Journal of Computing and Electronic Information Management

ISSN: 2413-1660

Optimization of Power Allocation in Marine VHF Communication System

Xia Liu, Zixi Zhou

College of Architecture and Civil Engineering, North China University of Technology, China

Abstract: VHF frequency band communication service demand is increasing, especially ship AIS service in the available frequency band has been very crowded. MIMO system with spatial modulation can improve the communication bandwidth and spectrum utilization. Combining our precoding technology with power allocation technology can greatly improve BER performance. The residual power reallocation method can optimize the power distribution, reduce the error rate and improve the performance of VDEs communication system.

Keywords: VHF, Spatial Modulation, MIMO, precoding, power allocation.

1. Introduction

VHF communication is the main method of short-distance communication at sea. The working frequency range is 156-174 MHz. Voice communication using analog signals is still the main method of communication between ships and between ships and shores. With the rapid development of maritime ship transportation in my country, the data business exchanges between ships and shores and between ships have become more frequent, and there is an increasing demand for the diversity, high speed, reliability and confidentiality of data transmission.

Due to the narrow maritime VHF frequency band and small communication capacity, the data transmission rate of its terrestrial wireless communication system cannot meet the demand for notification transmission; the demand for communication services in the VHF frequency band continues to increase, especially for ships' AIS (Automatic Identification System) services. The interior is already very crowded. In the world, especially in China's busy ports, AIS has reached an occupancy rate of more than 50% in the VHF frequency band.

With the development of terrestrial wireless communication technology, OFDM (orthogonal frequency division multiplexing) technology and MIMO technology [1] have become the primary problem for solving 4G mobile communication systems, that is, to achieve greater system capacity effectively within limited spectrum resources method. In the future, 5G networks are still committed to obtaining higher system capacity and pursuing breakthrough technologies to make 5G development possible. The 5G mobile communication system is defined as a new revolutionary wireless communication technology after 4G. The emergence of a new generation of wireless communication technology is expected to be applied to maritime communications to solve technical problems in the development of maritime high-speed data communications.

On the one hand, it is introduced that the combination of SVD decomposition method and precoding can realize the eigenvalue of the channel matrix and reduce the coding complexity in the data transmission process. On the other hand, it introduces the optimization scheme of power distribution, and finally achieves the purpose of improving the signal-to-noise ratio (BER) and improving the transmission efficiency.

2. Frequency Band and Spatial Modulation

2.1 Spatial Modulation

Spatial Modulation (Spatial Modulation) technology, as a new MIMO transmission scheme [2], utilizes the implicit information carried by the dimensions of the MIMO space, making spatial resources a new data transmission carrier.

All transmitting antennas in the spatial modulation system use the same modulation method, and the bit allocation does not consider the difference between each pair of transmitting/receiving channels, which will cause weak interference in the spatial modulation system, and the receiving end signal is more significantly affected by interference. Therefore, the adaptive modulation idea is introduced, and the difference of the corresponding channels of each transmitting antenna is considered, and the transmission data mapping method is adjusted according to the state of the channel to ensure transmission efficiency, effectively combat the influence of the fading of the transmission/reception channel, and reduce the bit error rate of data transmission And algorithm complexity.

2.2 VHF frequency band

The electromagnetic wave wavelength range of the maritime VHF frequency band is 1～10m. Because there are few obstacles that can block the signal at sea, when the VHF wireless signal is transmitted at sea, the signal clearance is large and the diffraction loss is much smaller than that on the land, but the reflection of the wireless signal Relatively increase. According to the characteristic that the ionosphere does not reflect electromagnetic waves in the VHF band, the VHF wireless signal is relatively limited within a certain range, and will not interfere with distant equipment. At the same time, the maritime VHF wireless signal is less affected by atmospheric noise and other interference. Interference of lower frequency electromagnetic signals.

Table 1. Existing marine VHF characteristics

VHF frequency band characteristics of 16QAM	
frequency	157.2MHz
Number of carriers	32
Bandwidth	100KHz
Subcarrier spacing	2.7KHz
Cyclic prefix	8
Modulation	QAM，OFDM
Channel model	Rayleigh

2.3 Precoding

In MIMO system, when the transmitting end cannot obtain any channel information (CSI), each parallel data stream is equally distributed in power and transmission rate and transmitted in omnidirectional mode. At this time, the system capacity is expressed as:

$$\begin{aligned} C &= \log_2(\det(I_{NT} + \frac{\rho}{N_T} H^H H)) \\ &= \sum_{i=1}^{N_s} (\log_2(1+\frac{\rho}{N_T}\sigma_i^2)) \end{aligned} \tag{1}$$

Where det() represents the determinant of the matrix, I represents the N-dimensional unit matrix, H is the channel matrix, and Nt is the number of transmitting antennas.

The link performance of open-loop MIMO is largely affected by the receiving algorithm. When the receiver uses simple linear processing algorithms such as ZF or MMSE, the system's error probability performance is often poor. When using interference cancellation algorithms such as SIC, it can effectively improve the error probability performance, but it will also cause an increase in the computational complexity of the receiver.

It can be seen from the formula that the MIMO channel can be equivalent to multiple parallel sub-channels. The maximum number of data streams that the system can support is determined by the rank of the channel matrix, and the transmission capacity of each data stream is determined by its corresponding singular value.

If the transmitter can obtain a certain CSI in some way [3], the power, rate and transmission direction of each data stream can be optimized through a certain preprocessing method, and it is possible to eliminate the inter-data stream through preprocessing. Part or all of the interference (ISI).

2.4 System implementation model

The data stream combines coding technology and channel information after spatial modulation technology, and then passes through our power distribution scheme. Channels with strong signal transmission capabilities are allocated more resources, and weaker channels are allocated less or no resources. Finally, an efficient parallel working channel group is achieved and the purpose of improving our transmission efficiency is achieved. The realization model of the system is shown in Figure 1.

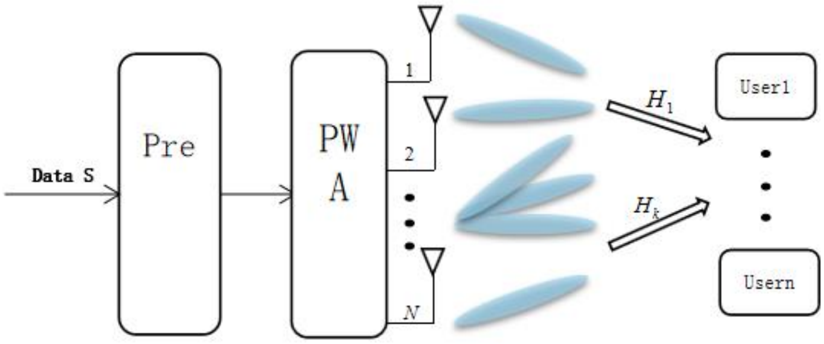

Figure 1 Multi-channel communication system model

3. PREDODING

According to whether linear operation is required in the precoding stage, it is divided into linear precoding and nonlinear precoding technologies. The computational complexity of linear precoding technology is much lower than that of nonlinear precoding technology, and as the number of antennas deployed at both ends of the transceiver increases, linear precoding technology can achieve near-optimal performance.

3.1 ZF Precoding

The characteristic of ZF precoding is simple and practical. The main idea is to generate the inverse matrix of the channel matrix, and then use the inverse matrix as the equivalent precoding matrix. The base station transmitter preprocesses the transmitted signal according to the equivalent inverse matrix to achieve Suppress interference between users. Figure 2 shows the principle diagram of the ZF precoding algorithm.

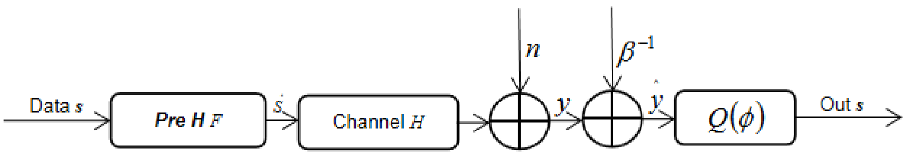

Figure 2 Principle diagram of ZF precoding algorithm

3.2 MMSE Precoding

The main idea of MMSE is to find the minimum mean square error between the transmitted signal and the received signal under power control conditions. That is to solve the following optimization problem.

$$\begin{cases} F^{opt} = \arg\min E\left[s - \beta^{-1}(HFs + n)\right] \\ E\left[\left\|F^{opt}s\right\|^2\right] \le N_t P_s \end{cases} \quad (2)$$

Derivation shows that by judging the received signal y, the original transmitted data stream can be restored.

3.3 MRT Precoding

Compared with ZF and MMSE, MRT is the simplest and the easiest to implement precoding algorithm. This algorithm mainly maximizes the SNR received by each user.

4. SVD MODULE

SVD (Singular Value Decomposition) can be used for PCA dimensionality reduction [4] for data compression and denoising. In our multi-antenna model, we perform SVD decomposition on the channel matrix H, which can make our channel eigenvalues reach the diagonal matrix we want, and combined with precoding technology greatly reduces the complexity of system encoding and decoding [5].

For our channel matrix, after SVD decomposition, it can be expressed as:

$$\mathbf{H} = \mathbf{U}\sum\mathbf{V}^{\mathbf{H}} \quad (3)$$

Among them, U and V are left and right unitary matrices, and the identity matrix can be obtained by multiplying them with their conjugate transpose.

So if the transmitter knows the channel matrix, it can derive SVD and use V to encode it to get a new transmission:

$$\mathbf{y} = \mathbf{U}\sum\mathbf{V}^{\mathbf{H}}\mathbf{V}\mathbf{x} + \mathbf{n} = \mathbf{U}\sum\mathbf{x} + \mathbf{n} \quad (4)$$

The receiving end then decodes through U:

$$\mathbf{U}^{\mathbf{H}}\mathbf{y} = \mathbf{U}^{\mathbf{H}}\mathbf{U}\sum\mathbf{x} + \mathbf{U}^{\mathbf{H}}\mathbf{n} \quad (5)$$

The final signal is:

$$\mathbf{y}^{*} = \sum\mathbf{x} + \mathbf{n}^{*} \quad (6)$$

The advantages of choosing the combination of SVD decomposition and precoding are obvious—it reduces the complexity of encoding and decoding, and maps our channel information (CSI) to the eigenvalues, that is, the diagonal matrix, so the eigenvalues can be further used as our power allocation later The coefficient.

5. POWER ALLOCATION

The channel matrix after SVD decomposition, that is, the singular value of our diagonal matrix is different in size, from large to small. The size of the value represents the quality of channel transmission. Therefore, we need to carry out a good allocation of the transmission power, so that the channel transmission quality is good to get more power and increase the data transmission efficiency.

For a multi-antenna system, the relationship between antenna power, channel information, channel noise variance and system capacity satisfies the following equation [6]:

$$C = \sum_{i=1}^{m} \log_2 (1 + \frac{P_i \lambda_i}{\sigma^2}) \quad (7)$$

Then the water injection power distribution scheme that maximizes the system capacity [7] is:

$$P_i = \max(0, \mu - \frac{\sigma^2}{\lambda_i}) \quad (8)$$

Obviously, the power distribution scheme obtained according to the water injection distribution power algorithm can maximize the system capacity. However, in practice, the limitation of the modulation order leads to the discretization of the system information rate, and the corresponding power allocation scheme is not optimal, so the system cannot obtain the maximum transmission rate under the same power constraint.

$$\tilde{P}(c) = \frac{\sigma^2}{3} [Q^{-1}(\frac{P_e}{4})]^{-2} (2^c - 1) \quad (9)$$

So the number of bits is:

$$c = floor[\log_2 (1 + \frac{3P}{\sigma^2} (Q^{-1}(\frac{P_e}{4}))^2)] \quad (10)$$

We can see from the implementation process of the power distribution scheme that the characteristic value obtained after SVD can be used as a redistribution coefficient to a large extent. Then through power allocation, more channels are allocated to channels with strong channel strength, and less allocated to channels with less channel strength, so that system resources are reasonably used to achieve the purpose of improving transmission efficiency.

6. SIMULATION

For our power allocation, the traditional gradient allocation water injection algorithm, greedy algorithm, etc. can obtain the local optimal solution of the problem. The distribution scheme obtained by the water injection power distribution algorithm can enable all the characteristic modes of the system to achieve the maximum amount of the system. However, in practice, affected by the modulation order, the corresponding power distribution scheme is no longer optimal.

The simulation environment of the experiment is data acquisition under LABVIEW and Ettus' software radio peripheral.

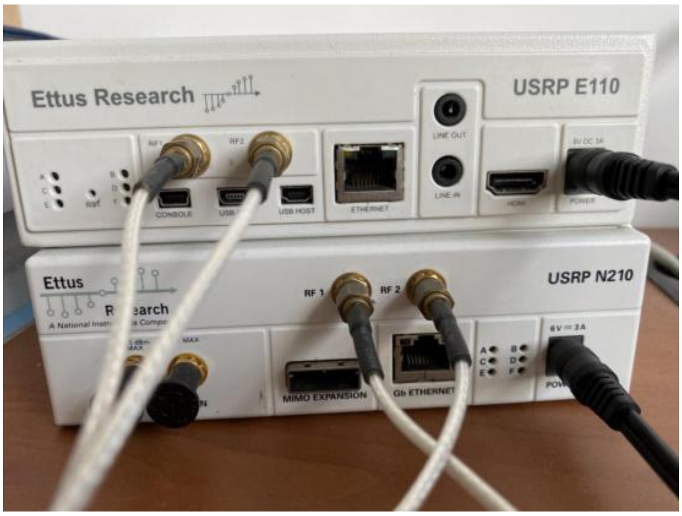

Figure 3 Software radio peripheral

The relationship between our signal-to-noise ratio and spectrum efficiency under different algorithms is shown in Figure 4.

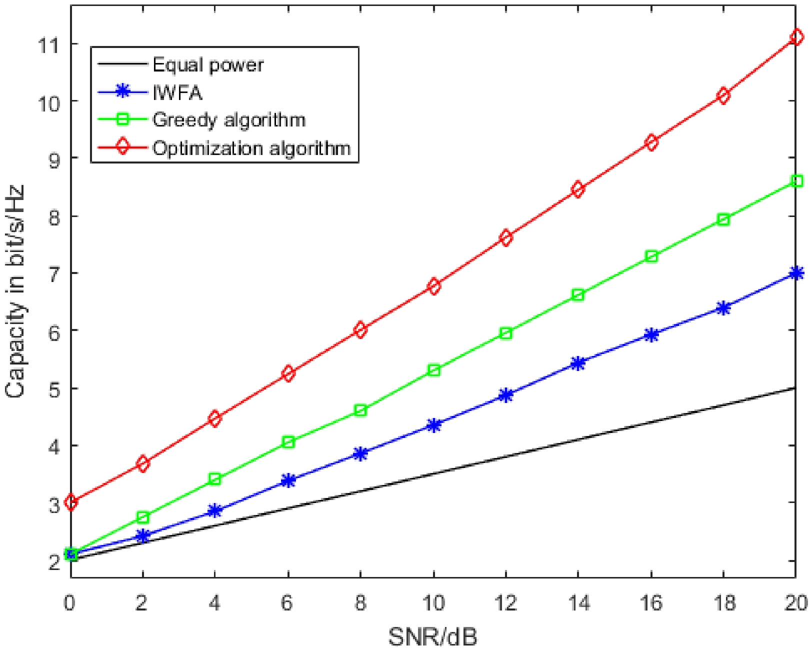

Figure 4 Spectrum efficiency under different algorithms

In our case of equal power, the spectral efficiency is the lowest, which is equivalent to our SISO system, which does not contribute much to the gain of the system. The water injection algorithm has improved our spectral efficiency, and the greedy algorithm is due to its complexity. Higher, [11] so the final improvement of the power allocation scheme can not only reduce the complexity, but also improve the selectivity of the antenna and improve the spectrum efficiency of the system[12].

In this way, our residual power redistribution problem is transformed into how to allocate total residual power to different characteristic modes. The simulation results show that it has good BER performance.

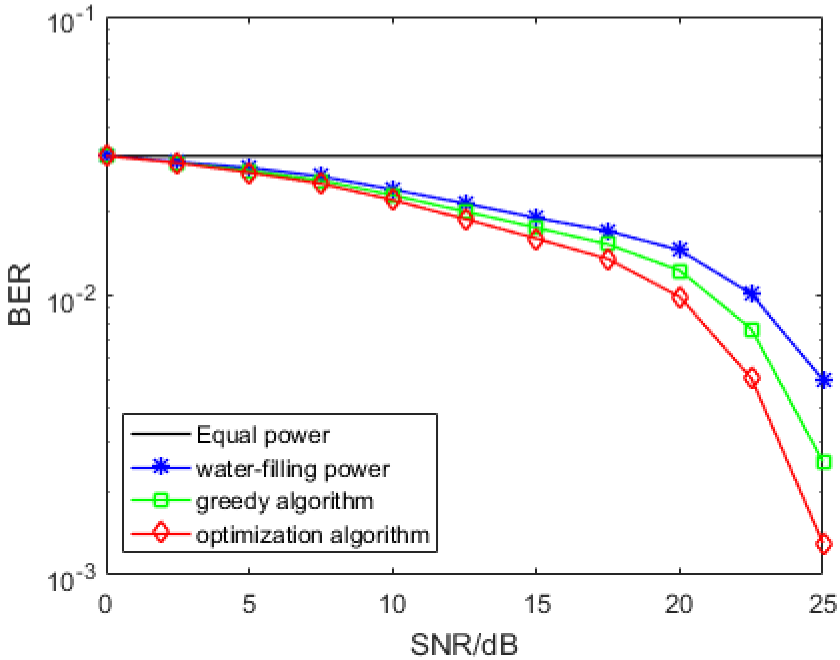

Figure 5 BER performance

Combining our bit error rate and signal-to-noise ratio problems together, we can conclude that our improved algorithm can increase the signal-to-noise ratio and reduce the bit error rate. Of course, this is closely related to the complexity of our system, so as The algorithm mentioned in the algorithm for bit allocation under a given bit error rate can improve our communication quality.

The experimental spatial modulation and optimized power allocation scheme can not only improve the system bandwidth and frequency band utilization, but also reduce the complexity of encoding and decoding, and increase the data communication rate.

References

[1] Yao H, Jian H, Shi Y. SVD Based Sphere Detector for MIMO Channels[C]// International Conference on Wireless Communications. IEEE, 2011.

[2] Sandmann A, Ahrens A, Lochmann S. Power allocation in PMSVD-based optical MIMO systems[C]// 2015 Advances in Wireless and Optical Communications (RTUWO). IEEE, 2015.

[3] Zhang J, Jiang B, Jin S, et al. Open Access On base station cooperation using statistical CSI in jointly correlated MIMO downlink channels[J]. Eurasip Journal on Advances in Signal Processing, 2012, 2012(1):81 .

[4] Chen Liang, Jin Yongxing, Hu Qinyou, etc. Transmission loss of maritime VHF wireless communication[J], China Navigation, 2015(03): 1～4.

[5] Sandmann A, Ahrens A, Lochmann S. Power allocation in PMSVD-based optical MIMO systems[C]// 2015 Advances in Wireless and Optical Communications (RTUWO). IEEE, 2015.

[6] Ahrens A, Benavente-Peces C, Cano-Broncano F. Power allocation in SVD- and GMD-

assisted MIMO systems[J]. Optimization and Engineering, 2016, 17(4):919-940.
[7] Li Liangpei, Wang Yanwen. Research on MIMO precoding based on SVD, GMD and UCD[J]. Modern Electronic Technology, 2010, 33(7).
[8] Deng Fei, Yin Hongdong, Duan Menglan. Optimized UKF algorithm based on AUV track tracking[J]. Ship Engineering, 2018, v.40(S1):212-217+235.
[9] Nagaradjane P, Rajan Y A, Muralidharan P, et al. Performance of multi-user transmitter preprocessing assisted MIMO system over correlated frequency-selective channels[J]. Physical Communication, 2013, 7(Complete):61-72.
[10]Zhang J, Jiang B, Jin S, et al. Open Access On base station cooperation using statistical CSI in jointly correlated MIMO downlink channels[J]. Eurasip Journal on Advances in Signal Processing, 2012, 2012(1):81 .
[11]Ahrens A, Peces C B, Aboltins A. Performance comparison of SVD- and GMD-assisted MIMO systems[C]// Advances in Wireless & Optical Communications. IEEE, 2015.
[12]Ahrens A, Benavente-Peces C, Cano-Broncano F. Power allocation in SVD- and GMD-assisted MIMO systems[J]. Optimization and Engineering, 2016, 17(4):919-940.