The University of Sydney

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Satellite Communication Systems

Group Project 2016

Group 7

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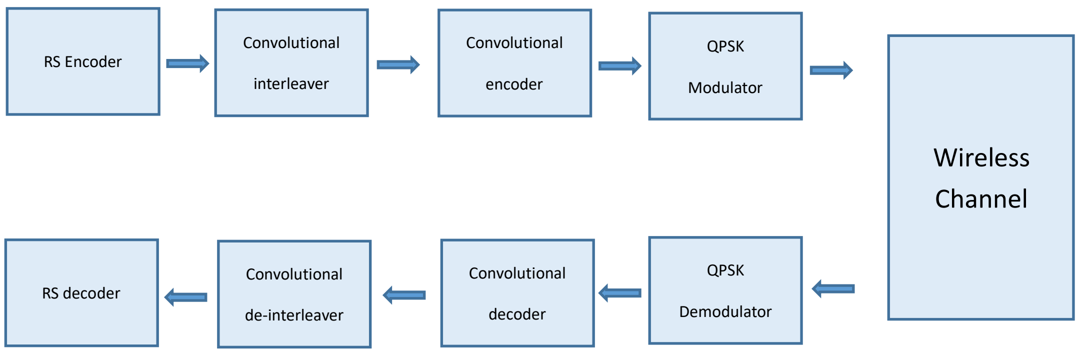
Introduction and background

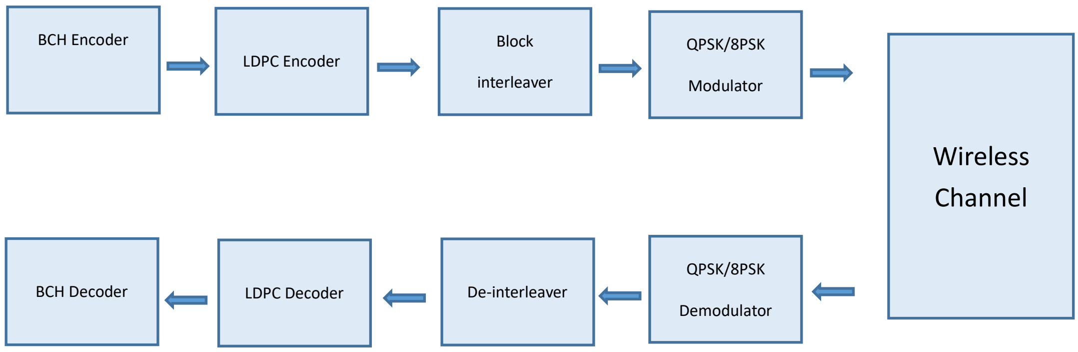
DVB-S

The digital video broadcasting-satellite is the physical layer standard for satellite television broadcast and data services. The overlaid transport stream is mandated as MPEG-2, known as MPEG transport stream (MPEG-TS). A DVB-S baseband transmitter consists of four blocks: the outer Reed-Solomon encoder; convolutional interleaver, inner convolutional encoder, and QPSK modulator.



DVB-S2

The DVB-S2 standard is a flexible standard which defines a second generation modulation and channel coding system for satellite communications. A t-error correcting BCH (Nbch, Kbch) code is applied to each input data stream of length Kbch to generate an error protected packet. In DVB-S2 4 the following different modulations are used: QPSK, 8PSK, 16 APSK, and 32 APSK.



Overview

In this project, we learned how to plan, implement, analyze and simulate satellite communication systems by utilize DVB-S and DVB-S II standards. First of all, we have finished some calculations about link budget in part I in different cases. In part II, baseband simulations and performance analysis of the DVB-S standard has been achieved with proper Matlab code words. Part III involves works of baseband simulations and performance and analysis of the DVB-S II standard.

Part I:

Clear sky condition

1) The system noise temperature Ts , including the antenna and the receiver, consisting of LNB, cable and set-top box noises.

$$\mathrm{Ts} = \mathrm{Ta} + \mathrm{Tr} = 40 + 75.9 = 115.9\mathrm{K} = 20.64 \ \ \mathrm{dB}$$

2) The receive antenna gain Gr , and hence the receiver figure of merit, the G/T ratio.

$$\mathrm{Gr} = \frac{4\pi Ae}{\lambda^2} = 2128.1 = 33.28 \ \ dB$$

And since the $\mathrm{Ts} = 20.64 \ \ \mathrm{dB},$ we can get $[\frac{\mathrm{Gr}}{\mathrm{Ts}}]$ = [Gr]-[Ts]=33.28-20.64 dB

3) The C/N0 ratio.

Since R=38500 km

f=3960 MHz

$$[\mathrm{losses}]\mathrm{p} = \left[\left(\frac{4\pi R}{\lambda}\right)^2\right] = 196 \ \ dB$$

Since the miscellaneous losses is [losses]m=2 dB

The total losses is

[losses]t=196 + 2=198 dB

$$\left[\frac{G}{T}\right] = \left[\frac{Gr}{Ts}\right] = 12.639\text{dB}$$

$$\left[\frac{C}{N_0}\right] = [\text{EIRP}] + \left[\frac{G}{T}\right] - [\text{losses}] - [\text{k}] = 39 - 198 + 12.639 + 228.6 = 82.23\text{dBHz}$$

4) For a DVB-S system, find the Eb/N0 ratio, where Eb refers to the information bits before the RS decoder. Comparing your calculated ratio to the required Eb/N0 in the DVB-S standard Table 3 [1], shown in Table 4 below, find the SNR margin. Is the reception quality acceptable? Which code rate should be selected for transmission and why?

Table 4. E_b/N_0 ratio requirement excluding outer codes [1]

Inner code rate	Required E_b/N_0 for BER = 2×10^{-4} after Viterbi QEF after Reed-Solomon
1/2	4,5
2/3	5,0
3/4	5,5
5/6	6,0
7/8	6,4

As we know, the $\left[\frac{C}{N_o}\right] = [r_b] + [\frac{E_b}{N_o}]$

$$[r_b] = [b * r_s]$$
$$b = log_2 M$$

For QPSK, M=4.

b = 2

$$[r_b] = 68.5 \ \ dB$$

$$\left[\frac{E_b}{N_o}\right] = 82.238 - 68.5 = 13.738 \ \ dB$$

The calculated Eb/No ration is

$$\left[\frac{E_b}{N_o}\right] = 13.738 - 10log_{10}FECcoderate$$

The SNR margin can be obtained by comparing the table,

For inner code rate 1/2, the SNR margin is 12.25 dB.

For inner code rate 3/4, the SNR margin is 9.483 dB.

For inner code rate 5/6, the SNR margin is 8.5 dB.

It is acceptable and 1/2 code rate should be selected for transmission, since larger SNR margin resulting in better signal.

5) For a DVB-S2 system, find the Eb/N0 ratio, where Eb refers to the information bits before the BCH decoder. Comparing your calculated ratio to the required Eb/N0 in the DVB-S2 standard Table 13 [2], is shown in Table 5 below, find the SNR margin. Is the reception quality acceptable? Which code rate should be selected for transmission and why?

$[\frac{E_b}{N_o}]_{cal} = \left[\frac{E_s}{N_o}\right] - 10\log FEC$

$[\frac{E_b}{N_o}]_{required} = \left[\frac{E_s}{N_o}\right] - 10\log(\eta)$

SNR= $[\frac{E_b}{N_o}]_{cal} - [\frac{E_b}{N_o}]_{required}$

for QPSK 1/4, $\left[\frac{E_s}{N_o}\right]$= -2.35 dB, $\eta = 0.49$, $[\frac{E_b}{N_o}]_{required} = 0.75 \ dB$

for QPSK 1/2, $\left[\frac{E_s}{N_o}\right]$= 1 dB, $\eta = 0.99$, $[\frac{E_b}{N_o}]_{required} = 1.05 \ dB$

for QPSK 1/4, $\left[\frac{E_s}{N_o}\right]$= 5.18 dB, $\eta = 1.655$, $[\frac{E_b}{N_o}]_{required} = 2.991 \ dB$

for QPSK 1/4, $\left[\frac{E_s}{N_o}\right]$= 6.2 dB, $\eta = 1.766$, $[\frac{E_b}{N_o}]_{required} = 3.73 \ dB$

For different QPSK mode, we get the result shown below,

For QPSK 1/4 : $\left[\frac{E_b}{N_o}\right] = 19.759 \ dB$, the SNR margin = 19.009 dB.

For QPSK 1/2: $\left[\frac{E_b}{N_o}\right] = 16.749 \ dB$, the SNR margin = 15.698 dB.

For QPSK 5/6: $\left[\frac{E_b}{N_o}\right] = 14.53 \ dB$, the SNR margin = 11.54 dB.

For QPSK 8/9: $\left[\frac{E_b}{N_o}\right] = 14.25 \ dB$, the SNR margin = 10.5 dB.

It is acceptable and the Mode QPSK 1/4 has largest SNR margin, which should be selected for transmission.

Table 5. E_b/N_0 ratio requirement excluding outer codes [2]

Mode	Spectral efficiency	Ideal E_s/N_0 (dB) for FECFRAME length = 64 800
QPSK 1/4	0,490243	-2,35
QPSK 1/3	0,656448	-1,24
QPSK 2/5	0,789412	-0,30
QPSK 1/2	0,988858	1,00
QPSK 3/5	1,188304	2,23
QPSK 2/3	1,322253	3,10
QPSK 3/4	1,487473	4,03
QPSK 4/5	1,587196	4,68
QPSK 5/6	1,654663	5,18
QPSK 8/9	1,766451	6,20
QPSK 9/10	1,788612	6,42
8PSK 3/5	1,779991	5,50
8PSK 2/3	1,980636	6,62
8PSK 3/4	2,228124	7,91
8PSK 5/6	2,478562	9,35
8PSK 8/9	2,646012	10,69
8PSK 9/10	2,679207	10,98
16APSK 2/3	2,637201	8,97
16APSK 3/4	2,966728	10,21
16APSK 4/5	3,165623	11,03
16APSK 5/6	3,300184	11,61
16APSK 8/9	3,523143	12,89
16APSK 9/10	3,567342	13,13
32APSK 3/4	3,703295	12,73
32APSK 4/5	3,951571	13,64
32APSK 5/6	4,119540	14,28
32APSK 8/9	4,397854	15,69
32APSK 9/10	4,453027	16,05

NOTE: Given the system spectral efficiency η_{tot} the ratio between the energy per information bit and single sided noise power spectral density $E_b/N_0 = E_s/N_0 - 10\log_{10}(\eta_{tot})$.

6) Calculate Es/N0 ratio, where Es refers to the energy per QPSK symbol before the RS decoder.

$$\left[\frac{Es}{N_0}\right] = \left[\frac{E_b}{N_0}\right] + [10\log\eta]$$

So, for Mode QPSK 1/4: $\left[\frac{E_s}{N_o}\right] = 19.759 + 10log0.49 = 16.66\ \ dB$

QPSK 1/2: $\left[\frac{E_s}{N_o}\right] = 16.748 + 10log0.988 = 16.69\ \ dB$

QPSK 5/6: $\left[\frac{E_s}{N_o}\right] = 14.53 + 10log1.65 = 16.70\ \ dB$

QPSK 8/9: $\left[\frac{E_s}{N_o}\right] = 14.25 + 10log1.766 = 16.719\ \ dB$

Rain condition

1) Calculate the rain attenuation.

   It is known that R=36.8 mm/h, a=0.0007, b=1.13

$$\gamma = ak^b = 0.0007 * 36.8^{1.13} = 0.04116\ \ dB$$

for the L, we can get from the latitude, which is 33.9 degrees,

$$L(km) = \begin{cases} 4 - 0.075(\emptyset - 36), & \emptyset > 36° \\ 4, & 0 \leq \emptyset \leq 36° \end{cases}$$

So, L=4

$$[\mathrm{A}] = [\gamma * \mathrm{L} * \mathrm{r}] = 0.054\mathrm{dB}$$

2) Assuming the rain attenuation is entirely absorptive, calculate the equivalent noise temperature caused by the rain attenuation Train.

$$\mathrm{Train} = \mathrm{Ta}\left(1 - \frac{1}{A}\right),$$

$$\mathrm{Ta} = 280\ \ \mathrm{k}$$

$$\mathrm{So,}\ \ \mathrm{Train} = 3.45\ \ \mathrm{k}$$

3) Calculate the SNR margin for both the DVB-S and DVB-S2 under the raining condition and comment on which code rate performs best.

$$T_{total} = T_{antenna} + T_{reveiver} + T_{rain}$$

T_{total}=40+73.9+3.45=119.35K

[T_{total}]=20.768dB

$$\left[\frac{G}{T}\right]' = 33.28 - 20.77 = 12.51dB$$

$$\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right]' - [loss] - [k] - [A]$$

$$= 12.51 + 82.23 - 12.639 = 82.056dB$$

For QPSK modulator:

$\left[\frac{E_b}{N_0}\right] = \left[\frac{C}{N_0}\right] - [r_b]$ =82.056-68.5=13.556dB

Required $\left[\frac{E_b}{N_0}\right] = \left[\frac{E_b}{N_0}\right] - 10logFEC$

SNR= calculated$\left[\frac{E_b}{N_o}\right] - required\left[\frac{E_b}{N_o}\right]$

For DVB-S system:

inner code rate 1/2, the $\left[\frac{E_b}{N_0}\right] = 16.576\ \ dB$, SNR margin = 12.076 dB.

inner code rate 3/4, the $\left[\frac{E_b}{N_0}\right] = 14.815\ \ dB$, SNR margin = 9.315 dB.

inner code rate 5/6, the $\left[\frac{E_b}{N_0}\right] = 14.358\ \ \mathrm{dB}$, SNR margin = 8.358 dB.

We choose the 1/2 code rate for DVB-S.

For DVB-S2 system:

inner code rate 1/4, the $\left[\frac{E_b}{N_0}\right] = 19.586\ \ dB$, SNR margin = 18.836 dB.

inner code rate 1/2, the $\left[\frac{E_b}{N_0}\right] = 14.815\ \ dB$, SNR margin = 15.526 dB.

inner code rate 5/6, the $\left[\frac{E_b}{N_0}\right] = 14.358\ \ \mathrm{dB}$, SNR margin = 11.368 dB.

inner code rate 8/9, the $\left[\frac{E_b}{N_0}\right] = 14.077\ \ \mathrm{dB}$, SNR margin = 10.347 dB.

We choose 1/4 code rate for DVB-S2.

4) Assume that the transponder is operating in the Ku band with the following parameters: Carrier frequency fc=12706.5 MHz EIRP=50 dBW Dish diameter D = 0.9 m Symbol rate rs=22.5 M symbols/sec CCIR rain attenuation parameters: a=0.05, b=1.28, r=0.33 All other parameters not mentioned here are not changed relative to the C-band transmission specified in Part I. Calculate the SNR margins under clear sky and raining condition for the code rates considered for both DVB-S and DVB-S2, respectively. Is the reception quality acceptable in each condition? Which code rates for DVB standards should be selected for transmissions and why?

1. under the clear sky

$$[\mathrm{Ts}] = 15.9\mathrm{k} = 20.64\ \ \mathrm{dB}$$

$$[\mathrm{Gr}] = 10\log\left\{0.55\times\left(\frac{\pi\times0.9\times12706.5\times10^6}{3\times10^8}\right)^2\right\} = 38.97\ \ dB$$

$$\left[\frac{G}{T}\right] = 38.97 - 20.64 = 18.33dB$$

$$\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right] - [Loss]_{total} - [k]$$

For Ku band, $[EIRP] = 50\ \ dBW$

$$[L_p] = 10log(\frac{4\pi Rf}{c})^2\text{=206.23 dB}$$

$$[Loss]_{total} = [loss]p + [loss]m = 206.23 + 2 = 208.23\ \ dB$$

$$\left[\frac{C}{N_0}\right] = 88.7\ \ dB$$

$$[r_b] = 10\log(22.5\times10^6) + [2] = 76.5\ \ dB$$

$$\left[\frac{E_b}{N_0}\right] = \left[\frac{C}{N_0}\right] - [r_b] = 12.2dB$$

$$required\left[\frac{E_b}{N_0}\right] = 12.2 - 10logFEC$$

$$\text{SNR= calculated}\left[\frac{E_b}{N_o}\right] - required\left[\frac{E_b}{N_o}\right]$$

For DVB-S system:

inner code rate 1/2, the $\left[\frac{E_b}{N_0}\right] = 15.2\ \ dB$, SNR margin = 10.7 dB.

inner code rate 3/4, the $\left[\frac{E_b}{N_0}\right] = 13.45\ \ dB$, SNR margin = 7.9 dB.

inner code rate 5/6, the $\left[\frac{E_b}{N_0}\right] = 12.99$ dB, SNR margin = 6.99 dB.

We choose 1/2 code rate for DVB-S.

For DVB-S2 system:

inner code rate 1/4, the SNR margin = 17.472dB.
inner code rate 1/2, the SNR margin = 14.161 dB.
inner code rate 5/6, the SNR margin = 10.003 dB.
inner code rate 8/9, the SNR margin = 9.983 dB.

2. under raining condition

$$\gamma = 0.03 \times 36.8^{1.28}$$

$$A = \gamma \cdot L \cdot r = 6.67 \text{ dB}$$

$$T_{rain} = 280 \times \left(1 - \frac{1}{A}\right) = 219.67\text{K}$$

$$T_S{}' = 40 + 73.9 + 219.67 = 335.67\text{K} = 25.258 \text{ dB}$$

$$\left[\frac{G'}{T}\right] = 38.97 - 25.258 = 13.712 \ dB$$

$$\left[\frac{C}{N_0}\right] = 50 + 13.712 - 208.23 + 228.6 - 6.67 = 77.42$$

For DVB-S system:

inner code rate 1/2, the SNR margin = -0.58 dB.
inner code rate 3/4, the SNR margin = -3.33 dB.
inner code rate 5/6, the SNR margin = -4.3 dB.

We can not choose any one, since the SNR margin all less than o, so the reception quality is not acceptable.

For DVB-S2 system:

inner code rate 1/4, the SNR margin = 6.182 dB.
inner code rate 1/2, the SNR margin = 2.872 dB.
inner code rate 5/6, the SNR margin = -1.286dB.
inner code rate 8/9, the SNR margin = -2.31 dB.

We can only choose 1/4 and 1/2 code rate as the SNR margin should be more than o.

Part II:

In part II, the objective is to achieve the simulation of channel coding in DVB-S. The inner code in the DVB-S standard is a convolutional code with a memory order m=6, three levels of puncturing is 1/2, 2/3 and 5/6 respectively. Puncturing pattern for code rate 1/2 is I=X1 Q= Y1, I=X1Y2Y3 Q=Y1X3X4 for the code rate 2/3, I=X1Y2Y4 Q=Y1X3X5 for the code rate 5/6. For baseband simulation without Reed-Solomon code, the we only need to define the parameters for convolutional coder, modulation function and AWGN channel, and we also define an uncoded stream to compare the BER performance.

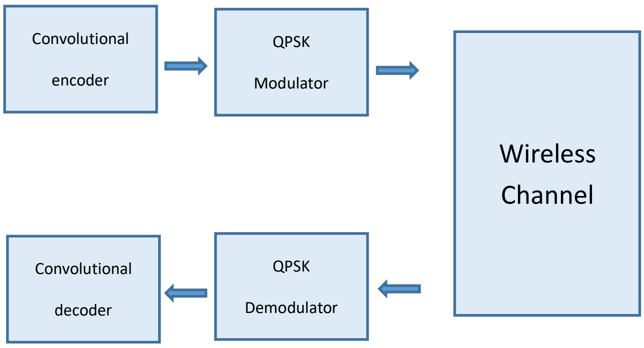


Figure 2.1 Block diagram of DVB-S baseband without outer RS code

In order to determine how the outer coding affects the BER performance of the AWGN channel, we also introduce Reed-Solomon codes and convolutional interleaver. For the other hand, we compare the differences of BER performance through Rayleigh channel and AWGN channel.

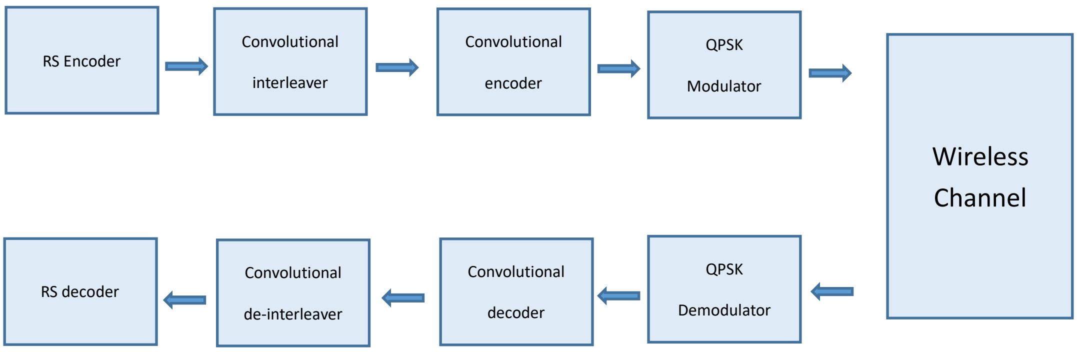


Figure 2.2 block diagram of DVB-S with outer codes

The figure below indicates that with the puncturing rate increasing, the BER performance shows the opposite trend, since the when the puncturing is used to discarded some bits in order to increase the code rate, resulting in when the rate is higher there will be more bits discarded, and the BER performance will be decreased.

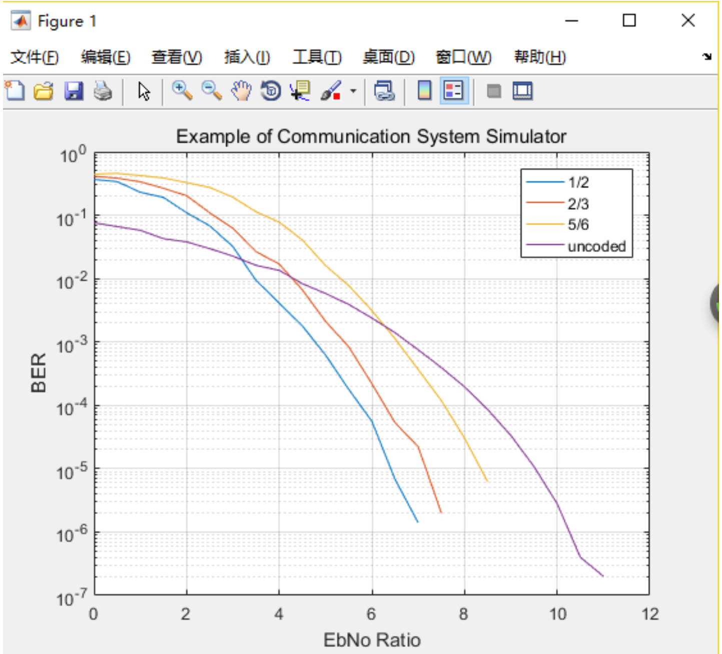


Figure 2.3 BER vs E_b/N_o curves for three levels and uncoded

when the standard RS outer code is used before the convolutional code, the BER will performance will be increased significantly, as the E_b/N_o is less to achieve the same BER.

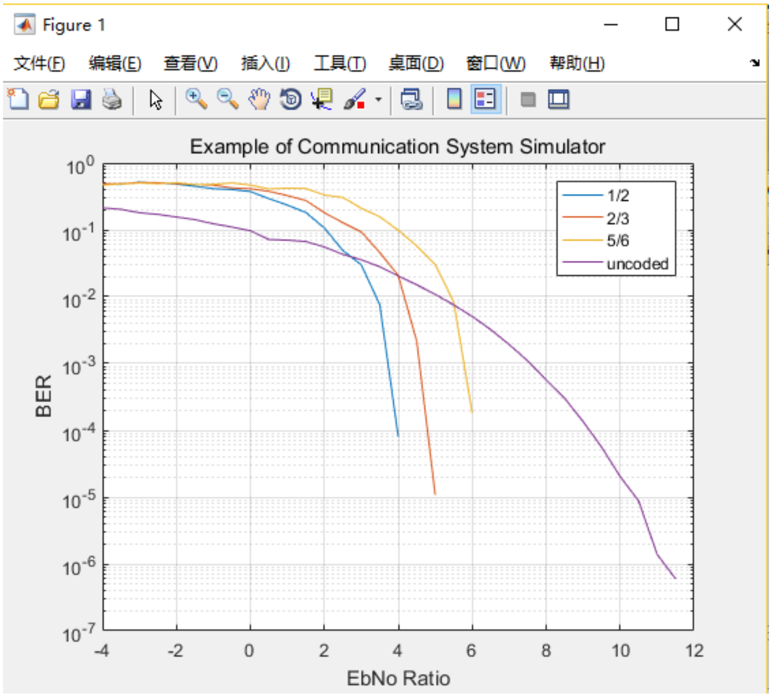


Figure 2.4 BER vs E_b/N_o with RS outer code

For 1/2 code rate, the minimum E_b/N_o is around 3.9 dB that meet BER=2*10^{-4}. For 2/3 code rate, the minimum E_b/N_o is around 4.7 dB that meet BER=2*10^{-4}. For 5/6 code rate, the minimum E_b/N_o is around 5.99 dB that meet BER=2*10^{-4}. So we can conclude that when the code rate is increase, the minimum E_b/N_o requirement is also increased. This is mainly because as the code rate increase, there is more redundancy, in this case, the capability of correcting error is higher. Therefore, it requires less minimum E_b/N_o to achieve the same BER.

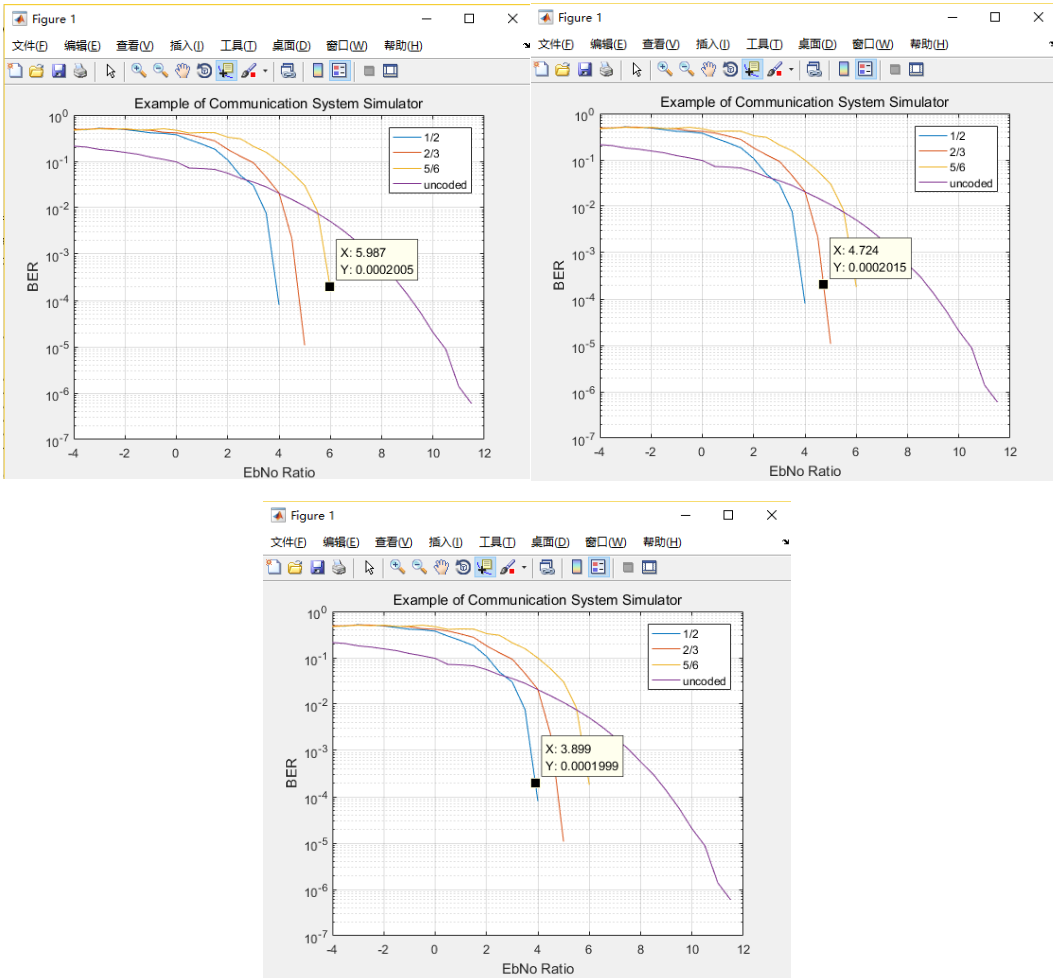


Figure 2.5 Three levels of code rate achieve the same BER

The required minimum Eb/No for the three levels code rates 1/2, 2/3, 5/6 are 4.5, 5.0 and 6.0, which are higher and almost consistent as the results from our simulation. This is mainly because there are some discrepancy happened when simulate.

In the case of only inner code, the coding gain with the code rate of 1/2 is around 2.53 dB, in contrast, the coding gain is around 1.95 dB with the code rate of 2/3. The coding gain with the code rate of 5/6 is around 0.71 dB. the formula of the asymptotic coding gain of a block code with hard decision decoding is

$$G=10\log_{10}\left(\frac{Rd_{free}}{2}\right)$$

Where the d_{free} of code rate 1/2 is 10, therefore the coding gain is calculated as 3.98 dB, in the case of the d_{free} of code rate 2/3 is 6, the coding gain is calculated as 3.01 dB. The d_{free} of code rate 5/6 is 4, the coding gain is calculated as 2.218 dB.

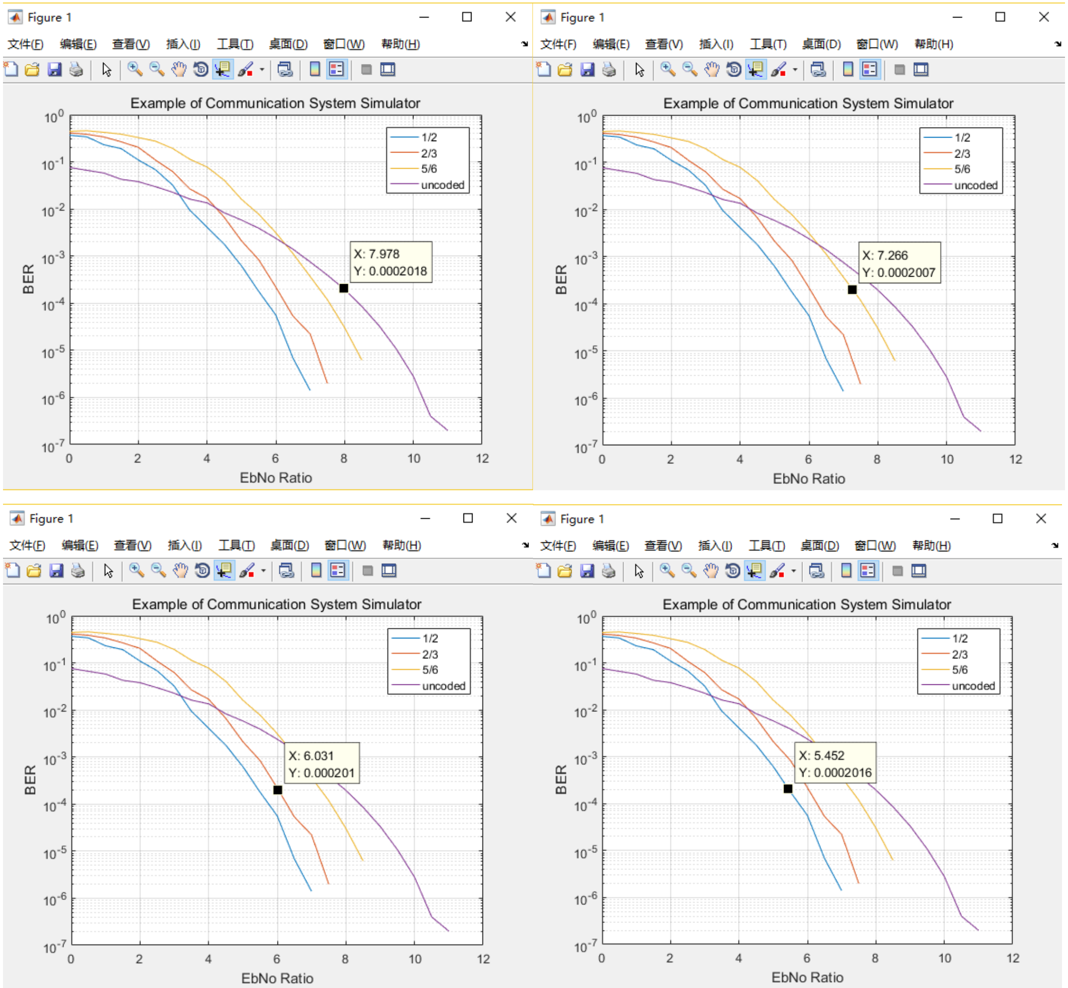


Figure 2.6 the minimum E_b/N_o for different inner codes

The simulation in the Rayleigh fading channel is shown below, by comparing it with the AWGN channel results, we can get the conclusion that, the BER performance will be decrease in the Rayleigh fading channel.

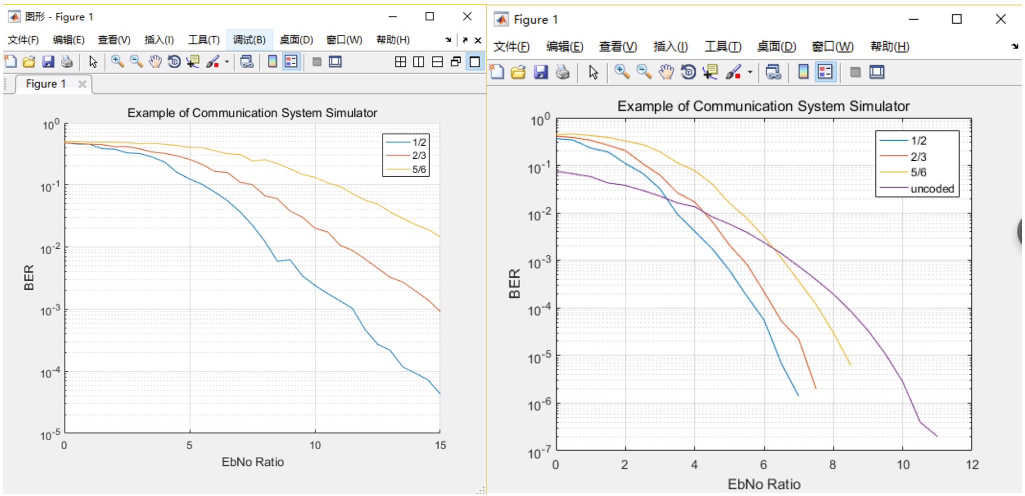


Figure 2.7 comparison Rayleigh fading channel with AWGN channel results

Part III:

In this part, the inner code in the DVB-S2 standard is an LDPC code, we determine the BER performance of the LDPC two different code rates (2/5,9/10) for QPSK modulation and two different code rates (2/3,8/9) for 8PSK modulation.

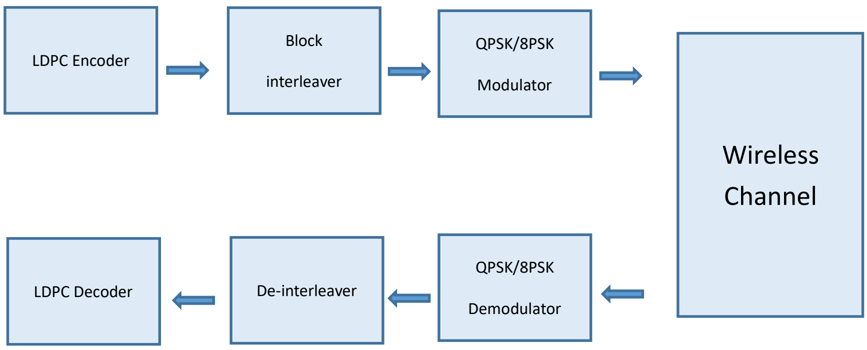


Figure 3.1 Block diagram of DVB-S2 using LDPC codes as inner codes

We also introduce BCH outer code before the LDPC code to determine how the interleaver affects the overall BER performance. For the other hand, we compare the differences of BER performance through Rayleigh channel and AWGN channel.

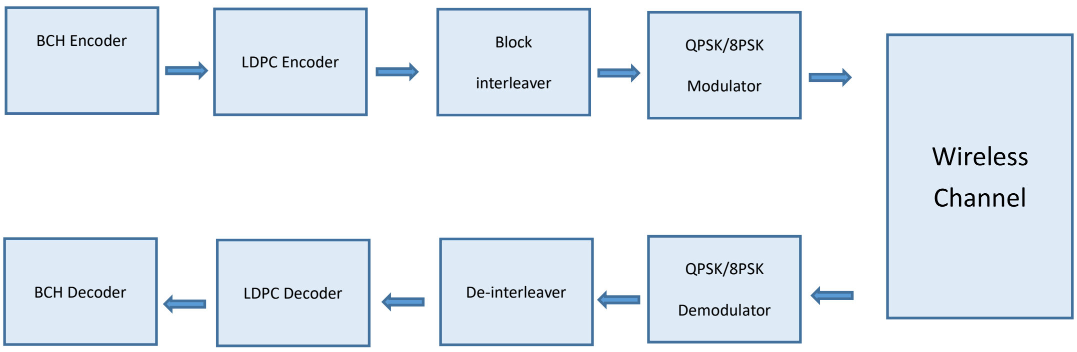


Figure 3.2 Block diagram of DVB-S2 using BCH codes as outer codes

The figure below indicates that with code rate increasing, the BER performance shows the opposite trend, since the lower code rates add more redundancy, and this will increase the capability of error correcting, thus the BER performance will be decreased. And the overall BER performance of QPSK is better than 8PSK, since the 8PSK has a smaller minimum Euclidian distance, and this will result in the higher probability of error, so the QPSK will have an overall BER performance.

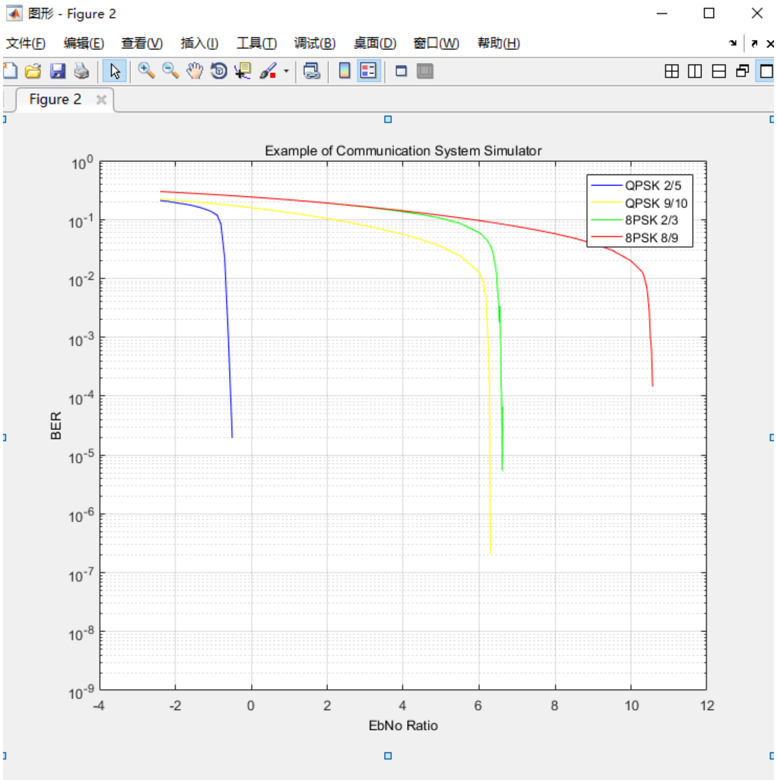


Figure 3.3 BER curves of LDPC in different code rate and modulation

Unfortunately, we did not finish the case when the standard BCH outer code is used before the LDPC code, but as we know the BCH is used to improve the BER performance, hence the outer coding will improve the overall BER performance.
When the block interleaver is used for 8psk modulated signals. We guess there will be a great improvement of BER.
We can also get the conclusion that, the BER performance will be decrease in the Rayleigh fading channel from the case in DVB-S.

CONCLUSION IV:

In the link budget calculation, our group get familiar with the formulas and in different cases how to do the calculation. In the DVB-S, the RS code affects the encoding and the outer coding affects the BER performance of the AWGN channel. The BER performance will increase when using the RS outer code before convolution. For the same BER, the larger coding rate,the less SNR it needs.Afterwards,in the Rayleigh fading channel, the BER performance will be decrease compared to the AWGN channel. In the DVB-S2,the BER performance shows the opposite trend, the lower code rate ,the worse BER performance.

It is important to note that although DVB-S2 has performance gains over DVB-S, DVBS is still used around the world, because it is simpler and more cost effective to maintain.

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