MODAL ANSWER

Q.No.1 a.) Explain Gram-Schmidt orthogonalization procedure. 08 Marks

Answer:

GRAM-SCHMIDT ORTHOGONALIZATION PROCEDURE

Having demonstrated the elegance of the geometric representation of energy signals, how do we justify it in mathematical terms? The answer lies in the *Gram-Schmidt orthogonalization procedure*, for which we need a *complete orthonormal set of basis functions*. To proceed with the formulation of this procedure, suppose we have a set of M energy signals denoted by $s_1(t), s_2(t), \ldots, s_M(t)$. Starting with $s_1(t)$ chosen from this set arbitrarily, the first basis function is defined by

$$\phi_1(t) = \frac{s_1(t)}{\sqrt{E_1}} \tag{5.19}$$

where E_1 is the energy of the signal $s_1(t)$. Then, clearly, we have

$$\begin{aligned} s_1(t) &= \sqrt{E_1}\phi_1(t) \\ &= s_{11}\phi_1(t) \end{aligned} \tag{5.20}$$

where the coefficient $s_{11} = \sqrt{E_1}$ and $\phi_1(t)$ has unit energy, as required.

Next, using the signal $s_2(t)$, we define the coefficient s_{21} as

$$s_{21} = \int_0^T s_2(t)\phi_1(t)dt \tag{5.21}$$

We may thus introduce a new intermediate function

$$g_2(t) = s_2(t) - s_{21}\phi_1(t) \tag{5.22}$$

which is orthogonal to $\phi_1(t)$ over the interval $0 \le t \le T$ by virtue of Equation (5.21) and the fact that the basis function $\phi_1(t)$ has unit energy. Now, we are ready to define the second basis function as

$$\phi_2(t) = \frac{g_2(t)}{\sqrt{\int_0^T g_2^2(t)dt}} \tag{5.23}$$

Substituting Equation (5.22) into (5.23) and simplifying, we get the desired result

$$\phi_2(t) = \frac{s_2(t) - s_{21}\phi_1(t)}{\sqrt{E_2 - s_{21}^2}} \tag{5.24}$$

where E_2 is the energy of the signal $s_2(t)$. It is clear from Equation (5.23) that

$$\int_0^T \phi_2^2(t)dt = 1$$

and from Equation (5.24) that

$$\int_0^T \phi_1(t)\phi_2(t)dt = 0$$

That is to say, $\phi_1(t)$ and $\phi_2(t)$ form an orthonormal pair, as required.

Continuing in this fashion, we may in general define

$$g_i(t) = s_i(t) - \sum_{j=1}^{i-1} s_{ij}\phi_j(t) \tag{5.25}$$

where the coefficients s_{ij} are themselves defined by

$$s_{ij} = \int_0^T s_i(t)\phi_j(t)dt, \qquad j = 1, 2, \ldots, i-1 \tag{5.26}$$

Equation (5.22) is a special case of Equation (5.25) with $i = 2$. Note also that for $i = 1$, the function $g_i(t)$ reduces to $s_i(t)$.

Given the $g_i(t)$, we may now define the set of basis functions

$$\phi_i(t) = \frac{g_i(t)}{\sqrt{\int_0^T g_i^2(t)dt}}, \qquad i = 1, 2, \ldots, N \tag{5.27}$$

which form an orthonormal set. The dimension N is less than or equal to the number of given signals, M, depending on one of two possibilities:

- The signals $s_1(t), s_2(t), \ldots, s_M(t)$ form a *linearly independent set*, in which case $N = M$.
- The signals $s_1(t), s_2(t), \ldots, s_M(t)$ are *not* linearly independent, in which case $N < M$, and the intermediate function $g_i(t)$ is zero for $i > N$.

Q.No.1 b.) What is the operating principle of MSK? Explain QAM modulator and de-modulator. 08 Marks

Answer: Minimum shift keying, MSK, is a form of is a type of continuous-phase frequency-shift keying, that is used in a number of applications. A variant of MSK modulation, known as Gaussian filtered Minimum Shift Keying, GMSK, is used for a number of radio communications applications including being used in the GSM cellular telecommunications system. In addition to this MSK has advantages over other forms of PSK and as a result it is used in a number of radio communications systems.

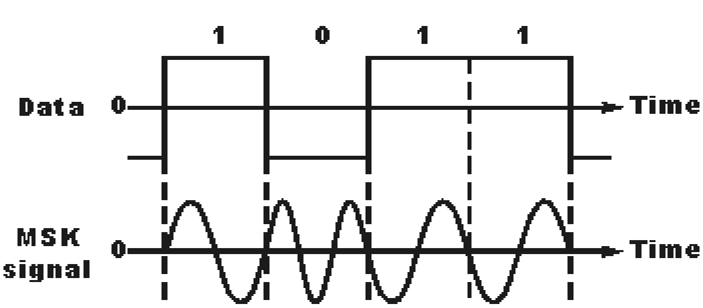
Reason for Minimum Shift Keying, MSK

It is found that binary data consisting of sharp transitions between "one" and "zero" states and vice versa potentially creates signals that have sidebands extending out a long way from the carrier, and this creates problems for many radio communications systems, as any sidebands outside the allowed bandwidth cause interference to adjacent channels and any radio communications links that may be using them.

Minimum Shift Keying, MSK basics

The problem can be overcome in part by filtering the signal, but is found that the transitions in the data become progressively less sharp as the level of filtering is increased and the bandwidth reduced. To overcome this problem GMSK is often used and this is based on Minimum Shift Keying, MSK modulation. The advantage of which is what is known as a continuous phase scheme. Here there are no phase discontinuities because the frequency changes occur at the carrier zero crossing points.

When looking at a plot of a signal using MSK modulation, it can be seen that the modulating data signal changes the frequency of the signal and there are no phase discontinuities. This arises as a result of the unique factor of MSK that the frequency difference between the logical one and logical zero states is always equal to half the data rate. This can be expressed in terms of the modulation index, and it is always equal to 0.5.



Signal using MSK modulation

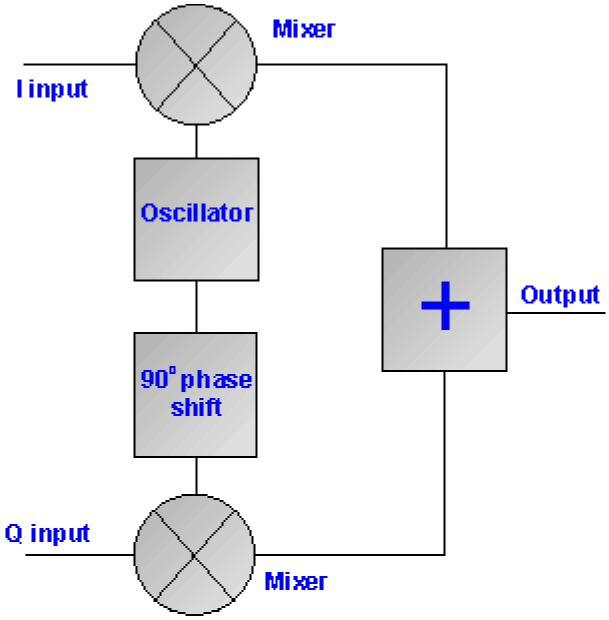
The QAM modulator and QAM demodulator are key elements within any quadrature amplitude modulation system.

The modulator and demodulator are used to encode the signal, often data, onto the radio frequency carrier that is to be transmitted. Then the demodulator is used at the remote end to extract the signal from the RF carrier so that it can used at the remote end.

As quadrature amplitude modulation is a complex signal, specialised QAM modulators and demodulators are required.

QAM modulator basics

The QAM modulator essentially follows the idea that can be seen from the basic QAM theory where there are two carrier signals with a phase shift of 90° between them. These are then amplitude modulated with the two data streams known as the I or In-phase and the Q or quadrature data streams. These are generated in the baseband processing area.



Basic QAM modulator diagram

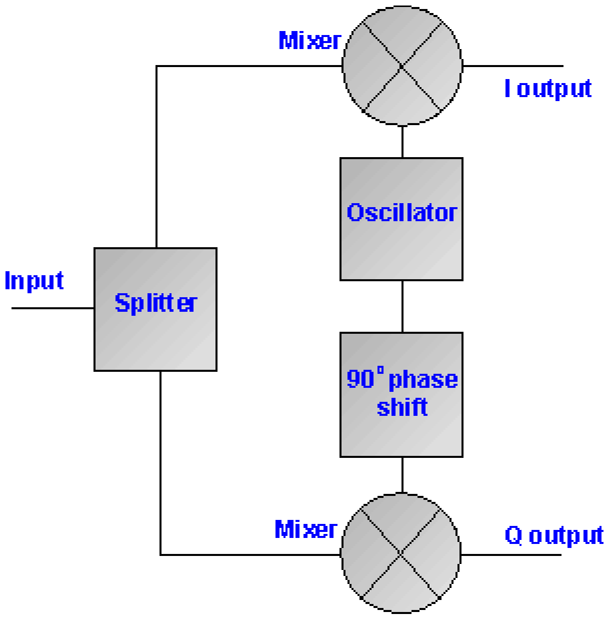
The two resultant signals are summed and then processed as required in the RF signal chain, typically converting them in frequency to the required final frequency and amplifying them as required.

It is worth noting that as the amplitude of the signal varies any RF amplifiers must be linear to preserve the integrity of the signal. Any non-linearities will alter the relative levels of the signals and alter the phase difference, thereby distorting he signal and introducing the possibility of data errors.

QAM demodulator basics

The QAM demodulator is very much the reverse of the QAM modulator.

The signals enter the system, they are split and each side is applied to a mixer. One half has the in-phase local oscillator applied and the other half has the quadrature oscillator signal applied.



Basic QAM demodulator diagram

The basic modulator assumes that the two quadrature signals remain exactly in quadrature.

A further requirement is to derive a local oscillator signal for the demodulation that is exactly on the required frequency for the signal. Any frequency offset will be a change in the phase of the local oscillator signal with respect to the two double sideband suppressed carrier constituents of the overall signal.

Systems include circuitry for carrier recovery that often utilises a phase locked loop - some even have an inner and outer loop. Recovering the phase of the carrier is important otherwise the bit error rate for the data will be compromised.

Q.No. 2

a.)What type of synchronization is used in QPSK system. **04 Marks**

Answer: ***Frequency Synchronization***

Frequency synchronization refers to ensuring that the receiver is locked and tracking the frequency drift of the transmitter, which can be caused by many real-world effects such as LO drift, Doppler, etc. Again, as is the case with time synchronization, lack of frequency synchronization adversely affects the receiver. A typical symptom of lack of frequency synchronization is a rotating constellation. The effect of a rotating constellation for a receiver is that the receiver will incorrectly map the symbols to bits, because they are perceived to be in different locations on the constellation plane. To be clear, a phase mismatch between the transmitter and receiver would result in a static rotation of the constellation, but a center frequency offset would result in a rotating constellation, with the rotation speed proportional to the frequency offset.

b.)Write a short note on M-ary orthogonal signals. **04 Marks**

Answer: In M-ary orthogonal signalling as k increase there is there is improved error performance or a reduction in required Eb/N0 at the expense of bandwidth.

Orthogonal signals are perpendicular to each other, the inner or dot product between those two signals must equal zero, one vector has zero projection over the other because they do not share same signal space.

In orthogonal set all cross correlation coefficients can be made zero.

c.)Give performance comparison of M-ARY PSK and FSK. **04 Marks**

Parameter	**M-ary PSK**	**M-ary FSK**
Probability of error	**More than that in M-ary FSK**	**Less than that in M-ary PSK**
Demodulation method	**Coherent**	**Non-coherent**
Synmbol duration	$T_s=NT_b$	$T_s=NT_b$
Bandwidth	$2f_b/N$	$2^{N+1}f_b/N$
Information is transmitted through	**Change in phase of carrier**	**Change in frequency of carrier**

d.) Enlist the different modules of Digital communication system with their features. **04 Marks**

Answer: ELEMENTS OF DIGITAL COMMUNICATION SYSTEMS:

Digital Communication System

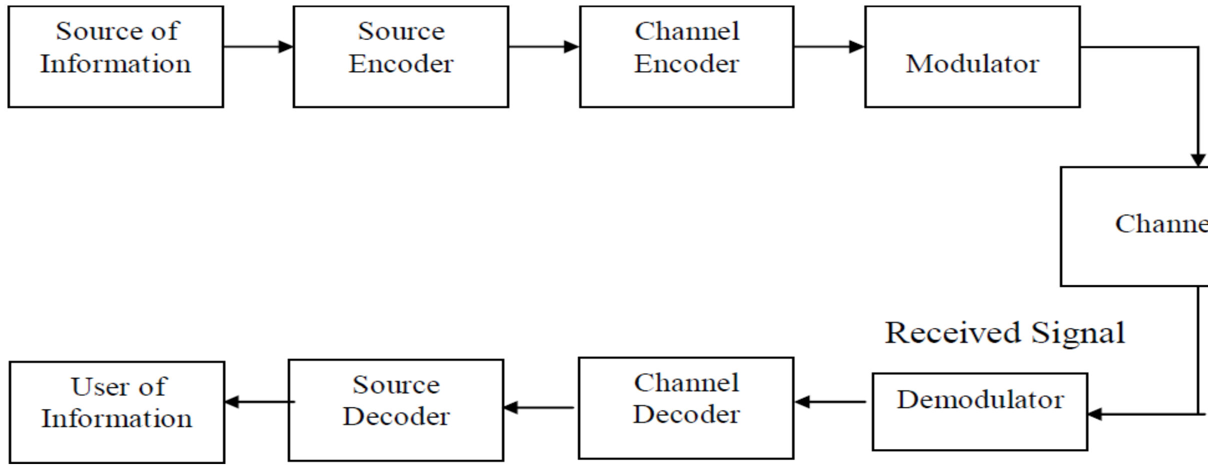


Fig 1.2: Block Diagram of a Digital Communication System

SOURCE ENCODER / DECODER: The Source encoder (or Source coder) converts the input i.e. symbol sequence into a binary sequence of 0‟ s and 1‟ s by assigning code words to the symbols in the input sequence.

CHANNEL ENCODER / DECODER: Error control is accomplished by the channel coding operation that consists of systematically adding extra bits to the output of the source coder. These extra bits do not convey any information but helps the receiver to detect and / or correct some of the errors in the information bearing bits. There are two methods of channel coding:

1. Block Coding: The encoder takes a block of „k‟ information bits from the source encoder and adds „r‟ error control bits, where „r‟ is dependent on „k‟ and error control capabilities desired.
2. Convolution Coding: The information bearing message stream is encoded in a continuous fashion by continuously interleaving information bits and error control bits.

MODULATOR: The Modulator converts the input bit stream into an electrical waveform suitable for transmission over the communication channel. Modulator can be effectively used to minimize the effects of channel noise, to match the frequency spectrum of transmitted signal with channel characteristics, to provide the capability to multiplex many signals.

DEMODULATOR: The extraction of the message from the information bearing waveform produced by the modulation is accomplished by the demodulator. The output of the demodulator is bit stream. The important parameter is the method of demodulation.

CHANNEL: The Channel provides the electrical connection between the source and destination. The different channels are: Pair of wires, Coaxial cable, Optical fibre, Radio channel, Satellite channel or combination of any of these. The communication channels have only finite Bandwidth, non-ideal frequency response, the signal often suffers amplitude and phase distortion as it travels over the channel. Also, the signal power decreases due to the attenuation of the channel. The signal is corrupted by unwanted, unpredictable electrical signals referred to as noise. The important parameters of the channel are Signal to Noise power Ratio (SNR), usable bandwidth, amplitude and phase response and the statistical properties of noise.