Using Direct Sequence Spread Spectrum in Marine Radio Communication

JACEK WSZOŁEK, JACEK DAŃDA
Department of Telecommunications
AGH University of Science and Technology
Al. Mickiewicza 30, 30-059 Kraków
POLAND

Abstract: This paper proposes application of the DSSS CDMA method (Direct Sequence Spread Spectrum Code Division Multiplexing Access) in marine voice and data transmission. The spread spectrum method is based on conversion of signal into the form of wider band, while signal power remains on the same level. This conversion causes decrease of power spectral density, which is proportional to the spreading factor. Spectrum spreading is achieved by multiplying the input signal by a code sequence (spreading code). Simultaneous transmission can be achieved by spreading multiple signals by uncorrelated and orthogonal sequences. Power spectral density of CDMA is usually lower than noise power, therefore the transmission remains transparent for other receivers and does not affect other systems. Another advantage of the CDMA is its robustness against the narrowband noise. For a correct reception of the CDMA signal, a precise synchronization is necessary. This results from a method of despreading, which is based on another multiplication of signal and the spreading code. This operation should be performed in-phase. If not, on the input of detector appears additional noise.

Key-Words: CDMA, marine communications, DSSS, radiotelephone, spreading, transmission security

1 Marine Radio Communication
For years, data transmission in case of marine ships was realized using FM radiotelephones. Originally radiotelephones for marine radio communication were plain, analogue devices based on the frequency modulation, enabling the voice transmission functionality only. Contemporary radiotelephones are not very different from these old type devices [1,2]. They are typically equipped with the DSC (Digital Selective Calling), that enables the device with short messages transmission functionality and selective calling other units. The simplicity of radiotelephones, which is no doubt a great plus, is the main reason of the low cost and popularity of these devices. However, the greatest disadvantage is the total lack of confidentiality. In some cases this feature can be considered valuable (e.g. when calling for help or sending a Distress Alert), but there is a lot of cases where this is threat for privacy or marine unit security [1], [2].

2 CDMA Basis
Idea of spread spectrum systems is known since a half of the last century and results directly from the Shannon’s equation. CDMA relies on dependency of data transmission channel throughput from signal to noise ratio and signal bandwidth. If the signal to noise ratio is low ($\gamma < 0.1$), bandwidth $B$ necessary to get the throughput of $C$ bits per second is given by (1) [3].

$$B \approx \frac{C}{1.44\gamma} \quad (1)$$

Therefore, if signal to noise ratio is relatively small, particularly: if signal power is much lower than noise power, transmission is still possible, but requires much wider bandwidth, according to (1). This case is shown in Fig. 1.

Fig. 1 Impact of spreading on spectral properties of a signal

Bandwidth widening in digital transmission systems is realized through the multiplication of the signal and
spreading codes. Spreading codes are also used in the receiver for despreading. For this reason, spreading codes are pseudo-random sequences, being in fact deterministic symbol sequences known at both the transmitter and the receiver. For a third party receiver such sequences are fully random and look like a noise, therefore CDMA signal is very tough for a third party detection and eavesdropping. An example of spreading codes are OVSF (Orthogonal Variable Spreading Factor) codes [4]. The most important feature of OVSF codes is orthogonality, i.e. OVSF codes are uncorrelated. This attribute enables multiple signal transmission in the same frequency band. In this case, every next signal for a CDMA receiver is an additional source of noise, and cannot be properly detected, if spreading code is unknown [4,5]. Spectrum spreading procedure is shown in Fig. 2. \(a(t)\) is input data and \(c(t)\) is a spreading code. A result of spreading, \(a(t)c(t)\) is shown in figure 2c. Fig. 2d) shows a result of despreading, i.e. result of multiplication of the spreaded sequence by the spreading code, which is equal to the input data [5].

![Signal spreading and despreading](image)

For a better protection of the transmission against eavesdropping, an additional scrambling code can be applied, which is known for transmitter and receiver only. In our department we are working on application of other codes, than commonly applied Gold sequences. Gold sequences are very demanding in terms of synchronization. Currently other self-synchronizing spreading sequences are verified. It is expected, that these verified sequences should enable at least the same level of system efficiency. Among others, Baker codes and their self-synchronizing variations are tested, and hybrid solutions are proposed. Another problem is codes distribution between both transmission parties, which is crucial for transmission safety. Codes can be exchanged using cipher connection, secured with the TKIP (Temporal Key Integrity Protocol) or AES (Advanced Encryption Standard).

3 CDMA in Marine Radio Communication

The CDMA transmission described in the previous chapter has several features, that are useful in marine radio communication:

1. Security

CDMA enables data transmission with the signal power level below noise level. Therefore it is invisible for other receivers. Furthermore, scrambling and ciphering additionally secures transmitted data from eavesdropping.

2. Technical issues

When a sixty years ago first CDMA devices were invented, their cost was so high, that practical application was possible only for military purposes. At the contemporary electronics level and popularity of CDMA technology (used among others for mobile telephony) cost of CDMA devices decreased drastically. A CDMA based radiotelephone can be cheaper than a traditional FM radiotelephone.

3. Range

Range of mobile phones based on DSSS CDMA is limited by:

a) number of users in range
b) transmitter power in a mobile phone, powered by a battery of low capacity

In case of marine radio communication both constraints are marginal. At a ship, high power sources are available, and temporary assignment of 100W for a CDMA transmitter is not a problem. Furthermore, number of concurrent users transmitting in the range is low enough to ensure enough system capacity [5].

4 Conclusion

In the paper basis of CDMA systems were described and the CDMA technology was proposed in marine radio communication. Main reason for this kind of CDMA application are CDMA advantages over the traditional FM devices, at the same cost.
References:
[4] 3GPP TS 25.213 Spreading and modulation (FDD), 3GPP, version 7.0.0, 2006-03-22