Research and Improvement of Adaptive Modulation and Coding Scheme for VDE-TER System

Zhe Li¹*, Hai Li², Qin Zhang³
¹, ², ³School of Information and Electronics, Beijing Institute of Technology, Beijing, 100081, China
*Corresponding author’s e-mail: 2120170791@bit.edu.cn

Abstract. VHF data exchange system (VDES) is an enhanced and updated system of AIS (Automatic Identification System) focused on maritime mobile communication, and VDE (VHF Data Exchange) is a main function of VDES. In this paper, we analyze the original adaptive modulation and coding (AMC) scheme of terrestrial VDE (VDE-TER). Because the original AMC scheme reserves several modulation and coding schemes for future use, we present an improved AMC scheme with more MCSs to increase system throughput. Simulation results have shown that the throughput performance of the proposed AMC scheme is improved.

1. Introduction
VDES is an enhanced and upgraded system for the AIS in the maritime mobile field, which integrates the functions of VHF data exchange (VDE), application specific messages (ASM) and the automatic identification system (AIS) in the VHF maritime mobile band[1].

The AMC technology is based on channel estimation. The basic principle is to determine the MCS according to the channel state information(CQI), such as SNR. The key technology of AMC is MCS selection algorithm, and the currently most widely used one is the fixed threshold algorithm (FTA) recommended by 3GPP [2]. The basic idea of the algorithm is to select the MCS with the highest throughput in each CQI interval to obtain the maximum throughput performance of the overall system [3][4]. In the TECHNICAL SPECIFICATION OF VDES [5] proposed by IALA (Recommendation G1139), a total of nine MCSs are proposed for the VDE-TER communication system, of which three schemes are currently adopted, and the remaining six are not adopted for future use. In this paper we analyzes the SNR-throughput performance of the nine MCSs proposed in the G1139 Recommendation first, and then analyze the system throughput performance of the AMC scheme proposed by G1139. Considering the unused MCSs, we present an improved AMC scheme. Finally, the analysis and comparison of system throughput performance with the original AMC scheme of G1139 was performed.

2. VDE-TER MCS analysis
In the G1139 Recommendation, link ID 11 to 19 represent MCS of VDE-TER. The basic information is shown in Table 1. It adopts PI/4 QPSK, 8PSK, 16 QAM three modulation methods, and the coding adopts turbo coding with the code rate of 1/2, 3/4. There are three options for the bandwidth of the channel, which are 25kHz, 50kHz, and 100kHz. We will analyze the BER and throughput performance of each MCS next.
Table 1. VDE-TER MCS parameters in G1139

| Link config ID | Channel BW (kHz) | Net bits (bits) | Modulation | FEC rate |
|----------------|------------------|-----------------|------------|----------|
| 11             | 25               | 432             | PI/4 QPSK  | 1/2      |
| 12             | 25               | 972             | 8PSK       | 3/4      |
| 13             | 25               | 1296            | 16 QAM     | 3/4      |
| 14             | 50               | 896             | PI/4 QPSK  | 1/2      |
| 15             | 50               | 2016            | 8PSK       | 3/4      |
| 16             | 50               | 2588            | 16 QAM     | 3/4      |
| 17             | 100              | 1872            | PI/4 QPSK  | 1/2      |
| 18             | 100              | 4032            | 8PSK       | 3/4      |
| 19             | 100              | 5616            | 16 QAM     | 3/4      |

For the nine MCSs of VDE-TER, it can be seen from the information in Table 1 above that the major differences between the schemes of 11, 12, 13 and 14, 15, 16, and 17, 18, 19 are the channel bandwidth, and the resulting symbol rate and the number of bits transmitted per time slot. However, there is no difference between the modulation method and the encoding / decoding method for link ID 11,14,17 and 12,15,18 and 13,16,19. Thus there are totally three types of SNR BER performance curve.

As the application scenario of VDE is the communication on the ocean, there are direct paths in the working environment, and there are basically no obstacles in the open environment [6]. The effects of selective fading caused by multipath can be ignored. Therefore, for theoretical analysis, the simulated channel can be an AWGN channel. According to the simulation conditions above, the resulting SNR BER curve using soft decision decoding is shown in Figure 1.

![Figure 1. BER performance of three types of MCS regardless of bandwidth](image)

After obtaining the SNR performance result of each MCS, the MCS throughput performance can be further obtained. The definition of throughput here is: the average number of valid data bits successfully received per unit time of the system. The VDE system is a TDMA communication system, so we set the unit time as the length of a slot (about 26.6ms). The formula for throughput is as follows [7]:

$$P_{PER} = 1 - (1 - P_{BER})^{N_i}$$

$$T = (1 - P_{PER}) \times R_S \times \log_2 M \times r \times \frac{L-C}{L}$$

Equation (1) is a formula for calculating the packet error rate, where $P_{PER}$ is the packet error rate, $P_{BER}$ is the bit error rate, and $N_i$ is the net number of bits per packet of the MCS. Equation (2) is a formula for calculating throughput, where $R_S$ is the symbol rate, $\log_2 M$ is the number of bits included in each symbol, $r$ is the channel coding efficiency, $L$ is the total data length of each packet, and $C$ is data overhead of each packet.
3. VDE-TER AMC scheme analysis and improvement

3.1 Performance measurement of MCS with different bandwidths

Because VDE-TER is a single-carrier communication system, and different MCSs may have different channel bandwidths, in addition to the SNR of the switching judgment between MCSs, additional bandwidth factors need to be considered in order to distinguish the performance between MCSs with different bandwidths. Assume that there are three total schemes of 1, 2, and 3, and the bandwidths are B, 2B, and 4B. The other conditions are the same. Because the carriers are sent by the same RF module, the signal power is the same S. The SNR of the three schemes in AWGN has the following relationship:

\[ SNR_1 (dB) = SNR_2 (dB) + 10 \log 2 = SNR_3 (dB) + 10 \log 4 \]  

(3)

For the critical point of the SNR of MCS1 to MCS2:

\[ T_2 (SNR_2) = T_2 (SNR_1 - 10 \log 2) = T_1 (SNR_1) \]  

(4)

Therefore, in order to analyze the above three schemes in the same SNR throughput curve graph, the coordinate conversion can be performed by the following formula.

\[ SNR_2 (dB) = SNR_1 (dB) - 10 \log 2 \]  

(5)

\[ SNR_3 (dB) = SNR_1 (dB) - 10 \log 4 \]  

(6)

3.2 VDE-TER AMC scheme analysis and improvement

G1139 VDE-TER uses three MCSs link ID 11, 17, and 19, besides the MCS switching method is FTA. From the analysis in section 2.2 and 3.1, we can get the SNR throughput performance curve of the VDE-TER adaptive modulation and coding scheme in G1139.[4]

![Figure 2. SNR throughput performance result of the VDE-TER AMC scheme in G1139](image)

From Figure 2, we can see that among the three MCSs selected by G1139, the scheme link ID 11 is the one with the best PER performance, which corresponds to the situation where the ship and shore communication distance is long; The scheme ID 19 is the scheme with the largest throughput, corresponding to the situation where the communication distance between the ship and the shore is short. However, according to the performance curve of Figure 2 and the performance analysis of each MCS in section 2, there are other MCSs with higher throughput in the interval where the SNR is approximately [2,7.5] and [8,16.2], i.e., the system throughput has not reach maximum.

Therefore, all nine MCSs of VDE-TER are adopted as alternatives for the new AMC scheme. Through simulation and analysis, the SNR throughput performance curve is shown in Figure 3:
Figure 3. SNR throughput performance result of the promoted VDE-TER AMC scheme

From the result in Figure 3, for the two schemes with link ID 12 and 13, there are higher-throughput schemes for any of the SNR interval, so these two schemes are not considered. According to the fixed threshold algorithm, the MCS with the highest throughput can be selected to obtain the SNR switching threshold of the adaptive modulation and coding scheme, as shown in Figure 4.

Figure 4. Comparison of two schemes' throughput

In the range of SNR of 4.49 ~ 7.55dB, the improved AMC scheme uses MCS ID 12 and its peak throughput is 972 bits per time slot, which is higher than the G1139 AMC scheme using MCS ID 11 with 432 bits; In the range of SNR of 7.55 to 14.58, the improved AMC scheme uses MCS ID 15, 16, and 18 with peak throughputs as 2016, 2688, and 4032 bits, which are higher than the one selected by G1139 in this SNR interval, MCS 17 only has a peak of 1872 bits. Therefore, it can be concluded that the improved AMC scheme has significantly improved system throughput compared with the G1139 AMC scheme. Especially in medium communication distance, the improved AMC scheme provides more MCS besides MCS 17.

4. Conclusion
Adaptive modulation and coding technology is an indispensable part of a multi-modulation coding system. It can significantly improve system throughput and improve spectrum utilization. This paper theoretically analyzes and improves the VDE-TER AMC scheme used by the original G1139, and the system throughput of the original scheme is significantly improved. The shortcoming is lack of practice. There is still a certain gap with the actual application, but it can provide certain theoretical support.

References
[1] Zeyu, Y. (2018). Research on the current situation and development of China's VDES. China Maritime Safety, 000(003), 45-48.
[2] Changling, M. & Zhi, L. (2012). Application of adaptive modulation and coding technology in low-orbit satellite communication. Science and Technology Innovation Herald (30), 57.

[3] Takeda, D., Chow, Y. C., Strauch, P., & Tsurumi, H. (2005). Threshold Controlling Scheme for Adaptive Modulation and Coding System. IEEE International Symposium on Personal. IEEE.

[4] Lee, J. (2002). Adaptive modulation switching level control in high speed downlink packet access transmission. International Conference on 3g Mobile Communication Technologies. IET.

[5] Guideline, I. A. L. A. (2017). G1139: The Technical Specification of VDES.

[6] Liang, C., Yongxing, J., Qinyou, H. U., Kecheng, T., Wanming, G., & University, S. M. (2015). Transmission loss in maritime vhf communications system. Navigation of China.

[7] Ping, S. & Aiqun, H. (2006). Application of link adaptation technology in ieee802.16 system. Journal of PLA University of Science and Technology, 7(6), 511-514.