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Simulation and Comparative Study of Key Modulation Technology 2ASK, 2PSK and PSK in WCDMA

[1]Sun Yan and [2]Zhang Yannan
[1]Department of Electronic and Electrical Engineering, University of Sheffield, China
[2]School of Management, University of Shanghai for Science and Technology, 200093, China

Abstract: In the third generation communication system, all the wireless network use digitalize transfer. Thus the analog transmission to ever proposed fundamentally have changed. WCDMA is one of the three mainstream standards, whose demodulation is also fundamentally different with GSM. This study uses the MATLAB's M files to model and simulate BPSK and QSPK which are used in WCDMA system, compared with 2ASK and 2FSK at the same time. The purpose of putting AWGN and Rayleigh fading in the different modulation system's route is to obtain the power spectrum, eye pattern and error rate. At last, from the transmission rate, the bandwidth efficiency and anti-interference performance these aspects, the performance of BPSK, QPSK, 2ASK, 2FSK can be analysed.

Key words: WCDMA, MATLAB, modulation system's route

INTRODUCTION

Modern communication system with the character of the third generation communication (3G) has adopted all the latest communication technology, which leads to the complexity of modern communication system. This complexity origins from the structure of mobile communication system and the environment of system in operation. However, CDMA that is widely applied in the third generation communication system is a interference restricted system that requires high rate and large capacity if the assurance of communication quality is given. These requirements which are interacted even contradictory with each other in technology lead to the adoption of complicated modulation system' route, pulse forming technology as well as the technology of error control and advanced signal processing (Liu *et al*., 1999). Regarding the serious communication environment and the usage of multi-operators, system and modulation in the same time at the same place, it is hard to analytically process in traditional ways. Meanwhile, it also needs to analyse the propagation character of signal in wireless system in the process of 3G network modeling and designing for mobile communication operators. Besides, unlike the planning and design of GSM at present, there is not existing mature experiences model and experience in optimization in many yeas which can be referred to for the lack of large-scale deployment (Pu and Wu, 1999).

Computer simulation technology is widely used to study character and problem of communication system on account of the complication of modern communication system. Especially the development of powerful communication system software package accelerates application of simulation in the field communication. Computer simulation technology not only can decrease the cost of design, increase the efficiency of planning, but also is a tool pf value in a further comprehension of the system character. It is convenient for a successful development of simulation program which is similar to the system in a laboratory to realize multi-point measurement and parameter study (Zhu, 2003; Lin, 2006).

A method was introduced in previous study that computes an estimation of the Bit Error Rate (BER) based on the WCDMA simulating soft output only. Simulating shows that the error of the estimation is below 2% (Cheng *et al*., 1999). Flynn presents an approximate method for blocking probability simulating in the WCDMA interface of the UMTS network with priorities. A theory of the multi-rate with different kinds of priorities is applied in the study (Adashi *et al*., 2006). Accurately evaluating wireless network modulation and rationally deploying network simulation is the key to solve the problems above. The modulation features of the WCDMA network traffic is analyzed and a new assessment method of WCDMA network traffic for the rational network resources allocation is also put forward (Holma and Toskala, 2011).

Corresponding Author: Zhang Yannan, School of Management, University of Shanghai for Science and Technology, 200093, China

This essay mainly compares the simulation among PSK, 2ASK and 2FSK which are the key technology in WCDMA. This is the reason that information transmission technology has developed into data communication, the significant problem of which is modulation system' route in today's information age. These dominating modulation system' route are amplitude shift keying, flitting shift keying and phase shift keying now (Li *et al*., 2001). In consequence, choosing which one as a digital modulation system' route is a important problem when designing a digital system. Baseband signal can be transmitted via limited channel, the distance of which is short, but it is necessary to modulate signal in order to make use of the bandwidth of communication channel and also for the purpose that the signal can be transmitted in long distance. In addition, wireless communication system can only transmit digital signal that has be simulated. In communication system, three parameters of sine wave viewed as carrier are amplitude, frequency and phase, the corresponding simulation method of which are amplitude modulation, frequency modulation and phase modulation (Proakis and Salehi, 2001). On account of the particularity that digital signal is different from analog signal, these three simulation method are called Amplitude Shift Keying (ASK), Flitting Shift Keying (FSK) and Phase Shift Keying (PSK) (Fan and Cao, 2008).

MATERIALS AND METHODS

In the design of program, the gaussian white noise added in the channel of all the modulation is:

$$\text{Noise} = 0.05^* \text{ randn } (1,3000) \quad (1)$$

Rayleigh fading:

$$H = \text{sqrt } ((1\text{^}2\text{*randn}(1,3000)\text{^}2+(1\text{^}2\text{* randn}(1,3000)\text{^}2)) \quad (2)$$

The sampling number selected by noise is 3000.

When drawing error rate, 100000 is operated at every signal-noise ratio.

Modeling and simulation of 2ASK: Editing program 2ASK is simulated by M files of MATLAB. The design step of simulated program is presented as follows:

Signal modulation:

- When producing a binary number randomly, 11 is selected as a code element number. This is baseband signal
- Multiplying it by a produced carrier, The carrier is showed as follow:

Fc--carrier frequency, choosing 5. $s = \cos(2\pi^* f_c *t)$ (3)

In order to assure the length of data, carrier signal is sampled in 100 times.

Rayleigh fading and gaussian white noise are added in the channel for interference during data transmission.

Signal demodulation: Coherent demodulation is used during demodulation:

- Signal is transformed from time domain to frequency domain. If adding low pass filter whose bandwidth is 1/12, cut-off frequency will be 12 because of filtering the waveform which is interfered by noise and has a overbig waveform
- Judging threshold is setted as 0.5 during sampling decision. It is the most effective way to decide in the middle of code element. When sampling point is more than 0.5, the decision is 1. When sampling point is less than 0.5, the decision is 0. In order to assure the precision of data, sampling number is setted as 100
- The output waveform is obtained then

Modeling and simulation of 2FSK: The modulation of 2FSK is a method that distinguishes the change of code element by different frequencies. Therefore it needs two carriers of different frequencies.

Signal modulation:

- When producing a binary number randomly, 11 is selected as a code element number
- It produces a modulation carrier. The carrier is showed as Eq. 4:

$$s = \cos(2\pi^* f_c *t) \quad (4)$$

where, f_c is selected as 5 and 10, respectively.

The value of baseband signal is been calculated opposite after it is produced. The purpose of opposition is to change the code element amplitude from 0 in original signal to -1. Then the former baseband signal multiplies by carrier 1. The opposite baseband signal multiplies by carrier 2. Therefore two signals are produced. One that the code element of original baseband signal is 1 has cosine wave and the frequency of it is 5. The other one that the code element of original baseband signal is 0 has cosine wave and the frequency of it is 10.

Putting two signals above together, it will produce modulation waveform.

Adding gaussian white noise and Rayleigh fading together in the channel.

Signal demodulation: Coherent demodulation is used during demodulation:

- It will produce two signals if modulation signal multiplies by two carriers of different frequencies, respectively
- The two signals are added low pass filter, respectively. The filtering bandwidth is 1/12. The cut-off frequency is 12
- If the value of the waveform from one signal is less than the waveform from the other signal during the process of Sampling decision, 1 stands for this wave. However, 0 stands for the other wave
- Adding two signals together
- The output waveform is produced then

Modeling and simulation of BPSK: Direct phase modulation system' route is used during the procedure of BPSK in program. Direct phase modulation system' route is a way to make the original signal of BPSK, bipolar non-return-to-zero impulse train, multiply by carrier directly. Therefore, BPSK equals to amplitude-modulated signal in the function of bipolar baseband signal, which shows as Eq. 5:

$$e(t) = s(t) \cos \omega_0 t e(t) = s(t) \cos \omega_0 t \quad (5)$$

where, s(t) is bipolar digital baseband signal. It shows as Eq. 6:

$$s(t) = \sum_{-\infty}^{\infty} a_n g(t - nT_b) \quad (6)$$

where, g(t) is a function whose heigh is 1 and width is Tb. The value of T_b is 1 in program.

Signal modulation:

- When producing a binary number randomly, 11 is selected as a code element number
- BPSK is a signal of bipolar non-return-to-zero. Therefore it needs to calculate the opposite value of baseband signal after it is produced randomly
- The opposite value of baseband signal multiplies by two different carriers whose phases are 0 and π added, respectively

The two carriers are:

$$s1 = \sin(2\pi * f_c * t) \quad (7)$$

$$s2 = \sin(2\pi * f_c * t + \pi) \quad (8)$$

The f_c of carrier frequency is selected as 4:

- It will obtain modulating signal BPSK after adding two carriers together
- Adding gaussian white noise and Rayleigh fading together in the channel

Signal demodulation: Coherent demodulation is used in BPSK of WCDMA. So as in the program:

- Modulating signal multiples by two carriers respectively. Then two signals are produced
- The low pass filter is added to two signals. And the bandwidth of filter is 1/12. Then the cut-off frequency is 12. The waveform which is higher than cut-off frequency is abandoned as well as the noise outside and interference from adjacent channel
- Sampling decision is used in two signals, respectively. The threshold is 0. The decision will be1 if the code element is more than 0. Otherwise, the decision will be 0 if the code element is less than 0. It will be reliable if sampling is taken in the middle of code element
- Adding two waveform after decision
- Output waveform is produced then

Modeling and simulation of QPSK: The modulation principle of QPSK is adding two BPSK together. Firstly, baseband signal forms two signals in the design of program, Signal I and Q, after the separation following cascade and parallel. Two signals are transformed into bipolar non-return-to-zero then. The two are designed by design idea of BPSK. At last the modulation waveform is produced after adding two signals together.

Signal modulation:

- When producing a binary number randomly, 11 is selected as a code element number
- Baseband signal is separated into Signal I and Q after cascade and parallel
- Two produced coherent carriers multiply by Signal I and Q, respectively. And then those are modulated by BPSK

The formula of carrier is:

$$s1 = \cos(2\pi * f_c * t) \quad (9)$$

$$s2 = \sin(2\pi * f_c * t) \quad (10)$$

Carrier frequency is selected as 4:

- Adding two signals together
- Adding gaussian white noise and Rayleigh fading together in the channel

Coherent demodulation is used in demodulation, so as BPSK:

- The waveform produced after being demodulated multiplies carriers S1 and S2, respectively so that Signal I and Q are separated
- The low pass filter is added into two waveforms in the process of frequency domain. If the cut-off frequency is 12, the low pass bandwidth is 1/12. The waveform which is higher than cut-off frequency is abandoned as well as the noise outside and interference from adjacent channel
- Sampling decision is used after waveform is processed by low pass filter. The threshold is 0.25 for the reason that two signals are the waveforms which form after original baseband signal is separated via cascade and parallel. The decision will be1 if the sampled value is more than 0.25. Otherwise, the decision will be 0 if the sampled value is less than 0.25
- The signal is transformed via cascade and parallel
- The output waveform is produced then

Summary: This part describes the design idea and procedure of simulated program in detail. The chosen simulation method uses. M files of MATLAB in program design. Using modulation theory to compile program is related to modulation theory closely (Zhang *et al*., 2007). The character of this part is adding noise interference in the program design of simulation, which are gaussian white noise and Rayleigh fading. Generally speaking, misjudgment, which lead to deviation between the ideal and the reality, happens if modulation signal is interfered by noise and fading. Therefore, this part compares anti-interference performance of different modulation system' routes by simulation analysis of deviation. Specifically speaking, the outcome of simulation program are power spectrum, error rate and eye diagram. From them, both the advantage and disadvantage of different modulation system' routes can be measured by transmission rate, spectrum efficiency and anti-interference performance of modulation system' route. And then the modulation system' route which is most suitable for channel and equipment is chosen for WCDMA system.

ANALYSIS OF SIMULATION RESULTS

Analysis of transmission rate: First of all, supposing the rate of code element of binary system is R_{S2} in the view of baud rate, the rate of code element R_{sm}, adopting M number system is:

$$R_{sm} = R_{s2} \log_2 m \quad (11)$$

In other words, the rate of code element of M number system is $\log_{2m}$ times than that of binary system. For message rate (baud rate), a code element is 1 bit in the situation of binary system. Whereas the amount of information of a code element is $\log_{2m}$ bit/s in the situation of M number system. Also the relationship between the rate of code element and message rate is:

$$R_{bm} = R_{b2} \log_2 m \quad (12)$$

Thus, it can be seen that adopting multi-system can increase the rate of information transmission.

The relationship among four kinds of information transmission rate of modulation system' route is showed as follow:

$$2ASK = 2FSK = BPSK = 1/2QPSK \quad (13)$$

Analysis of bandwidth efficiency: Bandwidth efficiency is also another important sign to reflect the rate of transmission, besides message rate.

Compared with binary system, every symbol of digital modulation system in multi-system carries $\log_{2m}$ bit. When channel bandwidth is limited, it can increase the rate of information transmission (baud rate), which leads to the adding of bandwidth efficiency in the end. However, it will take more cost of increase in signal power and complexity in equipment. Digital modulation system in multi-system is usually used in the field that needs high rate of information transmission (Jiang and Yang, 2010).

In power spectrum, the abscissa axis is frequency, whereas the vertical axis is power.

Figure 1a is a power spectrum of 2ASK. The wave peak of power is at its highest frequency in -0.05 and 0.05, which indicates that energy is concentrated between the frequency from -0.05 to 0.05. The transmission rate of code element in 2ASK in every bandwidth is:

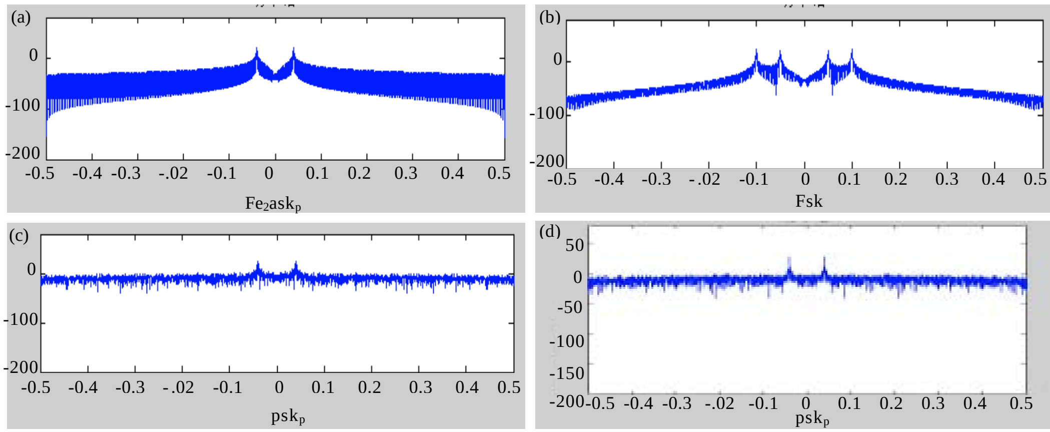

Fig. 1(a-d): Power spectrum, (a) Power spectrum of 2ASK, (b) Power spectrum of 2FSK, (c) Power spectrum of BPSK and (d) Power spectrum of QPSK

$$R_b = \frac{1}{(0.05+0.05)} = 10 \quad (14)$$

Supposing the bandwidth is 50, bandwidth efficiency of 2ASK can be calculated through formula:

$$n = R_b * \log_2 m/B = 10 * \log_2 2/50 = 20\% \quad (15)$$

Figure 1b is a power spectrum of 2FSK. The frequency of power is at its highest frequency in -0.1 and 0.1, which indicates that energy is concentrated between the frequency from -0.1 to 0.1. The transmission rate of code element in 2FSK in every bandwidth is:

$$R_b = \frac{1}{(0.1+0.1)} = 5 \quad (16)$$

Supposing the bandwidth is 50, bandwidth efficiency of 2FSK can be calculated through formula:

$$n = R_b * \log_2 m/B = 5 * \log_2 2/50 = 10\% \quad (17)$$

Figure 1c is a power spectrum of BPSK. The wave peak of power is at its highest frequency in -0.4 and 0.4, which indicates that energy is concentrated between the frequency from -0.4 to 0.4. The transmission rate of code element in BPSK in every bandwidth is:

$$R_b = \frac{1}{(0.04+0.04)} = 12.5 \quad (18)$$

Supposing the bandwidth is 50, bandwidth efficiency of BPSK can be calculated through formula:

$$n = R_b * \log_2 m/B = 12.5 * \log_2 2/50 = 25\% \quad (19)$$

The power spectrum of QPSK is as same as that of BPSK from D of Fig. 1. The wave peak of power is at its highest frequency in -0.4 and 0.4, which indicates that energy is concentrated between the frequency from -0.4 to 0.4. However, the bandwidth efficiency of QPSK is twice than that of BPSK for the reason that the rate of information transmission of QPSK is also twice than that of BPSK. The transmission rate of code element in QPSK in every bandwidth is:

$$R_b = \frac{1}{(0.04+0.04)} = 12.5 \quad (20)$$

Supposing the bandwidth is 50, bandwidth efficiency of QPSK can be calculated through formula:

$$n = R_b * \log_2 m/B = 12.5 * \log_2 4/50 = 50\% \quad (21)$$

Different kinds of bandwidth efficiencies can be compared clearly below. The bandwidth efficiency of modulation method 2ASK, 2FSK, BPSK, QPSK are 20, 10, 25, 50%, respectively.

From above, it is clear that the bandwidth efficiency of 2FSK is the lowest of all. And also there is 5% bandwidth efficiency between 2ASK and BPSK. However, the bandwidth efficiency of QPSK is the highest. It is the reason that not only its transmitted energy is concentrated but also its rate of information transmission is twice than any other modulation system' route. Although, the bandwidth efficiency of QPSK is the highest, it will take more cost of the increase in signal power and complexity in equipment. The uplink launch terminal is a portable cellphone in WCDMA system. Therefore t is impossible to achieve those two point. The modulation system' route of BPSK is the first choice in uplink data transmission. However, the downlink launch terminal is base station. Thus it is possible to achieve equipments which are in high power and complex. The modulation system' route of BPSK is used in downlink data transmission because of its higher transmission rate and bandwidth efficiency (Kim and Polydoros, 1988).

Analysis of against interference

Error rate: The gaussian white noise and Rayleigh fading are added in different channels of 2ASK, 2FSK, BPSK and QPSK, respectively, which can cause interference to data transmission.

It is easy to get anti-interference performance of every modulation system' route from the comparison among curve. It can use 100000 at every signal-noise ratio.

The abscissa axis of error rate is signal-to-noise ratio and the vertical axis of it is error rate. The value of error rate is from 0 to 10 dB.

As the a of Fig. 2 shows, the error rate of 2ASK decreases steadily, although not obvious, compared with the increase of signal-to-noise ratio. When the signal-to-noise ratio is below 5 dB, the error rate is more than 10%. When the signal-to-noise ratio increases to 8 dB, the error rate can decrease to 7%. That is to say 7 code element will be in mistake in every 100 code element. When the signal-to-noise ratio increases to 10 dB, the error rate is also as high as 4%.

It is easy to conclude the poor ability of 2ASK to resist interference of gaussian white noise and Rayleigh fading from the curve. For this reason, the error rate will be very high if 2ASK is used as a method of modulation. The anti-interference performance of 2ASK cannot meet

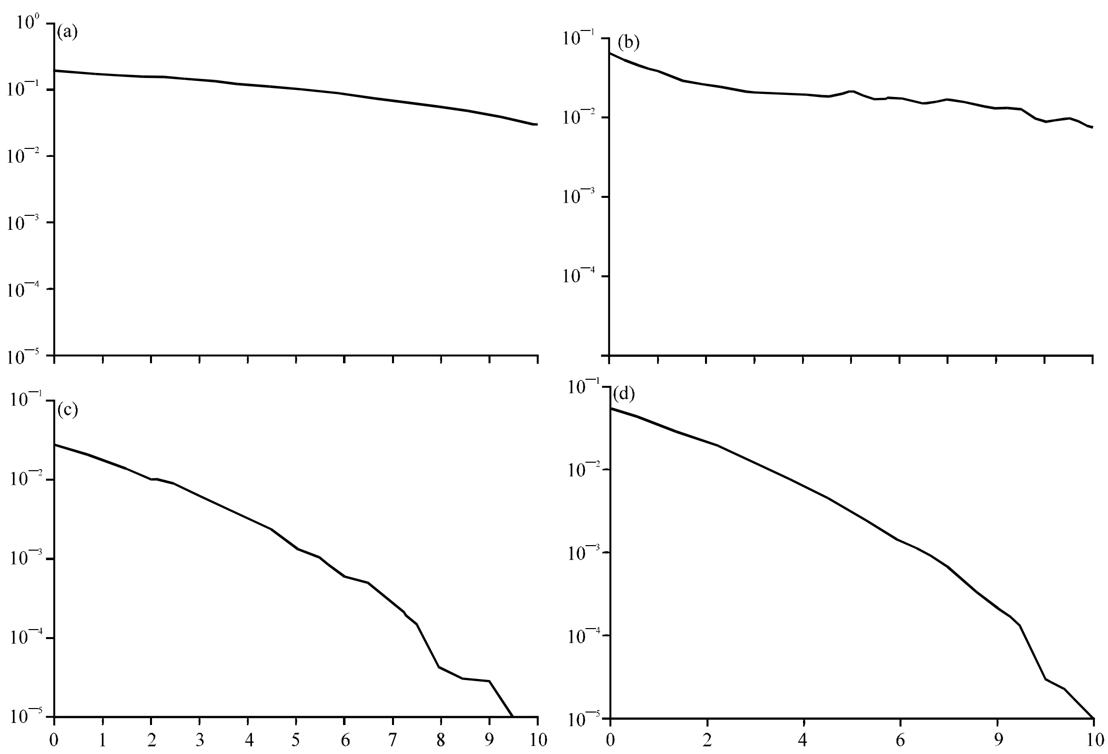

Fig. 2(a-d): Error rate, (a) Error rate of 2ASK which is added gaussian white noise and Rayleigh fading, (b) Error rate of 2FSK which is added gaussian white noise and Rayleigh fading, (c) Error rate of BPSK which is added gaussian white noise and Rayleigh fading and (d) Error rate of QPSK which is added gaussian white noise and Rayleigh fading the need of digital communication system WCDMA which is in long distance and requires strict requirement.

The error rate of 2FSK which is added gaussian white noise and Rayleigh fading is showed as B of Fig. 2. As the figure above shows, when the signal-to-noise ratio is below 4 dB, the error rate decreases steadily from 8 to 3%. When the signal-to-noise ratio is between 4 to 9 dB, the error rate can decrease unsteadily with mild shake. When the signal-to-noise ratio is 10 dB, the error rate is 0.8%.

It is easy to conclude that the anti-interference performance of 2 FSK is still very poor from the analysis of its error rate. When the signal-to-noise ratio is 9 dB, the error rate decreases below 1%. The ability of 2 FSK to resist noise is a bit better than 2 ASK, though not too much, which is concluded from the curve.

Figure 2c shows, the error rate of BPSK decreases steadily and fast, compared with the increase of signal-to-noise ratio. When the signal-to-noise ratio is between 8 to 9 dB, there is a mild shake among the error rate. When the signal-to-noise ratio increases to 9.5 dB, the error rate can decrease below 0.001%. That is to say one mistake can be made in every 100000 transmitted code element.

It shows that the well ability of 2 FSK to resist noise from the analysis of its error rate. The error rate can decrease below 10^{-5} if the signal-to-noise ratio is 10 dB, which has a better performance than 2 ASK and 2 FSK in this field.

The error rate of BPSK is showed in D of Fig. 2. The trend that the error rate of QPSK decreases with the increase of signal-to-noise ratio is almost the same as BPSK. When the signal-to-noise ratio is 4 dB, the error rate can decrease below 10^{-2}, 0.8% more or less. The decreasing trend of BPSK in error rate becomes fast than that of QPSK when the signal-to-noise ratio starts from 4 dB. When the signal-to-noise ratio is 10 dB, the error rate can decrease below 10^{-10}.

The anti-interference performance of QPSK is a little bit worse than BPSK, which is concluded from the outcome of simulation. Yet, it is still much better than 2 ASK and 2 FSK.

It is clear to see the comparison in signal-to-noise ratio of different modulation system' routes, which are added gaussian white noise and Rayleigh fading, in a same signal-to-noise ratio from the Table 1.

From Table 1, the error rate of PSK is the lowest of all from the table above, which indicates that it has the best anti-interference performance. Although, the error rate of PSK is the lowest, it still cannot meet the need of WCDMA system. This is because channel encoding and spread spectrum are adopted to resist interference in WCDMA, a huge system, besides modulation system' route.

Table 1: Signal-to-noise ratio of different modulation mode

	Signal-to-noise ratio (dB)					
Modulation mode	1	2	3	5	7	9
2ASK	0.30	0.20	0.150	0.100	0.0800	0.06
2FSK	0.06	0.04	0.030	0.030	0.0200	0.009
BPSK	0.02	0.01	0.007	0.002	0.0004	0.00004
QPSK	0.05	0.03	0.015	0.004	0.0006	0.00005

Eye pattern: The baseband signal is produced through low-pass filter after demodulation regarding code element as synchronous signal. The so-called eye pattern is a waveform that is presented in a oscilloscope screen. It is clear to see transmission distortion because of interference and distortion in the eye pattern (Liu and Feher, 2005).

The abscissa axis of eye pattern is time and the vertical axis of it is amplitude.

The amplitude in a best sampling time is from -0.3 to 0.6. At this time the "eye" is small. The slop of beveled edge is about 1, which shows that its sensitivity of timing error is at a general level. And if the trace of "eye" is in a mess, it shows that the distortion degree is serious due to noise interference. The best sampling time is the time when the "eye" is in a big form, half value of which is the tolerance of noise. And misjudgment can occur if the value of noise at one moment surpasses its tolerance. The tolerance of noise is about 0.45, which leads to the value of noise at one moment surpass it easily. So, a misjudgment can take place.

It is easy to calculate open degree of a "eye". And open degree of distortionless eye diagram is 100%:

$$n = (U - 2\Delta U)/U = (0.3+0.6-2\times 0.2)/(0.3+0.6) \approx 55\% \quad (22)$$

It is also easy to calculate the thickness of "eyelid". And the thickness of distortionless eye diagram is 0:

$$n = 2\Delta U/U = 2\times 0.2/(0.3+0.6) \approx 44\% \quad (23)$$

The amplitude in a best sampling time is from 0.5 to 0.8 for 2FSK, which decreases 0.6 compared with 2ASK. At this time the "eye" is nearly closed and almost all the trace overlap together. In addition, the shake of "eye", which not shakes up and down near amplitude 0, migrates. The slop of beveled edge is about 0, which shows that its insensitivity of timing error, still worse than 2ASK. The distortion degree is small, 0.1, for noise interference. The tolerance of noise is only 0.15, which leads to a higher probability of misjudgment than 2ASK. So, the code element rate of transmission in mistake will be high during the process of transmission.

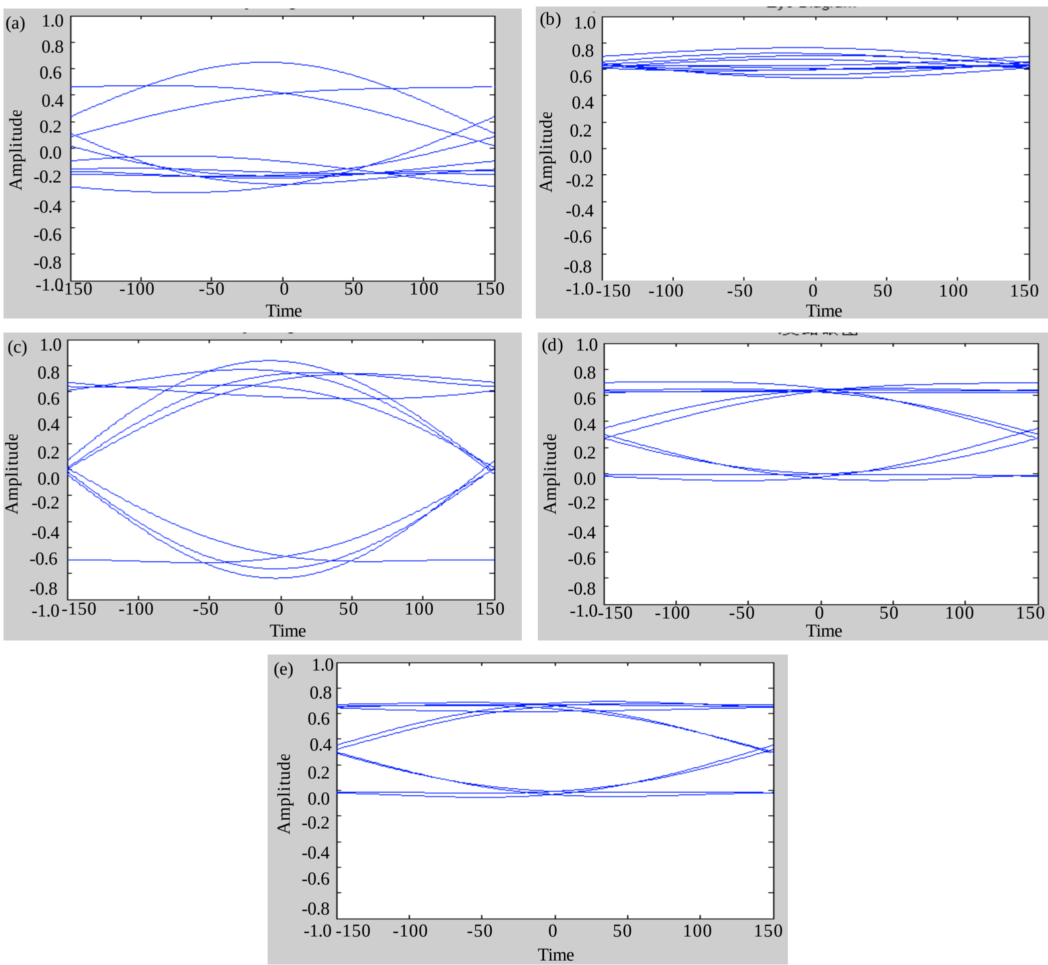

Fig. 3(a-e): Eye patterns, (a) Eye pattern of 2ASK, (b) Eye pattern of 2FSK, (c) Eye pattern of BPSK, (d) Eye pattern of QPSK in Signal I and (e) Eye pattern of QPSK in Signal Q

It is easy to calculate open degree of a "eye". And open degree of distortionless eye diagram is 100%:

$$n = (U - 2\Delta U)/U = (0.1+0.2-2\times 0.1)/(0.1+0.2) \approx 33\% \quad (24)$$

It is also easy to calculate the thickness of "eyelid". And the thickness of distortionless eye diagram is 0:

$$n = 2\Delta U/U = 2\times 0.1/(0.1+0.2) \approx 66\% \quad (25)$$

Figure 3c is the eye pattern of BPSK whose "eye" opens widely. The amplitude in a best sampling time is from -0.8 to 0.8, which is twice than 2ASK and five times than 2FSK. The slop of beveled edge is about 1.5, which is bigger than 2ASK and 2FSK. Therefore, it has a higher sensitivity of timing error.

The distortion degree is 0.2. The trace of "eye" is a little obscure because of noise interference. The tolerance of noise is about 0.8, which is 0.4 bigger than that of 2ASK and 0.65 bigger than that of 2FSK. Therefore, the probability of misjudgment is smaller than both 2ASK and 2FSK. That is to say, the ability to resist noise is better than those.

It is easy to calculate open degree of a "eye". And open degree of distortionless eye diagram is 100%:

$$n = (U - 2\Delta U)/U = (0.8+0.8-2\times 0.2)/(0.8+0.8) = 75\% \quad (26)$$

It is also easy to calculate the thickness of "eyelid". And the thickness of distortionless eye diagram is 0:

$$n = 2\Delta U/U = 2\times 0.2/(0.8+0.8) \approx 25\% \quad (27)$$

QPSK has two eye patterns because eye pattern can be drawn only in binary system. D and E of 3 are the eye patterns of QPSK in Signal I and Q, respectively, the two of which are almost the same as each other. It can be gotten from the figures above that amplitude in a best sampling time is from 0 to 0.6. The slop of beveled edge is about 1, which is the same as 2ASK. And its sensitivity of timing error is also no less than that of 2ASK.

The trace of "eye" is a little obscure because of being added gaussian white noise and Rayleigh fading. The distortion degree is 0.1, which is not too high. Because QPSK is transmitted through two signals that form after cascade and parallel, the tolerance of noise is the same as BPSK after two signals overlap. Therefore, the probability of misjudgment is the same as that of BPSK.

Both the open degree and thickness of "eyelid" of eye pattern can be figured up together because the high similarity between two.

It is easy to calculate open degree of a "eye". And open degree of distortionless eye diagram is 100%:

$$n = (U - 2\Delta U)/U = (0+0.7-2\times 0.1)/(0+0.7) \approx 71\% \quad (28)$$

It is also easy to calculate the thickness of "eyelid". And the thickness of distortionless eye diagram is 0:

$$n = 2\Delta U/U = 2\times 0.1/(0+0.7) \approx 28\% \quad (29)$$

The anti-interference performance of QPSK is a bit worse than that of BPSK, yet almost the same, which can be seen from the calculation.

It is easy to figure out the distortion degree and the ability to resist noise interference of different modulation system' routes due to crosstalk among code element. The "eye" open degree of both BPSK and QPSK are bigger than that of 2ASK and 2FSK. So as the definition of eye pattern as well as the trace. Consequently, the ability to resist noise interference of PSK is better than 2ASK and 2FSK.

Summary: The performance of various modulation system' routes, 2ASK, 2FSK, BPSK and QPSK, are obtained through the analysis of simulation outcome. These outcomes can be studied by transmission rate, bandwidth efficiency and anti-interference performance. And further conclusion can be seen from the Table 2.

Table 2 shows advantages and disadvantages of four modulation system' routes. The modulation rate of 2ASK, 2FSK and BPSK are the same, because all transmit data in binary system. Nevertheless, the transmission rate of QPSK is twice than the other three for the reason that it transmit data in quaternary. The bandwidth efficiency of 2FSK is the lowest as a result of its low transmission and wide transmission bandwidth. The bandwidth efficiency of 2ASK and BPSK are nearly the same, yet BPSK is a little better. However the bandwidth efficiency of QPSK is the best, which is twice than that of 2ASK and BPSK, on account of its fast transmission rate. In reality, it also takes cost of high power and complex equipment for the high frequency of QPSK (Jing, 2005). The error rate and eye pattern of BPSK and QPSK are better than 2ASK and 2PSK, because their advantages of anti-interference performance.

Table 2: Comparison of transmission rate, bandwidth efficiency and anti-interference performance of 2ASK, 2FSK, BPSK and QPSK

Modulation method	Transmission rate	Bandwidth efficiency	Anti interference performance
2ASK	1	Medium	Bad
2FSK	1	Low	Medium
BPSK	1	Medium	Very good
QPSK	2	High	Better

CONCLUSION

The transmission rate of 2ASK is the same as that of BPSK and also the half of that of QPSK. However, it has low bandwidth efficiency and wide bandwidth, which lead to low rate of transmitted code element in per frequency band if the channel bandwidth is given. The anti-interference performance of 2ASK is far worse than that of both 2FSK and PSK. Nevertheless, easy to achieve has became one advantage of 2ASK. Therefore, the maim field to apply 2ASK is in a low speed of information transmission. 2ASK which is used in telegraph system at the beginning is not widely applied in digital communication on account of its poor ability to resist noise (Luo, 2002).

2FSK is an important modulation system' route in digital communication. Its transmission rate is also the same as BPSK and the half of QPSK. The bandwidth of 2FSK is the widest of all, even wider than that of 2ASK, from power spectrum of simulation. As a result, it can conclude that the bandwidth efficiency is the lowest. 2ASK has a better performance than 2ASK, yet worse than BPSK and QPSK, in resisting noise. Generally, speaking, the advantage of 2ASK is its well anti-interference performance, whereas the disadvantage of it is the wide frequency band and low bandwidth efficiency. At present, low data transmission is the major application of 2FSK.

BSK is a modulation system' route of high transmission rate, which is widely used in main digital communication. In WCDMA, BPSK is used in uplink, whereas QPSK is used in downlink. The transmission rate of BPSK is the half of that of QPSK. Yet the bandwidth of them are nearly the same. The transmission rate of QPSK is twice than that of BPSK, considering bandwidth efficiency is calculated through bandwidth divided by transmission rate and the bandwidth efficiency of QPSK is twice than that of BPSK. However, it takes cost of increase in power and complex equipment if higher bandwidth efficiency is added, which explains that BPSK, other than QPSK, is applied in uplink of WCDMA although the transmission rate of BPSK is the half of that of QPSK. It is hard to increase power and use complicated equipment in uplink, the emission terminal of which is the common cellphone. While it is easy to offer the power and equipment QPSK need in downlink, the emission terminal of which is base station. Those above are the first reason. And the other reason is that anti-interference performance of BPSK is a bit better than that of QPSK. In a word, anti-interference performance of PSK is better than both 2ASK and 2FSK, which leads to widely application in high data transmission (Bennett, 1956).

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