Rotated multidimensional QAM constellations for Rayleigh fading channels

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Abstract — **With the aim of increasing the 'diversity order' of the signal set we propose the new multidimensional rotated QAM constellations. Very high diversity orders can be achieved and this results in an almost Gaussian performance over the fading channel. This new modulation technique enables to trade diversity for system complexity at no expense of power or bandwidth.**

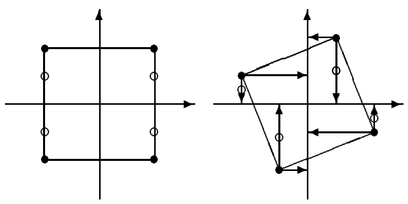
I. Introduction

The traditional approach in coding for the fading channel are the techniques such as time, frequency and antenna diversity.

In this work we present a different approach. We consider uncoded multidimensional modulation schemes with an intrinsic *diversity order*, which achieve substantial coding gains over fading channels. The *diversity order* L of a multidimensional signal set is the minimum number of distinct components between any two constellation points [1]. In other words, we define the diversity order as the minimum Hamming distance between any two coordinate vectors of constellation points. To distinguish from other well known types of diversity we talk about *modulation diversity* or *signal space diversity*.

The key point to increase the modulation diversity is to apply a certain rotation to a classical signal constellation in such a way that any two points achieve the maximum number of distinct components. The figure below illustrates this concept on a 4-PSK.

(a) 4-PSK (b) 4-RPSK

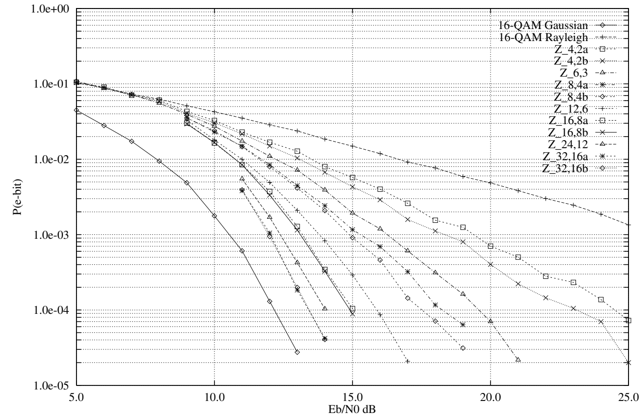


In fact, if we suppose that a deep fade hits only one of the components of the transmitted signal vector then we can see that the compressed constellation (empty circles) in (b) offers more protection against the effects of noise, since no two points collapse together as would happen with (a).

This simple operation already results in a gain of $8\,dB$ at 10^{-3} over the traditional 4-PSK. By increasing the dimensionality of the signal set it is possible to achieve significant gains over the corresponding non-rotated signal set without loosing any rate for coding.

II. Results

We select a spectral efficiency of $\eta = 4$ bit/symbol so that we will compare the performance with a traditional 16-QAM modulation scheme. We plot the BER curve of the 16-QAM over the Gaussian channel and over the independent Rayleigh fading channel. These two curves bound the region of potential gain over the fading channel, when the rotated multidimensional uncoded schemes are used.



The family of curves in the above figure corresponds to cubic shaped rotated multidimensional QAM constellations in dimensions n up to 32 and diversity $L = n/2$ extracted from the rotated integer lattices $Z_{n,n/2}$. As the diversity increases the bit error rate curves approach the one for the Gaussian channel. For the largest value of diversity the gap to the Gaussian BER curve is only about $1.5\,\text{dB}$ between 10^{-3} and 10^{-4}. These constellations can be constructed algebraically for any dimension $n = 2^{e_1}3^{e_2}$, $e_1, e_2 = 0, 1, 2\ldots$ The only limitation in going beyond dimension 32 is the decoder complexity.

III. Conclusions

In this work we have considered a new diversity technique. We have constructed high diversity modulation schemes which exhibit an almost Gaussian performance over the fading channel.

The great advantage of this type of diversity is that it is traded only for a higher demodulator complexity. No additional power or bandwidth is required.

Using the *Universal lattice decoder*, the ML detection complexity is independent of the spectral efficiency: only increasing the dimension slows down the demodulation operation [2, 3].

Future developments of this work include the analysis of additional error control coding techniques, the effects of imperfect CSI estimation, performance analysis with correlated fading channels.

References

[1] J. Boutros, E. Viterbo, C. Rastello, J. C. Belfiore: "Good lattice constellations for both Rayleigh fading and Gaussian channel," to appear in *IEEE Trans. on Information Theory*, March 1996.

[2] E. Viterbo, E. Biglieri:"A universal lattice decoder", 14-ème Colloque GRETSI, Juan-les-Pins, Sept. 1993.

[3] E. Viterbo, J. Boutros:'A universal lattice code decoder for fading channels," submitted to *Electronics Letters*, January 1996.