12 WEEK EXAM Practice

NAME: ___Solution___

ALPHA: ____________

SECTION: _______________

1. This is individual work.
2. SHOW ALL WORK!
3. Write legibly to receive credit.
4. Turn in your equation sheet.

1 mile = 1609 meters
\( c = 3 \times 10^8 \text{ m/s} \)

SCORE: ________/100

SCALE
>89.5%: 31337
79.5 – 89.5%: H@XX0R
69.5 – 79.5%: G33K
59.5 – 69.5%: $€RiPt K1DD13
<59.5%: WannaB
Lesson 11 – Intro to Communications Systems

1. Describe the main purpose of any communication system.

To get data from a Transmitter to a Receiver across some medium, even in the presence of noise.

2. Provide the names and approximate frequencies and applications for 3 bands that the FCC allocates for the Electromagnetic Spectrum.

- **MF** -300kHz-3MHz: AM Radio
- **VHF**- 30-300MHz: TV Channels and FM Radio
- **UHF** – 300MHz-3GHz: Higher TV channels and Flight NavAids
- **SHF** – 3GHz- 30GHz ; Satellite Comms

3. In music, a pure C₆ tone is defined as having a frequency of 1046.50Hz. Assuming that it has zero phase offset and an amplitude of 2volts:

   a) Write the mathematical formula for the sinusoid of this tone.

   \[ v(t) = 2V \sin(2\pi 1046.50t) \text{ OR } 2V \sin(2093\pi t) \]

   b) Sketch the time domain diagram for this tone, labeling all significant parts.

   c) Sketch the frequency domain diagram for this tone.
Lesson 12 – Intro to Modulation

4. From the pictured AM Radio Signal in which $V_{\text{max}}$ is 10V, $V_{\text{min}}$ is 2V, $f_c$ is 1000KHz, and $f_m$ is 5KHz, determine:

   (a) $V_m$ 4V
   (b) $V_c$ 6V
   (c) $m$, the modulation index 67%
   (d) $f_{\text{lsb}}$ 995kHz
   (e) $f_{\text{usb}}$ 1005kHz
   (f) $V_{\text{lsb}}$ 2V
   (g) $V_{\text{usb}}$ 2V
   (h) $BW_{\text{AM}}$ 10kHz

If the antenna resistance is 50 $\Omega$, what is the

$$P_c = \frac{V_c^2}{2*50}; \quad P_{\text{LSB}} = \frac{(V_m/2)^2}{2*50}$$

(i) $P_c$= 0.36W and $P_{\text{LSB}}$= 0.04W

5. In the United States, AM broadcasts are afforded 10KHz of bandwidth, while FM broadcasts may use up to 250KHZ of bandwidth. (T/F)

False- FM is allotted 180-200kHz

6. An Emergency Action Message must be sent to a submarine at sea at a frequency of 30KHz. How long of a quarter-wavelength wire must the submarine stream behind it in order to best receive the message? Include units. $\lambda = 3 \times 10^8 / 30 \times 10^3 = 10$km;

$$\lambda/4 = 2500 \text{ m}$$
Lesson 13 – Signal Gain and dB

7. An amplifier has an output of 25W. What is its gain both in dBm and dBW?
   \[ A_{dBm} = 44.0 \text{ dBm} \]
   \[ A_{dBW} = 14.0 \text{ dBW} \]

8. Given the following system, what is the minimum required signal power \( P_{in} \) to achieve the desired Signal to Noise ratio?

   \[ \text{SNR} = 29\text{dB} \]
   \[ P_n = 7nW \]

   \[ S/N = 10^{(29/10)} = 794.33 \]
   \[ 794.33 = P_s/P_n, \text{ so } P_s = 794.33 \times 7nW = 5.56\mu W \Rightarrow \text{THIS IS } P_{out} \]
   \[ P_{out}/P_{in} = 10^{-1.8} = 0.015849 \quad \text{so } P_{in} = P_{out}/0.015849 = 350 \mu W \]

9. The SNR of a system is 20dB and signal power is 4.5W, determine noise power.
   Noise Power = .045W or 45mW

10. Is noise present across all frequencies, in what band of frequencies is it the largest?

   Yes, highest at low frequencies below 1kHz, and at higher frequencies beyond 10MHz.

Lesson 14 –Fourier and Filters

11. For the circuit below, answer the following questions:

   \[ L = 222 \text{ mH} \]
   \[ R = 8200 \Omega \]

   \[ V_s \]
   \[ + \]
   \[ V_o \]
   \[ - \]

   a) What type of filter does this circuit represent? (Remember to substitute values for frequency of 0 and infinity to analyze the transfer function \( V_o/V_s \) vs frequency.) \( V_o/V_s(f=0) = 1, V_o/V_s(f=\infty) = 0. \)

   Low pass filter
b) The filter cut-off frequency, $f_B$ is defined to be what value in (power) dB, and in voltage?

-3dB for $\frac{1}{2}$ power

\[ \frac{1}{\sqrt{2}} = 0.707 \] for voltage

c) Show a plot of $V_o/V_s$ vs frequency indicating any specific values.

.707 defines the cutoff frequency, $f_B$, 5.88kHz

12. Using the same circuit analysis as above, determine what type of filter this circuit is?

High Pass Filter

\[
\frac{V_o}{V_s} = \frac{R}{R + \left(\frac{1}{j2\pi fC}\right)} = \frac{j(f/f_B)}{[j(f/f_B) + 1]} \\
|\frac{V_o}{V_s}| = \frac{(f/f_B)}{\sqrt{1+(f/f_B)^2}}
\]
13. Draw a magnitude vs frequency plot for a tuned circuit and indicated all the important characteristics and variables.

![Graph showing magnitude vs frequency plot for a tuned circuit]

Lesson 15 – Antennas

14. What are the advantage(s) of a directional antenna vs a (theoretical) isotropic radiator? Check any that apply.

a) For the same power, directional allows communication over longer distances vs isotropic.

b) With less power, directional can communicate same distance as isotropic.

c) Directional antennas require fewer parts than an isotropic antenna.

d) Directional antennas fit more easily onto Humvees than isotropic antennas.
15. Use the radiation pattern to answer the follow-on questions about this antenna:

- **a.** What is the beamwidth of this antenna?
  
  $\text{beamwidth} = 22.5^\circ \text{ to } -22.5^\circ$, so approximately $45^\circ$

- **b.** What is the Side Lobe Level with respect to the side lobe positioned at $90^\circ$?

  \[
  \text{SLL (dB)} = G_{\text{bore sight (dB)}} - G_{\text{sidelobe (dB)}} = 0\text{dB} - \sim -15\text{dB} = \sim 15\text{dB}.
  \]

- **c.** If this antenna has a gain of $9\text{dBi}$ and is transmitting at a power of $10\text{W}$, what is the EIRP for this antenna?

  \[
  G_t = 10^{9/10} = 7.94 \\
  \text{EIRP} = G_t P_t = (7.94)(10\text{W}) = 79.4\text{W}
  \]

- **d.** For the yagi antenna associated with this radiation pattern, the center frequency is $400\text{Mhz}$. What is the physical size of the driven element of the yagi antenna?

  \[
  \lambda = \frac{c}{f} = \frac{3\times10^8 \text{m/s}}{400\times10^6 \text{Hz}} = 0.75\text{m} \\
  \text{Antenna size} = \frac{\lambda}{2} = \frac{0.75\text{m}}{2} = 0.375\text{m}
  \]

16. **a)** Describe the purpose of a director as it pertains to the parasitic element of a yagi antenna.

  Focuses the electromagnetic beam, thus increasing gain in that direction and narrowing the beamwidth.

  **b)** Would additional directors enhance these effects or provide no further benefit?

  These benefits continue to improve up to around 20 directors.
Lesson 16 – Propagation

17. If electromagnetic waves with low frequencies come into contact with a relatively large and smooth surface (reflection / scattering) is more likely to occur, whereas high frequency waves coming into contact with relatively smaller and rougher surfaces will tend to undergo (reflection / scattering).

18. a) What type of propagation will occur for communications in the Very High Frequency (VHF) band?
   Space Wave

   b) If someone is standing in a life raft with a hand-held VHF radio (assume antenna height of 6 ft), what is the maximum range from which they could contact a search and rescue helicopter flying 100 ft above the surface?

   \[ D = d_r + d_t = \sqrt{2h_r} + \sqrt{2h_t} = \sqrt{2(6 \text{ ft})} + \sqrt{2(100 \text{ ft})} = 17.6 \text{ mi} \]

19. Your cell phone transmits at a power level of 500 mW, and an antenna gain of 2.0 dB. The cell tower has an antenna gain of 8.0 dB, and for LTE, you’re transmitting at 700 MHz.
   How far from the tower could you be while maintaining the capability to communicate? (Cellular “dead zone” occurs when \( P_r < -110 \text{dBm} \).)

   \[ P_{\text{rec}} = 10^{-110/10} = 10^{-11} \text{ W} \quad P_t = 0.5 \text{ W} \quad g_t = 10^{2/10} = 1.58 \quad g_r = 10^{8/10} = 6.3 \]

   \[ \lambda = c/f = \frac{3 \times 10^8}{700 \times 10^6} = 0.4286 \text{ m} \]

   \[ \frac{p_t g_t g_r \lambda^2}{(4\pi d)^2} \]

   Solve \( P_{\text{rec}} = \left(\frac{p_t g_t g_r \lambda^2}{(4\pi d)^2}\right) \) \( \Rightarrow d = 24.1 \text{ km} \)
Lesson 17 – Analog to Digital Conversion

20. For the signal given by the formula
   \[ v(t) = 10\sin(2 \pi \cdot 450t) + 3\sin(2 \pi \cdot 600t + 300^\circ) + 7\sin(2\pi \cdot 1100t): \]
   
   a. What is the minimum sampling rate that could be used to transmit this signal digitally such that a receiver could accurately reconstruct the signal?
   b. **Nyquist Rate** – \(2f_{\text{max}} = 2 \cdot 1100 \text{Hz} = 2.2 \text{ kHz}\)

   c. If the signal were mapped by a 5-bit quantizer with a resolution of 1V, what would this imply is the **minimum voltage** found in the waveform?

   5 bits \(\rightarrow\) \(2^5 = 32\) one-volt quantization levels \(\rightarrow\) 16V to positive and negative peaks
   \(\Rightarrow\) Minimum possible voltage is -16V

   d. Given your above answer, what bitstream would be generated by the sampled point (2.5s, -11.6V)?

   Level 4-5th bin from the bottom \(\Rightarrow\) 00100

   e. If a receiver was decoding the incoming bitstream of 10100, what voltage level would be recovered?

   Center value of the 20th possible bin \(\Rightarrow\) 3.5V

21. Which action below will reduce the effects of quantization error?

   a. Use AM instead of FM
   b. Use less bits per sample in your A/D converter
   c. Increase the size of the quantization intervals
   d. Use more bits in your A/D converter
Lesson 18 – Bandwidth and Multiplexing

22. What dictates the bandwidth requirements of a channel for a communication system? (Provide as many as you can and state their applications)

1. FCC regulates the bandwidths for comm systems to use the EM Spectrum.
2. The antenna that is used is specific for certain frequencies.
3. Each transmitter modulates the specific information to place it on the channel based upon its output filter and its bandwidth.
4. Each receiver tunes into the specific frequency it wants to receive with a specific band of frequencies.

23. What are 4 ways that a channel can be shared?

Spatial MUX, Time division MUX, Frequency Division MUX, Code Division Multiple Access (CDMA).

24. Which multiplexing techniques are better for analog and which are better for digital, or both?

CDMA and TDM - digital
FDM - analog mainly (except for frequency hopping modulation)
Spatial MUX could be digital or analog

25. What bandwidth would be correct for 12 TV stations to share a UHF band of 540MHz, what form of multiplexing is this?

$$540 \times 10^6 / 12 = 45 \text{MHz}$$

FDM
Lesson 19 – Digital Modulation

26. What Modulation Techniques are combined in Quadrature Amplitude Modulation?

Amplitude Shift Keying, Phase Shift Keying

27. Given the following time domain graph of an FSK signal:

a) Using your best guesstimate- What is f_L? ; What is f_H? Show your work.

\[ t_L = 33.33 \mu s / 2 = 16.667 \mu s; \ f_L = \frac{1}{16.667 \mu s} = 60 kHz \]
\[ t_H = 33.33 / 4 = 8.333 \mu s; \ f_H = \frac{1}{8.333 \mu s} = 120 kHz \]

b) What is \( f_c \) and what is \( f_d \)?

\[ f_d = 120 kHz - 60 kHz / 2 = 30 kHz \]
\[ f_c = 90 kHz \]

c) Sketch this signal on a frequency domain plot (with appropriate labels) Show where variables above appear on plot with relative amplitudes.
Lesson 20 – Electronic Warfare

28. You are trying to locate an unknown transmitter with two receivers. The first receiver (R1) receives the transmission at \( t = 35 \mu\text{sec} \). The second receiver (R2) receives the transmission at \( t = 12 \mu\text{sec} \).

a) Assuming the transmissions left at \( t = 0 \), which receiver is closer to the target?

\[
d = ct_{TOA}
\]

\[
d_1 = (3 \times 10^8 \text{m/s})(35 \times 10^{-6} \text{s}) = 10500\text{m}
\]

\[
d_2 = (3 \times 10^8 \text{m/s})(12 \times 10^{-6} \text{s}) = 3600\text{m}
\]

**R2 is closer**

b) If R1 is located at (3000, 2000) meters and R2 is located at (2000, 3000) meters, where is the target?

\[
d_1 = 10500\text{m} = \sqrt{(3000 - x_t)^2 + (2000 - y_t)^2}
\]

\[
d_2 = 3600\text{m} = \sqrt{(2000 - x_t)^2 + (3000 - y_t)^2}
\]

29. You are located 5500 meters from the omnidirectional receiver you are jamming. The transmitted signal you are jamming originates 3000 meters from the receiver. The signal transmitter’s EIRP is 14.5 dBW. Assuming both the transmitter and jammer have line of sight, your jammer EIRP of 44W will allow you to jam the receiver with what \( J/S \) ratio?

\[
10 \log(44W) = 16.43 \text{ dBW}
\]

\[
\frac{J}{S_{\text{dB}}} = EIRP_J - EIRP_S + 20 \log d_s - 20 \log d_j
\]

\[
\frac{J}{S_{\text{dB}}} = 16.43 \text{dBW} - 14.5 \text{ dBW} + 20 \log 3000 - 20 \log 5500
\]

\[
\frac{J}{S_{\text{dB}}} = -3.33 \text{dBW} \text{ Unsuccessful jamming attempt}
\]
Lesson 21 – Jamming Mitigation

30. If the frequency range of a Frequency Hopping Spread Spectrum system shown below is 45kHz to 65kHz, and the bit rate is 40kbps, what is the dwell time? (Note: Both graphs are on the same time scale)

31. a) What type of modulation scheme is used for Direct Sequence Spread Spectrum (DSSS)? Show a block diagram of the transmission communication system.

\[ R_b = 40 \text{kbps}; \quad t_b = 1/R_b = 1/40,000 = 25 \mu s; \quad 25 \mu s/\text{bit}/(4 \text{ shifts/\text{bit}}) = 6.25 \mu s \]

b) What benefit does the higher rate, the chip rate, over the bit rate, in the DSSS scheme, provide?

BPSK

c) Does the bandwidth of a modulated signal increase or decrease as chip rates and bit rates get higher? Use the Processing Gain equation to discuss. Mention the advantages and disadvantages of wideband modulation.

The bandwidth increases with the higher chip rate and the signal is spread out and looks like noise.

\[ G = \text{BW}/f_b \] So G goes up as BW increases with higher chip rate, for a given bit rate, \( f_b \).