UNIT–04

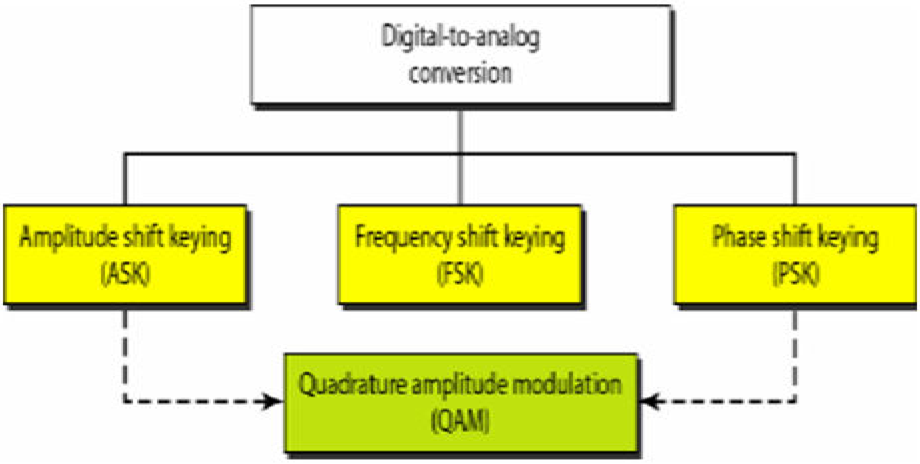
UNIT-04/LECTURE-01

DIGITAL TRANSMISSION TECHNIQUES

Introduction:- **(DEC 2013)(7)**

There are three major classes of digital modulation techniques used for transmission of digitally represented data:

- Amplitude-shift keying (ASK)
- Frequency-shift keying (FSK)
- Phase-shift keying (PSK)



All convey data by changing some aspect of a base signal, the carrier wave (usually a sinusoid), in response to a data signal. In the case of PSK, the phase is changed to represent the data signal. There are two fundamental ways of utilizing the phase of a signal in this way:

- By viewing the phase itself as conveying the information, in which case the demodulator must have a reference signal to compare the received signal's phase against; or
- By viewing the change in the phase as conveying information—differential schemessome of which do not need a reference carrier (to a certain extent).

Amplitude-Shift Keying (ASK) Modulation:-

Introduction

The transmission of digital signals is increasing at a rapid rate. Low-frequency analogue signals are often converted to digital format (PAM) before transmission. The source signals are generally referred to as baseband signals. Of course, we can send analogue and digital signals directly over a medium. From electro-magnetic theory, for efficient radiation of electrical energy from an antenna it must be at least in the order of magnitude of a wavelength in size; $c = f\lambda$, where c is the velocity of light, f is the signal frequency and λ is the wavelength. For a 1kHz audio signal, the wavelength is 300 km. An antenna of this size is not practical for efficient transmission. The low-frequency signal is often frequency-translated to a higher frequency range for efficient transmission. The process is called modulation. The use of a higher frequency range reduces antenna size.

In the modulation process, the baseband signals constitute the modulating signal and the high-frequency carrier signal is a sinusiodal waveform. There are three basic ways of modulating a sine wave carrier. For binary digital modulation, they are called binary amplitude-shift keying (BASK), binary frequency-shift keying (BFSK) and binary phase-shift keying (BPSK). Modulation also leads to the possibility of frequency multiplexing. In a frequency-multiplexed system, individual signals are transmitted over adjacent, non-overlapping frequency bands. They are therefore transmitted in parallel and simultaneously in time. If we operate at higher carrier frequencies, more bandwidth is available for frequency-multiplexing more signals.

Binary Amplitude-Shift Keying (BASK):-

A binary amplitude-shift keying (BASK) signal can be defined by

$$s(t) = A\, m(t) \cos 2\pi f_c t, \qquad 0 \le t \le T$$

Where A is a constant, m (t) = 1 or 0, f_c is the carrier frequency, and T is the bit duration. It has a power $P = A^2/2$, so that A = 2P . Thus equation can be written as

$$s(t) = 2P \cos 2\pi f_c t, \qquad 0 \le t \le T$$

2

Type equation here.

$$= PT \; . \cos 2\pi f_c t, \qquad 0 \le t \le T$$

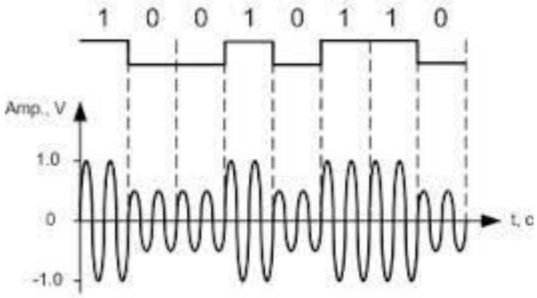
T

$$= E \;\; 2 \cos 2\pi f_c t, \qquad 0 \le t \le T$$

where $E = P T$ is the energy contained in a bit duration. If we take

$\phi_1(t) = \frac{2}{T} \cos 2\pi f_c t$ as the orthonormal basis function, the applicable signal space or

constellation diagram of the BASK signals is shown in Figure



Amplitude shift keying (ASK)

	RGPV QUESTIONS	Year	Marks
Q.1	Explain 1) what is ON-OFF keying 2) ASK is simplest among the keying system, still it is really used why ?	DEC 2013	7
Q.2	Explain the generation and reception of QAM signal. What is the bandwidth of QAM signal.	DEC 2009	10

UNIT-04/LECTURE-02

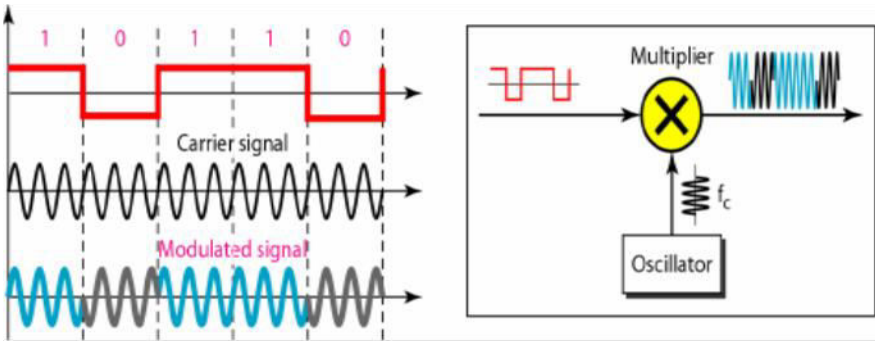
PHASE SHIFT KEYING

Phase-shift keying:- **(DEC 2013)(7)**

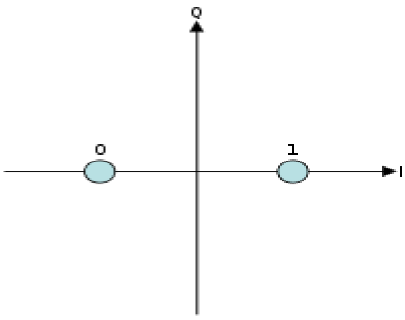
Phase-shift keying (**PSK**) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave).

Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases, each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal — such a system is termed coherent (and referred to as CPSK).

Alternatively, instead of operating with respect to a constant reference wave, the broadcast can operate with respect to itself. Changes in phase of a single broadcast waveform can be considered the significant items. In this system, the demodulator determines the changes in the phase of the received signal rather than the phase (relative to a reference wave) itself. Since this scheme depends on the difference between successive phases, it is termed **differential phase-shift keying (DPSK)**. DPSK can be significantly simpler to implement than ordinary PSK since there is no need for the demodulator to have a copy of the reference signal to determine the exact phase of the received signal (it is a non-coherent scheme). In exchange, it produces more erroneous demodulation.



Binary phase-shift keying (BPSK):-



BPSK (also sometimes called PRK, phase reversal keying, or 2PSK) is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis, at 0° and 180°. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol (as seen in the figure) and so is unsuitable for high data-rate applications.

In the presence of an arbitrary phase-shift introduced by the communications channel, the demodulator is unable to tell which constellation point is which. As a result, the data is often differentially encoded prior to modulation.

BPSK is functionally equivalent to 2-QAM modulation.

Implementation

The general form for BPSK follows the equation:

$$s_n(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi(1-n)), n = 0, 1.$$

This yields two phases, 0 and π. In the specific form, binary data is often conveyed with the following signals:

$$s_0(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi) = -\sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t)$$ for binary "0"

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t)$$ for binary "1"

Where f_c is the frequency of the carrier-wave.

Hence, the signal-space can be represented by the single basis function

$$\phi(t) = \sqrt{\frac{2}{T_b}} \cos(2\pi f_c t)$$

where 1 is represented by $\sqrt{E_b}\phi(t)$ and 0 is represented by $-\sqrt{E_b}\phi(t)$. This assignment is, of course, arbitrary.

This use of this basis function is shown at the end of the next section in a signal timing diagram. The topmost signal is a BPSK-modulated cosine wave that the BPSK modulator would produce. The bit-stream that causes this output is shown above the signal (the other parts of this figure are relevant only to QPSK).

Bit error rate

The bit error rate (BER) of BPSK in AWGN can be calculated as:[5]

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$ or $$P_b = \frac{1}{2} \operatorname{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Since there is only one bit per symbol, this is also the symbol error rate.

	RGPV QUESTIONS	Year	Marks

Q.1	Explain generation and reception of BPSK system. Compare it with BFSK system.	DEC 2013	7
Q.2	Calculate probability of error for BPSK signal.	DEC 2012	10

UNIT-04/LECTURE-03

DPSK

Differential phase-shift keying (DPSK):- **(DEC 2010)(20)**

Differential encoding

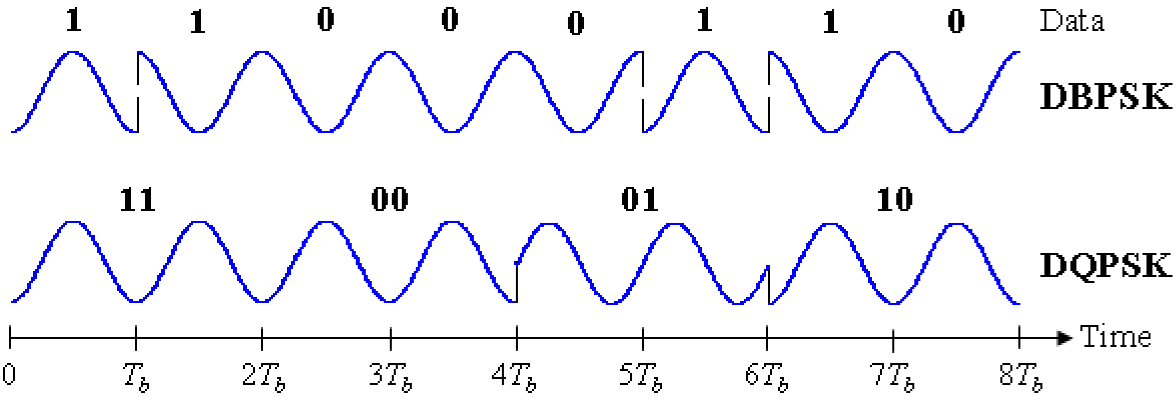
Main article: differential coding

Differential phase shift keying (DPSK) is a common form of phase modulation that conveys data by changing the phase of the carrier wave. As mentioned for BPSK and QPSK there is an ambiguity of phase if the constellation is rotated by some effect in the communications channel through which the signal passes. This problem can be overcome by using the data to *change* rather than *set* the phase.

For example, in differentially encoded BPSK a binary '1' may be transmitted by adding 180° to the current phase and a binary '0' by adding 0° to the current phase. Another variant of DPSK is Symmetric Differential Phase Shift keying, SDPSK, where encoding would be +90° for a '1' and -90° for a '0'.

In differentially encoded QPSK (DQPSK), the phase-shifts are 0°, 90°, 180°, -90° corresponding to data '00', '01', '11', '10'. This kind of encoding may be demodulated in the same way as for non-differential PSK but the phase ambiguities can be ignored. Thus, each received symbol is demodulated to one of the M points in the constellation and a comparator then computes the difference in phase between this received signal and the preceding one. The difference encodes the data as described above. Symmetric Differential Quadrature Phase Shift Keying (SDQPSK) is like DQPSK, but encoding is symmetric, using phase shift values of -135°, -45°, +45° and +135°.

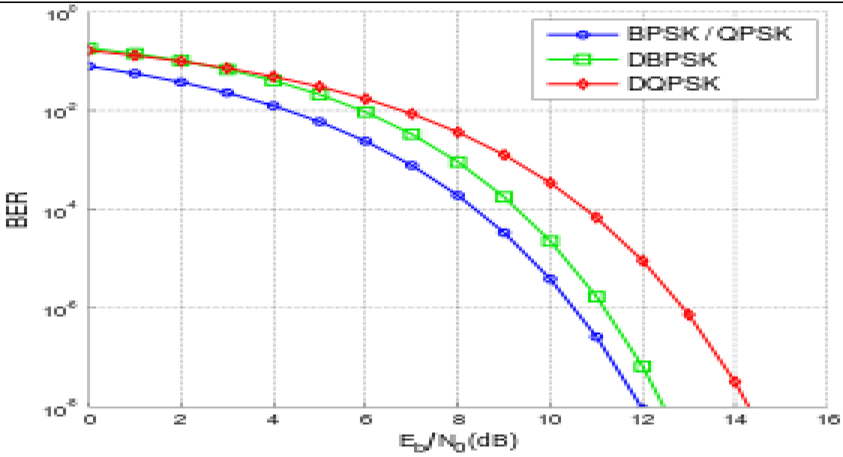
The modulated signal is shown below for both DBPSK and DQPSK as described above. In the figure, it is assumed that the *signal starts with zero phase*, and so there is a phase shift in both signals at $t = 0$.



Timing diagram for DBPSK and DQPSK. The binary data stream is above the DBPSK signal. The individual bits of the DBPSK signal are grouped into pairs for the DQPSK signal, which only changes every $T_s = 2T_b$.

Analysis shows that differential encoding approximately doubles the error rate compared to ordinary M-PSK but this may be overcome by only a small increase in E_b/N_0. Furthermore, this analysis (and the graphical results below) are based on a system in which the only corruption is additive white Gaussian noise(AWGN). However, there will also be a physical channel between the transmitter and receiver in the communication system. This channel will, in general, introduce an unknown phase-shift to the PSK signal; in these cases the differential schemes can yield a *better* error-rate than the ordinary schemes which rely on precise phase information.

Demodulation



BER comparison between DBPSK, DQPSK and their non-differential forms using gray-coding and operating in white noise.

For a signal that has been differentially encoded, there is an obvious alternative method of demodulation. Instead of demodulating as usual and ignoring carrier-phase ambiguity, the phase between two successive received symbols is compared and used to determine what the data must have been. When differential encoding is used in this manner, the scheme is known as differential phase-shift keying (DPSK). Note that this is subtly different from just differentially encoded PSK since, upon reception, the received symbols are *not* decoded one-by-one to constellation points but are instead compared directly to one another.

Call the received symbol in the k^{th} timeslot $r_k$and let it have phase ϕ_k. Assume without loss of generality that the phase of the carrier wave is zero. Denote the AWGN term as n_k. Then

$$r_k = \sqrt{E_s} e^{j\phi_k} + n_k.$$

The decision variable for the $k-1^{\text{th}}$ symbol and the k^{th} symbol is the phase difference between $r_k$and r_{k-1}. That is, if $r_k$is projected onto r_{k-1}, the decision is taken on the phase of the resultant complex number:

$$r_k r_{k-1}^* = E_s e^{j(\theta_k - \theta_{k-1})} + \sqrt{E_s} e^{j\theta_k} n_{k-1}^* + \sqrt{E_s} e^{-j\theta_{k-1}} n_k + n_k n_{k-1}$$

where superscript * denotes complex conjugation. In the absence of noise, the phase of this is $\theta_k - \theta_{k-1}$, the phase-shift between the two received signals which can be used to determine the data transmitted.

The probability of error for DPSK is difficult to calculate in general, but, in the case of DBPSK it is:

$$P_b = \frac{1}{2} e^{-E_b/N_0},$$

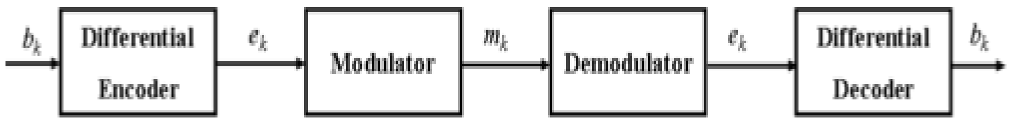
which, when numerically evaluated, is only slightly worse than ordinary BPSK, particularly at higher E_b/N_0 values.

Using DPSK avoids the need for possibly complex carrier-recovery schemes to provide an accurate phase estimate and can be an attractive alternative to ordinary PSK.

In optical communications, the data can be modulated onto the phase of a laseriin a differential way. The modulation is a laser which emits a continuous wave, and a Mach-Zehnder modulator which receives electrical binary data. For the case of BPSK for example, the laser transmits the field unchanged for binary '1', and with reverse polarity for '0'. The demodulator consists of a delay line interferometer which delays one bit, so two bits can be compared at one time. In further processing, a photodiode is used to transform the optical field into an electric current, so the information is changed back into its original state.

The bit-error rates of DBPSK and DQPSK are compared to their non-differential counterparts in the graph to the right. The loss for using DBPSK is small enough compared to the complexity reduction that it is often used in communications systems that would otherwise use BPSK. For DQPSK though, the loss in performance compared to ordinary QPSK is larger and the system designer must balance this against the reduction in complexity.

Example: Differentially encoded BPSK

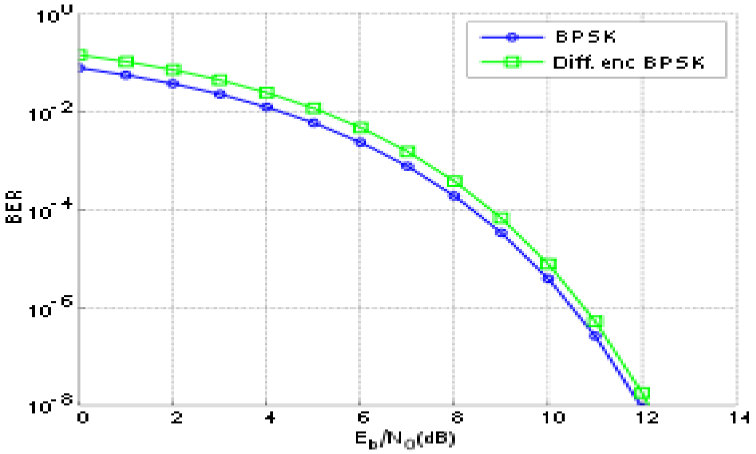


Differential encoding/decoding system diagram.

At the k^{th} time-slot call the bit to be modulated b_k, the differentially encoded bit e_k and the resulting modulated signal $m_k(t)$. Assume that the constellation diagram positions the symbols at ±1 (which is BPSK). The differential encoder produces:

$$e_k = e_{k-1} \oplus b_k$$

Where $\oplus$ indicates binary or modulo-2 addition.



BER comparison between BPSK and differentially encoded BPSK with gray-coding operating in white noise.

So e_k only changes state (from binary '0' to binary '1' or from binary '1' to binary '0') if b_k is a binary '1'. Otherwise it remains in its previous state. This is the description of differentially encoded BPSK given above.

The received signal is demodulated to yield $e_k =$±1 and then the differential decoder reverses the encoding procedure and produces:

$b_k = e_k \oplus e_{k-1}$Since binary subtraction is the same as binary addition.

Therefore, $b_k = 1$ if e_k and e_{k-1} differ and $b_k = 0$ if they are the same. Hence, if both e_k and e_{k-1} are inverted, $b_k$will still be decoded correctly. Thus, the 180° phase ambiguity does not matter.

Differential schemes for other PSK modulations may be devised along similar lines. The waveforms for DPSK are the same as for differentially encoded PSK given above since the only change between the two schemes is at the receiver.

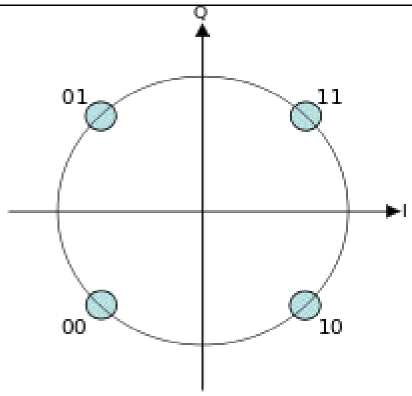
The BER curve for this example is compared to ordinary BPSK on the right. As mentioned above, whilst the error-rate is approximately doubled, the increase needed in E_b/N_0 to overcome this is small. The increase in E_b/N_0 required to overcome differential modulation in coded systems, however, is larger - typically about 3 dB. The performance degradation is a result of non coherent transmission - in this case it refers to the fact that tracking of the

	RGPV QUESTIONS	Year	Marks
Q.1	Explain the generation and reception of DPSK signal. Justify how the error rate of DPSK is greater than PSK.	DEC 2010	20
Q.2	Explain differential PSK system.	JUNE 2010	10

UNIT-04/LECTURE-04

QPSK

<u>Quadrature phase-shift keying (QPSK)</u>:- **(DEC 2013)(7)**



Constellation diagram for QPSK with Gray coding. Each adjacent symbol only differs by one bit.

Sometimes this is known as quadriphase PSK, 4-PSK, or 4-QAM. (Although the root concepts of QPSK and 4-QAM are different, the resulting modulated radio waves are exactly the same.) QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with Gray coding to minimize the bit error rate (BER) — sometimes misperceived as twice the BER of BPSK.

The mathematical analysis shows that QPSK can be used either to double the data rate compared with a BPSK system while maintaining the same bandwidth of the signal, or to maintain the data-rate of BPSK but halving the bandwidth needed. In this latter case, the BER of QPSK is exactly the same as the BER of BPSK - and deciding differently is a common confusion when considering or describing QPSK. The transmitted carrier can undergo numbers of phase changes.

Given that radio communication channels are allocated by agencies such as the Federal Communication Commission giving a prescribed (maximum) bandwidth, the advantage of QPSK over BPSK becomes evident: QPSK transmits twice the data rate in a given bandwidth compared to BPSK - at the same BER. The engineering penalty that is paid is that QPSK transmitters and receivers are more complicated than the ones for BPSK. However, with modern electronics technology, the penalty in cost is very moderate.

As with BPSK, there are phase ambiguity problems at the receiving end, and differentially encoded QPSK is often used in practice

Implementation

The implementation of QPSK is more general than that of BPSK and also indicates the implementation of higher-order PSK. Writing the symbols in the constellation diagram in terms of the sine and cosine waves used to transmit them:

$$s_n(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right), \quad n = 1, 2, 3, 4.$$

This yields the four phases π/4, 3π/4, 5π/4 and 7π/4 as needed.

This results in a two-dimensional signal space with unit basis functions

$$\phi_1(t) = \sqrt{\frac{2}{T_s}} \cos(2\pi f_c t)$$
$$\phi_2(t) = \sqrt{\frac{2}{T_s}} \sin(2\pi f_c t)$$

The first basis function is used as the in-phase component of the signal and the second as the quadrature component of the signal.

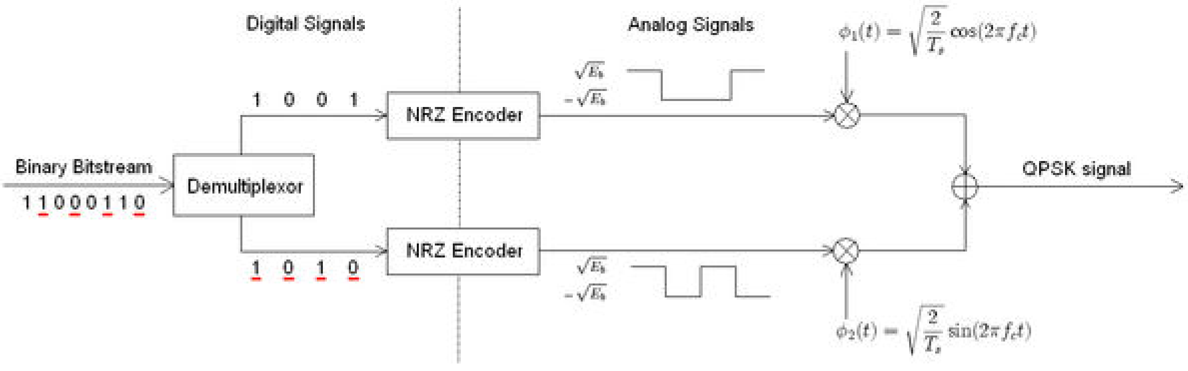
Hence, the signal constellation consists of the signal-space 4 points

$$\left(\pm\sqrt{E_s/2}, \pm\sqrt{E_s/2}\right).$$

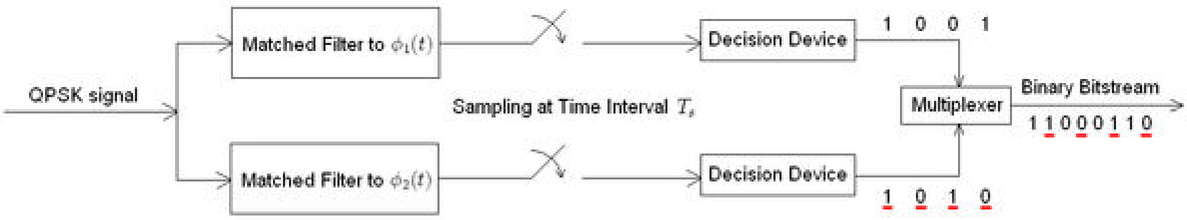
The factors of 1/2 indicate that the total power is split equally between the two carriers.

Comparing these basis functions with that for BPSK show clearly how QPSK can be viewed as two independent BPSK signals. Note that the signal-space points for BPSK do not need to split the symbol (bit) energy over the two carriers in the scheme shown in the BPSK constellation diagram.

QPSK systems can be implemented in a number of ways. An illustration of the major components of the transmitter and receiver structure is shown below.



Conceptual transmitter structure for QPSK. The binary data stream is split into the in-phase and quadrature-phase components. These are then separately modulated onto two orthogonal basis functions. In this implementation, two sinusoids are used. Afterwards, the two signals are superimposed, and the resulting signal is the QPSK signal. Note the use of polar non-return-to-zero encoding. These encoders can be placed before for binary data source, but have been placed after to illustrate the conceptual difference between digital and analog signals involved with digital modulation.



Receiver structure for QPSK. The matched filters can be replaced with correlators. Each detection device uses a reference threshold value to determine whether a 1 or 0 is detected.

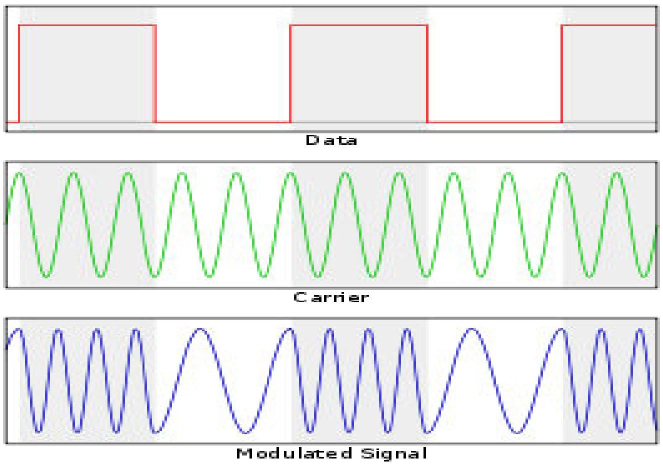
	RGPV QUESTIONS	Year	Marks
Q.1	Explain the principle of QPSK. Differentiate between offset QPSK and non offset QPSK.	DEC 2013	7
Q.2	Draw the block diagram of QPSK transmitter and QPSK Receiver and their operation	DEC 2012	10

UNIT-04/LECTURE-05

FSK

Frequency shift keying:- **(DEC 2012)(10)**

Frequency-shift keying (**FSK**) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK is binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information.[2] With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency. The time domain of an FSK modulated carrier is illustrated in the figures to the right.



Frequency modulation in general changes the center frequency over time:
x(t) = cos(2πf(t)t).
Now, in frequency shift keying, symbols are selected to be sinusoids with frequency selected among a set of Mdifferent frequencies {f0, f1, . . . fM−1}.
Orthogonal Frequencies
We will want our cosine wave at these M different frequencies to be orthonormal. Consider fk = fc +k_f, and thus
ϕk(t) = √2p(t) cos(2πfct + 2πk_ft)

where p(t) is a pulse shape, which for example, could be a rectangular pulse:
p(t) = 1/√Ts, 0 ≤ t ≤ Ts 0, otherwise

Transmission of FSK
At the transmitter, FSK can be seen as a switch between M different carrier signals.

Reception of FSK
FSK reception is either phase coherent or phase non-coherent. Here, there are M possible carrier frequencies, so we'd need to know and be synchronized to M different phases θ_i, one for each symbol frequency:

$$\cos(2\pi f_c t + \theta_0)$$
$$\cos(2\pi f_c t + 2\pi \; f\, t + \theta_1)$$
.
.
.
$$\cos(2\pi f_c t + 2\pi(M-1)\Delta f\, t + \theta_{M-1})$$

	RGPV QUESTIONS	Year	Marks
Q.1	Explain frequency shift keying. Describe coherent detection of FSK signal. What should be retain ship between bit rate and frequency shift for a better performance.	DEC 2012	10
Q.2	Briefly explain BFSK technique. specify the bandwidth requirement.	JUNE 2008	10

UNIT-04/LECTURE-06

PROBABILITY ERROR

Probability of Error for Coherent Binary FSK

First, let’s look at coherent detection of binary FSK.

1. What is the detection threshold line separating the two decision regions?

2. What is the distance between points in the Binary FSK signal space?

What is the probability of error for coherent binary FSK? It is the same as bipolar PAM, but the symbols are spaced differently (more closely) as a function of E_b. We had that

$$P[error]_{2ary} = Q\left(\sqrt{\frac{d_{0,1}^2}{2N_0}}\right)$$

Now, the spacing between symbols has reduced by a factor of $\sqrt{2}/2$ compared to bipolar PAM, to $d_{0,1} = \sqrt{2E_b}$. So

$$P[error]_{2-Co-FSK} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

For the same probability of bit error, binary FSK is about 1.5 dB better than OOK (requires 1.5 dB less energy per bit), but 1.5 dB worse than bipolar PAM (requires 1.5 dB more energy per bit).

Probability of Error for Noncoherent Binary FSK

The energy detector shown in Figure 46 uses the energy in each frequency and selects the frequency with maximum energy.

This energy is denoted r_m^2 in Figure 46 for frequency m and is

$$r_m^2 = r_{mc}^2 + r_{ms}^2$$

This energy measure is a statistic which measures how much energy was in the signal at frequency f_m. The ‘envelope’ is a term used for the square root of the energy, so r_m is termed the envelope.

Question: What will r_m^2 equal when the noise is very small?

As it turns out, given the non-coherent receiver and r_{mc} and r_{ms}, the envelope r_m is an optimum (sufficient) statistic to use to decide between $s_1 \ldots s_M$.

What do they do to prove this in Proakis&Salehi? They prove it for binary non-coherent FSK. It takes quite a bit of 5510 to do this proof.

1. Define the received vector r as a 4 length vector of the correlation of r(t) with the sin and cos at each frequency f_1, f_2.

2.They formulate the prior probabilities $f_{R|HI}$ $(r|H_i)$. Note that this depends on θ_m, which is assumed to be uniform between 0 and 2π, and independent of the noise.

Bandwidth of FSK

Carson's rule is used to calculate the bandwidth of FM signals. For M -ary FSK, it tells us that the approximate bandwidth is,

$$B_T = (M - 1)\Delta f + 2B$$

where B is the one-sided bandwidth of the digital baseband signal. For the null-to-null bandwidth of raised-cosine pulse shaping, $B = (1 + \alpha)/T_s$. Note for square wave pulses, $B = 1/T_s$.

Figure Demodulation and square-law detection of binary FSK signals

	RGPV QUESTIONS	Year	Marks
Q.1	Explain generation and reception of BPSK system. Compare it with BFSK system.	DEC 2013	7
Q.2	Discribe generation and detection of binary FSK.compare BPSK andBFSK.	DEC 2012	10