Question (1)  (18 Marks)

a. What is the difference between receiver sensitivity and selectivity? What is the reason of using AGC in a radio receiver system? 3 Marks

Sensitivity
The minimum input signal voltage required to produce an acceptable output level.

Selectivity
The extent to which a receiver is capable of differentiating between the desired signal and disturbances at other frequencies (unwanted radio signal and noise)

The AGC control allows for a constant receiver output for widely variable radio signals by controlling the gain of the Mixer and RF stages and/or IF stages

b. A TRF receiver is to be tuned over the range 550 to 1550 kHz with a 25 µH inductor. Calculate the required capacitance range. Determine the tuned circuit’s necessary Q if a 10 kHz bandwidth is desired at 1000 kHz. Calculate the receiver’s selectivity at 550 and 1550 kHz. 3 Marks

Answer:

AM range 550 to 1550 kHz  RF tuning has  L = 25 µH
\[ f = \frac{1}{2\pi \sqrt{LC}} \rightarrow C = \frac{1}{(2\pi f)^2} \cdot L \]  C has a range 0.422 to 3.35 nF
If \( BW = 10 \text{ kHz} \) and \( f_r = 1000 \text{ kHz} \)  \( Q = f_r / BW = 100 \)
Receiver selectivity \( (BW) = f_r / Q \) at 550 kHz = 550 kHz/100 = 5.5 kHz
Receiver selectivity \( (BW) = f_r / Q \) at 1550 kHz = 1550 kHz/100 = 15.5 kHz
c. **Draw** the block diagram of superheterodyne FM receiver. **What’s the purpose of the limiter and deemphasis network stages in an FM receiver? 5 Marks**

![Block diagram of superheterodyne FM receiver](image)

**Limiter** is a circuit whose o/p is a constant amplitude for all inputs above a critical value. The use of limiters in FM receivers essentially provide an AGC function. It removes any residual unwanted amplitude variations due to noise.

As Higher modulating frequencies are affected by noise to a great extent compared to lower ones, they are boosted ‘pre-emphasized’ at the transmitter and correspondingly attenuated at the receiver ‘de-emphasized’. This provides greater noise immunity. **The deemphasis network** is required to bring the high-frequency intelligence back to the proper amplitude relationship with the lower frequencies.
d. The local FM stereo rock station is at 96.5 MHz. Calculate the local oscillator frequency and the image frequency for a 10.7 MHz IF receiver.  

**Answer:**

\[ f_{RF} = 96.5 \text{ MHz} \rightarrow \text{The local oscillator frequency} \ f_{LO} = f_{RF} + f_{IF} \]

In FM \( f_{IF} = 10.7 \text{ MHz} \rightarrow \text{Local oscillator frequency} = 96.5 + 10.7 = 107.2 \text{ MHz} \]

The image frequency = \( f_{LO} + f_{IF} = 107.2 + 10.7 = 117.9 \text{ MHz} \)

e. Draw the block diagram of a typical FM stereo transmitter and draw its frequency spectrum.  

**Typical FM stereo transmitter**
Question (2) (20 Marks)

a. Draw only the block diagram of TV receiver. What is the purpose of synchronization pulses of TV transmitted signal? Draw the horizontal synchronization pulse of TV transmitted signal.  

6 Marks

Block diagram of TV receiver
• When TV camera starts scanning line 1, the receiver must also start scanning line 1 on the CRT output display. You do not want the top of a scene appearing at the centre of the TV screen. Synchronization pulses is used to set the speed that the transmitter scans each line to be exactly duplicated by the receiver scanning process to avoid distortion.

**Horizontal Sync Pulses**

To emphasize that the CRT is black before starting retrace

- Line 2
- Line 4
- Horizontal sync pulse
- Horizontal blanking pulse
- Video signal
- Blanking pulses
- Front porch
- Back porch
- Pulse peak level, 100%
- Blanking level, 75% (±2.5%)
- Reference black level, 70% (±2.5%)
- Reference white level, 12.5% (±2.5%)
- Zero carrier level
- Used to calibrate the receiver color subcarrier generator

8 cycle color burst on back porch

b. Calculate the frequency required for the horizontal and vertical Sync pulses? If 10 µs is left for the blanking period, Determine the increase in horizontal resolution of TV transmitter if the video bandwidth frequency is increased from 4 MHz to 5 MHz.

**4 Marks**

**Answer:**

- The vertical retrace (sync) pulses must occur after each 1/60 second
  The frequency of the vertical \( f_V \) sync pulses 60 Hz

Horizontal sync pulses occur once for each of the 525 lines every 1/30 seconds
The frequency of the horizontal \( f_H \) sync pulses 525 x 30 = 15.75 kHz

- Line Duration = 1/Line Frequency = 1/15.75 kHz = 63.5 µs
  Each line lasts 63.5 ms with 10 ms for the blanking period leaving 53.5 µs
  The total number of horizontal lines resolvable is 53.5 µs x 5 MHz x 2 = 535 lines
c. If a television broadcast station transmits the video signals on channel 6 (82 to 88 MHz), what is the center frequency of the aural transmitter. Draw a detailed spectrum of the input and output signal of the mixer stage.  

**Answer:** The center frequency of the aural carrier is $82 + 5.75 = 87.75$ MHz

![Diagram of frequency spectrum](image)

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d. Explain the function of wavetrap and the need of such traps in TV receivers.  

**Wavetrap** (notch filter) is needed to obtain the steep attenuation curve for the sound carrier. They are employed in quality sets to eliminate the carrier signal of an upper and lower adjacent channels occur at 39.75 and 47.25 MHz respectively. This minimizes interference effects that the sound would have on the picture. If the IF sound signal is not attenuated enough visual interference may be present.
e. Draw a block diagram of the quadrature modulation part in a color TV transmitter. Show the frequency spectrum of the composite color TV transmission. **4 Marks**

**TV Quadrature Modulation**

![Block diagram of TV Quadrature Modulation](image)

**Composite Color TV Transmission**

![Frequency spectrum of composite color TV transmission](image)

**Question (3) (22 Marks)**

a. Compare between time division and code division multiple access techniques (TDMA and CDMA). **3 Marks**

- **TDMA** systems use digital technology to divide the radio spectrum by time so that each RF carrier is shared by several users. This multiplies system capacity. The RF carrier is divided into units of time called **frames**. Each frame is further divided into **time slots**. Each user is assigned a time slot (or slots) in every time frame. Once time slots are assigned, they remain dedicated until the caller hangs up or is handed-off to another channel.
Buffer zones in the form of **guard times** are inserted between the assigned time slots. This is done to reduce interference between users by allowing for time uncertainty that arises due to system imperfections especially in synchronization schemes.

**CDMA** supports many users on each RF carrier with relatively wide bandwidth, and distinguishes users by using digital codes rather than frequency or time. The same process that encodes speech signals also spreads them over a much wider bandwidth than other multiple access systems. IS-95 has 1.23 MHz CDMA carriers. CDMA transmissions appear more like noise than like information signals.

b. The downlink $C/N_0$ ratio in a direct broadcast satellite (DBS) system is estimated to be 85 dB-Hz. The specifications of the link are:

- Satellite EIRP = 57 dBW,
- Downlink carrier frequency = 12.5 GHz
- Data rate = 10 Mb/s,
- Required $(E_b/N_o)$ at the receiving earth terminal = 10 dB
- Distance of the satellite from the receiving earth terminal = 41,000 km

Calculate the minimum diameter of the dish antenna needed to provide a satisfactory TV reception, assuming that the dish has an efficiency of 55% and it is located alongside the home where the temperature is 310 K. For this calculation, assume that the operation of the DBS system is essentially downlink-limited. **6 Marks**
For the downlink, the relationship between
\[
\left( \frac{C}{N_0} \right)_{\text{downlink}} \text{ and } \left( \frac{E_b}{N_0} \right)_{\text{req}}, \text{ expressed in decibels, is described by}
\]
\[
\left( \frac{C}{N_0} \right)_{\text{downlink}} = \left( \frac{E_b}{N_0} \right)_{\text{req}} + 10 \log M + 10 \log R
\]
(1)

where \( M \) is the margin and \( R \) is the bit rate in bits/second.

Solving Eq. (1) for the link margin in dB and evaluating it for the problem at hand, we get

\[
10 \log_{10} M = 85 - 10 - 10 \log_{10}(10^6) = 5 \text{ dB}
\]

For the downlink budget, the equation for \( \left( \frac{C}{N_0} \right) \), expressed in decibels, is as follows:

\[
\left( \frac{C}{N_0} \right)_{\text{downlink}} = \text{EIRP} + \left( \frac{G_r}{T} \right)_{\text{dB}} - L_{\text{freespace}} - 10 \log_{10} k
\]

where \( k \) is Boltzmann's constant.

For a satisfactory reception at any situation, we consider additional losses due to rain etc. up to the calculated link margin of 5 dB. Hence, we may write

\[
\left( \frac{C}{N_0} \right)_{\text{downlink}} = \text{EIRP} + \left( \frac{G_r}{T} \right)_{\text{dB}} - L_{\text{freespace}} - 10 \log_{10} k - 10 \log_{10} M (\text{dB})
\]
(2)

where

- \( \text{EIRP} = 57 \text{ dBW} \)
- \( L_{\text{freespace}} = \text{free-space loss} \)

\[
= 92.4 + 20 \log_{10}(12.5) + 20 \log_{10}(40,000)
\]

\[
= 206 \text{ dB}
\]

- \( 10 \log_{10} k = 228.6 \text{ dBK} \)
- \( 10 \log_{10} M = 5 \text{ dB} \)

Using these values in Eq. (2) and solving for \( G_r/T \), we get

\[
\left( \frac{G_r}{T} \right)_{\text{dB}} = 85 - 57 + 206 - 228.6 + 5 \approx 10.4 \text{ dB}
\]
With $T = 310K$, we thus find

$$G_r = 10.4 + 10\log_{10}(310)$$

$$= 35.31 \text{ dB}$$

The receiving antenna gain in is given by

$$10\log_{10} G_r = 10\log_{10} \left( \frac{4\pi A \eta}{\lambda^2} \right)$$

For a dish antenna (circular) with diameter $D$, the area $A$ equals $\pi D^2/4$. Thus,

$$10\log_{10} G_r = 20\log_{10} D + 20\log_{10} f + 10\log_{10}(\eta) + 20.4(\text{dB})$$

where $D$ is measured in meters and $f$ is measured in GHz. Solving for the antenna diameter for the given system, we finally get

$$D_{\text{min}} = 0.6 \text{ meters}$$

c. In wireless communication systems, the carrier frequency on the uplink (reverse link) is smaller than the carrier frequency on the downlink (forward link). **Justify** the rational for this choice.  

2 Marks

In a wireless communication system, transmit power is limited at the mobile unit, whereas no such limitation exists at the base station. A sensible design strategy is to make the path loss (i.e., free-space loss) on the downlink as small as possible, which, in turn, suggests that we make

$$(\text{Path loss})_{\text{uplink}} < (\text{Path loss})_{\text{downlink}}$$

Recognizing that path loss is inversely proportional to wavelength, it follows that

$$\lambda_{\text{uplink}} > \lambda_{\text{downlink}}$$

or, equivalently,

$$f_{\text{uplink}} < f_{\text{downlink}}$$
d. State if the following statements are (✓) or (✗) and justify your answer ‘Note: Negation is not the answer’:  

5 Marks

1. The carrier frequency for satellite communications is in the MHz range (C-band), whereas in wireless communication it is in the GHz range (Ku-band). (✗)
   
   Correct: The carrier frequency for satellite communications is in the GHz range (Ku-band), whereas in wireless communication it is in the MHz range.

2. Cellular radio systems consist of an array of circular cells with a base station located at the center of each cell. (✗)
   
   Correct: Cellular radio systems consist of an array of hexagonal cells with a base station located at the center of each cell.

3. The base station controller ‘BSC’ handles the interface between the cellular radio system and the public switched telephone network ‘PSTN’. (✗)
   
   Correct: The mobile switching center ‘MSC’ handles the interface between the cellular radio system and the public switched telephone network ‘PSTN’.

4. Cell splitting handles the additional growth in traffic within a particular cell by reducing its interference with other sectors using the same frequencies. (✓)

5. The frequency reuse factor within a TDMA network is one, while that of a CDMA network is 1/4. (✗)
   
   Correct: The frequency reuse factor within a CDMA network is one, while that of a TDMA network is 1/7.

e. Discuss the following terms: 1. Frequency reuse 2. Multipath Fading 3. Handoff

6 Marks

**Frequency reuse**

Refers to the use of radio channels on the same carrier frequency to cover different areas, which are physically separated from each other sufficiently to ensure the co-channel interference is not objectionable. Frequency reuse makes it possible to keep the transmitted power from each BS to a minimum and position the BS’s just high enough to provide the required coverage area for the cell.
**Multipath Fading**

There is rarely a direct line of sight signal between Tx and Rx. Large objects that can block the line of sight (hillsides, buildings, and other vehicles) can also reflect the RF signal. When this occurs, radio signals arrive at the receiving antenna from different directions at different times. This is called *multipath propagation*. The received signal is actually the sum of several signals, each traveling over a separate path and arriving at a different time. The effect of the differential time delay is to introduce a relative phase shift between the two components of the received signal (zero → constructive or 180° → destructive).

In a dynamic multipath environment, the receiver is in motion and 2 versions of the transmitted narrowband signal reach the receiver via paths of different lengths. Due to motion of the receiver, there is a continuous change in the length of each propagation path. The relative phase shift between the two components of the received signal is a function of the spatial location of the receiver. As the receiver moves, the received amplitude varies with the distance “*signal fading*”

**Hand off**

When the SNR falls below a specified threshold ‘when the MS leaves its cell or when the radio channel fades, it is switched to another BS. This switching process is called “*handover or handoff*” to move the MS from one BS to another during a call in without an interruption of service.

*(Good Luck)*