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An Efficient Hierarchical Modulation based Orthogonal Frequency Division Multiplexing Transmission Scheme for Digital Video Broadcasting

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ABSTRACT

Due to the increase of users the efficient usage of spectrum plays an important role in digital terrestrial television networks. In digital video broadcasting, local and global content are transmitted by single frequency network and multifrequency network respectively. Multifrequency network support transmission of global content and it consumes large spectrum. Similarly local content are well supported by single frequency network. In order to provide better spectral efficiency both local and global contents are transmitted in single constellation using hierarchical modulation. Hierarchical modulated OFDM system provides good spectral efficiency and robustness to the fading environment. In this paper a hierarchical modulated OFDM system for local service insertion is analyzed and its performance under various channels is been discussed. Convolutional encoder is used in this paper.

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NOMENCLATURE

X_g	Magnitude of modulated global content	d_l	Distanest between message point within quadrants
X_l	Magnitude of modulated local content	$d_l^{'}$	Distanest between message point between two quadrants
X_{HP}	Complex high priority signal	$I_{Fictituous}$	Real value of the complex fictituous point
X_{LP}	Complex Low priority signal	$Q_{Fictituous}$	Imaginary value of the complex fictituous point
X_{HQAM}	Complex hierarchical modulated signal	E_g	Average energy per symbol of HQAM signal.
θ	Phase location of signal point.	X_k	Complex hierarchical modulated signal
a_1, b_1	Constellation location of global content	Y_T	Output of IFFT
c_1, d_1	Constellation location of local content	N_L	Noise compenent added during transmission
d_g	Distance between two fictitous point.	X_k^{Est}	Out put of FFT block at the receiver.

1. INTRODUCTION

Digital broadcasting is widely used in various services like digital terrestrial television, digital radio, satellite etc; Mobile multimedia broadcasting becomes a developing research area because of advancement in smart technologies. As the expectation of user increases incorporating latest technologies in broadcasting technique must provide significant coverage and spectral efficiency. Meanwhile Existing digital broadcasting technique transmits local content using multi frequency network consume more spectrum whereas single frequency network is efficiently used to transmit global contents. The task of transmitting both global and local content in SFN achieved using

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hierarchical modulation. Hierarchical modulation is highly recommended for digital broadcasting. Hierarchical modulation is also called as multilayer modulation which is quite different from multilayer coding which is a source coding technique in wireless network that provides unequal error protection in each layer of the transmitted signal. Hierarchical modulation offers different modulation scheme for both base and enhancement layers after the data is subjected to channel coding techniques. It offers layered modulation for transmission of multiclass signal in a single frequency network. The base layer carries the high priority or global content which is basically a Quadrature Phase Shift Keying (QPSK) modulated signal allots two bits with four combinations. The enhancement layer carries the low priority local content which is mapped with QAM modulation. Based on the order of layered constellation four, eight or sixteen QAM is used for low priority stream. Both local and global information can be embedded into single constellation and transmitted in an OFDM system. Digital video broadcasting is based on coded OFDM. In fact, OFDM is a multicarrier system supports broadcast application with single frequency network; where the bit streams are divided in to blocks of data among the separated serial streams are modulated parallelely with orthogonal subcarriers which does not interfere with each others [1]. OFDM system provides system efficiency and robustness to the signal in the fading channel. In single frequency network demands for both global and local content to be overplayed in single constellation before transmission, in order to provide better spectral efficiency than multifrequency network. The user with good reception detects both global and local content perfectly. The reception of the local content is based on the detection technique of the receiver. Although HM itself enables the multiplexing of different quality signal in single channel. Both the layers are provided with the same level of protection in DVB. The code rate determines the coverage area and service coverage quality. In order to provide higher data rate higher level modulator is used but there is a trade off with interference and in turn coverage radius. Digital video broadcasting project transforms the classical TV channel to a data transmission medium which may carry huge data rates at extremely low bit error rate. DVB makes possible reception of digitized signals by portable and mobile receiver. DVB signal will be delivered via all sorts of broadcasting media like MMDS, satellite, cable and terrestrial. Heirarchical modulation is well suited to upgrade the existing broadcast system which gave provision to transmit additional data in the secondary constellation in addition to base constellation [2]. It allows significant gain improvement in terms of spectral efficiency in DVB S2. It supports the insertion of local content in single frequency network in DVB SH [3] and other DVB standards include next generation handheld [4]. It allows different rate of signal transmission in a given channel capacity [5, 6]. The hierarchical modulation is included in digital broadcasting standard, media Flo ultra mobile broadband, terrestrial digital multimedia broadcasting digital video broadcasting standards like DVB-T2, DVB SH and DVB NGH.

2. PREVIOUS WORK

Jiang et al. [2] proposed the hierarchical modulation scheme to upgrade broadcasting system and gave analysis and showed the trade-off between bitrate of the data in both constellations. Xu et al. [7] analyzed the hierarchical modulation for DVB SH to increase flexibility using turbo encoder. Also, Jiang et al. [3] introduced hierarchical modulation for providing local content in a hybrid satellite and terrestrial single frequency network in DVB SH. Stukavec [8] gave the simulation and performance of hierarchical modulation in DVB.T/H. Shah et al. [9] gave the analysis of hierarchical modulation in DVB H system for image transmission. Ghani et al. [10] described the hierarchical modulation with 16QAM for transmission of image through erroneous wireless channel and analyzed the performance with non-hierarchical 16QAM. Mohamed et al. [11, 12] proposed hierarchical modulation with improved scheme for DVB SH where a turbo BICM reception scheme is used to improve Low priority performance. Zamkotsian et al. [13] proposed layered offset hierarchical QAM to enhance high priority stream error performance by reducing ISI from super imposed symbols of the low priority stream. Hugomeric et al.[14, 15] proposed hierarchical modulation for DVB S2 and DVB SH for time sharing and to optimise the spectrum efficiency. Lopez-Sanchez [4, 16] proposed two techniques namely the hierarchical modulation and orthogonal local service insertion method to insert the local services in single frequency network and gave the performance analysis of both the technique. Adam et al. [17] reported the BER performance of Hierarchical Modulated non OFDM system.

3. CONCEPT OF HIERACHICAL MODULATION

In hierarchical modulation, the low priority and high priority streams are separately and independently encoded before being mapped in to a single uniformly spaced constellation. In this technique, the global and local bits are embedded in a single constellation. The global bits are transmitted as high priority stream. Minimum distance Euclidean decoder is used to estimate the information bits of both LP and HP streams. Both streams can be equally or unequally protected based on the channel environment in the receiver.

The LP stream is perfectly demodulated only at good operating condition; the HP stream is decoded efficiently even in bad channel condition. The concept behind this technique is well explained using a block diagram shown in Figure 1.

The multilayer modulation uses either QPSK, 16QAM, 64QAM modulation schemes. In the case of lower order 16HQAM high priority global bit and low priority local bit are separately encoded using convolutional encoder and modulated using QPSK mapping with different phase of (2i-1)π/4., i=1, 2, 3, 4 for 00, 01, 11 and 10 respectively. The mapping of the QPSK signal in the space follows gray coding. The complex modulated high priority, X_{HP} and low priority, X_{LP} signal located in the space at the location $\pm a_1 \pm b_1$, $\pm c_1 \pm d_1$ can be represented mathematically as:

$$X_{HP} = \left|X_g\right| \angle e^{j\theta} \ and \ X_{LP} = \left|X_l\right| \angle e^{j\theta} \tag{1}$$

The term $\left|X_g\right|$ and $\left|X_l\right|$ represented as the magnitude of the complex signal, theta refers the phase whose value locate the signal on the space. a_1, b_1, c_1 and d_1 are the constellation location of global and local conent. The two resultant QPSK modulated complex signals is summed results in a HQAM signal X_{HQAM} to transmit in the noisy channel is given below as:

$$X_{HQAM} = X_{HP} + X_{LP} \tag{2}$$

This result in QAM constellation with 16 message points located in four quadrants the two bits in the left, which is same for the four message points in each quadrant, is recognized as the global bit and rightmost two bits that differ within the quadrant is the local bit as shown in Figure 2. The distance between the constellation points are mathematically expressed by Vithalatheveni [18]. Assume the distances between the message points within a quadrant is d_1 and the nearest message points between two quadrant be $d_1^{'}$. The distance between the two fictitous point d_g is given as follows:

$$d_g = 2\left[d_l^{'} + \frac{\sqrt{M}-1}{2}\right]d_l \tag{3}$$

The average energy per symbol, E_s for HQAM given by Vidheladevuni [18] as:

$$E_s = 2\left(\frac{d_g}{2}\right)^2 + \frac{2}{3}\left(\frac{M}{4}-1\right)\left(\frac{d_i}{2}\right)^2 \tag{4}$$

Since the HP bits for each quadrant is same. Therefore a fictious point is considered at the centre of the constellation points. This point is highly recommended for the detection at the receiver. In the case of 16HQAM system it is found using the following formula.

$$\begin{aligned} I_{Fictious} &= \frac{Max[\mathrm{Re}(X_{HQAM})] + Min[\mathrm{Re}(X_{HQAM})]}{2} \\ Q_{Fictious} &= \frac{Max[\mathrm{Im}(X_{HQAM})] + Min[\mathrm{Im}(X_{HQAM})]}{2} \end{aligned} \tag{5}$$

where $I_{Fictious}$ and $Q_{Fictious}$ are the real and imaginary value of the fictitious point selected. In case of QAM constellation with 2^n message points with n bits are arranged is square grid with equal Spacing in vertical and horizontal axes.

Layered modulation with Number of message points $M = 2^n$ is derived from the combination of QPSK modulated base layer complex signal and QAM modulated enhancement layer complex signal with 2^{n-2} constellation points.

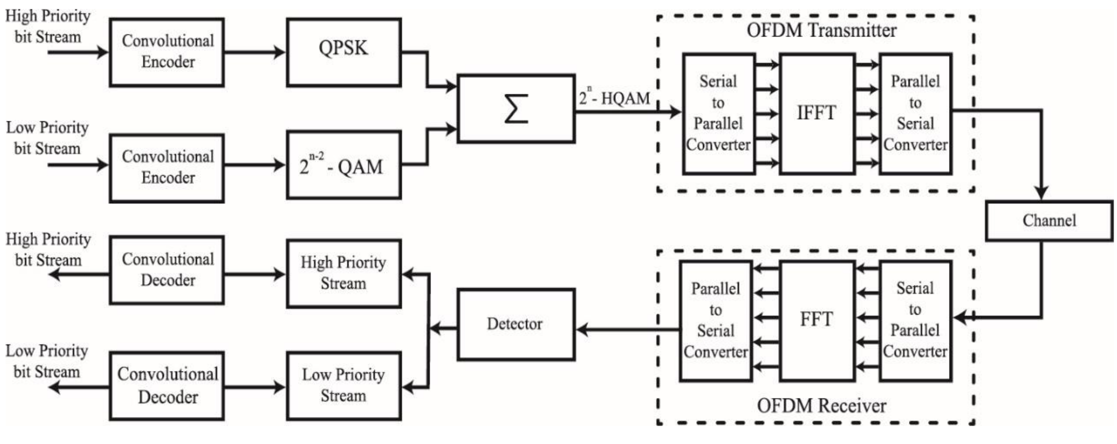

Figure 1. Hierarchical modulated OFDM system for DVB system

The constellation diagram of 64HQAM system is shown in Figure 3. Higher order modulation locate more points on the constellation enable us to transmit more bits per symbol. This happens with trade off in performance due to closed arrangement of points as the value of M increases.

It offers faster data rate and higher level of spectral efficiency for the radio communication system. QAM is the preferred modulation schemes with many practical applications in wireless technologies such as optical wireless communication system [19], WiFi cable modems, digital video broadcasting and wimax etc. In many digital video broadcasting standards 64QAM is used. Although QAM takes its step in wireless and cellular technology application.

4. HIERARCHICHAL MODULATED OFDM SYSTEM

Due to advancement in wireless digital broadcasting technology, the requirement of high data rate increases in many application.

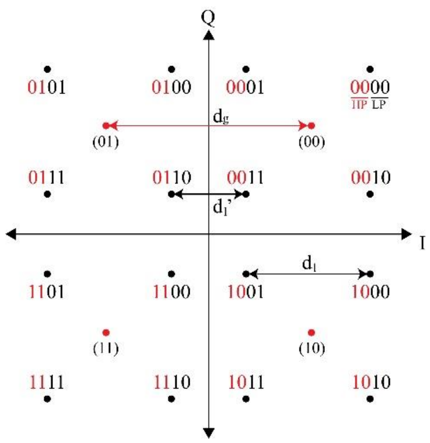

Figure 2. Constellation diagram of 16HQAM signal

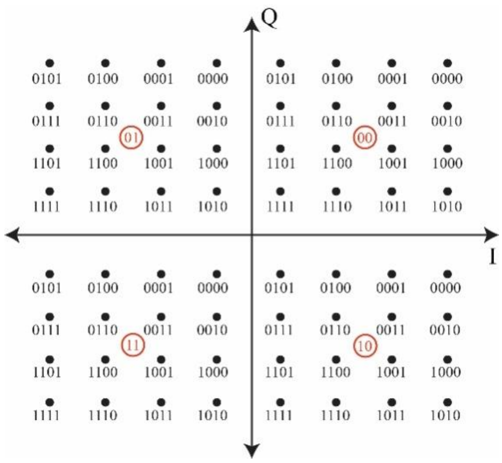

Figure 3. Constellation diagram of 64 HQAM signal

The multipath effect in the wireless channel is the major difficulty in single carrier system that limit the data rate. Considerable data rate achieved only by tradeoff with inter symbol interference. Thus the multi carrier system that satisfies the candidature like high data rate mitigate ISI in dispersive fading channel is required. In recent years, OFDM becomes a better alternative for single carrier system for WLAN,ndigital broadcasting system and WIMAX.

OFDM is a parallel transmission scheme where a high rate serial data stream is split up in to a set of low rate sub streams each of which is modulated on a separate single carrier. The single carrier occupies less bandwidth than the coherence bandwidth of the channel. Orthogonal carrier frequency selected to obtain high spectral efficiency will allow the single carrier to overlap but avoid the mutual interference. The IFFT and FFT are used for modulating and demodulating the HQAM constellation with the orthogonal carriers. Although the IFFT replaces the requirement of banks of I/Q Modulators. The complex hierarchically modulated QAM signal Y_T subjected to N point IFFT at the transmitter given by:

$$Y_T = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kl}{N}}, 0 \le l \le N-1. \tag{6}$$

The complex hierarchical modulated signal is transmitted through the AWGN and fading channel. The received signal Y_R, subjected to the fading environment is represented as:

$$Y_R = \alpha(t) e^{j\omega(t)} Y_T(t) + n(t),\ 0 \le t \le T \tag{7}$$

where $\alpha(t)$ is Rayleigh fading envelope, $\omega(t)$ represent the phase shift of the channel and $n(t)$ refers the additive white Gaussian noise. At the receiver, the complex HQAM signal is recovered by performing a FFT. The estimated signal in frequency domain is given as follows:

$$X_K^{Est} = \frac{1}{N} \sum_{L=1}^{N-1} Y_T e^{\frac{-j2\pi kL}{N}} + \frac{1}{N} \sum_{L=0}^{N-1} N_L e^{\frac{-j2\pi kL}{N}}, \quad 0 \le k \le N-1 \tag{8}$$

5. RESULTS AND DISCUSSION

The simulated results shown in Figures 4-6 show the performance analysis of hierarchical modulated OFDM system for AWGN and Rayleigh fading channels with 16HQAM and 64HQAM constellation order. Number of carriers selected for OFDM varies from different DVB standards. The specifications for OFDM carriers in

DVB H is 2K, 4K, 8K, DVB SH is 1K, 2K, 4K, 8K and for DVB T2 is 1K, 2K, 4K, 8K, 16K. In this simulation 2K mode is preferred. In case of 16HQAM, the performance of AWGN channel is better compared to the fading channel. Generally, the bit error rate of fading channel is greater than AWGN channel for all the system including CDMA and OFDM systems [20].

The bit error rate of high priority stream is less compared to the low priority stream because of complexity in detection algorithm. The error rate of the LP stream is 34% higher than HP in AWGN channel, 46% in Rayleigh channel and 35% in Rician channel. The error rate of HP stream almost reduces to 10^{-4} at 9db itself and at 18db for LP stream in AWGN. In case of Rayleigh channel it happens at 20db for high priority stream.

For Rician fading channel, the error rate reduces to 10^{-4} at 11db for HP stream and 19db for LP stream. AS the SNR increases, the error rate gets reduces exponentially in case of AWGN channel and inversely with SNR for fading channel.

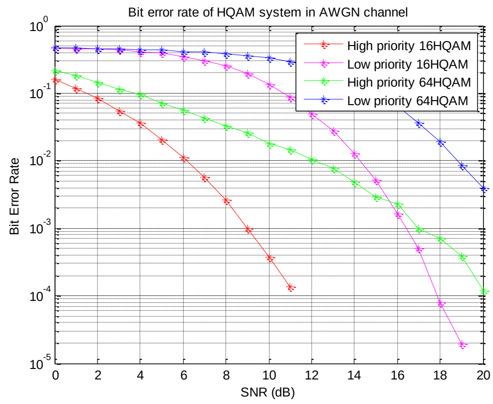

Figure 4. BER plot of hierarchical modulated OFDM system in AWGN channel

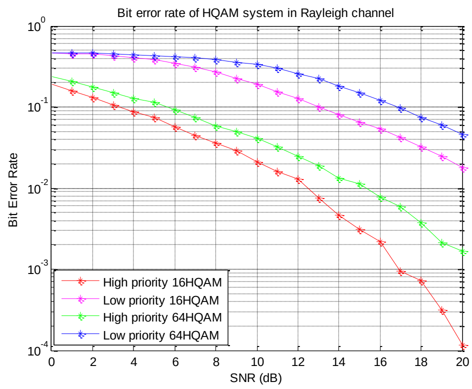

Figure 5. BER plot of hierarchical modulated OFDM system in Rayleigh fading channel

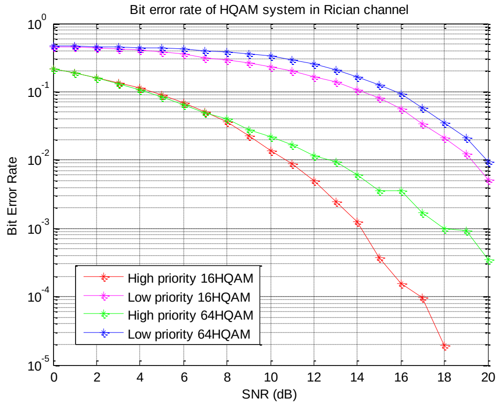

Figure 6. BER plot of hierarchical modulated OFDM system in Rician channel

With increase in order of modulation the data rate increases with increase in error rate. BER of 64HQAM system increases by almost 13% at 14db.

6. CONCLUSION

This paper introduces hierarchic al modulated OFDM system for local service insertion in single frequency network. This paper includes the analysis of the system in various channels. The performance in AWGN channel is better compared to fading channel. This system is strongly recommended for multiplexing different types of data and for transmitting both local and global contents in single constellation for a single frequency network. It outperforms the MFN for local service transmission in DVB by spectral efficiency. Higher order system like 64HQAM system is also discussed. The selection of decision rules plays an important role in detection process. The BER of low priority stream is comparatively more than high priority stream. This technique is also comply with LTE systems. The performance of the system can be improved by selection of proper channel estimation technique and block coders for encoding as the future work.

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چکیده

بدلیل افزایش کاربران نقش استفاده از طیف در شبکه تلویزیونی دیجیتالی از اهمیت خاصی برخوردار است. در زمینه پخش ویدئو دیجیتالی محتوی شبکه با فرکانس چندگانه بصورت محلی یاجهانی پخش می شوند. شبکه با فرکانس چندگانه با پشتیبانی از محتوی جهانی در طیف وسیع پخش می گردد. بهمین منوال شبکه با محتوی محلی با فرکانس منفرد پخش می شود. برای بهبود راندمان شبکه محلی و جهانی با فرکانس مستقل از مدولاسیون سلسله مراتبی استفاده گردید. استفاده از چنین مدولاسیون با فرکانس ارتوگونال بخش مولتی پلکس راندمان مناسبی را فراهم می سازد که درمقابل محو شدن امواج در محیط استحکام مناسبی دارد. در این مقاله سیستم مدولاسیون OFDM برای خدمات محلی آنالیز شده و کارائی کانال های مختلف بحث شده است. در این مقاله از رمزگذار انقباضی استفاده گردید.

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