Revision 2020

Examination paper 2019

Question Q.1.a

Explain why a Pulse Position Modulation (PPM) system requires the transmission of a synchronization signal, whereas a single channel Pulse Amplitude Modulation (PAM) or Pulse Width Modulation (PWM) system does not.

Solution Q.1.a

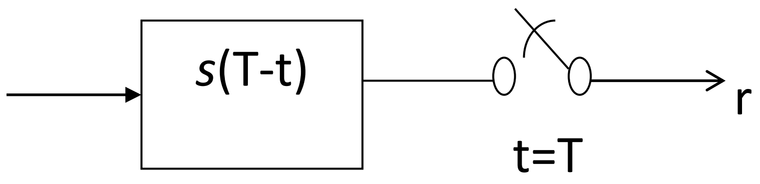
PPM requires synchronisation because the information is contained in the position of the pulse with regard to reference time. However, the reference time is not available with the transmitted pulse hence this requires additional synchronisation. In PWM, the information is contained in the width of the pulse and the start and end can be obtained from the rising and falling edges of the pulses. In PAM the information is contained in the amplitude and thus the pulses position is not influenced.

Question Q.1.b

Binary data are transmitted by using a pulse *s*(t) for 0 and a pulse 3*s*(t) for 1. Show that the optimum receiver for this case is a filter matched to *s*(t) with a detection threshold $2E_s$ as shown in Figure Q.1. Assume that 0 and 1 are equi-probable, determine the probability of error of this receiver as a function of E_s/N where N is the noise power of additive white Gaussian noise with zero mean as expressed in equation (1.1).

$$p(v) = \frac{1}{\sqrt{2\pi\sigma_v^2}} exp - \left(\frac{v^2}{2\sigma_v^2}\right)$$

and the noise power $N = \sigma^2{}_v$



Detection

0 if $r < 2E_s$

1 if $r > 2E_s$

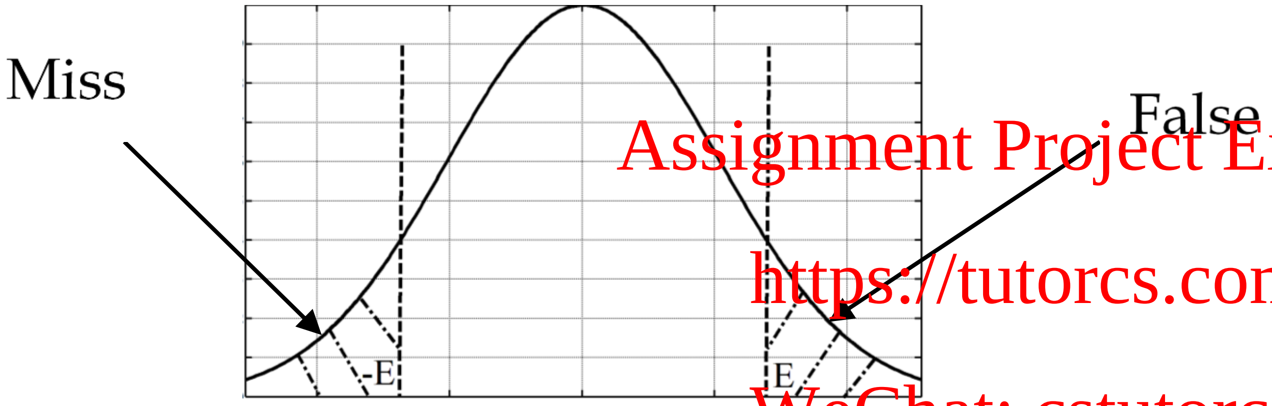
Solution Q.1.b

The optimum receiver is the matched filter with the signal component being equal to the convolution with the impulse response of the filter, thus when input is s(t), the output at t=T, is equal to E_s, whereas when input is 3s(t), the output at t=T, is equal to $3E_s$,

Thus to discriminate the 1 and 0, we set the threshold in the middle at $2E_s$

An error will occur if transmitted signal is a mark and $n_0(t)<-E_s$ since the output signal will fall below $2E_s$ this is referred to as a miss; or if the transmitted signal is a space and $n_0(T)>+E_s$, since the output signal will be greater than $2E_s$ this is referred to false alarm.

Solution Q.1.b cont.



From symmetry of the p.d.f. of noise, $p_{FA} = p_{miss}$

total probability of error
$= p(\text{transmitting mark}).p_{miss} + p(\text{transmitting space}).p_{FA}$

Solution Q.1.b. cont

$p_e = p_{FA}(p(m) + p(s))$

since we are transmitting either a mark or a space, then

$p(m) + p(s) = 1$

$$p_e = p_{miss} = p_{false\ alarm} = \int_{E_p}^{\infty} \frac{1}{\sqrt{2\pi}\sigma_v} e^{-\frac{v^2}{2\sigma_v^2}} dv = \int_{E_p}^{\infty} \frac{1}{\sqrt{2\pi N}} e^{-\frac{v^2}{2\sigma_v^2}} dv$$

Solution Q.1.b. cont

Let $u = \frac{v}{\sqrt{2\sigma_v}}$ then $du = \frac{dv}{\sqrt{2\sigma_v}}$

$$p_e = p_{miss} = p_{false\ alarm} = \frac{1}{\sqrt{\pi}} \int_{\frac{E_p}{\sqrt{2\sigma_v^2}}}^{\infty} e^{-u^2} du$$

$$P_e = \frac{1}{2} erfc \frac{E_p}{\sqrt{2N}} \; where\ N = \sigma_v^2$$

$$where\ erfc(x) = 1 - erf(x) = 1 - \frac{2}{\sqrt{\pi}} \int_0^x e^{-z^2} dz = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-z^2} dz$$

Question Q.1.c

Five messages bandlimited to W, W, 2W, 4W, and 4W Hz, respectively are to be time-division multiplexed. Devise a commutator configuration such that each signal is periodically sampled at its own minimum transmission rate and the samples are properly interlaced. What is the minimum transmission bandwidth required for this Time Division Multiplexing (TDM) signal?

Solution Q.1.c

W, W, 2W, 4W, and 4W Hz,

For the above signals, the first two signals need to be sampled at 2W, the third at 4W, and the fourth and fifth at 8W.

So for each sample of the first signal S1 and second signal S2, 2 samples are needed for the 3rd signal S3, and 4 samples are needed for the 4th and 5th signals, S4 and S5.

A possible interleaving is as follows:

S1 S4 S5 S3 S4 S5 S2 S4 S5 S3 S4 S5 S1 S4 S5 S3 S4 S5 S2 S4 S5 S3 S4 S5

Total number of samples in one cycle is equal to: 2+2+4+8+8= 24.

So the bandwidth needed is 12W.

Question Q.1.d

A baseband transmission system transmits the Manchester code where binary 1 is represented by +V for the first half of the bit duration and -V for the second half. Determine the correlation coefficient between the two baseband signals representing the one and the zero.

Solution Q.1.d

The one is +V for first half the bit and -V for the second half. For the zero it will be -V for the first half of the bit and +V for the second half of the bit. So the representation of the zero is -1 of the one bit. This gives a correlation coefficient of -1.

Question Q.1.e

- Give the output of a Phase Shift Keying (PSK) correlation detector if the stored replica has identical frequency as the incoming signal but has a phase offset equal to $\Delta\phi$. Comment on the result.

Solution Q.1.e

Replica at the receiver $s(t) = Acos(2\pi f_o t + \Delta\emptyset)$

The product in the correlation detector gives

$$p(t) = Acos(2\pi f_o t + \Delta\emptyset). Acos(2\pi f_o t) = A^2/2(cos(4\pi f_o t + \Delta\emptyset) + cos\Delta\emptyset)$$

This is then followed by the integrator which gives

$$\frac{A^2 T}{2} cos\Delta\emptyset$$

When the phase difference is zero we get the optimum output. For all other values the output is less than the optimum and gives a higher error rate and can give zero output when the phase difference is as large as 90 degrees.

Question Q.2.a

A transmitter produces 10 W of power which are applied to a unity gain antenna at 2 GHz carrier frequency.

(i) Express the transmitter power in dBm and dBW.

(ii) Rewrite the free space equation given in equation (2.1)

(1) to express the free space path loss in dB

(2) to give the ratio of received powers at two distances, d1 and d2.

(iii) Find the received power in dBm at a free space distance of 10 m and 1 km from the transmit antenna. Assume unity gain for the receive antenna.

Question Q.2.a cont

Free space propagation equation is given by

$$\frac{P_R}{P_T} = G_T G_R \left(\frac{c}{4\pi f d}\right)^2$$

where P_T and P_R are the transmit and receive powers, respectively, c is the speed of light, G_T and G_R are the gains of the transmit and receive antennas, respectively, f is frequency and d is distance.

Solution Q.2.a

$10\log_{10}(10)$= 10 dBW

To convert to dBm we add 30 =40 dBm or evaluate $10\log_{10}(10{,}000)$=40 dBm

Free space equation can be rewritten as

$$L = 10\log_{10}\frac{P_R}{P_T} = 10\log_{10} G_T + 10\log_{10} G_R - 20\log_{10} f - 20\log_{10} d + k$$

$$k = 20\log_{10}\frac{c}{4\pi} = 147.6$$

free space equation can be rewritten as $\frac{P_r(d_2)}{P_r(d_1)} = \left(\frac{d_1}{d_2}\right)^2$

Solution Q.2.a cont

$$\frac{P_R}{P_T} = G_T G_R \left(\frac{c}{4\pi f d}\right)^2$$

For unity gain antennas this gives $\frac{P_R}{P_T} = \left(\frac{c}{4\pi f d}\right)^2$

$$P_R = P_T \left(\frac{c}{4\pi f d}\right)^2$$

For distance of 10 m at 2 GHz this gives -18.46 dBm
For 1 km we can use the ratio equation which gives an additional 40 dB loss.
The received power is -58.46 dBm

Question Q.2.b

Discuss the different modes of radiowave propagation for the waves with frequency ranges in Table 1.

Frequency bands	frequency range
Extremely Low Frequency (ELF)	< 3 kHz
Very Low Frequency (VLF)	3-30 kHz
Low Frequency	30-300 kHz
Medium Frequency	300 kHz-3 MHz
High Frequency	3-30 MHz
Very High Frequency (VHF)	30-300 MHz
Ultra High Frequency (UHF)	300 MHz-3 GHz
Super High Frequency (SHF)	3-30 GHz
Extra High Frequency (EHF)	30-300 GHz

Table 1

Solution Q.2.b

Modes of radio-wave propagation are:

Ionospheric or Sky-waves

Tropospheric waves

Ground waves which can be

(i) Space waves which can be Direct waves or Ground-reflected waves

(ii) Surface waves

Waves travelling via the ionosphere which is an ionised region of the atmosphere extending above the earth from about 60 –500 km are termed sky-wave whereas waves travelling via the lower parts of the atmosphere (below 17 km) are termed tropospheric waves and forward scatter may be used for long range propagation of waves between about 300 MHz and 10 GHz.

Solution Q.2.b. cont

VLF waves are transmitted via a waveguide effect formed between the D-layer (the lower part of the ionosphere) and the earth and is used to transmit worldwide telegraphy, navigation and communication with submerged submarine since higher frequencies get rapidly attenuated in water. LF and MF propagate via ground wave where LF is mainly a surface wave and is used for navigation, and MF is normally surface wave in the day and skywave via the D-layer at night (AM radio). VHF and UHF propagation is mainly space wave including both ground-reflected and direct waves.

Solution Q.2.b. cont

SHF is usually termed microwave which also includes frequencies above 1.5 GHz and is mainly line of sight (LOS). This band is used for satellite communication, short range communications and point to point radio links. Finally, the EHF band is termed as millimetre wave band and permits the use of very large bandwidths where propagation is mainly by LOS and ground reflection is insignificant due to losses. Only over very smooth grounds or water surfaces does ground reflection become significant. These frequencies are affected by scattering in rain and snow and at certain frequencies absorption by fog, water vapour and other atmospheric gases. These frequency bands are mainly used for very short secure communication systems for example at 60 GHz.

Question Q.2.c

Explain what is meant by handoff and discuss soft and hard handover used in cellular systems.

Solution Q.2.c

Handoff: When a mobile moves into a different cell while a conversation is in progress, the Mobile Switching Centre automatically transfers the call to a new channel belonging to the new base station. This handoff operation involves:

identifying a new base station, and

allocation of voice and control signals to channels associated with the new base station.

Solution Q.2.c

Hard and soft Handoff: Code division multiple access (CDMA) spread spectrum cellular systems such as IS-95 provides a unique handoff capability that cannot be provided with other wireless systems. Unlike channelised wireless systems that assign different radio channels during a handoff (called a hard handoff), spread spectrum mobiles share the same channel in every cell. Thus, the term handoff does not mean a physical change in the assigned channel, but rather that a different base station handles the radio communication task.

Solution Q.2.c cont

By simultaneously evaluating the received signals from a single subscriber at several neighbouring base stations, the MSC may actually decide which version of the user's signal is best at any moment in time. This technique exploits macroscopic space diversity provided by the different physical locations of the base stations and allows the MSC to make a soft decision as to which version of the user's signal to pass along to the PSTN at any instance. The ability to select between the instantaneous received signals from a variety of base stations is called soft handoff.

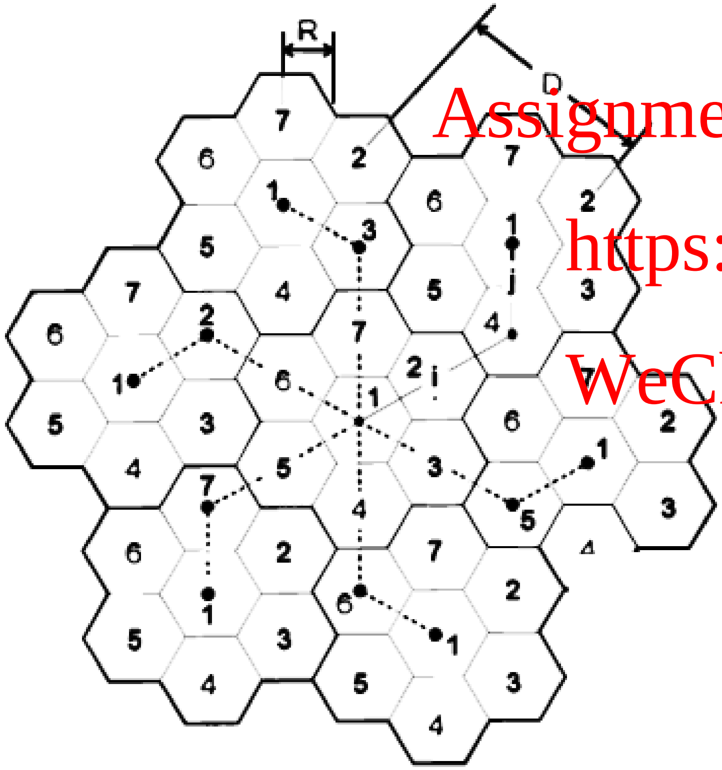
Question 2.d

Discuss the causes of co-channel interference in cellular networks.

Solution Q.2.d

Co-channel interference: Frequency reuse implies that in a given coverage area there are several cells that use the same set of frequencies. These cells are called *co-channel cells*, and the interference between signals from these cells is *called co-channel interference*. Unlike thermal noise, which can be overcome by increasing the signal-to-noise ratio (SNR), co-channel interference cannot be combated by simply increasing the carrier power of a transmitter. This is because an increase in carrier transmitted power increases the interference to neighbouring co-channel cells. To reduce co-channel interference, co-channel cells must be physically separated by a minimum distance as illustrated in figure

Solution Q.2.d cont



Cell Cluster with K= 7