Studies on Layered Modulation for SVC Signals in DVB-S2 System

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Summary

The paper describes a Layered Modulation using the SVC signals and studies the properties of the modulation with respect to several parameters by the computer simulation. The SVC signals will include a base layer signal and an enhancement signal, and the base layer signal is the more important one in its channel robustness. The parameters will include a carrier frequency, a bandwidth, power level, modulation type and code rate.

We analyze the demodulating and decoding process of the Layered Modulation system through several scatter plots. And then we discuss the affect of the layer signal power difference to the BER performance, which also proves the base layer signal is more important than the enhancement layer signal.

1. Introduction

The Scalable Video Coding (SVC) has been an attractive research and standardization area recently. It enables transmission and decoding of part of the whole bit stream, as a result, it provides a number of video services which is a good property especially in a satellite broadcasting system.[1,2] DVB-S2, which is the second generation DVB system, can take advantages of more recent developments in channel coding (LDPC codes) and modulation (QPSK, 8PSK, 16APSK, and 32APSK), as a result, it achieves higher capacity or spectrum efficiency.[3,4] In the paper, we consider Layered Modulation for SVC signals in DVB-S2 system.

Layered Modulation is also an attractive technique in satellite communications. It consists of two layers, different layer signal can be distinguished from its magnitude. These two layers are independent from each other, as a result, Layered Modulation achieves higher capacity than a usual single layer system. Another advantage of Layered Modulation is that there is a high degree of flexibility in designing the signals.[5] We will describe a Layered Modulation system and the process of demodulating and decoding in the paper.

The power level relationship between the two layers is one of the most important properties in a Layered Modulation system. The power level difference should be larger than a certain value in order to separate signals in different layer. Obviously, the BER performance of the system is affected by the power difference, further, the BER performance gets better as the power difference increasing which is shown in the result of our computer simulation. This means, when the channel condition is not good enough, we can increase the power difference to make the BER performance better.

The remainder of this paper is organized as follows. Section 2 gives a Layered Modulation model in details, where also includes a few computer simulation results. Performance analysis of our proposed system is shown in Section 3. Finally, Section 4 draws the conclusion.

2. Layered Modulation description

A Layered Modulation signal consists of a base layer signal and an enhancement layer signal. There is a high flexibility of designing these two signals in respect that the base layer and the enhancement layer are independent from each other. Signals in different layer can use the same or different signal bandwidth, carrier frequency, modulation type and so on.

Let $s_B(t)$ and $s_E(t)$ denote the base layer signal and the enhancement layer signal, respectively. the signals before transmission are shown in the following equations.

$$s_B(t) = M_B \exp(j\omega_B t + \theta_B) \sum_{m=-\infty}^{\infty} S_{Bm} p(t - mT) \quad (1)$$

$$s_E(t) = M_E \exp(j\omega_E t + \theta_E) \sum_{m=-\infty}^{\infty} S_{Em} p(t - mT) \quad (2)$$

M_B and M_E are the magnitude of the base layer signal and the enhancement layer signal, respectively. M_B should be larger than M_E. ω_B, θ_B and ω_E, θ_E are the signal frequencies and phase. S_{Em}, S_{Bm} are modulated symbols, for example, QPSK modulation, they're elements of $\{\exp(jn\pi/2), n = 0,1,2,3\}$. These two signals in (1) and (2) are combined in RF signal.

The base and the enhancement signals can be transmitted at the same or different transmit station. After being transmitted through the uplink channel, the base layer signal and the enhancement layer signal will be detected as a combined signal at the satellite transponder. Each user can receive the combined signals which are passed through the downlink channel.

At the receiver side, received signal can be expressed as follows.

$$\begin{aligned} S_{BE}(t) = {} & f_B(M_B \exp(j\omega_B t + \theta_B) \sum_{m=-\infty}^{\infty} S_{Bm} p(t - mT)) \\ & + f_E(M_E \exp(j\omega_E t + \theta_E) \sum_{m=-\infty}^{\infty} S_{Em} p(t - mT + \Delta T_m)) + n(t) \end{aligned} \quad (3)$$

where f_B and f_E are distortion functions of the TWTAs for the respective signals. $n(t)$ is the system noise.

Ignoring f_B, f_E and $n(t)$, the following represents the output of the demodulator after removing the base layer signal carrier.

$$\begin{aligned} S'_{BE}(t) = {} & M_B \sum_{m=-\infty}^{\infty} S_{Bm} p(t - mT)) \\ & + M_E \exp(j(\omega_E - \omega_B)t + \theta_E - \theta_B) \sum_{m=-\infty}^{\infty} S_{Em} p(t - mT + \Delta T_m) \end{aligned} \quad (4)$$

Because $M_B >> M_E$, the base layer decoder perceives the M_E component of $S'_{BE}(t)$ as part of noise. So we can decode $S'_{BE}(t)$ to get the base layer signal.

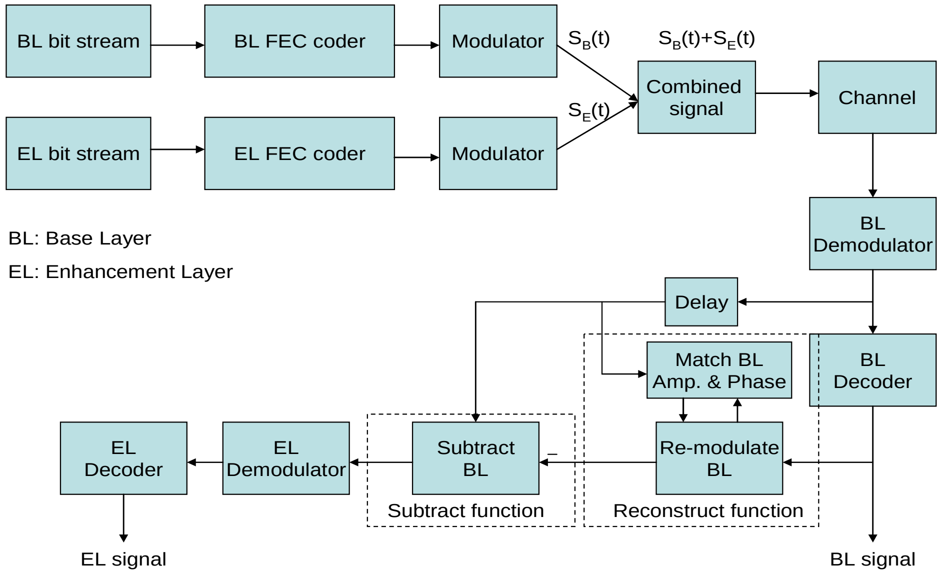

Figure 1: Block diagram of the Layered Modulation system

In order to detect and decode the enhancement layer signal from this combined signal, a function of reconstructing and subtracting about layer signals should be included in receivers.

After reconstructing the base layer signal, we subtract it from $S'_{BE}(t)$, the following signal is extracted:

$$S'_{BE}(t) = M_E \exp(j(\omega_E - \omega_B)t + \theta_E - \theta_B)\sum_{m=-\infty}^{\infty} S_{Em} p(t - mT + \Delta T_m) \qquad (5)$$

The enhancement layer signal can be decoded from $S'_{BE}(t)$.

From equation (4) we can find that the base layer signal is more important than enhancement signal, because we first decode the base layer signal which will help decoding the enhancement layer signal. If a large number of errors exist in the detected base layer signal, it will affect the decode process of the enhancement layer signal and make the BER performance very bad as we use functions of reconstructing and subtracting,. In another words, the base layer signal is the more important one in its channel robustness.

In the paper, we consider both layers to employ DVB-S2 standard. The Layered Modulation we talk about is for SVC signals which consist of a base signal and an enhancement signal. We assign the base signal and the enhancement signal to the base layer and the enhancement layer, respectively. When the channel condition is good, receiver can decode both the base layer and enhancement layer signals, but if there is a bad channel, i.e., severely rain fading, receiver will only decode the base layer signal which is more important and robust.

3. Performance analysis

We analyzed layer signals using computer simulation. Figures 2 to 5 denote scatter plots of the demodulating and decoding process of a Layered Modulation system.

For simplicity, we assume the base layer and the enhancement layer signals have the same carrier frequency, the same symbol rate of 20 MHz, and the enhancement layer signal affects the base layer signal like an additive white Gaussian noise. We also assume that the function of reconstructing the base layer signal is perfect. The satellite non-linearity is not considered.

Figure 2 shows a scatter plot of a baseband Layered Modulation signal in the AWGN channel. This is the combined signal at the receiver side which includes both the base and the enhancement layer signals. In this simulation, M_E is 6dB lower than M_B, and the Gaussian noise is 15dB lower than the base layer signal. The mean diameter of the annulus corresponds to the base layer signal power M_B, and the thickness is determined by the enhancement layer signal power M_E.

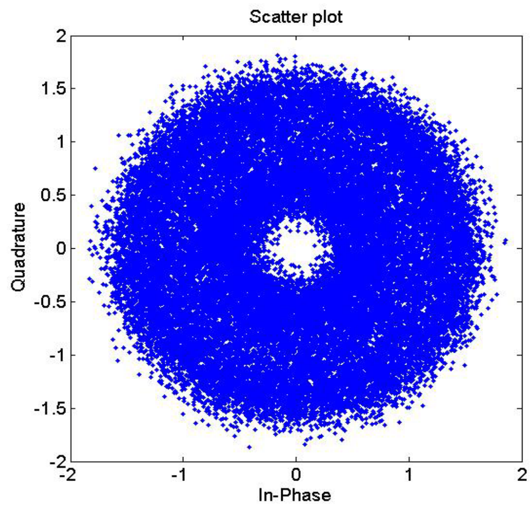

Figure 2: Combined base and enhancement layer signals with AWGN.

The signal shown in Figure 2 is the input to the BL (base layer) demodulator. After the base layer signal carrier frequency is removed, the resulting signal is shown in Figure 3. The QPSK constellation in the base layer signal space is revealed with a smaller annulus in each quadrant. The four annuli have the same center diameter which indicates the enhancement layer signal power. The thickness indicates the noise corresponding to the enhancement layer signal. So the signal shown in Figure 3 is the input of the base layer decoder.

After the base layer signal is decoded, a noise-free base layer signal is reconstructed and subtracted. This results the signal in Figure 4. The scatter distribution in Figure 4 is just a collapsed version of Figure 3. As mentioned above, the mean diameter denotes the power of the enhancement layer signal while the thickness is determined by the additive white Gaussian noise.

After we remove carrier frequency from Figure 4, in Figure 5, we can get the enhancement layer signal which is ready to be decoded to recover the enhancement layer bit stream.

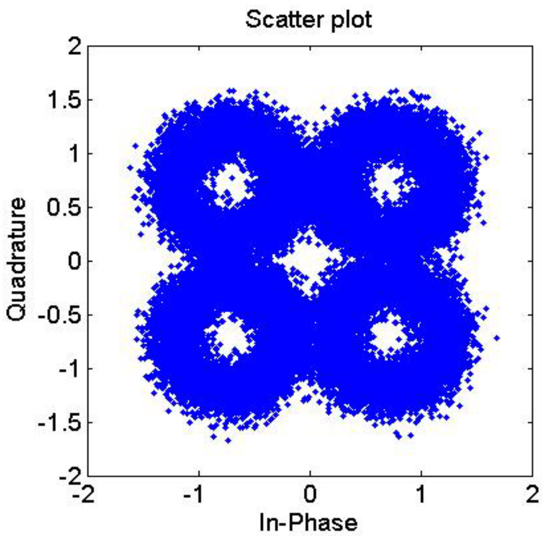

Figure 3: Signal after base layer carrier frequency is removed.

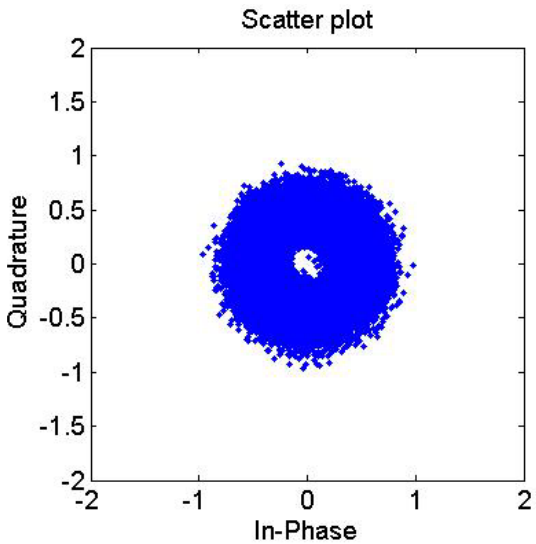

Figure 4: Recoverd enhancement layer signal.

This is the process of demodulating and decoding a Layered Modulation signal. We can find that the power relationship between the base layer and enhancement layer signals is an important parameter which directly helps us to separate these two layer signals.

As the base layer signal power M_B should be larger than the enhancement layer signal power M_E, we can set the power difference in different value. As shown in Figure 6, the BER performance of the base layer and the enhancement layer signals varies according to the power difference $M_B - M_E$. We apply DVB-S2 LDPC code and QPSK modulation to both layers' signals which are transmitted in an AWGN channel. We have observed that the BER performance of the base layer and the enhancement layer signals gets better as the power difference increasing from 3dB to 9dB. This is because the demodulating and decoding of the enhancement layer signal are based on the detected base layer signal.

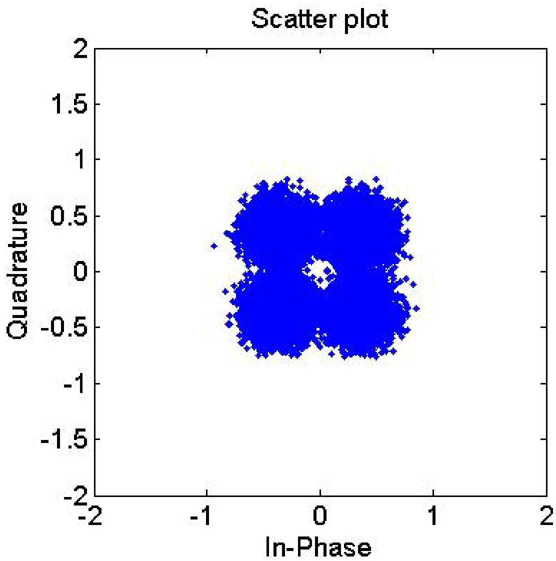

Figure 5: The enhancement layer signal with carrier frequency removed.

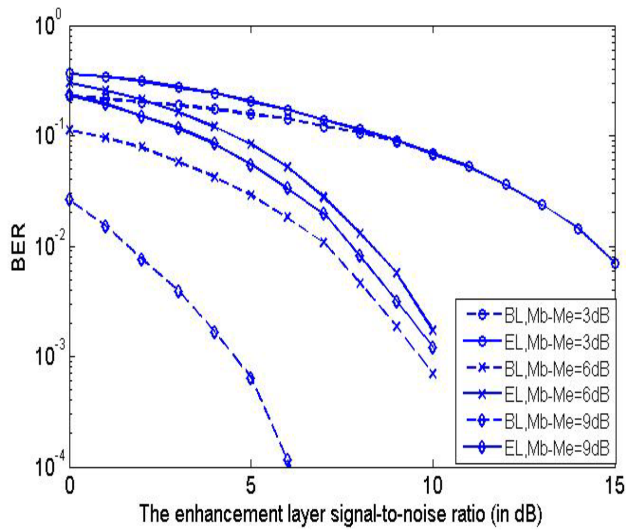

Figure 6: The BER performance of a Layered Modulation system according to power difference.

More in detail, when the power difference is lower, the enhancement layer signal introduces more interference to the base layer signal as the enhancement layer signal is a kind of noise for base layer signal. When we increase power difference, the enhancement layer signal affects the base layer signal little, as a result, less error appear in the detection of base layer, and then, less error appear in the reconstruct and subtract progress, so the BER performance of the enhancement layer is also better than before.

This is an efficient way to improve the BER performance of our proposed system, but there is a limitation. In fact, we increase the power difference by increasing the base layer signal power and holding the enhancement layer signal power in our proposed system, this means that the performance improvement derives from the increase of system transmission power.

In our simulations, we assume that the function of reconstructing the base layer signal is perfect, but in practice, some problems such as synchronization and re-modulating error in the reconstruct process should be considered. We prefer to use a single parameter to denote all the effect, we call it as the reconstructing error which is measured in percentage. 1% reconstructing error denotes additional 1% error appear in the process of reconstructing, in another words, extra 1% error exist in the reconstructed base layer signal. Obviously, the reconstructing error will only affect the BER performance of the enhancement layer, because it's considered after the demodulating and decoding of the base layer signal. The effect of reconstructing error to the enhancement layer signal is shown in Figure 7. In the simulation, we set the power difference equals to 6dB. We observe that the reconstructing error affects the BER performance of the enhancement layer significantly, and the affect becomes more obviously when the enhancement layer SNR increases. The enhancement layer BER performance changes from 10^{-5} to 10^{-3} as the reconstructing error varies from 0% to 0.2% under the condition that the EL (enhancement layer) SNR equals to 15dB. As a result, we have to control the reconstructing error carefully according to requirements, otherwise, much interference will be introduced to our system.

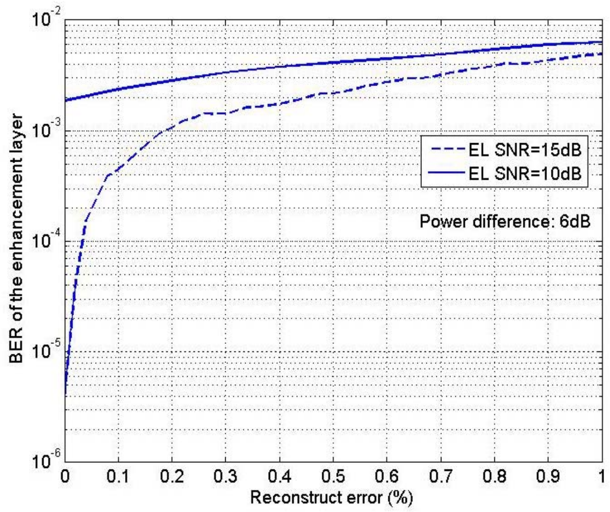

Figure 7: The BER performance of the enhancement layer signal versus the reconstruct error.

4. Conclusion

The Layered Modulation is an attractive technique in satellite communications. It can increase system capacity and has a high flexibility of designing the signals. We describe the process of demodulating and decoding through computer simulations, actually, this part plays an important role in a Layered Modulation system. We can adjust the power difference between the base and the enhancement layer signals to change the BER performance, it's an efficient way to improve the BER performance. Another problem should be regarded carefully is the reconstructing error in the Layered Modulation system.

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