Homework Assignment No. 5 - Solutions

Problem 1 - (10 points)

Sketch the time variation and frequency spectrum of an RF signal with 75 percent amplitude modulation. Show several cycles of the modulated wave. Make the modulation frequency 1/10 of the carrier frequency. The unmodulated carrier has a peak amplitude of 1.0V.

Solution

The expression for the general form of amplitude modulation is,

$$v(t) = 1.0\left[1 + m_a\, cos\left(\frac{\omega_c t}{10}\right)\right]cos(\omega_c t) = [1 + 0.75cos(0.1\omega_c t)]cos\omega_c t$$

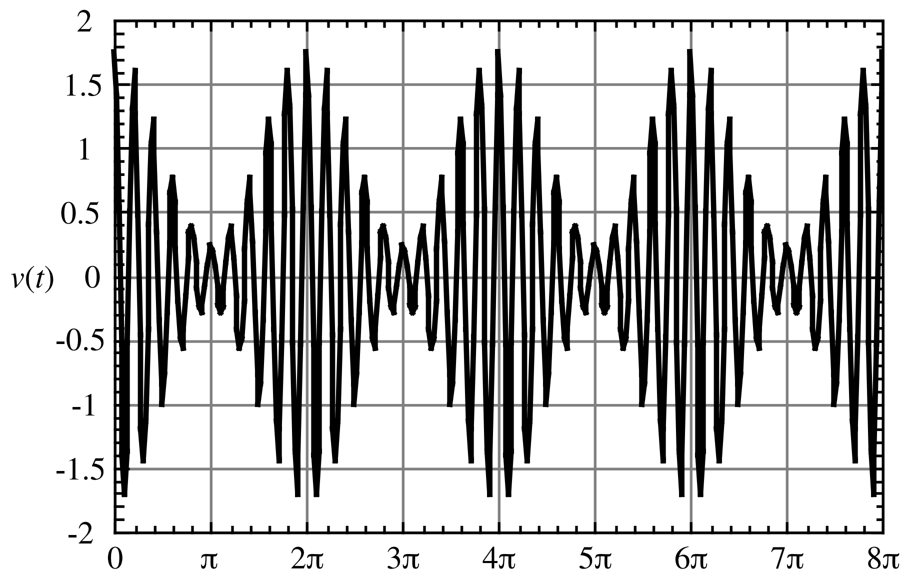


Fig. SU03H05S1

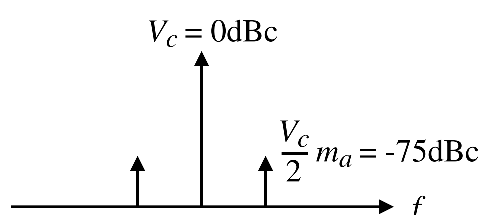
$v_{max.} = 1.75V$ and $v_{min.} = 0.25V$

Problem 2 – (10 points)

The level of an SSB AM spur is observed to be –75 dBc. If the carrier has a peak amplitude of 1V, what is the variation of the carrier in ±V needed to produce the observed spur?

Solution

The observed spectrum is



SU03H05S2

$$SSB = 20\, log_{10}\left(\frac{m_a}{2}\right) \quad \rightarrow \quad m_a = 2{\cdot}10^{SSB/20}$$

$$\therefore \quad m_a = 2{\cdot}10^{-75/20} = 335.6\text{x}10^{-6}$$

If $V_{peak} = 1V$, then $m_a = \frac{\Delta v}{V_p}$ $\rightarrow$ $\Delta v = 3.35.6\mu V$

Problem 3 – (10 points)

A pair of 5 kHz PM/FM spurs appear on a 10 MHz carrier. The level of each spur is –50dBc. (a.) What phase deviation in ±degrees is need to produce the spurs? (b.) What frequency deviation in ±Hz is needed to produce the spurs?

Solution

(a.) The single sideband spurs can be expressed as,

$$SSB = 20\ log_{10}\left(\frac{\theta_d}{2}\right) = 20\ log_{10}\left(\frac{\beta}{2}\right)$$

Solving for θ_d gives,

$$\theta_d = 2\cdot 10^{SSB/20} = 2\cdot 10^{-50/20} = 2\cdot 0.003162 = 6.325 \text{ milliradians} = \underline{\underline{\pm 0.3624°}}$$

(b.) We know that $\theta_d = \beta = \frac{\Delta f_c}{f_m}$ which gives

$$\Delta f_c = \beta f_m = \theta_d f_m = 6.325\text{x}10^{-3}\cdot 5\text{x}10^{+3} = \underline{\underline{\pm 31.6\text{ Hz}}}$$

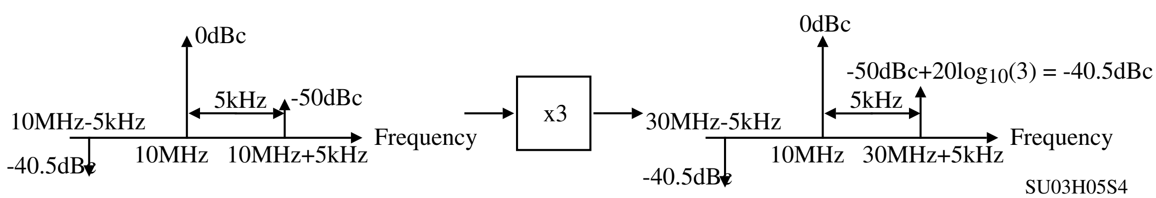
Problem 4 – (10 points)

The carrier and spurs of Problem 3 above are passed through a frequency tripler. Make a sketch of the output spectrum of the tripler. Label and show all important features of the spectrum.

Solution

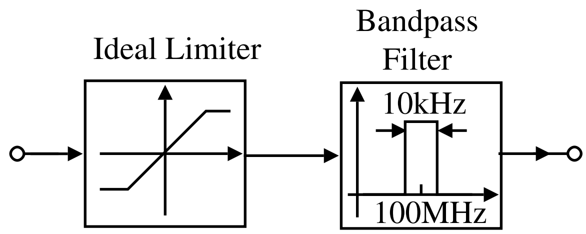
After passing through a tripler, the SSB spur is increased by $20log_{10}(3)$ or +9.54dB.

The resulting spectrum is shown as,



Problem 5 – (10 points)

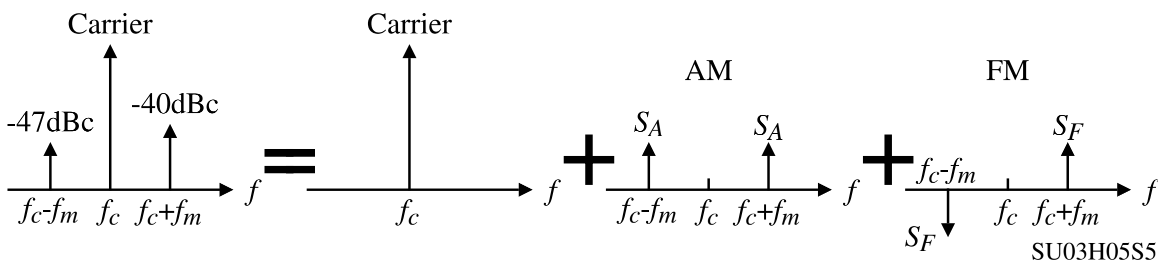
A 100 MHz carrier having a –40 dBc upper sideband at 100.002 MHz and a –47 dBc lower sideband at 99.998 MHz is passed through an ideal limiter followed by a bandpass filter centered at 100 MHz with a 10 kHz total bandwidth. Make a sketch of the spectrum at the output of the filter. Label all frequencies and amplitudes.



SU03H05P5

Solution

Asymmetrical sidebands imply the presence of both AM and FM as show below.



$$-40\text{dBc} = 10^{-40/20} = 0.01 \qquad \text{and} \qquad -47\text{dBc} = 10^{-47/20} = 4.467\text{x}10^{-3}$$

Solve for S_A and S_F as follows,

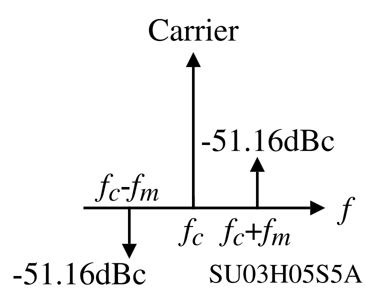
$$S_A + S_F = \text{Upper sideband} = 0.01$$

$$S_A - S_F = \text{Lower sideband} = 4.467\text{x}10^{-3}$$

$$S_A = \frac{\text{Upper sideband + Lower sideband}}{2} = 7.234\text{x}10^{-3}$$

$$S_F = \frac{\text{Upper sideband - Lower sideband}}{2} = 2.767\text{x}10^{-3}$$

The limiter will remove all AM sidebands and the filter removes all products other than the sidebands at ±2kHz. Therefore the output spectrum will appear as,



where f_c = 100MHz and f_m = 2kHz.