1.

(a) Please briefly describe what the image interference is.

(b) Suppose the receiver use local oscillator at L_o MHz and receive two RF signals respectively centered at 0.55 MHz and 1.75 MHz. Please choose a local oscillator frequency L_o causing the image interference.

(c) As a system designer, how to solve the problem mentioned in (b) ?

Sol:

As two distinct RF signals mix with local oscillator signal, the two signal exist at the same frequency in IF section and cannot be distinguished. Therefore, the desired signal is interfered by the other.

$|0.55 \pm L_o| = |1.75 \pm L_o|$

If the desired signal centered at 1.75MHz

$$1.75\text{-Lo}=|0.55 \pm L_o|$$

$$\text{Lo}=1.15,0.6$$

If the desired signal centered at 0.55MHz

$$0.55\text{-Lo}=|1.75 \pm L_o|$$

$$\text{Lo}=-0.6,1.15$$

Thus, L_o = 0.6 MHz or 1.15 MHz might cause image interference.

Method 1: Change the frequency of local oscillator

Method 2: Employ a highly selective stages in RF session.

2. Using the message signal

$$m(t) = \frac{1}{1+t^2}$$

Determine the modulated waves for the following methods of modulation:

(a) Amplitude modulation with 50 percent modulation.

(b) Double sideband-suppressed carrier modulation.

(c) Single sideband modulation with only the upper sideband transmitted.

(d) Single sideband modulation with only the lower sideband transmitted.

Sol:

(a) $s(t) = A_c(1 + k_a m(t))\cos(2\pi f_c t)$

$$= A_c\left(1 + \frac{k_a}{1+t^2}\right)\cos(2\pi f_c t)$$

To ensure 50 percent modulation, $k_a = 0.5$ in which case we get

$$s(t) = A_c\left(1 + \frac{1}{1+t^2}\right)\cos(2\pi f_c t)$$

(b) $s(t) = A_c m(t)\cos(2\pi f_c t)$

$$= \frac{A_c}{1+t^2}\cos(2\pi f_c t)$$

(c) $s(t) = \frac{A_c}{2}[m(t)\cos(2\pi f_c t) - \hat{m}(t)\sin(2\pi f_c t)]$

$$= \frac{A_c}{2}\left[\frac{1}{1+t^2}\cos(2\pi f_c t) - \frac{t}{1+t^2}\sin(2\pi f_c t)\right]$$

(d) $s(t) = \frac{A_c}{2}\left[\frac{1}{1+t^2}\cos(2\pi f_c t) + \frac{t}{1+t^2}\sin(2\pi f_c t)\right]$

As an aid to the sketching of the modulated signals in (c) and (d), the envelope of either SSB wave is

$$a(t) = \frac{1}{2}\sqrt{\frac{t^2+1}{(1+t^2)^2}} = \frac{1}{2}\sqrt{\frac{1}{1+t^2}}$$

3. An FM signal with a frequency deviation of 10 kHz at a modulation frequency of 5 kHz is applied to two frequency multiplier connected in cascade. The first multiplier doubles the frequency and the second multiplier triples the frequency. Determine the frequency deviation and the modulation index of the FM signal obtained at the second multiplier output. What is the frequency separation of the

adjacent side frequencies of this FM signal?

Sol:

The overall frequency multiplication ratio is

$$n = 2 \times 3 = 6$$

Assume that the instantaneous frequency of the FM wave at the input of the first frequency multiplier is

$$f_{i1}(t) = f_c + \Delta f \cos(2\pi f_m t)$$

The instantaneous frequency of the resulting FM wave at the output of the second frequency multiplier is therefore

$$f_{i2}(t) = nf_c + n\Delta f \cos(2\pi f_m t)$$

Thus, the frequency deviation of this FM wave is equal to

$$n\Delta f = 6 \times 10 = 60 \text{ kHz}$$

and its modulation index is equal to

$$\frac{n\Delta f}{f_m} = \frac{60}{5} = 12$$

The frequency separation of the adjacent side-frequencies of this FM wave is unchanged at $f_m = 5$ kHz.