



Efficient Implementation of Hybrid QAM using Golay Sequence

Mr.E.Vinothkumar, Harikrishnan.M, Krishnan.N, Pachamuthu.S

Muthayammal Engineering College, Rasipuram, Tamil Nadu, India

Department of Electronics and Communication Engineering, Muthayammal College of Engineering, Rasipuram, Tamil Nadu, India

Publication History: Received: 25.02.2026; Revised: 20.03.2026; Accepted: 25.03.2026; Published: 28.03.2026.

ABSTRACT: Hierarchical quadrature amplitude modulation (HQAM) enables unequal priority transmission through the use of non-uniformly spaced constellations. We propose an adaptive HQAM (A-HQAM) scheme where the ratios between the constellation distances are regularly adjusted based on the channel condition with the objective of maximizing the transmission efficiency. For very-low-cost mobile terminals, it is desirable to have grossly nonlinear power amplifiers, which are simpler to implement and have higher amplification efficiency and output power. In this case, QAM modulations are strongly recommendable since the transmitted signals can have very low fluctuations. It should be pointed out that for QAM constellations the main degradation due to a short distance constellation mapping that leads to interference in In-phase and quadrature phase signals. For noninterference signals we uses golay sequence that provide make constellation sequence adapt to channel conditions. The proposed scheme offers reduced complexity by using one constellation size, unlike conventional adaptive schemes which require the use of several constellation sizes.

KEYWORDS: AHQAM, QAM, Constellation size, Golay sequence

I. INTRODUCTION

Hierarchical modulation is an interesting variation of conventional modulation. Using hierarchical modulation, a bit stream can be separated into several multiplexed sub-streams with different levels of priority, a high priority (HP) sub-stream and lower priority (LP) sub-streams. It supports unequal priority control without an increase in bandwidth requirement unlike channel coding techniques which add redundancy to the transmitted data. Moreover, hierarchical modulation is a promising technique to provide differentiated quality of service (QoS). For example, in multimedia transmission, a base layer and enhancement layer bit streams can be multiplexed and transmitted using hierarchical modulation. The base layer corresponds to the HP data while the enhancement layer corresponds to the LP data. Users with good reception conditions or advanced receiver capabilities can receive both layers and enjoy high QoS. On the other hand, users with poor reception conditions or less sophisticated receivers can still receive basic QoS (i.e. the base layer only). Therefore, hierarchical modulation could be a promising solution for upgrading existing digital broadcast systems and 3rd generation or beyond radio access networks while maintaining forward compatibility for existing user terminals. In addition, hierarchical modulation when combined with scalable source coding provides a graceful degradation in the quality of the received information when the channel condition deteriorates without requiring feedback from the receiver. It has already been incorporated in some digital video transmission standards such as [DVB-T]. In HQAM was proposed as an unequal error protection scheme for transmitting scalable and data-partitioned H.264 video. Hierarchical modulation can also be applied to other modulation schemes such as differential phase shift keying (DPSK).

A.Related work

Many adaptive hierarchical modulation schemes have been proposed in the literature. These schemes utilize adaptive hierarchical modulation to support simultaneous transmission of different classes of traffic or to maintain a desired quality of service such as a specified target error probability. An adaptive hierarchical PSK was proposed in to support simultaneous transmission of different types of traffic which have different QoS requirements. Their proposed algorithm maximized the throughput for the additional message but not for all messages. An adaptive HQAM transmission system was proposed in which the HP capacity could be adjusted while maintaining the HP protection level by adapting the constellation distances. The constellation size, the priority parameters of the hierarchical

constellation, and the assigned bit positions were changed based on the channel condition to maintain a target bit error rate (BER) for each class of service regardless of the achieved spectral efficiency.

II. QUADRATURE AMPLITUDE MODULATION

A. Overview

As mentioned QAM systems are widely used in modern communication systems where maximum throughput is required under limited bandwidth conditions thus being considered an alternative way of increasing the spectral efficiency in optical communication. Furthermore the benefits of M-QAM have been widely accepted for microwave digital radio applications and voice band modems, including Digital Video Broadcasting cable (DVB-C) in addition to wireless 802.11 protocols or personal communications for the military. In general terms QAM can be defined as the digital modulation format where information is conveyed in the amplitude and phase of a carrier signal. This scheme combines two carriers whose amplitudes are modulated independently with the same optical frequency and whose phases are shifted by 90 degrees with respect to each other. These carriers are called in-phase carriers (I) and quadrature-phase carriers (Q). Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components —hence the name of the scheme. The modulated waves are summed, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift

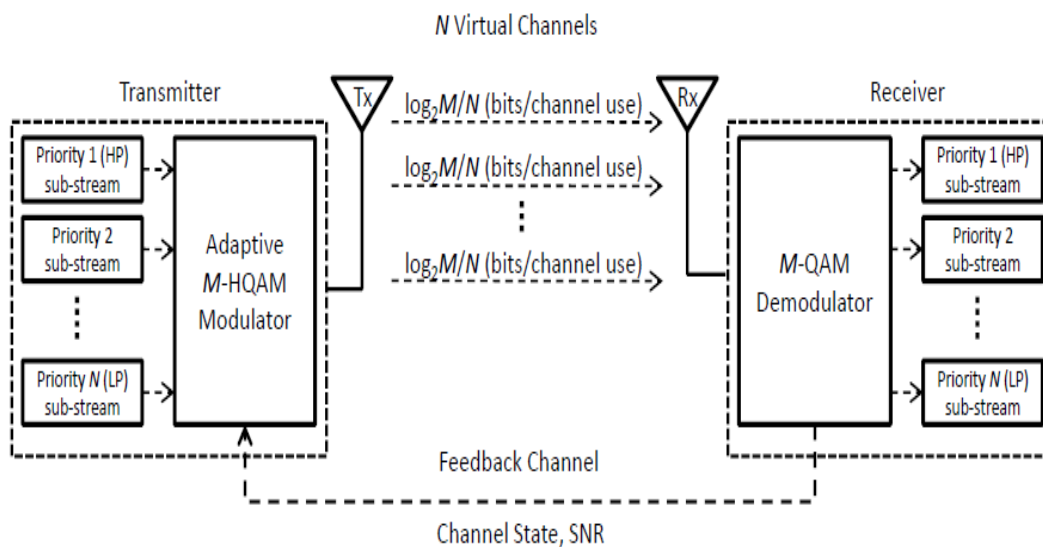


Fig 1: Adaptive H-QAM system

keying (ASK), or (in the analog case) of phase modulation (PM) and amplitude modulation. QAM is used extensively as a modulation scheme for digital telecommunication systems.

III. EXISTING ADAPTIVE H-QAM

Above figure 1 describes the proposed A-HQAM scheme. At the transmitter, the message (packet) to be transmitted is first divided into N sub-packets. Each sub-packet undergoes a cyclic redundancy check (CRC). HQAM is then employed to transmit each sub-packet using a pair of contiguous bits in the modulation symbol. The two MSBs correspond to priority 1 sub-stream while the subsequent pairs represent the lower priority sub-streams. Therefore, N virtual parallel sub channels with different BER performances are created. At the receiver, the received signal is demodulated and the integrity of each sub-packet is checked. When errors are detected in a sub-packet retransmission requests for that sub-packet are triggered. Moreover, the transmission channel condition is monitored at the receiver and fed back through a reliable feedback channel with neglected delay. When the transmission channel is in a bad state,



the proposed algorithm selects constellation spacing parameters which result in an acceptable BER for the high priority sub packet at the expense of the BER

performance of the lower priority sub-packets. As the channel condition improves, the required protection for the high priority sub-packet is reduced. Hence, the constellation spacing is adjusted to increase the protection level of lower priority sub-packets. This way some bits (i.e. sub-packets) of the original packet can be rescued under channel conditions in which the whole packet would normally be lost. Hence, the A-HQAM provides a cumulative transmission efficiency which exceeds the transmission efficiency of both non-adaptive HQAM and conventional adaptive QAM. For a given packet size, an exhaustive search is initially done offline to define SNR switching points at which the constellation distance ratios are changed to maximize the transmission efficiency. The exhaustive search also finds the constellation distance ratios that reduce the PAPR at good channel conditions. Our A-HQAM scheme provides reduced complexity when compared to conventional adaptive QAM schemes which use several constellation sizes. It utilizes a fixed constellation size and hence eliminates the need for synchronization mechanisms which are needed in conventional adaptive QAM receivers to know the used constellation size whenever the transmitter changes the modulation level. Moreover, in our proposed adaptive scheme, we employ a practical implementation of HQAM which enables the receiver to demodulate the received signal successfully without being informed of the used constellation distance ratios at the transmitter as needed by a conventional HQAM receiver. HQAM implementation which allows the receiver to successfully demodulate the received signal without the need for knowing the employed constellation distance ratios at the transmitter.

IV. PROPOSED ADAPTIVE H-QAM

Golay complementary sequences, often referred to as Golay pairs, are characterised by the property that the sum of their a periodic autocorrelation functions equals to zero, except for the zero shift. Because of this property, Golay complementary sequences can be utilised to construct QAM of the lengths not necessary being a power of 2. In the project, we present an evaluation, from the viewpoint of Adaptive QAM modulation of some sets of spreading sequences derived from Golay complementary sequences. We then modify those sets of sequences to enhance their correlation properties for asynchronous operation and simulate a AHQAM system utilising the modified sequences.

A. Advantages of proposed system

- It is modify those sets of sequences to enhance their correlation properties for asynchronous operation and simulate a AHQAM system utilizing the modified sequences.
- Because of small constellation size, the errors in in-phase and quadrature-phase signals can be avoided.

B. Block diagram of transmitter section

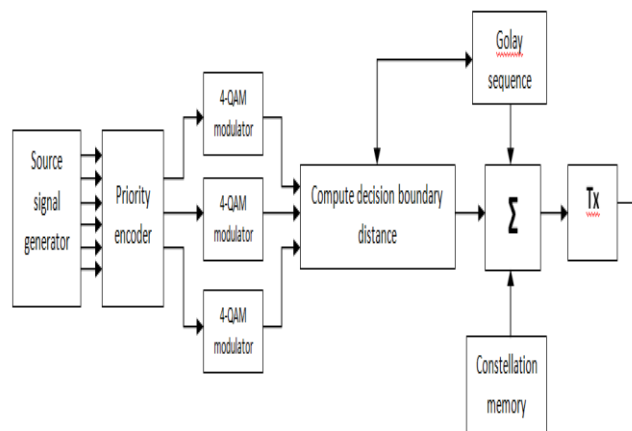


Fig 2: QAM transmitter section

Contents

- Source signal generator
- Priority encoder



- 4-QAM modulator
- Compute decision boundary distance
- Golay sequence
- Constellation memory

C. Block diagram of receiver section

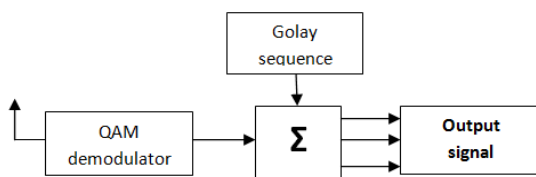


Fig 3: QAM receiver section

Contents

- QAM demodulator
- Golay sequence
- Output signal

D. Golay sequence

A pair of Golay complementary sequences is a pair of sequences A and B, each of the same length n, such that all sequences elements are +i or -i and the k-autocorrelation of A together with the k-autocorrelation of B sums to zero for all k. To avoid interference between signals in Rayleigh channels, we need to add integrity between transmitted signals. For this purpose we add golay complementary sequence to signals where its sum of dot product is zero. Difference between in phase and quadrature phase component is calculated, if the sum of dot product of difference is zero, there is no need to add golay sequence and if there is non-zero element exists we need to add golay sequence. This enhance correlation property between in phase and quadrature phase component and avoids interference.

Eg:-

```

1 0 1 1 1 1 0 1 0
1 1 1 0 1 0 1 1 0
1 0 1 0 1 0 0 1 0
    
```

In above example two sequences, dot product is taken and resulting sum is zero. Here we don't need to add any complementary golay sequence to signal.

```

1 0 1 1 1 1 0 1 0
1 1 1 0 1 0 1 0 0
1 0 1 0 1 0 0 0 0
    
```

The SOP for above sequence is not equals to zero so that it does not exhibit correlation property. For this we need to add the pattern 00000010 which makes the sequence to get sum of product as zero.

V. CONCLUSION

The continuing evolution of communication standards and competitive pressure in the market-place dictate that communication system architects must start the engineering design and development cycle while standards are still in a fluid state. Third and future generation communication infrastructure must support multiple modulation formats and air interface standards. FPGAs provide the flexibility to achieve this goal, while simultaneously providing high levels of



performance. Our QAM design shows better stability over noise channel that can be easily estimated at receiver end. We have reviewed several aspects of carrier recovery for communication systems using QAM modulation. In the existing system constellation size is more and there are many sub streams through which signals simultaneously transmitted with different priority causing error. In the proposed system constellation size is small and also it avoids inter symbol interference in in-phase and quadrature-phase signals using golay sequence.

REFERENCES

1. Husameldin Mukhtar, Student member, IEEE, and Mohamed El-Tarhuni, Senior member, IEEE, "An adaptive hierarchical QAM scheme for enhanced bandwidth and power utilization" IEEE TRANSACTIONS ON COMMUNICATIONS.VOL., 60, NO.8, AUGUST 2012.
2. C. Hellge, S. Mirta, T. Schierl, and T. Wiegand, "Mobile TV with SVC and hierarchical modulation for DVB-H broadcast services," in Proc. 2009 IEEE International Symp. Broadband Multimedia Syst. Broadcasting, pp. 1–5.
3. D. Kwon, W. Kim, K. Suh, H. Lim, and H. Kim, "A higher data-rate T-DMB system based on a hierarchical A-DPSK modulation," IEEE Trans. Broadcast., vol. 55, no. 1, pp. 42–50, 2009.
4. H. Zhao, X. Zhou, Y. Yang, and W.Wang, "Hierarchical modulation with vector rotation for E-MBMS transmission in LTE systems," J. Electr. Comput. Eng., vol. 2010, p. 2.
5. Kyongkuk Cho and Dongweon Yoon, Member, IEEE " On the General BER Expression of One- and Two-Dimensional Amplitude Modulations", IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 50, NO. 7, JULY 2002.
6. M. M. Ghandi, M. Ghanbari " Layered H.264 video transmission with hierarchical QAM". Preprint submitted to Elsevier Science 1 May 2005.
7. M.Hossian, M. Alouini, and V. Bhargava, "Rate adaptive hierarchical modulation assisted two-user opportunistic scheduling"., IEEE Transactions Wireless Commun., vol. 6, pp. 2076–2085, 2007.
8. P. Vitthaladevuni and M. Alouini, "A recursive algorithm for the exact BER computation of generalized hierarchical QAM constellations," IEEE Trans. Inf. Theory, vol. 49, no. 1, pp. 297–307, 2003.
9. S. Jakubczak and D. Katabi, "A cross-layer design for scalable mobile video," in Proc. 2007 Annual International Conf. Mobile Comput. Netw., pp. 289–300.
10. Xiaoyi Tang, Mohamed-Slim Alouini, Member, IEEE, and Andrea J. Goldsmith, Senior Member, IEEE "Effect of Channel Estimation Error on M-QAM BER Performance in Rayleigh Fading" IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 47, NO. 12, DECEMBER 1999.
11. Y. Cheng, W. Li, H. Chou, and Y. Huang, "Wideband video transmission MIMO-OFDM platform using LLR-based adaptive hierarchical modulation," in Proc. 2010 IEEE International Symp. on Broadband Multimedia Syst. Broadcast., pp. 1–6.
12. C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- Taylor & Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011. DOI: 10.1080/15325008.2010.541746
13. C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of Electrical Engineering, Vol.63 (6), pp.365-372, Dec.2012. DOI: 10.2478/v10187-012-0054-2
14. C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011. DOI 10.1007/s00202-011-0203-9
15. S.Tamilselvi, R.Prakash, C.Nagarajan, "Solar System Integrated Smart Grid Utilizing Hybrid Coot-Genetic Algorithm Optimized ANN Controller" Iranian Journal Of Science And Technology-Transactions Of Electrical Engineering, DOI10.1007/s40998-025-00917-z, 2025
16. S.Tamilselvi, R.Prakash, C.Nagarajan, " Adaptive sliding mode control of multilevel grid-connected inverters using reinforcement learning for enhanced LVRT performance" Electric Power Systems Research 253 (2026) 112428, doi.org/10.1016/j.epr.2025.112428
17. S.Thirunavukkarasu, C. Nagarajan, 2024, "Performance Investigation on OCF and SCF study in BLDC machine using FTANN Controller," Journal of Electrical Engineering And Technology, Volume 20, pages 2675–2688, (2025), doi.org/10.1007/s42835-024-02126-w
18. C. Nagarajan, M.Madheswaran and D.Ramasubramanian- 'Development of DSP based Robust Control Method for General Resonant Converter Topologies using Transfer Function Model'- Acta Electrotechnica et Informatica Journal , Vol.13 (2), pp.18-31, April-June.2013, DOI: 10.2478/aei-2013-0025.



19. C.Nagarajan and M.Madheswaran - 'DSP Based Fuzzy Controller for Series Parallel Resonant converter'- Springer, Frontiers of Electrical and Electronic Engineering, Vol. 7(4), pp. 438-446, Dec.12. DOI 10.1007/s11460-012-0212-0.
20. C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.
21. C.Nagarajan and M.Madheswaran, "Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation" has been presented in ICTES'08, a IEEE / IET International Conference organized by M.G.R.University, Chennai. Vol.no.1, pp.190-195, Dec.2007
22. Suganthi Mullainathan, Ramesh Natarajan, "An SPSS and CNN modelling based quality assessment using ceramic materials and membrane filtration techniques", Revista Materia (Rio J.) Vol. 30, 2025, DOI: <https://doi.org/10.1590/1517-7076-RMAT-2024-0721>
23. M Suganthi, N Ramesh, "Treatment of water using natural zeolite as membrane filter", Journal of Environmental Protection and Ecology, Volume 23, Issue 2, pp: 520-530,2022
24. Yoong Choon Chang, Sze Wei Lee and Ryoichi Komiya, Members, IEEE "A Low-Complexity Unequal Error Protection of H.264/AVC Video Using Adaptive Hierarchical QAM" IEEE Transactions on Consumer Electronics, Vol. 52, No. 4, NOVEMBER 2006.
25. Y. Pei and J.W. Modestino "Cross-Layer Design for Video Transmission over Wireless Rician Slow-Fading Channels Using an Adaptive Multiresolution Modulation and Coding Scheme" Hindawi Publishing Corporation EURASIP Journal on Advances in Signal Processing Volume 2007, Article ID 86915, 12 pages doi:10.1155/2007/86915.