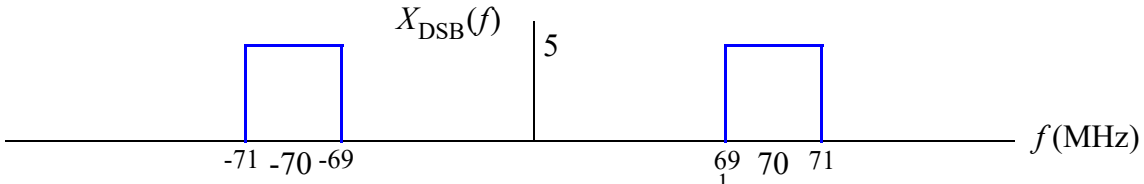
ECE 5/4625 • Quiz 6 • March 5, 2020

Topic: DSB and AM Modulation **Name:** _____

1.) A DSB signal has the following spectrum.



10 pts. a.) Develop the mathematical expression for $x_{DSB}(t) = F^{-1}\{X_{DSB}(f)\}$. In particular identify the message signal.

10 pts. b.) The coherent demodulator for recovery of $m(t)$ from $x_{DSP}(t)$ employs multiplication by reference carrier $c(t) = 2\cos(2\pi f_c t + \phi)$ followed by a lowpass filter. Choose proper values for f_c and ϕ. Also select a reasonable lowpass filter bandwidth, W. Justify. If ϕ is shifted by π what happens to the demodulated output?

2.) An AM transmitter has message signal

$$m(t) = 10\cos[2\pi(200)t - \pi] - 2\cos[2\pi(50)t]$$

and transmit signal configured as (1 ohm system)

$$x_{AM}(t) = 100[1 + am_n(t)]\cos(2\pi f_c t).$$

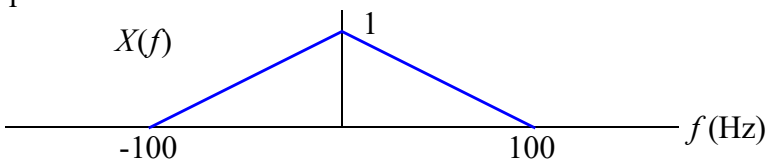
5 pts. a.) Find the scaling factor to convert $m(t)$ to $m_n(t)$. Hint: Can be found by inspection.

15 pts. b.) Find the power in the sidebands for the case $a = 1/2$. Provide proper units.

ECE 5/4625 • Quiz 6 • March 1, 2018

Topic: Hilbert Transform & SSB **Name:** _____

1.) A signal $x(t)$ has spectrum:



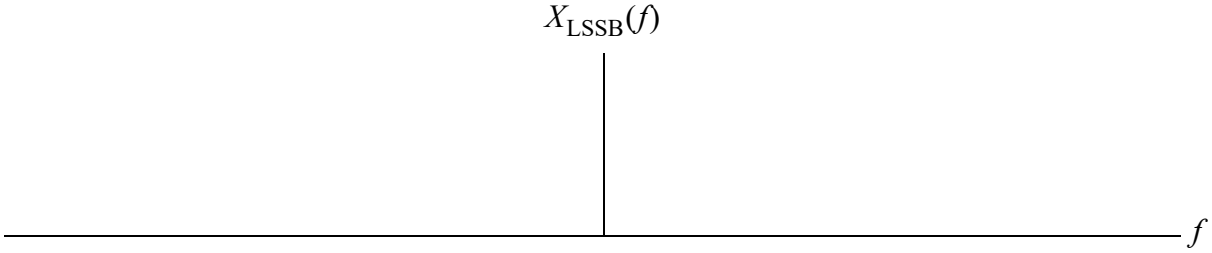
20 pts. Find and sketch the spectrum of

$$y(t) = \frac{1}{2}x(t) - j\hat{x}(t)$$

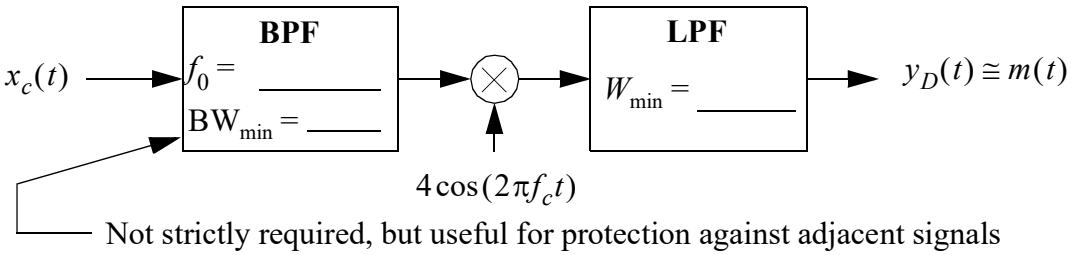
where $\hat{x}(t)$ is the Hilbert transform of $x(t)$.

2.) A lower SSB signal, $x_c(t)$, is generated using a message having spectrum $M(f) = \Lambda(f/5000)$ and carrier frequency 100 kHz.

a.) Sketch the magnitude spectrum $X_c(f)$, carefully labeling the frequency axis.



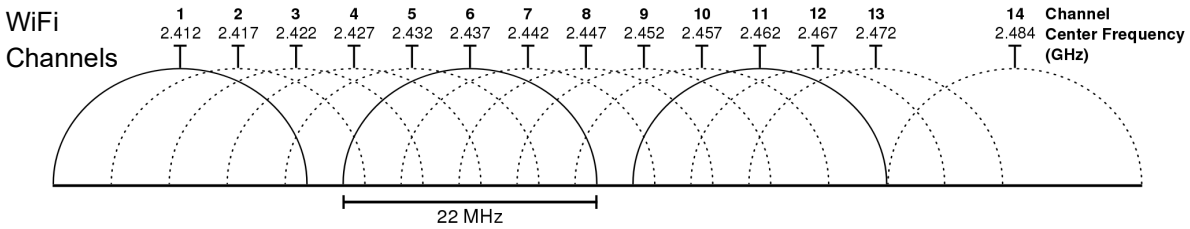
b.) Coherent demodulation of SSB, in particular LSSB, can be implemented using the following block diagram. Fill in the missing information.

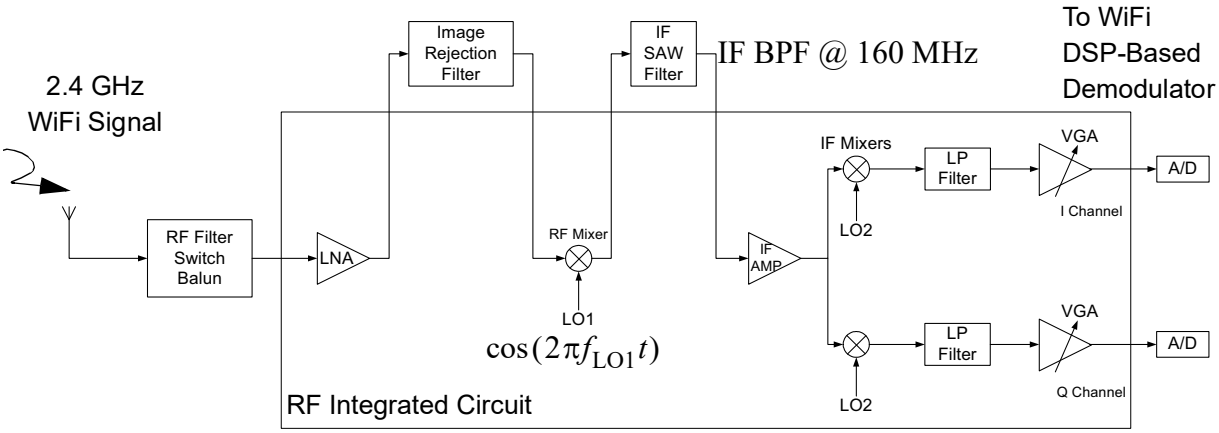


ECE 5/4625 • Quiz 7 • April 2, 2020

Topic: Freq. Translation & Mixing **Name:** _____

1.) A receiver front-end is designed to convert a 2.4 GHz WiFi signal to 160 MHz intermediate frequency (IF). The 14 available WiFi channels, each occupying 22 MHz with overlap, are shown below along with a receiver block diagram:





10 pts. a.) Find two choices for f_{LO} that will translate WiFi channel 6 to 160 MHz.

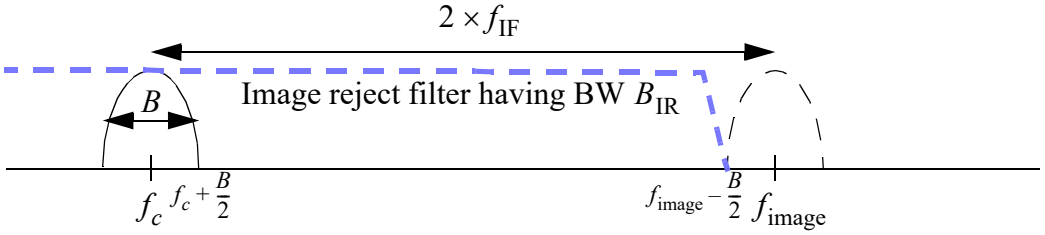
10pts. b.) For the f_{LO} choices find the corresponding image frequencies f_{IM}.

10pts. c.) What bandwidth is required for the surface acoustic wave (SAW) IF bandpass filter?

10 pts. d.) Briefly describe the purpose and the requirements of the image reject filter.

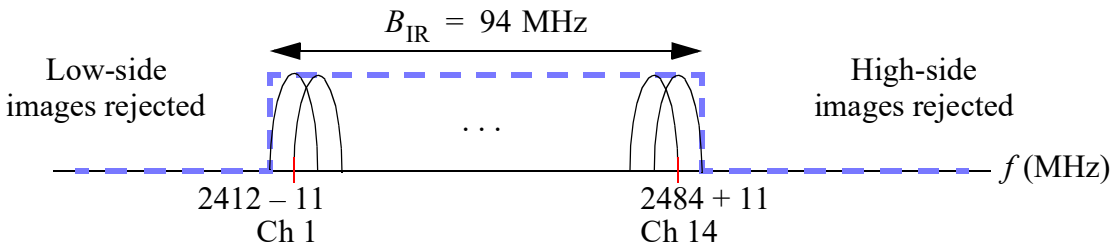
ECE 5/4625 • Quiz 7 • Part d Detailed Solution

A more detailed look at the part (d) solution is to consider how a fixed image rejection filter can be designed to reject images yet allow LO1 to tune all 14 WiFi channels. Consider the case of highside tuning also taking into account the 22 MHz signal bandwidth. The image rejection filter needs a passband above the carrier center frequency of at least $B/2$ MHz and less than $2 \times f_{\text{IF}} - B/2$. Assuming a symmetrical RF bandwidth:



$$B_{\text{IM}} = 2 \cdot [2 \times f_{\text{IF}} - B/2]$$
$$= 2[140 - 11] = 258 \text{ MHz for 70 MHz IF}$$
$$= 2[320 - 11] = 618 \text{ MHz for 160 MHz IF}$$

For the 14 WiFi channels the total bandwidth required, including the upper and lower side-bands, is $11 + (2484 - 2412) + 11 = 94$ MHz. Thus a fixed image rejection filter can be designed that will pass all of the WiFi channels, including the upper and lower sidebands, at 11 MHz each, and still reject image frequencies.



The fractional bandwidth of image reject filter is $94/[(2484 + 2412)/2] \times 100 = 3.83\%$. When using a 70 MHz IF, the fractional bandwidth corresponding to 22 MHz is $22/70 \times 100 = 31.4\%$ and when using 160 MHz the fractional bandwidth is 13.75%. The 160 MHz SAW filters are available off-the-shelf:

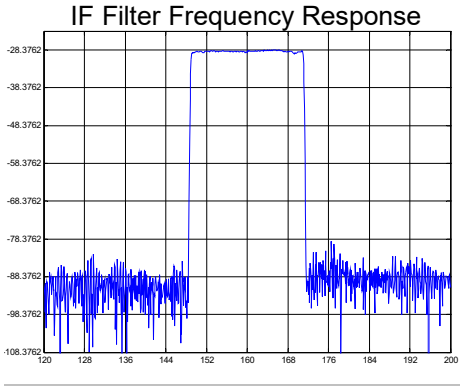
CETC China Electronics Technology Group Corporation
No.26 Research Institute
SIPAT Co., Ltd.
www.sipatsaw.com

160MHz SAW Filter
22MHz Bandwidth

Part Number: LBN16043

Specifications

Parameter	Unit	Minimum	Typical	Maximum
Center Frequency	MHz	159.92	160	160.08
Insertion Loss	dB	-	28.4	30
3 dB Bandwidth	MHz	22	22.08	-
30 dB Bandwidth	MHz	-	22.73	22.8
40 dB Bandwidth	MHz	-	22.84	23.2
50 dB Bandwidth	MHz	-	22.93	-
Passband Variation	dB	-	1	1.5
Absolute Delay	usec	-	3.6	4
Ultimate Rejection	dB	50	51	-
Material Temperature coefficient	KHz/°C		-13.12	
Ambient Temperature	°C		25	
Package Size			DIP3512 (35.0x12.8x4.7mm3)	



An example 160 MHz SAW filter with 22 MHz bandwidth

ECE 5/4625 • Quiz 8 • April 2, 2020

Topic: Sampling and Pulse Mod. **Name:** _____

1.) Consider the signal

$$m(t) = 20\cos[2\pi(15\times10^3)t] + 10\cos^2[2\pi(5\times10^3)t]$$

is to be sampled using the lowpass sampling theorem.

10 pts. a.) Find the minimum sampling rate to avoid aliasing.

10 pts. b.) Can the bandpass sampling theorem be used for this signal to get by with a lower sampling rate? Explain.

20 pts. 2.) A time division multiplexing system is used to bring together two high quality analog audio channels each having bandwidth 24 kHz, a digital stream at 1 Mbps, two more digital streams, each at 2 Mbps, and an analog voice channel having bandwidth of 4 kHz. The high quality audio channels require 18 bits/ sample, while the voice quality audio requires only 8 bits/sample. Draw the system block diagram showing input processing blocks, the multiplexer itself, and the output stream noting the final serial bit rate. Fancy interleaved multiplexing is not required, but include a 10% increase in the final serial bit rate to account for data framing and synchronization.

ECE 5/4625 • Quiz 9 • April 9, 2020

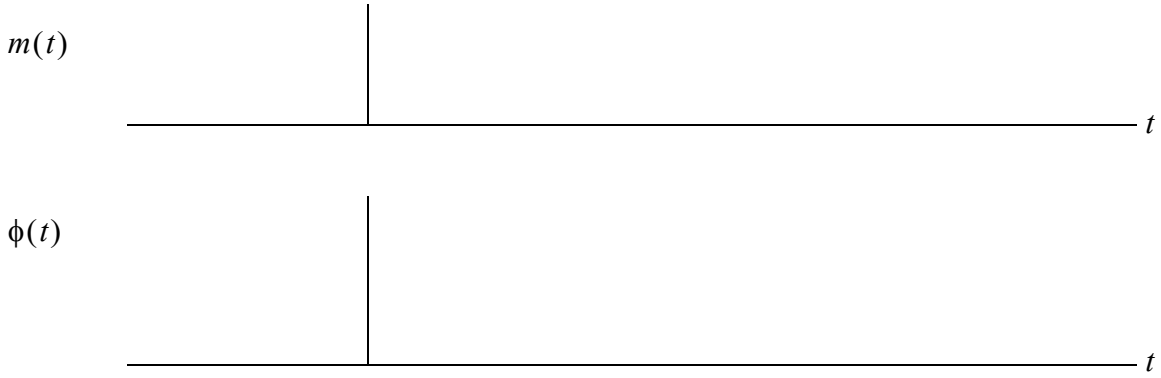
Topic: Angle Modulation **Name:** _____

1.) An FM modulated carrier is given by

$$x_c(t) = 10\cos\left[2\pi f_c t + 2\pi f_d \int^t m(\alpha)d\alpha\right]$$

with $m(t) = 3[u(t) - u(t-4)]$, where $u(t)$ is the unit step function and $f_d = 10$ kHz/v.

10 pts. a.) Find and sketch the phase deviation of $x_c(t)$. Be sure to label the axes.



10 pts. b.) What is the peak frequency deviation in Hz resulting from $m(t)$?

2.) A VCO having voltage to frequency sensitivity of $f_d = 1$ kHz/V is used as an FM modulator. The VCO center frequency is 100 MHz.

$$x_c(t) = \cos[2\pi(10^8)t + \phi(t)]$$
$$m(t) = A\cos[2\pi(10^3)t]$$

10 pts. a.) With $A = 5$ V find the FM modulation index β and the strength of the sidebands at $10^8 \pm (6 \times 10^3)$ Hz.

10 pts. b.) Find the second smallest value of A that makes the carrier component of the spectrum zero.

ECE 5/4625 • Quiz 10 • April 16, 2020

Topic: Angle Modulation **Name:** _____

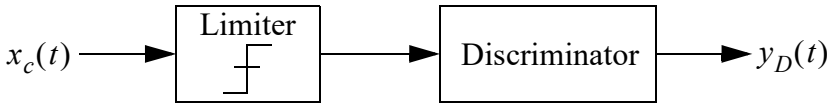
1.) A VCO having voltage to frequency sensitivity of $f_d = 10^3$ Hz/V, outputs a carrier amplitude of 5 V peak in a 1Ω system, at a quiescent frequency of 10 MHz. The input is driven by a message signal $m(t)$ having lowpass bandwidth of 12 kHz. We also know that the peak deviation under $m(t)$ is 240 kHz.

5 pts. a.) Find the deviation ratio D.

10 pts. b.) Using Carson's rule find the approximate RF bandwidth of the signal.

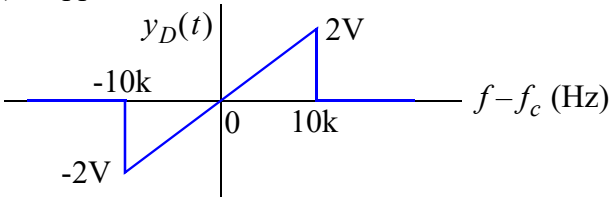
5 pts. c.) Find the power in the modulated carrier. Don't forget units.

1.) An FM discriminator, as shown below, is typically preceded by a limiter:



5 pts. a.) Explain the purpose of the limiter.

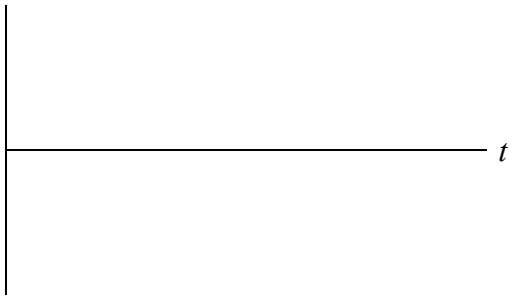
15 pts. b.) Suppose the discriminator characteristic is as shown below:



Let $x_c(t)$ be an FM carrier with sinusoidal modulation.

$$x_c(t) = A_c \cos\left[2\pi f_c t + 2\pi f_d \int^t m(\alpha)\, d\alpha\right]$$

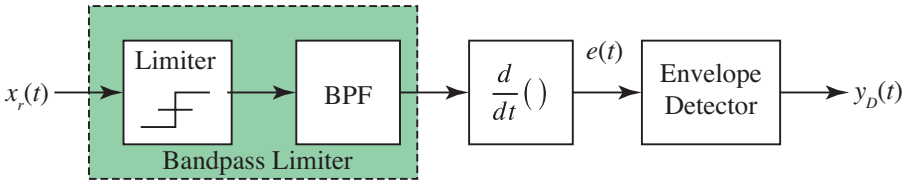
with $m(t) = \cos(2\pi(1000)t)$ and $f_d = 5$ kHz/V. Sketch the output $y_D(t)$



ECE 5/4625 • Quiz 11 • April 13, 2018

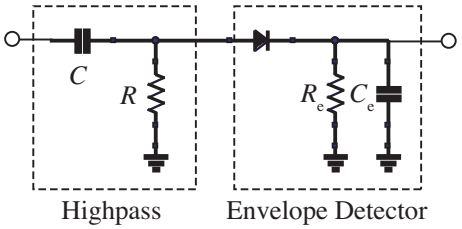
Topic: FM Discrim & PLL **Name:** _____

1.) A general FM discriminator block diagram is of the form:



5 pts. a.) Explain the purpose of the limiter.

15 pts. b.) A circuit implementation of a *slope-detection* discriminator is shown below:



Sketch the frequency response magnitude of the highpass filter making note of the cutoff frequency in terms of component values. Show where would you place the FM carrier frequency on your magnitude response sketch. Finally, briefly explain how the complete circuit demodulates an FM carrier.

2.) A first-order PLL has closed-loop transfer function

$$H(s) = \frac{2\pi \cdot 10^4}{s + 2\pi \cdot 10^4} \text{ (recall here } H(s) = K_t/(s + K_t)\text{)}$$

10 pts. a.) Given that the center of the lock range is 10 MHz, describe the lock range of the loop.

10 pts. b.) The loop is subject to a 1 kHz frequency step at the input relative to the quiescent 10 MHz lock frequency. Using the general steady-state phase error result:

$$\psi_{ss} = \lim_{s \to 0} \frac{s(\theta_0 s^2 + 2\pi f_\Delta s + 2\pi R)}{s^3 + K_t s^2 + K_t a s + K_t b} \text{ for loop filter } F(s) = 1 + \frac{a}{s} + \frac{b}{s^2}\text{, find } \psi_{ss} \text{ in degrees.}$$

ECE 5/4625 • Quiz 11a • April 23, 2020

Topic: PLL & PLL Synth **Name:** _____

1.) A first-order PLL has closed-loop transfer function

$$H(s) = \frac{2\pi \cdot 10^4}{s + 2\pi \cdot 10^4}$$

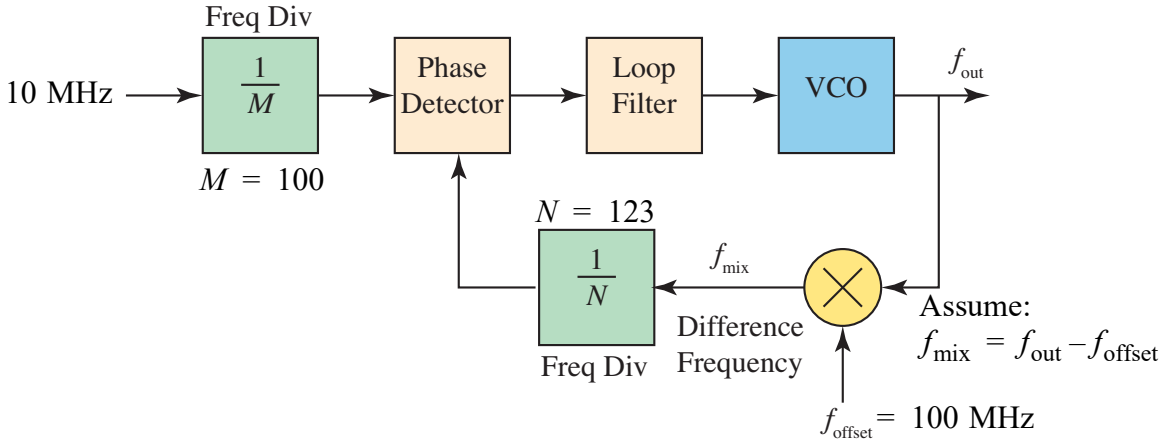
10 pts. a.) Given that the center of the lock range is 10 MHz, describe the lock range of the loop.

10 pts. b.) The loop is subject to a phase deviation at the input of the form

$$\phi(t) = \left[2\pi \cdot 20\times10^3 \cdot t + \frac{\pi}{3}\right] u(t) \text{ rad}.$$

Using the final value theorem find the steady-state phase error in the loop, ψ_{ss}

2.) Consider the PLL synthesizer shown below



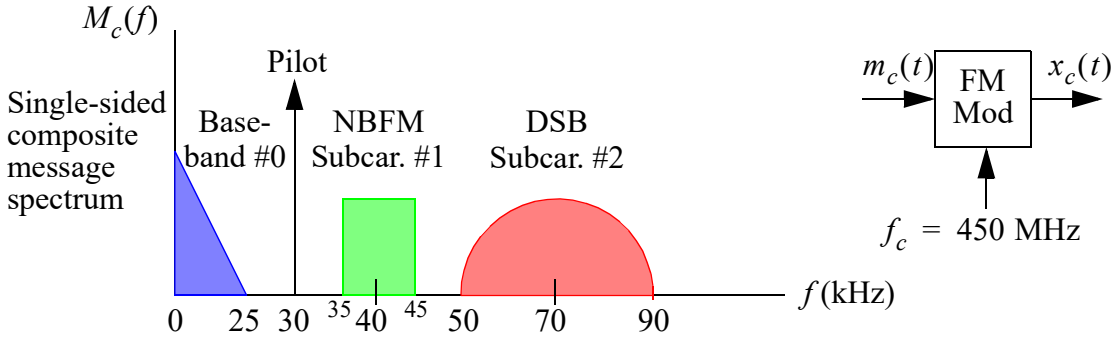
15 pts. a.) Find f_{out} for the parameters given in the above figure. Show your work

5 pts. b.) What value of M is required to make the frequency step size of the synthesizer be 10 kHz?

ECE 5/4625 • Quiz 11b • April 23, 2020

Topic: Mulitplexing – FDM **Name:** _____

20 pts. 1.) An FDM signal with composite spectrum shown below frequency modulates a 450 MHz carrier. Draw a block diagram of a complete receiving system for the recovery of messages #0, #1, and #2 from $x_c(t)$. Include coherent demodulators which use the 30 kHz pilot carrier and use signal multipliers, frequency dividers, and frequency multipliers, as appropriate.



ECE 5/4625 • Quiz 12a • May 7, 2020

Topic: Physical Noise Sources **Name: _____**

An antenna with a temperature of 900 K is fed into a receiver consisting of a cascade of an amplifier having gain 20 dB, noise figure 1 dB, a 3 dB attenuator, a mixer having 10 dB gain and noise figure 2 dB, and an IF amplifier having gain 40 dB and noise figure 5 dB.

a.) Find the noise figure in dB, F_{dB}.

b.) Find the overall noise temperature T_e.

c.) Find the SNR in dB by first finding the receiver output signal power P_s in dBm and the receiver output noise power P_n in dBm.

ECE 5/4625 • Quiz 12b • May 7, 2020

Topic: Physical Noise Sources **Name:** _____

Given a ground-to-aircraft link is described by the following parameters:

Average transmit power TBD to achieve a 20 dB link SNR
Transmit frequency: 5 GHz
Transmit antenna gain G_T of 20 dB
Noise temperature of user receiver including antenna: 800 K
Aircraft antenna gain G_R of 10 dB
Total system losses: 2 dB
System bandwidth: 1 MHz
Link range: 10 km

a.) Find the received output signal power level at the user in dBm.

b.) Find the receiver output noise power in dBm.

c.) Find transmit power in dBm needed to achieve an SNR at the receiver output of 20 dB.