Multidimensional Modulation Method based on Grouped Subcarrier Index Modulated OFDM

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Introduction

With the development of communication technology, we always try our best to obtain faster transmission speed and higher spectrum efficiency. SIM-OFDM is a good choice. However it will not only put higher requirements on the hardware, but also reduce the computing speed. In order to solve the above problem, grouped subcarrier index modulated OFDM (GSIM-OFDM) is proposed. Usually, there are two kinds of grouping methods: adjacent grouping (ASIM-OFDM) and interleaved grouping (ISIM-OFDM). However, no matter which grouping method we use, the bits carried on GSIM-OFDM symbol will reduce, and the advantage of SIM-OFDM in spectrum efficiency will be weakened.

So, a multidimensional modulation method based on GSIM-OFDM(MSIM-OFDM)is proposed. According to the proposed method, the computing complexity is reduced, and the loss of spectrum efficiency caused by grouped modulation is compensated to some extent.

Principle

A. Process of Multidimensional Modulation

The principle of multidimensional modulation based on GSIM-OFDM is shown in Fig.1. As we can see, there are N subcarriers in each SIM-OFDM symbol, which are grouped into G groups. And there are M subcarriers in each group, including S_n (S_n=S_1, S_2, S_3…$S_{M/2}$) silent subcarriers and M-S_n active subcarriers. The modulation order of symbols carried on active subcarriers is L. For each group, the process of multidimensional modulation is as follows:

a) Determine the number of silent subcarriers in this group according to the first $\log_2(M/2)$ bits.
b) Determine the location of silent subcarriers according to the following $\lfloor \log_2(C_M^{S_n}) \rfloor$ bits.
c) The remaining subcarriers work as active subcarriers, carrying symbols representing $\log_2(L)$ bits.

B. Spectrum Efficiency

For multidimensional modulation method based on GSIM-OFDM, the average number of silent subcarriers in each group is:

$$S_{AVE} = 1/(M/2)*(1+2+3+\cdots+M/2) \quad (1)$$

The number of silent subcarriers in each GSIM-OFDM symbol is about:

$$S_{sum} = S_{AVE} * G \quad (2)$$

The number of bits representing the number of silent subcarriers in each GSIM-OFDM symbol is:

$$B_1 = G * \log_2(M/2) \quad (3)$$

The number of bits representing the location of the silent subcarriers in each GSIM-OFDM symbol is about:

$$B_2 = G*\left\{1/(M/2)*\left[\lfloor \log_2(C_M^1) \rfloor + \lfloor \log_2(C_M^2) \rfloor + \cdots \lfloor \log_2(C_M^{M/2}) \rfloor\right]\right\} \quad (4)$$

The number of bits carried on each GSIM-OFDM symbol is about:

$$B = B_1 + B_2 + G*(M - S_{AVE})*\log_2(L) \quad (5)$$

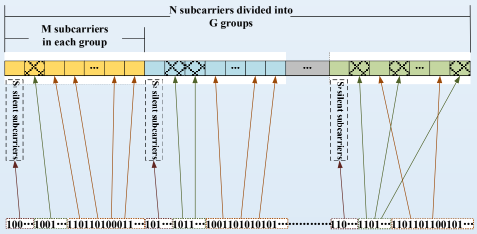

Fig.1. Principle of multidimensional modulation based on GSIM-OFDM

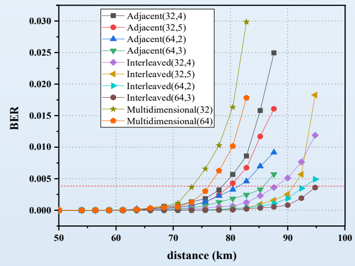

Fig.2. Comparison o f BER of system with different modulation format

Compared with traditional grouped subcarrier index modulation method, the multidimensional modulation method has an additional modulation dimension, which is the number of silent subcarriers. So the MSIM-OFDM symbol can carry more bits. And the proposed method can make up for the loss of spectrum efficiency caused by grouped subcarrier index modulation method to some extent.

Simulation and results

The simulation result is shown in Fig.2. From the figure we can see, no matter which modulation format is used, the BER decreases with the increase of group number. When BER is 0.0038, the MSIM-OFDM signal with 32 groups transmits 5~8km and 14~18km less than ASIM-OFDM signal with 32 groups and ISIM-OFDM signal with 32 groups, respectively. The MSIM-OFDM signal with 64 groups transmits 5~10km and 17~19km less than ASIM-OFDM signal with 64 groups and ISIM-OFDM signal with 64 groups, respectively. This is because the bit error of MSIM-OFDM signal is caused by not only the judgment error of silent subcarrier location and the symbol, but also the judgment error of silent subcarrier number. And the error of the silent subcarrier number directly results in the error of the silent subcarrier location and symbol. Although the BER of MSIM-OFDM system is a little higher than that of ASIM-OFDM and ISIM-OFDM system, the advantage of MSIM-OFDM in spectrum efficiency is enough to make up for this deficiency.

TABLE I. THE NUMBER OF BITS CARRIED BY A SIM-OFDM SYMBOL WITH 512 SUBCARRIERS MODULATED BY DIFFERENT MODULATION FORMATS

Group number		16	32	64	128
16QAM	No group	1926	1906	1862	1763
	Adjacent/Interleaved	1880	1824	1696	1536
	Multidimensional	1904	1884	1824	1664
32QAM	No group	2302	2274	2214	2083
	Adjacent/Interleaved	2256	2192	2048	1856
	Multidimensional	2280	2252	2176	1984
64QAM	No group	2678	2642	2566	2403
	Adjacent/Interleaved	2632	2560	2400	2176
	Multidimensional	2656	2620	2528	2304
128QAM	No group	3054	3010	2918	2723
	Adjacent/Interleaved	3008	2928	2752	2496
	Multidimensional	3032	2988	2880	2624

TABLE II. THE NUMBER OF BITS CARRIED BY A SIM-OFDM SYMBOL WITH 1024 SUBCARRIERS MODULATED BY DIFFERENT MODULATION FORMAT

Group number		16	32	64	128
16QAM	No group	3878	3858	3816	3728
	Adjacent/Interleaved	3824	3760	3648	3392
	Multidimensional	3820	3808	3768	3648
32QAM	No group	4638	4610	4552	4432
	Adjacent/Interleaved	4584	4512	4384	4096
	Multidimensional	4580	4560	4504	4352
64QAM	No group	5398	5362	5288	5136
	Adjacent/Interleaved	5344	5264	5120	4800
	Multidimensional	5340	5312	5240	5056
128QAM	No group	6158	6114	6024	5840
	Adjacent/Interleaved	6104	6016	5856	5504
	Multidimensional	6100	6064	5976	5760

Conclusion

Based on GSIM-OFDM, a multidimensional method is proposed. Although the BER of MSIM-OFDM system is a little higher than that of ASIM-OFDM system and ISIM-OFDM system, the spectrum efficiency of MSIM-OFDM system is also higher than that of ASIM-OFDM system and ISIM-OFDM system. So the proposed multidimensional modulation method can make up for the loss of the spectrum efficiency caused by group modulation in ASIM-OFDM and ISIM-OFDM. And it has research value.

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