO system. Among them, the distance between the receiving array elements has a greater impact on co-channel interference.
4) The water depth and the depth of the transceiver array have little effect on the interference suppression performance in the time reversal MIMO system. The increase in the communication distance will slightly reduce the interference suppression capability, so the interference suppression performance of the time reversal technology in the MIMO system Has a wide range of environmental adaptability.
5) The interference suppression capability of the time reversal MIMO system will decrease as the signal bandwidth increases. Based on the above points, the interference suppression capability of the time reversal MIMO system is mainly determined by the richness of the multipath of the channel.

The richer the multipath, the smaller the number of time reversal array elements and the smaller the receiving and transmitting apertures required to obtain the same interference suppression capability.

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