Demapping for Pragmatic Odd-Powered Cross QAM Constellations

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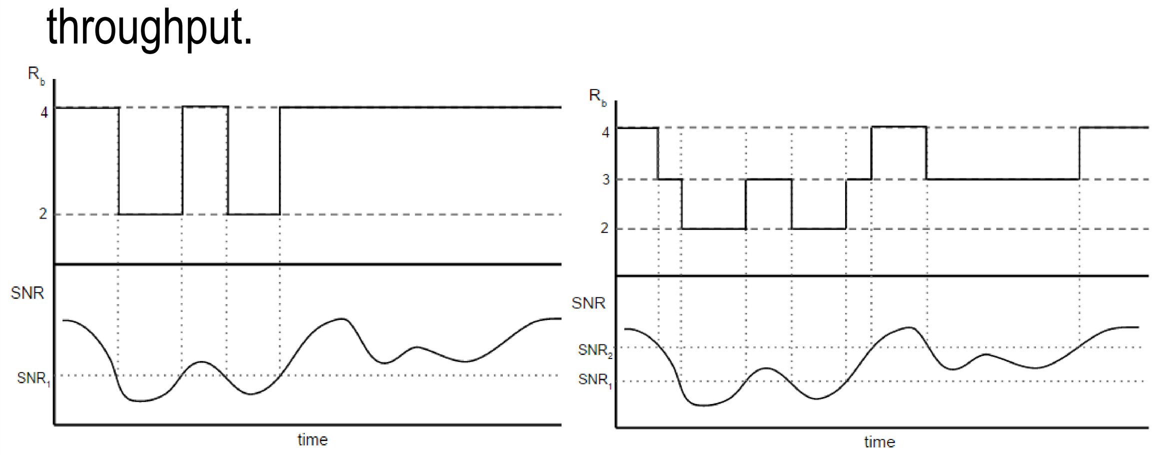
Introduction

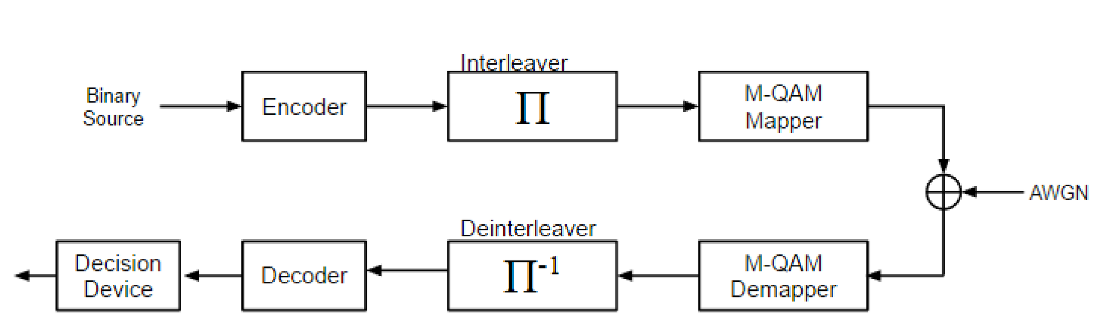
Today's wireless communication system is improving expanding at a fast rate with different techniques being explored. Currently, industry standards including WLAN IEEE 802.11 supports conventional QAM (Quadrature Amplitude Modulation) for even-bits per symbol. Conventional QAM is defined as M-QAM systems where M = 2^k , where k = even integers. Popular conventional QAMs include QPSK (k=2), 16-QAM (k=4) and 64-QAM (k=6). In contrast, non-conventional QAM, defined as M-QAM systems, where k = odd integers, has little support. Non-conventional QAM's that are included in this project were 8-QAM (k=3), 32-QAM (k=5), and 128-QAM (k=7).

This project explored techniques to improve the communication systems by extending bit rate options and using different mapper and demapper metric algorithms on non-conventional QAM. In particular, the bit rate options are extended by including odd bit rates using non-conventional QAM. By doing so, the bit rate changes become smoother. In the figure on the left, the bit rate, R_b, changes are shown for only even numbered R_b . The figure on the right shows changes with odd numbered R_b included. Using the same SNR figure, it is clear that be including more bit rate options, the plot become less discrete, smoother and the jumps between levels are less severe. This change will improve overall system throughput.



Methodology

The project explored the log likelihood ratio (LLR) metric for mapping and demapping for 8-, 32, and 128-QAM. It extended to a system implementation with two error correcting codes: Reed-Muller and LDPC with interleaving through an AWGN channel. All simulations were done through C coding and Matlab.

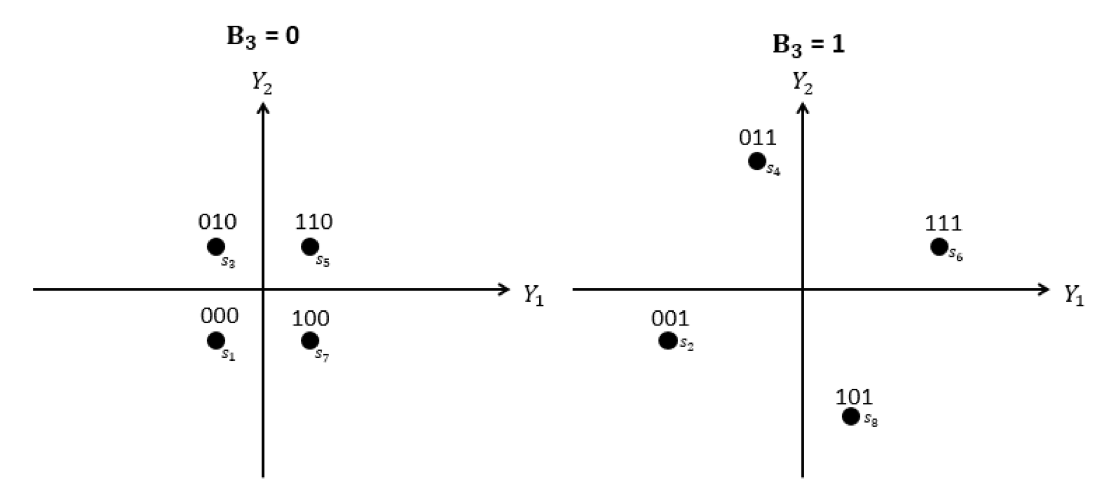


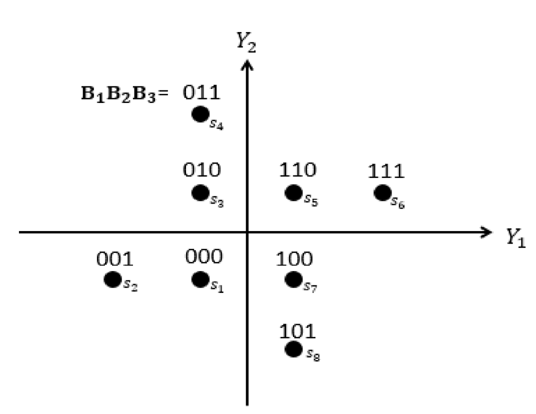
Methodology

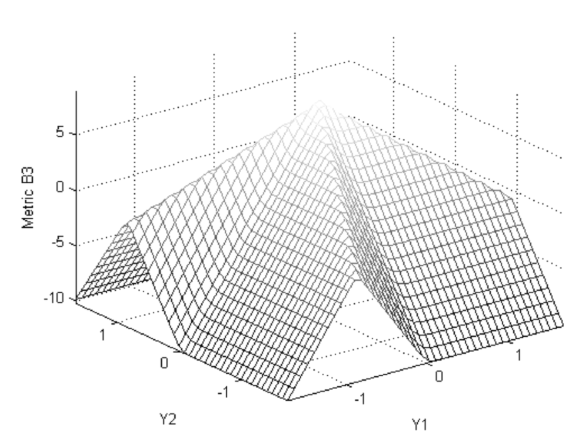
Generally, the received symbol will have added noise. The LLR metrics are used to determine which symbol was initially transmitted.

$$m(B_i) = log\left(\frac{P[B_i=0|\hat{y}]}{P[B_i=1|\hat{y}]}\right) = log\left(\frac{\sum_\alpha e^{-1/N_o|\hat{y}-\alpha|^2}}{\sum_\beta e^{-1/N_o|\hat{y}-\beta|^2}}\right)$$

The LLR metric equation is seen above where $\hat{y}$ represents the received signal, α represents symbols where $B_i = 0$, β represents symbols where $B_i = 1$, and i = 1,…,k. Each metric was models using c coding and displayed as a 3D surface plot. This was done to show the LLR metric characteristics in terms of all inphase and quadrature values of a constellation map. The results shown below is the 3D surface metric plot corresponding to B_3 for 8-QAM.







From the metric equation, and using the properties of logarithmic functions, we can decompose the equation to:

- $P[B_i = 0|\hat{y}] > P[B_i = 1|\hat{y}]$, $m(B_i) = postive$
- $P[B_i = 0|\hat{y}] < P[B_i = 1|\hat{y}]$, $m(B_i) = negative$

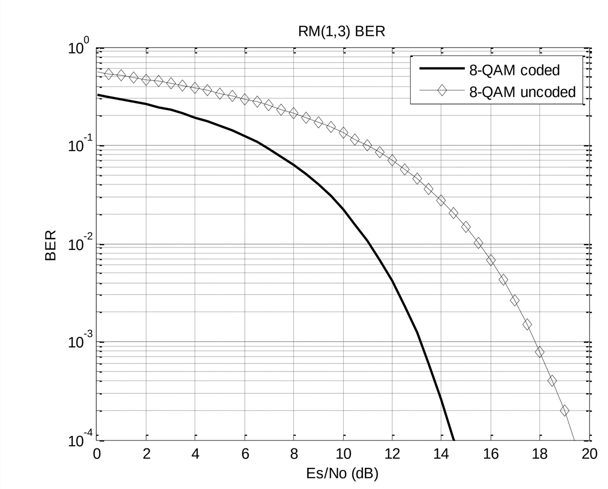
In can be seen from the results above, the metrics is highly positive when the inphase and quadrature values are close to the origin and more negative when it is further away, which corresponds when B_3 = 0 and B_3 = 1 respectively.

This same characteristic plotting was performed for each metric for 8-, 32, and 128-QAM. In additional, each constellation was scaled to achieve unit energy.

Results

The LLR metric mapper and dempper was incorporated with a system with error correcting coding to improve performance. Two types of block coding were used: Reed-Muller and LDPC (Low-Density Parity Check). In addition, interleaving and deinterleaving was added after encoding and before decoding respectively.

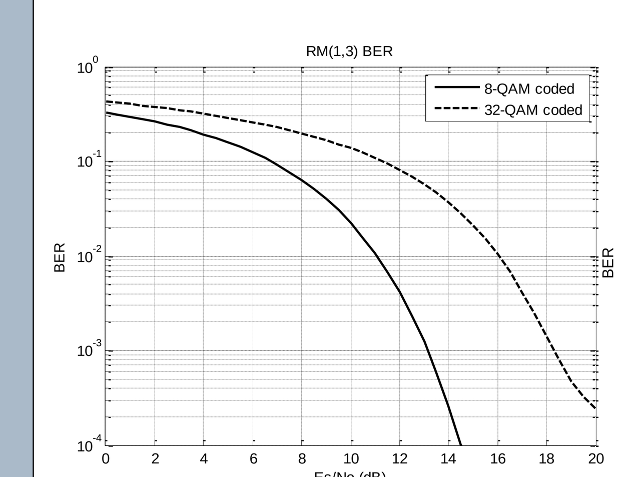
Reed-Muller Encoder
The Reed-Muller encoder, noted as RM[1,3] corresponds with extending Hamming code (8,4,4). Here, the encoder takes in 4 bit messages, adds 4 parity bits and outputs 8-bit length codewords. The decoder implements soft decision decoding. BER of uncoded and coded system is shown below for 8-QAM.

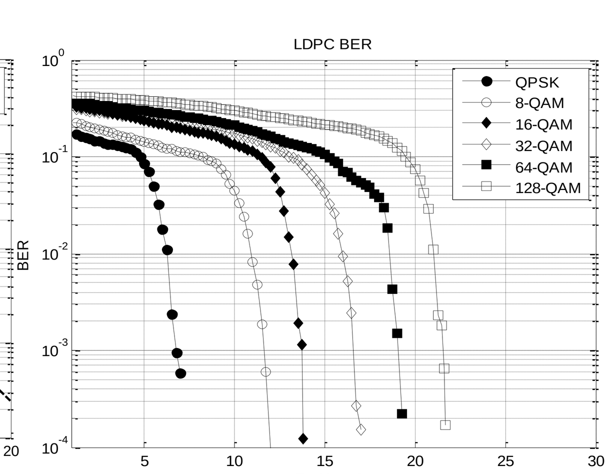


It is confirmed that using hamming coding in the system improves performance. For BER = 10^{-3}, coding gain was approximately 4.5 dB.

Low-Density Parity Check (LDPC)
To extend error correcting coding even further, the encoder used LDPC (273, 191), which now creates code length = 273 and 17 parity nodes. The LDPC decoder uses a combination of Pearl's belief propagation algorithm [7] as well as Mackay's algorithm [6]. The LDPC simulation was run over 1000 iterations.

In addition to the non-conventional QAM system, this LDPC simulation also ran for conventional QAM. This was done to show how each the bit rate will perform in comparison with one another and show the results when odd bit rates are included. The conventional QAM constellation mappings were taken from IEEE 802.11 standard [3].





Summary

A mapper and demapper using log likelihood ratio metrics was created and implemented for non-conventional QAM's including 8-QAM, 32-QAM and 128-QAM. The metric characteristic was calculated and graphed over the entire constellation plane in terms of inphase and quadrature values.

In addition, this mapper and demapper system was simulated over an AWGN channel where both Hamming codes and LDPC were used for error correcting coding. The performance was calculated and shown as BER for bit rate, R_b = 2,3,4,5,6, and 7. Purposed future work includes using LDPC codes from the IEEE 802.11 standard.

Key References

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[2] A. Goldsmith, *Wireless Communications*. Cambridge University Press, 2005
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[7] J. Pearl, *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Interference.* San Mateo, CA, Kaufmann, 1988

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Further Information

Please contact *quynhquach1@gmail.com*. MATLAB code, C code, simulation files, export data files and additional results are available upon request.