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Analysis of Three - Channel SW Interference Adaptive Cancellation System

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Abstract. Aiming at the adjacent channel interference problem of short-wave, a model of three-way short-wave interference signals has been established. The interference cancellation of the short-wave interference signal of three adjacent channels is analyzed, and the time-domain characteristics of the adaptive interference cancellation system are simulated. The theoretical and simulation analysis of the adaptive system show that the offset of the bypass signal will be affected when the intermediate signal frequency is biased to one side because of the existence of the intermediate channel bandwidth.

1 Introduction

Due to its simple structure and low cost, the short-wave communication is still widely used in military communications. In the short-wave communication between ships, the multiple transmitters and receivers are usually working on the ship at the same time. When the two are working, the receiving antenna will receive the transmitting signal of the transmitting antenna through coupling, and the signal is received. The antenna is an interference signal that affects the receiver receiving useful signals. Not only will the receiver block, but also will seriously affect the performance of short-wave communication[1]. With the development of adaptive interference cancellation technology, it provides a strong support for solving such problems.

Adaptive interference cancellation technology is an effective way to solve this problem. The previous Widrow B literature has been introduced in detail[2]. For the study of signal interference, we only need to extract the relevant reference signal input from the noise, and then it can be attenuated or filtered out from the useful signal by the relevant system to obtain the useful signal we want. Later, J.Glover studied the adaptive interference cancellation of sinusoidal signals from the perspective of frequency domain.Then people have studied a lot of research on adaptive interference cancellation technology and corresponding performance improvement[3-6].

In this paper, the problem of adjacent channel interference of short-wave signals has been studied. A model of three-way short-wave interference signals has been established, and adaptive interference cancellation technology has been used to suppress interference[7]. In the system simulation process, it is assumed that the interference signal is a narrowband signal, and the influence of the frequency fluctuation of the interference signal in the intermediate channel on the interference cancellation of the adjacent channel signal is theoretically and simulated. In this paper, the steady-state characteristics and cancellation performance of the system are analyzed from the perspective of time domain. Finally, the corresponding simulation results and analysis are given.

2 The system model

The model of adaptive interference cancellation system is shown in fig 1. $I_\gamma(t)$ is the interference signal received by the receiving antenna, $I_\varepsilon(t)$ is the offset error signal, and $I_{si}(t)$ is reference signals obtained through the transmitting antenna and passed through the orthogonal network. The $M_i(t)$ is weights, $O_i(t)$ is the weighted output signal, $O(t)$ is the weighted output composite signal,the k is the system gain, τ *is t*he time constant.

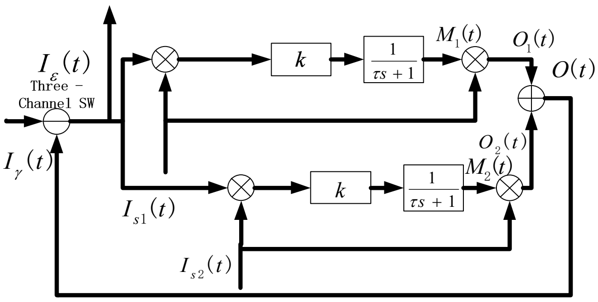

Figure 1. Adaptive interference cancellation system

Let reference signal be

$$I_s(t) = \sum_{i=1}^{3} I_{si}\cos(\omega_i t - \alpha_i) \quad (1)$$

, where I_{si} is the amplitude of the ith signal component of the reference signal, ω_i is the angular frequency, α_i is the initial phase.
and interference signal be

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$$I_\gamma(t) = \sum_{i=1}^{3} I_{\gamma i} \cos(\omega_i t - \phi_i) \quad (2)$$

, where $I_{\gamma i}$ is the amplitude of the ith signal component of the interfering signal, ω_i is the angular frequency of the interfering signal, α_i is the initial phase of the interfering signal.

As can be seen from Figure 1, the offset residual signal can be expressed as

$$I_\varepsilon(t) = I_\gamma(t) - [M_1(t)I_{s1}(t) + M_2(t)I_{s2}(t)] \quad (3)$$

3 Time domain analysis

It can be obtained from Fig. 1 and formula (1) that two orthogonal reference signals are

$$\begin{pmatrix} I_{s1}(t) \\ I_{s2}(t) \end{pmatrix} = \begin{pmatrix} \sum_{i=1}^{3} I_{si} \cos(\omega_i t - \alpha_i) \\ \sum_{i=1}^{3} I_{si} \sin(\omega_i t - \alpha_i) \end{pmatrix} \quad (4)$$

According to the method of[8], the product of reference signal and error signal can be represented as

$$\begin{pmatrix} \delta_1(T) \\ \delta_2(T) \end{pmatrix} = \begin{pmatrix} I_{s1}(t) \\ I_{s2}(t) \end{pmatrix} I_\varepsilon(t) \quad (5)$$

$$= \begin{pmatrix} \sum_{i=1}^{3} I_{si} \cos(\omega_i t - \alpha_i) \sum_{j=1}^{3} I_{\gamma j} \cos(\omega_j t - \phi_j) \\ \sum_{i=1}^{3} I_{si} \sin(\omega_i t - \alpha_i) \sum_{i=1}^{3} I_{\gamma j} \cos(\omega_j t - \phi_j) \end{pmatrix}$$

$$- \begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix} \begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} \quad (6)$$

Where, d_{11}, d_{12}, d_{21}, and d_{22} are

$$d_{11} = \sum_{i=1}^{3} I_{si} \cos(\omega_i t - \alpha_i) \sum_{j=1}^{3} I_{sj} \cos(\omega_j t - \alpha_j)$$

$$d_{12} = \sum_{i=1}^{3} I_{si} \cos(\omega_i t - \alpha_i) \sum_{j=1}^{3} I_{sj} \sin(\omega_j t - \alpha_j)$$

$$d_{12} = \sum_{i=1}^{3} I_{si} \sin(\omega_i t - \alpha_i) \sum_{j=1}^{3} I_{sj} \cos(\omega_j t - \alpha_j) \quad (7)$$

$$d_{12} = \sum_{i=1}^{3} I_{si} \sin(\omega_i t - \alpha_i) \sum_{j=1}^{3} I_{sj} \sin(\omega_j t - \alpha_j)$$

After considering the input-output relationship of the system, the differential equation of weights can be expressed by the first-order differential equation as

$$\frac{d}{dt}\begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} + \begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} = k \begin{pmatrix} \delta_1(T) \\ \delta_2(T) \end{pmatrix} \quad (8)$$

Substituting equation (6) into equation (8)

$$\frac{d}{dt}\begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} + \begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} = k$$

$$* \begin{pmatrix} \sum_{i=1}^{3} I_{si} \cos(\omega_i t - \alpha_i) \sum_{j=1}^{3} I_{\gamma j} \cos(\omega_j t - \phi_j) \\ \sum_{i=1}^{3} I_{si} \sin(\omega_i t - \alpha_i) \sum_{i=1}^{3} I_{\gamma j} \cos(\omega_j t - \phi_j) \end{pmatrix}$$

$$- \begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix} \begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} \quad (9)$$

Because the i and the j are uncertain in the above formula, the differential equation is a time-varying differential equation and is not easy to solve. Here, the simplification analysis is performed from its average model. Taking the average of equation (9) means removing the amount of communication, removing the amount of communication and reducing it to

$$\frac{d}{dt}\begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} + \begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} = \frac{k}{2} \begin{pmatrix} \sum_{i=1}^{3} I_{si} I_{\gamma i} \cos(\phi_i - \alpha_i) \\ \sum_{i=1}^{3} I_{si} I_{\gamma i} \sin(\phi_i - \alpha_i) \end{pmatrix}$$

$$- \frac{k}{2} \sum_{i=1}^{3} I_{si}^2 \begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} \quad (10)$$

Solving the equation, we find

$$\begin{pmatrix} M_1(t) \\ M_2(t) \end{pmatrix} = \begin{pmatrix} M_1(0) \\ M_2(0) \end{pmatrix} e^{-(1+\frac{k}{2}\sum_{i=1}^{3} I_{si}^2)t} + \frac{k}{1 + \frac{k}{2}\sum_{i=1}^{3} I_{si}^2}$$

$$* \begin{pmatrix} \sum_{i=1}^{3} \frac{I_{si} I_{\gamma i}}{2} \cos(\phi_i - \alpha_i) \\ \sum_{i=1}^{3} \frac{I_{si} I_{\gamma i}}{2} \sin(\phi_i - \alpha_i) \end{pmatrix} (1 - e^{-(1+\frac{k}{2}\sum_{i=1}^{3} I_{si}^2)t}) \quad (11)$$

Analyze the above formula, when $t \to \infty$, the steady weight of the system can be obtained.

$$\begin{pmatrix} M_1(\infty) \\ M_2(\infty) \end{pmatrix} = \frac{1}{\frac{2}{k} + \sum_{i=1}^{3} I_{si}^2} \begin{pmatrix} \sum_{i=1}^{3} I_{si} I_{\gamma i} \cos(\phi_i - \alpha_i) \\ \sum_{i=1}^{3} I_{si} I_{\gamma i} \sin(\phi_i - \alpha_i) \end{pmatrix} \quad (12)$$

From (6) and (12) we can find residual error is

$$I_\varepsilon(t) = I_\gamma(t) - [M_1(\infty)I_{s1}(t) + M_2(\infty)I_{s2}(t)]$$

$$= \sum_{j=1}^{3} [I_{\gamma j} \cos(\phi_j - \alpha_j) - \frac{I_{sj}}{\frac{2}{k} + \sum_{i=1}^{3} I_{si}^2} \sum_{i=1}^{3} I_{si} I_{\gamma i} \cos(\phi_i - \alpha_i)]$$

$$* \cos(\omega_j t - \alpha_j) + \sum_{j=1}^{3} [I_{\gamma j} \sin(\phi_j - \alpha_j) - \frac{I_{sj}}{\frac{2}{k} + \sum_{i=1}^{3} I_{si}^2}$$

$$* \sum_{i=1}^{3} I_{si} I_{\gamma i} \sin(\phi_i - \alpha_i)] \sin(\omega_j t - \alpha_j)$$

$$= \sum_{i=1}^{3} \sqrt{Q_j^2 + P_j^2} \cos(\omega_j t - \alpha_j - tg^{-1}(\frac{P_j}{Q_j})) \quad (13)$$

Where,

$$\begin{cases} Q_j = I_{\gamma j}\cos(\phi_j - \alpha_j) - \dfrac{I_{sj}}{\dfrac{2}{k} + \sum_{i=1}^{3} I_{si}^{\,2}} \sum_{i=1}^{3} I_{si} I_{\gamma i}\cos(\phi_i - \alpha_i) \\ P_j = I_{\gamma j}\sin(\phi_j - \alpha_j) - \dfrac{I_{sj}}{\dfrac{2}{k} + \sum_{i=1}^{3} I_{si}^{\,2}} \sum_{i=1}^{3} I_{si} I_{\gamma i}\sin(\phi_i - \alpha_i) \end{cases} \tag{14}$$

So, the ICR of each signal is

$$ICR_j = 20\lg\left(\frac{I_\gamma}{\left|I_\varepsilon(t)\right|}\right) = 20\lg\left(\frac{I_{\gamma j}}{\sqrt{Q_j^{\,2} + P_j^2}}\right) \tag{15}$$

For this issue, we take ICR_2 as an example. The simplification formula is equation (16).

Since the formulas of the three contrast ratios are similar, we can see that the ratio of the cancellation ratio is related to the frequency of the intermediate signal

$$ICR_2 = 10\lg\left(\frac{I_{\gamma 2}^2(2 + k(I_{s1}^2 + I_{s2}^2 + I_{s3}^2))^2}{k^2 I_{s2}^2 (I_{\gamma 1}^2 I_{s1}^2 + 2\cos[(\phi_1 - \alpha_1) - (\phi_3 - \alpha_3)] I_{\gamma 1} I_{\gamma 3} I_{s1} I_{s3} + I_{\gamma 3}^2 I_{s3}^2) - 2k I_{\gamma 2} I_{s2} (\cos[(\phi_1 - \alpha_1) - (\phi_2 - \alpha_2)] I_{\gamma 1} I_{s1} + \cos[(\phi_2 - \alpha_2) - (\phi_3 - \alpha_3)] I_{\gamma 3} I_{s3})(2 + k(I_{s1}^2 + I_{s3}^2)) + I_{\gamma 2}^2 (2 + k(I_{s1}^2 + I_{s3}^2))^2}\right) \tag{16}$$

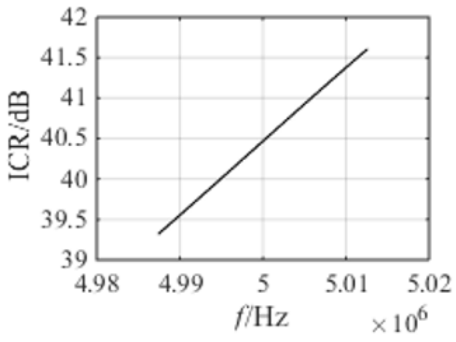
4 Simulation results and analysis

We take a narrowband signal as an example, we take its carrier frequency and keep the amplitudes of three adjacent signals equal. And the channel bandwidth of the short-wave signal is 3.7 KHz, the channel spacing (narrowband) is 12.5 KHz, and the system gain is taken as k=100[8]. f_1, f_2, and f_3 are the frequencies of the three signals, and the values are as shown in Table 1.

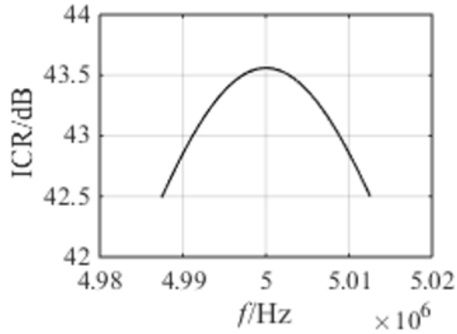
Table 1. Setting Word's margins.

frequency	Value
f_1	5016200
f_2	4987500-5012500
f_3	4983800

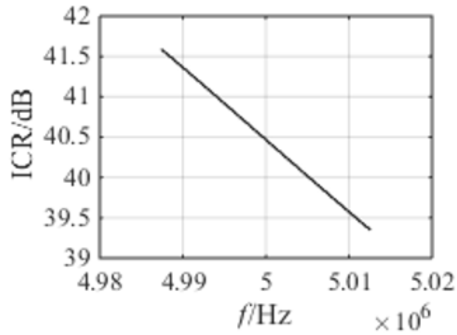
The ICR of the three signals varies with the frequency of the signal 2 as shown in Fig. 2(a), (b), (c). The ICR of each signal in the figure is the variation curve calculated according to the formula theory. Fig. 3(a), (b), (c) shows the results obtained by simulation using the system model. It can be seen that the two changes are basically the same. As the frequency of the signal 2 shifts, the ICR of the side channel signal changes accordingly.



(a) ICR_1

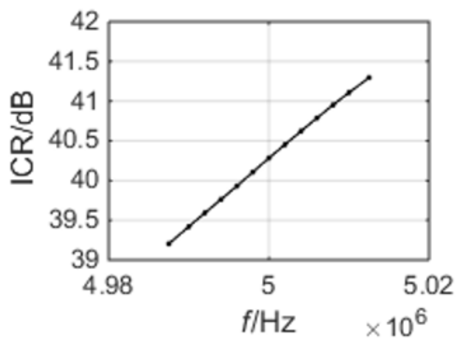


(b) ICR_2

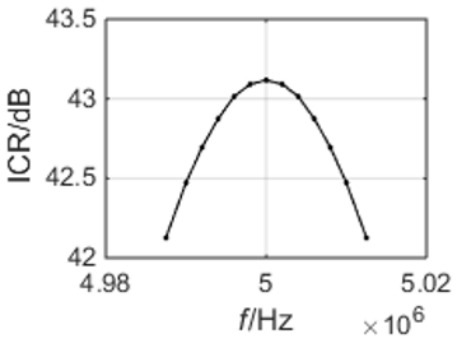


(c) ICR_3

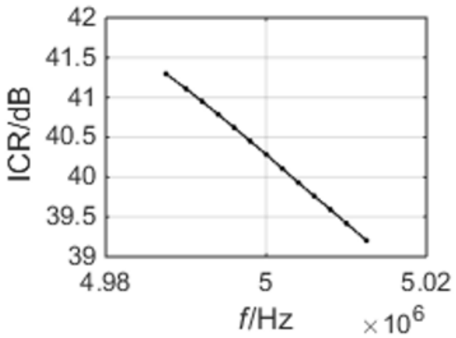
Figure 2. Theoretical calculation of ICR for 3 signals



(a) ICR_1



(b) ICR2



(c) ICR3

Figure 3. Simulated ICR of 3 signals

5 Conclusion

In this paper, the steady-state performance of the three-channel adaptive interference cancellation system is derived and analyzed. The influence of the intermediate signal frequency variation on the bypass signal interference ratio is deeply studied and analyzed. The simulation results confirm that the correctness of the theoretical theory analysis. The main conclusions are as follows:

There is a certain mutual influence between the adjacent channel signal interference cancellation ratio. When the intermediate signal fluctuates within its channel, the offset signal ratio of the adjacent channel signal will be slightly reduced, and the interference cancellation ratio of the adjacent adjacent channel signal will increase slightly. However, the fluctuation range is within the acceptable range. The result of simulation indicates that the adaptive cancellation system has good cancellation performance.

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