Research & Development of Telecommunication Systems Lab.

PASIPHAE

Technological Educational Institute of Crete, *Informatics Engineering department*

Review questions in "Digital TV Principles"

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Question 1

Calculate the bit rate (in Mbits/sec) that is required for the transmission of an uncompressed digital video 1080p (i.e. with a resolution of 1920x1080) and a frame rate of 50fps, for the following two cases:

i) Values in RGB, and
ii) Values in YCrCb, where we associate one Cr value and 1 Cb value for every four luminance values.

In both cases, please consider 1 byte for every Colour or Luminance value

Answer 1

i) Values in RGB

Each frame has 1920x1080 pixels => 2.073.600 pixels

We need 2.073.600 values for every Colour, i.e. 2.073.600 bytes for every Colour.

Thus each frame has 6.220.800 bytes.

For 50 frames per second, we require 6.220.800 x 50 = 311.040.000 bytes/sec = 2.488 GBits / sec.

ii) Values in YCrCb

Each frame has 1920x1080 pixels => 2.073.600 pixels

We need 2.073.600 values for the luminance, i.e. 2.073.600 bytes for the luminance.

We also need 2.073.600/4 = 518.400 bytes for Cr and 518.400 bytes for Cb.

Thus, each frame has a total of 3.110.400 bytes.

For 50 frames per second, we require 3.110.400 bytes x 50 = 155.520.000 bytes/sec = 1.244 GBits/sec.

Question 2

Consider a video encoded in MPEG-2. The frame rate is 25 frames / sec. Assume that an I-frame size is 100 Kbytes, a P-frame size is 30 Kbytes and a B-frame size is 20 Kbytes. We also use GOP size = 12 (IBBPBBPBBPBB).

i) Calculate the bit rate (in Mbits / sec) of the encoded video
ii) If we used GOP size = 6 (IBBPBB), what is the bit rate required? What do we gain and what we lose in this case?

Answer 2

i) Each GOP needs 1x100 + 3x30 + 8x20 = 350 Kbytes. Each GOP contains 12 frames, thus in 1 sec (25 frames) we transmit 350x (25/12) = 729.1 Kbytes. Therefore, the transmission rate is 5.832 Mbits/sec.

ii) Each GOP needs 1x100 + 1x30 + 4x20 = 210 Kbytes. Each GOP contains 6 frames, thus in 1 sec (25 frames) we transmit 210x (25/6) = 875 Kbytes. Therefore, the transmission rate is 7.0 Mbits/sec.

By utilizing smaller GOP size, we lose in encoding performance, since we need less bit rate bit rate for the transmission. The gain refers to the more frequent transmission of independent I-frames (1 for every 6 frames for a GOP size = 6 instead of 1 for every 12 frames in a GOP size = 12), which allows the decoder to continue the video reproduction more efficiently especially in case of errors or loss of data.

Question 3

Assume the following GOP

. . . I B B P B B P B B **P** B B. . .

If during transmission the underlined P frame is lost (or distorted) due to errors, which frames may be affected?

Answer 3

The I frame is independent and the next two P frames depend only on this and the previous P frames. Reference to the erroneous P frame may have only the B frames of the GOP, thus only these frames may be affected.

Question 4

You are given the following values of DCT coefficients of an MPEG-2 block, which have resulted after the DCT transformation:

99	66	32	9	0	0	0	0
54	21	9	5	0	0	0	0
13	1	0	0	0	0	0	0
6	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

You are also given the standardised quantization matrix:

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

Calculate the DCT coefficients that are finally transmitted, by utilizing a quantizer scale q, where

i) q=2 and
ii) q=4.

What do we lose and what do we gain by utilizing higher quantizer scale?

Answer 4

The matrix (table) of the coefficients that are transmitted is obtained by dividing the initial coefficients with the corresponding element of the quantization matrix (table) and then the quantizer scale. The result is rounded to the nearest integer.

i) For quantizer scale q=2:

6	2	1	0	0	0	0	0
2	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

ii) For quantizer scale q=4:

3	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

We observe that for q=4 (since the "zero" coefficients are not transmitted) we transmit only 3 values, while for quantizer scale q=2 we transmit 5 values. Thus, for q=4 we need less bytes for the representation of a block – and generally less bit rate for the video. However, for q=4 more DCT coefficients are zeroed, an issue denoting that more spatial frequencies are lost from the block. Therefore, we may observe loss in the image details, and in sometimes "blockiness effect".

Question 5

An MPEG-2 video contains the following two frames. Which one requires more bytes during encoding and why?

Frame A

Frame B

Answer 5

Most blocks of frame B contain more high spatial frequencies compared to the corresponding blocks of frame A.

Therefore, for each block of the frame B to be transmitted most DCT coefficients representing spatial frequencies.

Therefore most of the blocks in frame B require more bytes to describe them in relation to those in frame A.

Thus the B frame requires more bytes for coding at MPEG-2.

Question 6

In an MPEG-2 encoded video we assign 1 block of blue chromaticity (Cb) and 1 block of red chromaticity (Cr) for every 4 luminance blocks (Y). Calculate how many blocks (in total) comprise a frame of high definition video HD (1280 x 720).

Answer 6

1280/8 = 160 and 720/8 = 90. Thus, each frame has 160x90 = 14400 luminance blocks (Y), of 8x8 pixels.

Additionally, since 1 block Cr = 1 block Cb = 4 blocks Y, we require 14400/4= 3600 blocks Cb, as well as 3600 blocks Cr.

Therefore, in total, the frame is consisted of 14400 + 3600 + 3600 = 21600 blocks.

Question 7

For a GOP size = 12, find the total number of GOPs that an MPEG-2 video sequence is composed of, given that it exploits a frame rate of 25fps and has a duration of 5 minutes.

Answer 7

The sequence has duration of 5 minutes = 300 seconds, thus it consists of 300x25 = 7500 frames.

Thus, the total number of GOPs that the video sequence is composes of is equal to 7500 / 12 = 625.

Question 8

An MPEG-2 Elementary Stream has a bit rate of 6 Mbps. During its conversion to Packetized Elementary Stream, the PES packet headers increase the transmitted bytes by 5%.

i) What is the bit rate of the Packetized Elementary Stream?
ii) How many Transport Packets are needed per second for delivering this video?
iii) What is the bit rate (in Mbps) of the final Transport Stream?

Please note that in each Transport Packet of 188 bytes the useful payload is 184 bytes and the header is 4 bytes.

Answer 8

i) Since the bit rate increases by 5% the PES bit rate will be 6 Mbps x (1 + 0,05) = 6.3 Mbps.

ii) Since the PES bit rate is at 6.3 Mbps -> every second we have 6.300.000 bits = 787.500 bytes to be transmitted. These bytes must be placed in the Transport Packets payload. Therefore, we need 787.500 / 184 = 4280 Transport Packets per second.

iii) The Transport Stream is delivered with a rate of 4280 packets per second. Since each packet has a length of 188 bytes, the bit rate is 4280x188 = 804640 bytes/sec = 6.437.120 bits/sec = 6.4 Mbps

Question 9

The following 4 streams are inserted at the input of an MPEG-2 multiplexer:

Video of TV Programme A: 5 Mbps

Audio of TV Programme A: 0.4 Mbps

Video of TV Programme B: 4 Mbps

Audio of TV Programme B: 0.4 Mbps

i) Calculate the total useful bit rate of the multiplexing process
ii) Assuming that the mupliplexer has a constant output bit rate at 12 Mbps, calculate how many stuffing Transport Packets per second must be inserted in order to achieve this rate.

Answer 9

i) In TDM, the total useful bit rate at the output of the multiplexer is the sum of all inputs. That means that the multiplexing will have a useful bit rate equal to: 5 + 0.4 + 4 + 0.4 = 9.8 Mbps.

ii) Given that the useful bit rate is at 9.8 Mbps, in order to achieve the final output rate of 12 Mbps, we need to add stuffing packets with a rate of 12 – 9.8 = 2.2 Mbps. Thus 2.2 Mbps = 275.000 bytes/sec = (275.000/188) Transport Packets / sec = 1463 Transport Packets / sec.

Question 10

In an MPEG-2 Transport Stream of 10 Mbits/s we add Reed-Solomon code.

i) What is the bit rate (in Mbits/s) of the final encoded stream?
ii) If during the transmission the Bit Error Rate (BER) is equal to $2 \cdot 10^{-3}$ and we assume that the errors are uniformly applied (group errors) to the Transport Packets, will the R-S decoder be able to recover the original Transport Stream?

Please note that the byte error rate (ByER) may be found from the percentage of the erroneous bits (bit error rate - BER) utilising the following formula:

$$ByER = 1 – (1\text{-}BER)^8$$

Answer 10

i) The 10 Mbits/s are equal to 10/8 Mbytes/s = 1,25 Mbytes/s. As long as each Transport Packet has a length of 188 bytes, the transmission rate will be ($1,25 \cdot 10^6$ bytes/s) / (188 bytes/packet) = 6648,9 packets/sec.

After the encoding, the length of each packet is increased from 188 to 204 bytes by adding the redundant bytes. In this way, the 6648,9 packets/sec correspond to (6648,9 packets/sec) · (204 bytes/packet) = 1,356 Mbytes/sec = **10,84 Mbits/s**

ii) In order to estimate the average erroneous bytes within a transport packet we need to know the byte error rate. This is calculated as follows:

$ByER = 1 – (1\text{-}BER)^8 = 1 – (1 - 2\cdot10^{-3})^8 = 1{,}58\cdot10^{-2}$

Each protected packet has a length of 204 bytes. Assuming a uniform distribution of the errors, each protected byte will receive (in an average) $204 \cdot (1{,}58\cdot10^{-2}) = 3{,}22$ erroneous bytes. Since the R-S algorithm can correct up-to 8 bytes per coded packet, it comes that **the original Transport Stream can be fully recovered**.

Question 11

We feed an DVB-T transmitter with an MPEG-2 Transport Stream of 15 Mbits/s. In this TS we add Reed-Solomon code and after that convolutional code with a code rate equal to 2/3.

i) What is the bit rate (in Mbits/s) of the final protected stream?
ii) Assuming a QPSK modulation, how many symbols per second (i.e. changes in the phase of the modulated signal) do we need for the transmission of this stream?

Answer 11

i) The 15 Mbits/s are equal to 15/8 Mbytes/s = 1,875 Mbytes/s. Since each Transport Packet has a length of 188 bytes, the transmission rate is equal to ($1{,}875\cdot10^6$ bytes/s) / (188 bytes/packet) = 9973,4 packets/sec.

After the Reed-Solomon coding, the length of each packet will be increased from 188 to 204 bytes with the addition of the redundancy bytes. Therefore, the 9973,4 packets/sec correspond to (9973,4 packets/sec) · (204 bytes/packet) = 2,034 Mbytes/sec = 16,27 Mbits/s.

The convolutional coder will produce 3 "output" bits for every 2 "input" ones. As a result, the total bit rate after the two coding mechanisms will be equal to 16,27 Mbits/s · (3/2) = **24,40 Mbits/s**.

ii) In QPSK, a pair of bits (2 bits) corresponds to a phase change in the carrier signal (i.e. 2 bits/symbol). Therefore, for transmitting $24{,}40\cdot10^6$ bits/s we will need $(24{,}40/2)\cdot10^6$ symbols/s = **12,2 Msymbols/s.**

Question 12

In a DVB-T network, the minimum SNR that we measure at the receivers' side is 6 dB.

i) What is the rate of the convolutional code that we have to select at the transmitter, so that the receivers will be able to correctly decode the Transport Stream at any time?

ii) Assuming that the bit rate at the input of the convolutional encoder is 5 Mbps, what is the output rate?

Modulation	Code Rate	Useful bit rate (Mbits/s)	Minimum SNR required at the receiver (dB)
QPSK	**1/2**	**5,53**	**3,1**
QPSK	**2/3**	**7,37**	**4,9**
QPSK	**3/4**	**8,29**	**5,9**
QPSK	**5/6**	**9,22**	**6,9**
QPSK	**7/8**	**9,68**	**7,7**

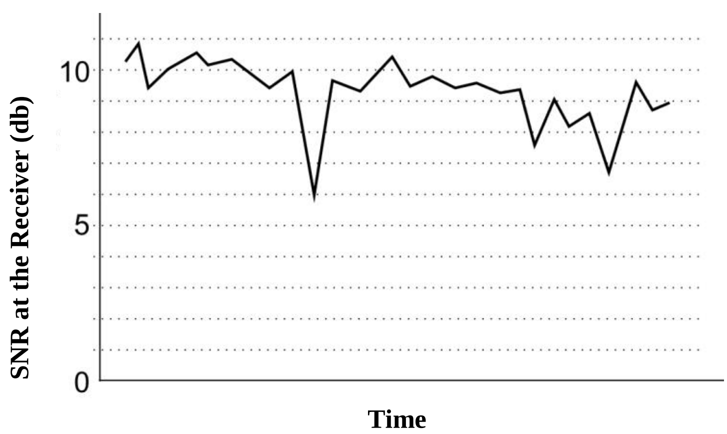
Answer 12

i) From the table depicting the transmission mode of DVB-T we select the QPSK with Code Rate ¾, which can guarantee maximum useful bit rate and error-free operation at 5.9dB.

ii) The convolutional code that we selected has a rate 3/4, i.e. creates 4 bits at tits output for every 3 input . Therefore, for an input rate of 5 Mbps, the output rate will be 5 Mbps · 3/4 = **6,67 Mbps.**

Question 13

The following graph depicts the signal-to-noise ratio (SNR) in a digital terrestrial DVB-T, as recorded during a specific time period.



i) What is the rate of the convolutional code that we have to select at the transmitter, so that the receiver can always decode correctly the Transport Stream;
ii) By exploiting a transmission bit rate, how many the terrestrial TV programs (MPEG-2 rate of 1,524 Mbits / s each) can the multiplex carry? How many empty (stuffing) Transport Packets per second should be inserted in this case?

Modulation	Code Rate	Useful bit rate (Mbits/s)	Minimum SNR required at the receiver (dB)
QPSK	**1/2**	**5,53**	**3,1**
QPSK	**2/3**	**7,37**	**4,9**
QPSK	**3/4**	**8,29**	**5,9**
QPSK	**5/6**	**9,22**	**6,9**
QPSK	**7/8**	**9,68**	**7,7**

Answer 13

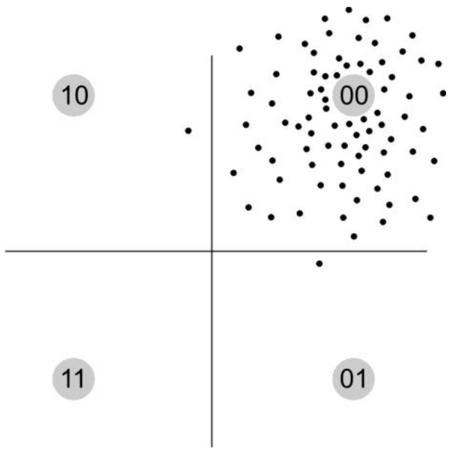
i) In the graph of the signal-to-noise ratio, we observe that the minimum value of SNR is 6 dB. From table of DVB-T operational modes, we select a code rate 5/6, which ensures maximum payload bit rate and proper function SNR> 6.9.

ii) For code rate = 5/6, the total useful bit rate of the multiplexing process that can be transmitted is equal to 9.22Mbps. In this capacity we can transfer five programs of 1,524 Mbits/sec, which will occupy a total of 7,62 Mbits/sec. The remaining 1.6 Mbits/sec will be stuffing packets. 1.6 Mbits/sec = 200 Kbytes/sec = (200000/188) Transport Packets/sec = **1063,8 TPs/sec.**

Question 14

At a DVB-T receiver, we record the following constellation diagram of a QPSK modulation, where 80 consecutive symbols are appeared. The transmitter continually sends the symbol "00" for test purposes.

i) What is the BER (Bit Error Rate) without coding?
ii) Assuming a uniform error distribution in the transport packets, can Reed-Solomon encoding correct the errors occur? Please note that the byte error rate – ByER = 1 – $(1\text{-BER})^8$



Answer 14

i) From the constellation diagram we observe that from the 80 symbols (each symbol has 2 bits) the 78 symbols are received correctly as "00", one symbol is received incorrectly as "10", and another one symbol is also received incorrectly as "01" (instead of "00"). Therefore in 160 total bits we receive 2 bits are received with errors. Thus BER is equal to 2/160 = $\mathbf{1{,}25 \cdot 10^{-2}}$**.**

ii) ByER = $1 - (1\text{-BER})^8 = 1 - (1 - 1{,}25 \cdot 10^{-2})^8 = 9{,}57 \cdot 10^{-2}$

Each protected packet has a length of 204 bytes. Assuming uniform distribution of errors, each protected packet will be received with an average of $204 \cdot (9{,}57 \cdot 10^{-2})$ = **19,52 erroneous bytes**. Since the R-S algorithm may correct up-to 8 bytes per coded packet, **the receiver could not recover the Transport Stream**.

Question 15

In a DVB-T network we recorded the SNR at a number of receivers for a long time period, as depicted in the following Table. Assuming that the minimum requirement is to receive the transmitted signal by at least 95% receivers;

i) Choose the operating mode of the transmitter
ii) We want to multiplex 3 TV programmes. If the audio bit rate for each programme is at 384kbps and the total bit rate for ancillary programme information is at 110kbps, which video encoding bit rate shall we choose at the MPEG-2 encoders?

SNR	**Receiver percentage**
< 12 dB	5%
12 – 14 dB	35%
14 – 16 dB	30%
16 – 18 dB	25%
> 18 dB	5%

Answer 15

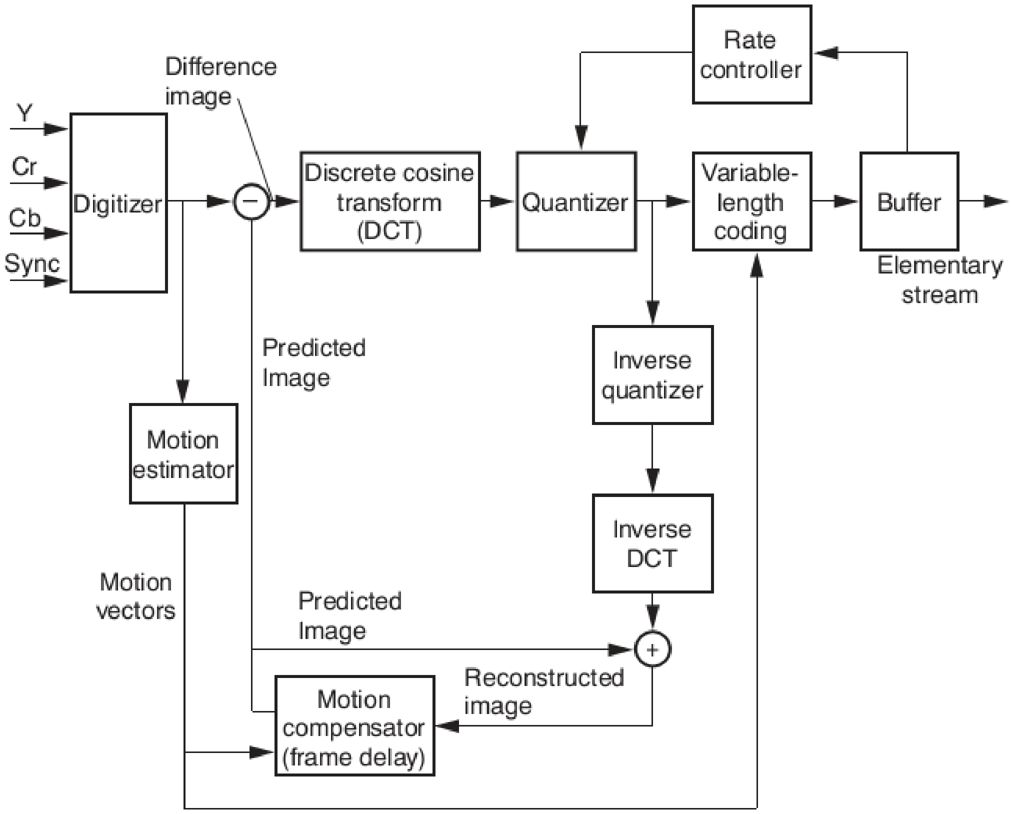
i) From the results Table we can observe that at 95% of the receivers the SNR is at least 12 dB. So, we must choose an operation mode that can provide maximum useful bit rate and error-free operation for SNR > 12dB. Therefore, we select 16-QAM modulation and Code Rate at 2/3.

ii) For the above operational mode (16-QAM, 2/3), the maximum useful bit rate is at **14,75 Mbps**. If "$\mathbf{BR_V}$" is the bit rate of the encoded video for every MPEG-2 TV programme, then it should:

$$3 \cdot \left(BR_V + 0{,}384\right) + 0{,}110 = 14{,}75 \Leftrightarrow BR_V = 4{,}49\,Mbps$$

Question 16

Identify the diagram below.



Answer 16

(a) **MPEG-2 encoder.**

(b) MPEG-2 decoder.

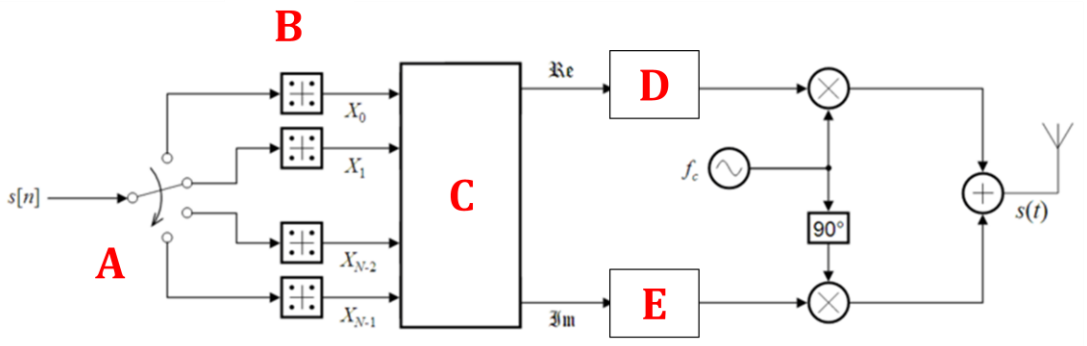
(c) MPEG-2 multiplexer.

(d) MPEG-2 de-multiplexer.

(e) None of these.

Question 17

The diagram in the following Image an OFDM modulator. Please identify the modules.



Answer 17

A = Serial to Parallel

B = Constellation mapping

C = Inverse FFT

D = ADC

E = ADC

Analogue TV

Question 18

Modulation is done in

A. Receiver
B. Transducer
C. Between transmitter and radio receiver
D. Transmitter

Answer 18

D: Transmitter combines the signal which is to be carried with the radio frequency signal, or carrier signal. This process is called modulation.

Question 19

In TV transmission, picture signal is ________ modulated.

A. Phase
B. Amplitude
C. Frequency
D. Pulse

Answer 19

B: All analog television systems use vestigial sideband modulation, which is a form of amplitude modulation. In VSB one sideband is partially removed which further reduces the bandwidth of transmitted signal.

Question 20

In TV transmission, sound signal is ________ modulated.

A. Phase
B. Pulse
C. Frequency
D. Amplitude

Answer 20

C: Amplitude Modulation is invariably used for picture transmission while frequency modulation is generally used for transmission of sound due to its inherent advantages over amplitude modulation. It is not suitable for transmitting videos due to it's large bandwidth.

Question 21

Square Law modulators are?

A. used for frequency modulation
B. used for pulse width modulation
C. used for amplitude modulation
D. used for phase modulation

Answer 21

C: Square Law modulators are generally used for generation of amplitude modulation. They have nonlinear current-voltage characteristics. They are highly nonlinear in low voltage region.

Question 22

Ring Modulator is ________

A. used for DSB-SC generation
B. used for SSB-SC generation
C. is a summation modulator
D. consists three diodes connected in form of a ring

Answer 22

A: Ring Modulator is used for generating DSB-SC waves. It is a product modulator having four diodes connected in the form of a ring.

Question 23

What is the role of transmitter in communication system?

A. to transmit message
B. to convert one form of energy into other
C. to detect and amplify information signal from the carrier
D. to process the electrical signal from different aspects

Answer 23

D: Transmitter is used process the electrical signal from different aspects. Transducer is used to convert one form of energy into another form and the role of receiver is to detect and amplify information signal from the carrier and Channel is a medium through which a message is transmitted.

Question 24

What is the maximum transmission efficiency?

A. 67.88%
B. 33.33%
C. 73%
D. 54.03%

Answer 24

B: The maximum transmission efficiency is 33.33%. Since 2/3 of power is in carrier which conveys no useful information. So we left with only 1/3 of power.

Question 25

What is the role of Amplitude limiter in FM receiver?

A. Filteration
B. Amplification
C. Demodulation
D. Remove amplitude variation due to noise

Answer 25

D: If there are any variations in the amplitude of received wave, it is due to noise. The limiter eliminates this by clipping the received modulated wave.

Question 26

What is Carrier swing?

A. Frequency deviation
B. Width of sideband
C. Frequency deviation less than carrier frequency
D. Total variation in frequency

Answer 26

D: Carrier swing is defined as the total variation in frequency from the lowest to highest point. It is equal to two times frequency deviation of FM signal.