**Benha Faculty of Engineering** | **Electrical Engineering Department**

**5th Year Telecommunication** | **Final Exam: 20 May 2013**

**Examiner: Dr. Hatem ZAKARIA** | **Time allowed: 3 Hours**

# Radio and Television (E522)

**Model Answer** | **No. of Questions: 3**

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**Question (1)** **(20 Marks)**

a. What is the difference between receiver sensitivity and selectivity? Describe the difficulties in listening to an AM receiver without AGC? *(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)

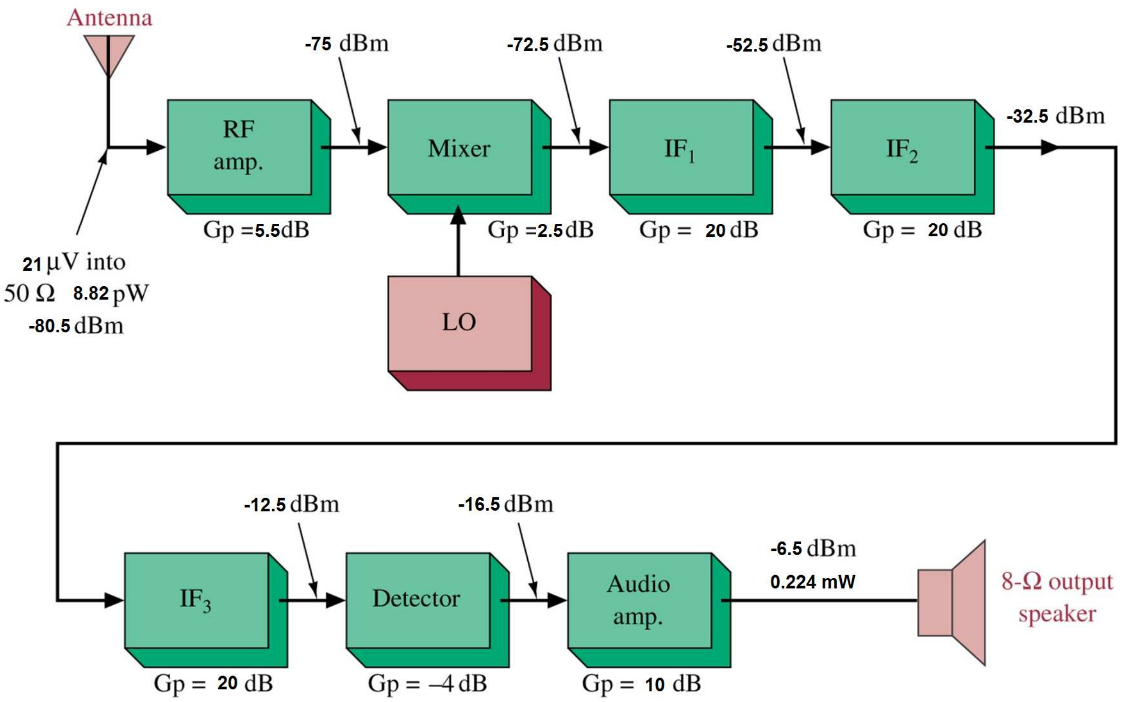
**Without AGC** we have to regularly control the volume while switching from one station to another.

b. A superheterodyne receiver tuned to 1.3 MHz has the following specifications:

***RF Amplifier***: $P_G$ = 5.5 dB, $R_{in}$ = 50 Ω, ***Detector***: 4 dB attenuation
***Mixer***: $P_G$ = 2.5 dB, ***Audio amplifier***: $P_G$ = 10 dB and ***3 IFs***: $P_G$ = 20 dB each at 455 kHz

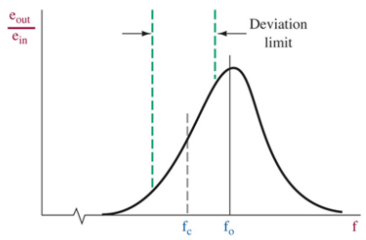
The antenna delivers a 21 μV signal to the RF amplifier. Calculate the receiver's image frequency and input/output power in watts and dBm. Draw a block diagram of the receiver and label dBm power through. *(4 marks)*

**Answer**
Receiver image frequency = 1.3 MHz + 2(455kHz) = 2.21 MHz
Input Power = $V^2/R_{in}$ = $(21\mu V)^2/50$ = 8.82 pW
Input Power (dBm) = 10 log (8.82 pW/1mW) = -80.5 dBm
Output Power = -80.5 dBm + 5.5 dB + 2.5 dB - 4 dB + 3*20 dB + 10 dB = -6.5 dBm →0.224 mW



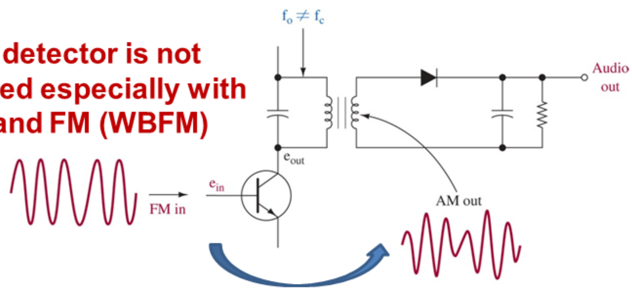

c. Draw a diagram of the slope detector and explain its principle of operation. What is the main disadvantage of such circuit? Name other two alternative circuit solutions. *(4 marks)*

LC circuit is detuned so that $f_c$ is in the middle of the linear region of response




When FM signal > $f_c$ the o/p amplitude increases, while deviations below $f_c$ cause a smaller o/p

**Slope detector is not widely used especially with wideband FM (WBFM)**




- Slope detector is an easiest FM discriminator
- A tuned circuit which is tuned so that the carrier frequency of the FM signal is in a linear region of the filter edges
- Thus turning FM into AM that can be recovered with a diode detector

**The main disadvantage**

- Slope Detector has small linear response which is not suitable for detecting WBFM

**Alternative Circuits**

- Foster-Seely Discriminator
- Ratio Detector

d. For a PLL, a VCO natural frequency, $f_n$= 200 KHz, an external input frequency, $f_i$ = 210 KHz, and the transfer functions $K_d$ = 0.2 V/rad, $K_f$ = 1, $K_a$ = 5, and $K_o$ = 20 KHz, determine: *(5 marks)*

1. PLL open-loop gain in Hz/rad and rad/s.
2. PLL output voltage ($V_{out}$).
3. Static phase error ($\theta_e$).
4. Hold-in range ($\Delta f_{max}$).

$$K_L = \frac{0.2V\ .\ 1V\ .\ 5V\ .20KHz}{(rad)(volt)(volt)(volt)} = \frac{20\ KHz}{rad}$$

$$K_v = 2\pi K_L = \frac{20\text{KHz}}{\text{rad}} = \frac{20\text{ kilo cycles}}{\text{rad . s}} \times \frac{2\pi\text{ rads}}{\text{cycle}} = 125{,}600\,\frac{\text{rad}}{\text{s}}$$

$$K_{v(dB)} = 20\log 125{,}600 = 102\ dB$$

$$\Delta f = f_i - f_n = 210\text{ KHz} - 200\text{ KHz} = 10\text{ KHz}$$

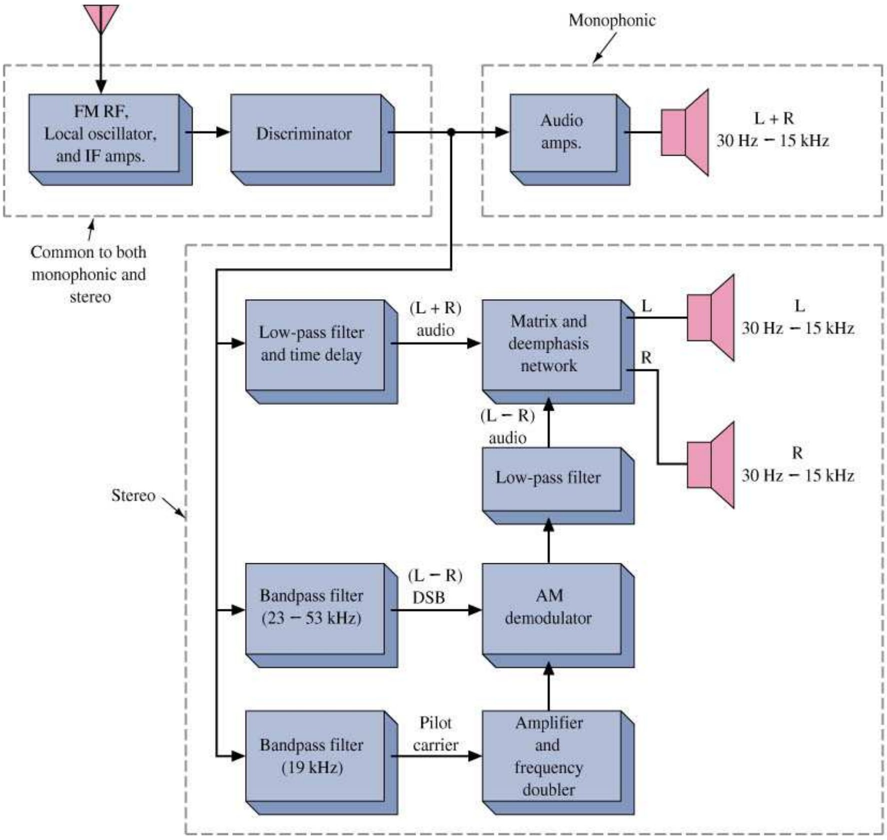
$$V_{out} = \frac{\Delta f}{K_o} = \frac{10\ KHz}{20\ KHz/V} = 0.5\ V$$

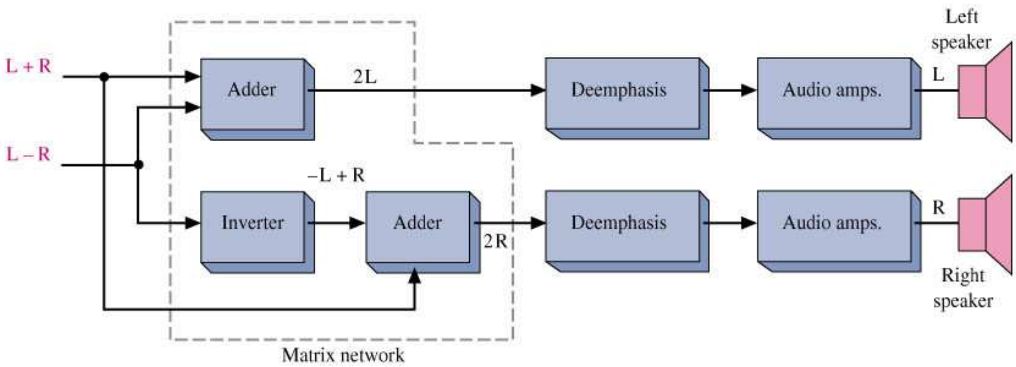
$$V_d = \frac{V_{out}}{K_f K_a} = \frac{0.5}{(1)(5)} = 0.1\ V$$

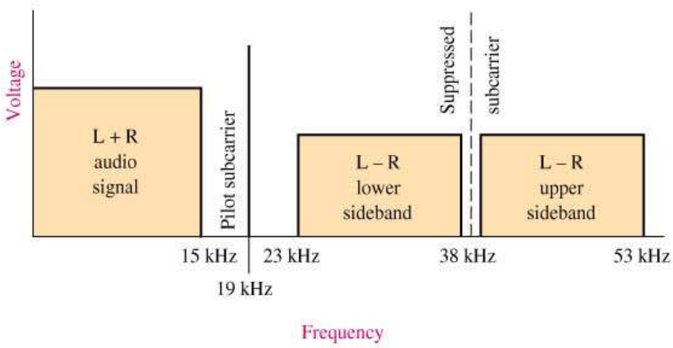
$$\theta_e = \frac{V_d}{K_d} = \frac{0.1\ V}{0.2\ V/rad} = 0.5\ rad\ or\ 28.65°$$

$$\Delta f_{max} = \frac{(\pm\frac{\pi}{2}rad)(20\ KHz)}{rad} = \pm 31.4\ KHz$$

e. <u>Draw</u> the block diagram of a typical FM monophonic and stereo broadcast receiver and <u>show</u> its signal processing part. <u>Draw</u> the antenna input frequency spectrum. *(4 marks)*


Monophonic
FM RF,
Local oscillator,
and IF amps.
Discriminator
Audio
amps.
L + R
30 Hz – 15 kHz
Common to both
monophonic and
stereo
Low-pass filter
and time delay
(L + R)
audio
Matrix and
deemphasis
network
L
R
L
30 Hz – 15 kHz
(L – R)
audio
Low-pass filter
R
30 Hz – 15 kHz
Stereo
Bandpass filter
(23 – 53 kHz)
(L – R)
DSB
AM
demodulator
Bandpass filter
(19 kHz)
Pilot
carrier
Amplifier
and
frequency
doubler


L + R
L – R
Adder
2L
Deemphasis
Audio amps.
Left
speaker
L
–L + R
Inverter
Adder
2R
Deemphasis
Audio amps.
R
Right
speaker
Matrix network


Voltage
L + R
audio
signal
Pilot subcarrier
Suppressed
subcarrier
L – R
lower
sideband
L – R
upper
sideband
15 kHz
23 kHz
38 kHz
53 kHz
19 kHz
Frequency

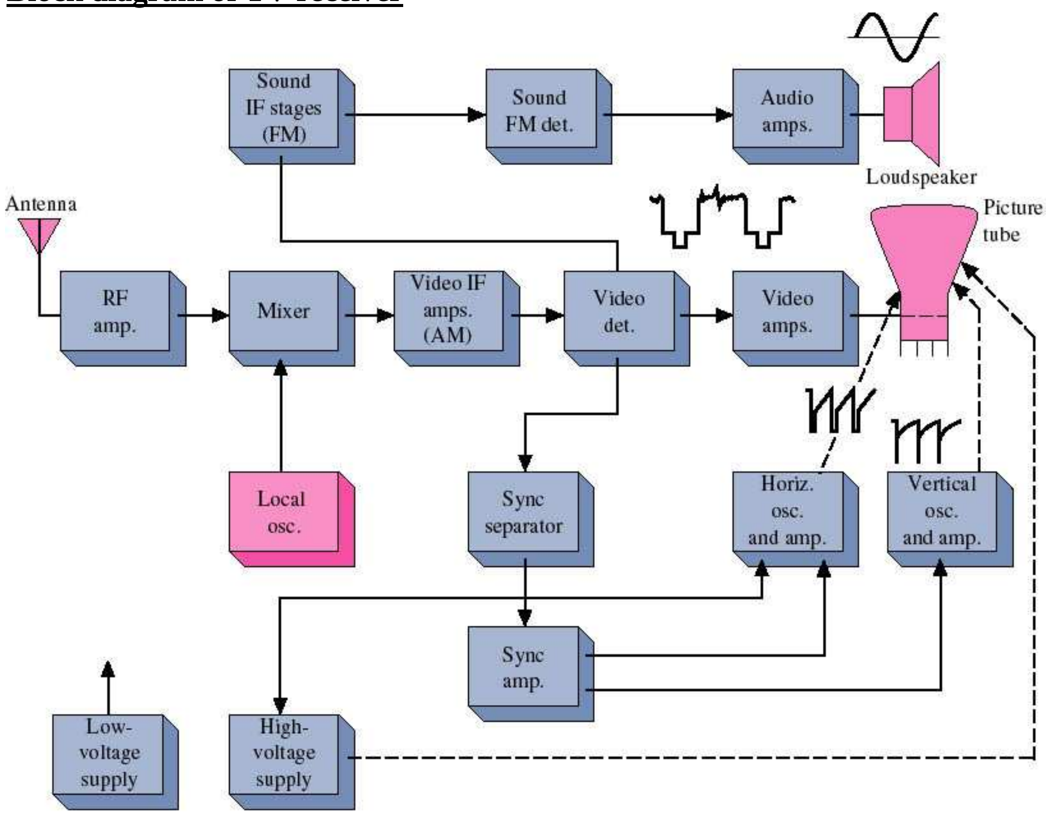
**Question (2)** **(22 Marks)**

a. Why is a diplexer a necessary stage of most TV transmitters? Why is interlacing used in television broadcasting? *(2 marks)*

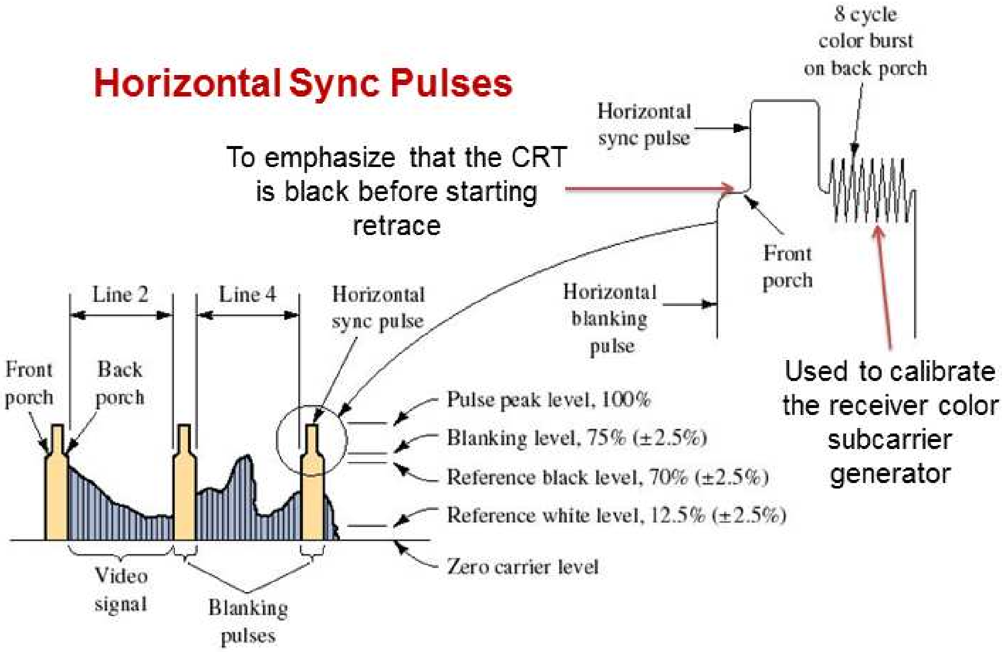
- Diplexer combines the AM modulated video signal with the FM modulated sound signal for feeding to the antenna. It does not allow the two transmitters to interfere with each other 'fed back into the other transmitter'.
- 30 frame/second is not enough to keep the human eye from perceiving flicker → noncontinuous visual presentation. If the frame frequency is doubled → no flicker. However, the video signal bandwidth have to be doubled. *Interlaced scanning* is used to trick the human eye into thinking that it is seeing 60 pictures/second

b. 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. *(5 marks)*

**Block diagram of TV receiver**




**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.




c. Calculate the frequency required for the horizontal and vertical Sync pulses? If 10 µs is left for the blanking period, determine the decrease in horizontal resolution of TV transmitter if the video bandwidth frequency is decreased from 4 MHz to 3.5 MHz. *(3 marks)*

**Answer**:

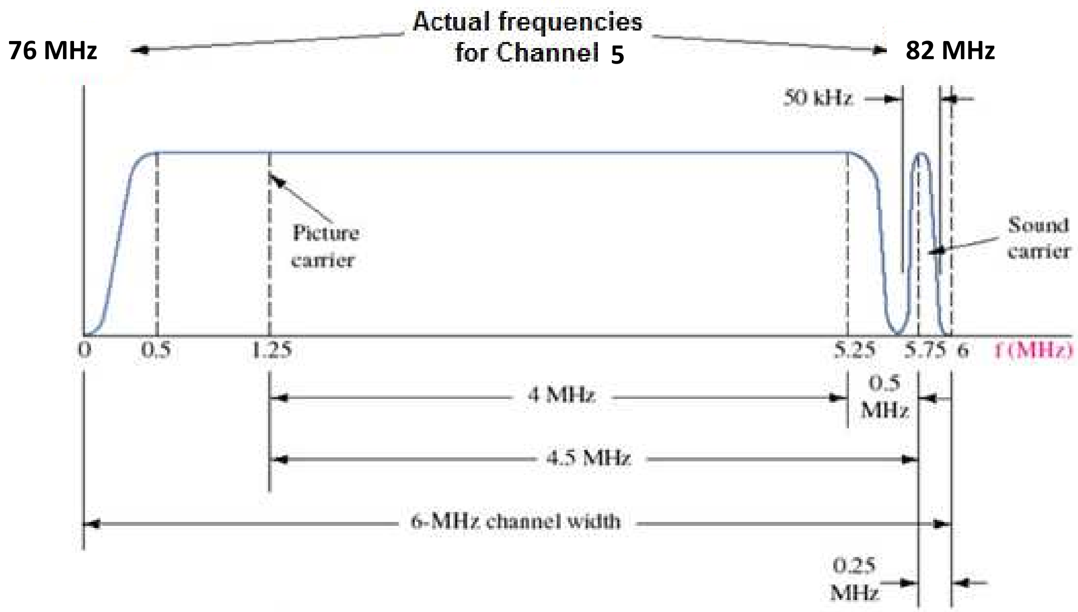
- The vertical retrace (sync) pulses must occur after each 1/60 second
  The frequency of the vertical $f_V$ sync pulses 60 Hz

  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

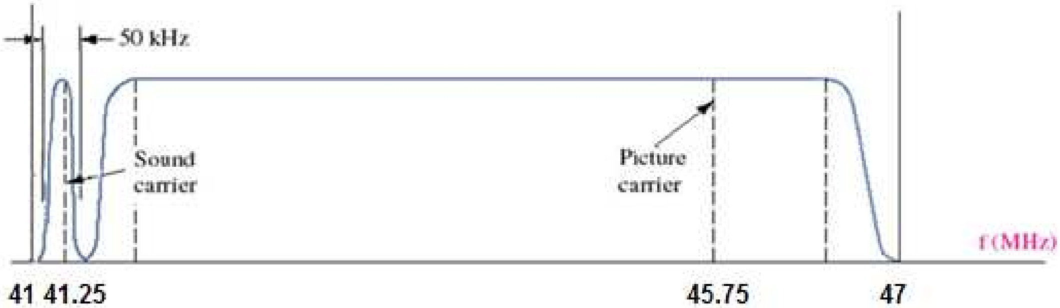
- Line Duration = 1/Line Frequency = 1/15.75 kHz = 63.5 µs
  Each line lasts 63.5 ms with 10 ms for the blanking period leaving 53.5 µs
  The total number of horizontal lines resolvable is 53.5 µs x 4 MHz x 2 = 428 lines

d. If a television broadcast station transmits the video signals on channel 5 (76 to 82 MHz), what is the center frequency of the aural transmitter. Draw a detailed spectrum of the input and output signal of the mixer stage. *(3 marks)*

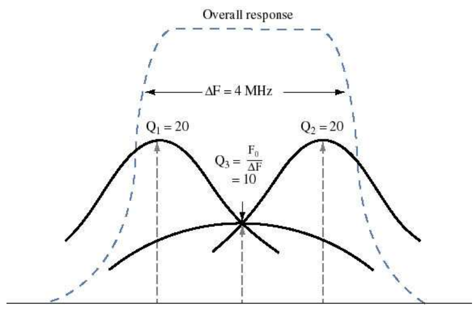
**Answer**: The center frequency of the aural carrier is 76 + 5.75 = 81.75 MHz




Frequency Spectrum at Mixer Output

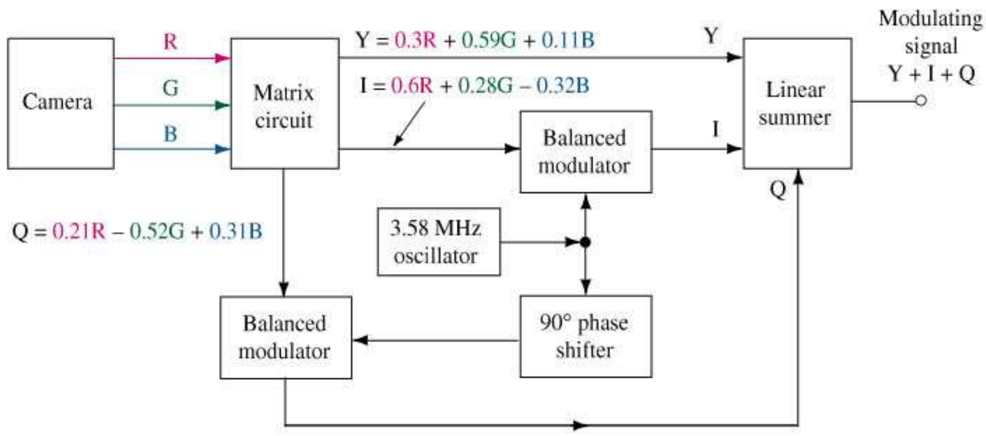


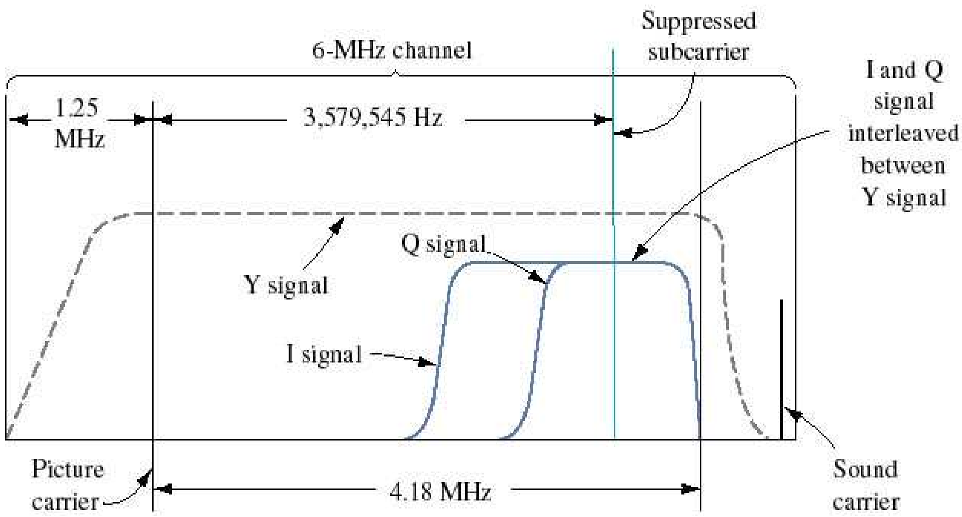

e. Explain why stagger tuning is often used in TV IF amplifiers. What is the function of the sync sync separator and what types of circuits are used for such purpose? *(3 marks)*




- ***stagger tuning*** is used to get a relatively wide bandwidth filter (6 MHz) which is reasonably flat in the passband but still has sharp falloff at the band edges.it uses several narrowband filters in cascade with slightly different centre frequencies.
- The sync separator
  - Separates the horizontal and vertical sync pulses, and use them to precisely and periodically calibrate the horizontal and vertical oscillators
  - Clips the sync pulses off the video signal to prevent the sweep instability that could occur because of false synchronization
- Once the sync separator has clipped the sync signals from the lower-level video signal, the two types of sync pulses are applied to both low and high pass filters

f. Draw a block diagram of the quadrature modulation part in a color TV transmitter. Show the frequency spectrum of the composite color TV transmission. Explain the operation of the color killer. Describe the effect of a defective color killer. *(6 marks)*




- If the broadcast is black and white only, the colour burst is omitted and the phase locked loop phase detector will produce a large dc output. This is detected and used to switch off the I and Q signal bandpass amplifier "*colour killer*". This is to prevent any signal out of the Chroma circuits during a monochrome broadcast.

- A defective colour killer results in coloured noise called "*confetti*" on the screen of a colour TV receiver during a black and white transmission. The confetti looks like snow but with larger spots in colour

**Question (3)** **(18 Marks)**

a. Compare between TDMA and CDMA multiple access techniques. *(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.
- **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 $C/N_o$ ratio in a direct broadcast satellite (DBS) system is estimated to be 80 dB-Hz. The specifications of the link are:

Satellite EIRP = 57 dBW, Downlink carrier frequency = 13 GHz
Data rate = 10 Mb/s, Required $(E_b/N_o)$ at the receiving earth terminal = 12 dB
Distance of the satellite from the receiving earth terminal = 45,000 km

Calculate the minimum diameter of the dish antenna needed to provide a satisfactory TV reception, assuming that the dish has an efficiency of 60% and it is located alongside the home where the temperature is 300 K. For this calculation, assume that the operation of the DBS system is essentially downlink-limited. *(6 marks)*

**Answer**

For the downlink, the relationship between

$\left(\frac{C}{N_0}\right)$ and $\left(\frac{E_b}{N_0}\right)_{req}$, expressed in decibels, is described by

$$\left(\frac{C}{N_0}\right)_{downlink} = \left(\frac{E_b}{N_0}\right)_{req} + 10\log M + 10\log R \qquad (1)$$

where $M$ is the margin and $R$ is the bit rate in bits/second.

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

$$10\log_{10}M = 80 - 12 - 10\log_{10}(10 * 10^6) = -2\text{dB}$$

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

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

where

$$\text{EIRP} = 57 \text{ dBW}$$

$$L_{\text{freespace}} = \text{free-space loss}$$

$$= 92.4 + 20\log_{10}(13) + 20\log_{10}(45\,000)$$

$$= 196.6 \text{ dB}$$

$$10\log_{10}k = 228.6 \text{ dBK}$$

$$10\log_{10}M = -2 \text{ dB}$$

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

$$\left(\frac{G_r}{T}\right)_{\text{dB}} = 80 - 57 + 196.6 - 228.6 - 2 = -11 \text{ dB}$$

$$G_r = -11 + 10\log_{10}(300)$$

$$= 13.77 \text{ dB}$$

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

$D_{\min}$ = 0.05meters

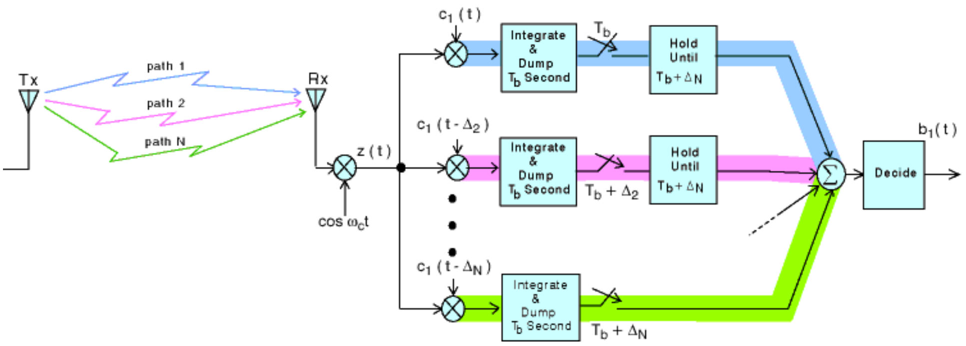
c. State if the following statements are (✓) or (×) and justify your answer *'Note: Negation is not the answer'*: *(3 marks)*

1. (×) **Correct**: Cellular radio systems consist of an array of hexagonal cells with a base station located at the center of each cell.
2. (×) **Correct**: The mobile switching center 'MSC' handles the interface between the cellular radio system and the public switched telephone network 'PSTN'.
3. (×) **Correct**: The frequency reuse factor within a TDMA network is 1/7, while that of a CDMA network is one.

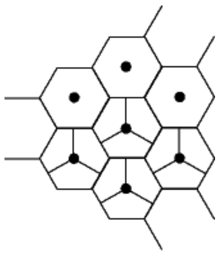
d. Discus the following terms: 1. Rake Receiver 2. Cell Splitting 3. Handoff *(6 marks)*

**Rake Receiver**

- The rake receiver is a CDMA feature that turns what is a problem in other technologies into an advantage for CDMA. It's multiple receivers in one. It identifies the 3 strongest multi-path signals and combines them to produce one very strong signal. It uses multipath to reduce the power the Tx must send. Both the mobile and the BTS use rake receivers




**Cell Splitting**



Cell splitting is used to handle the additional growth in traffic within a particular cell. A single cell contains a number of smaller cells called *microcells*. Sectorizing cells reduce interference with other sectors using the same frequencies. A 3-sector cell site uses three directional antennas with propagation of 120 degrees.

**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.