INSTRUCTOR'S MANUAL

Electronic Communications

A Systems Approach

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Text Solutions for

Electronic Communications

A Systems Approach

1. Process of putting information onto a high-frequency carrier for transmission.

2. The frequency that is used to "carry" the intelligence.

3. to provide separate carriers for different intelligence
   the difficulty of transmitting signal at very low frequencies

4. amplitude, frequency, and phase

5. MF - 300kHz to 3MHz
   HF - 3 to 3- MHz
   VHF - 30 to 300MHz
   UHF - 300 MHz to 3GHz
   SHF - 3 to 30 GHz

6.
$$dB\mu V = 20\log\frac{.4\mu V}{1\mu V} = -\mathbf{7.95}$$

7.
$$10\,dBm = 20\log\frac{V}{.774}$$
$$[\log^{-1}(.5)][.774] = V = \mathbf{2.45\,V}$$

8.
$$P = \frac{V^2}{R}$$
$$\frac{P_{out}}{P_{in}} = 15 = \frac{(V_{out})^2/R}{(V_{in})^2/R}$$
$$\frac{V_{out}}{V_{in}} = \sqrt{15} = \mathbf{3.87}$$

9.
$$(a)\;\; dBm = 10\log\frac{1}{.001} = \mathbf{30\,dBm}$$
$$(b)\;\; dBm = 10\log\frac{.001}{.001} = \mathbf{0\,dBm}$$
$$(c)\;\; dBm = 10\log\frac{.0001}{.001} = -\mathbf{10\,dBm}$$
$$(d)\;\; dBm = 10\log\frac{25\times10^{-6}}{.001} = -\mathbf{16\,dBm}$$

10.
$$(a)\;\; 38dBm = 10\;\log\frac{P}{.001} \quad P = \mathbf{6.3W}$$

$$(b)\quad 10\log\frac{6.3}{1} = \mathbf{8\,dBW}$$

11. $$-70\,dBm = 20\log\frac{V}{.774}$$
$$\therefore V = \mathbf{.245\,mV}$$

12. $$dBmV = 20\log\frac{50\,\mu V}{1\mu V} = \mathbf{34\,dB\mu V}$$

13. $$dBm = 20\log\frac{2.15V}{.774\,V} = \mathbf{8.86\,dBm\,(600)}$$

14. $$dBm = 20\log\frac{2.15}{.2236} = \mathbf{19.66\ dBm\,(50)}$$

15. information theory - concerned with the optimization of transmitted information

16. Hartley's Law - information that can be transmitted is proportional to the product of the bandwidth times the time of transmission. This means that the greater the bandwidth the more information that can be transmitted.

17. harmonic - it is a multiple of the fundamental frequency

18. $7 \times 360\ kHz = \mathbf{2{,}520\ kHz}$

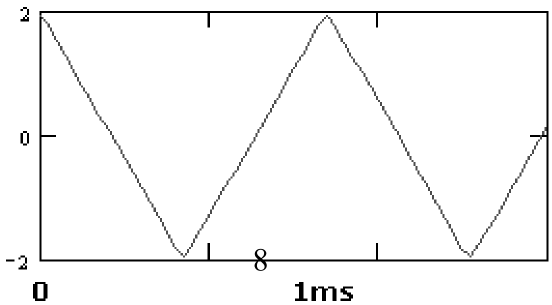
19. the square wave contains many harmonic frequencies; the sine wave just contains the fundamental frequency.

20. use Figure 1-7 as a reference. The period and the harmonics will change because of the 2 kHz sine wave signal.

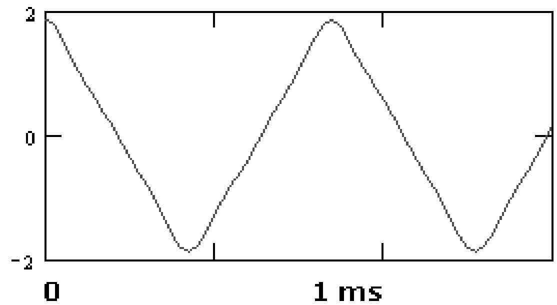
21. Fourier Analysis - method of representing complex repetitive waveforms by sinusoidal components

22. Refer to Figure 1-8

23. $v = \frac{8V}{\pi^2}[\cos\omega t + \frac{1}{9}\cos 3\omega t + \frac{1}{25}\cos 5\omega t]$



11th harmoinic



5th harmonic

24. $(a)\ 10\,ks/s$

$(b)\ 750\,Hz$

25. $(a)\ 37.5\,kHz, 62.5\,kHz$

(b) *The period of the square wave is* $80\,\mu s$.

$f = \frac{1}{T} = \frac{1}{80\times10^{-6}} = 12.5\,kHz$. *Also, the first harmonic in the FET spectrum is at* $12.5\,kHz$

26. any undesired voltages or currents that end up appearing in a circuit

27. external noise - noise in a received radio signal that has been introduced by the transmitting medium
internal noise - noise in a radio signal introduced by the receiver

28. man-made noise, atmospheric noise, space noise

29. white noise, thermal noise

$$
\begin{aligned}
e_{noise} &= (4kT\Delta f R)^{1/2} \\
&= 4\times1.38\times10^{-23}(273+27)\times10^6\times10^6)^{1/2} \\
&= (16.56\times10^{-9})^{1/2} \\
&= 128.7\times10^{-6} \\
&= \mathbf{128.7\,\mu V\ rms}
\end{aligned}
$$

30. $e_{noise} = (4kT\Delta fR)^{1/2}$

$240\mu V/75 = (4 \times 1.38 \times 10^{-23} \times (273+27) \times 10^5 \times R)^{1/2}$

$3.2 \times 10^{-6} = (1.711 \times 10^{-15} R)^{1/2}$

$(3.2 \times 10^{-6})^2 = (1.711 \times 10^{-15} R)$

$$R = \frac{10.24 \times 10^{-12}}{1.711 \times 10^{-15}}$$

$R = \mathbf{5.985\,k\Omega}$

At 25 kHz bandwidth,

$e/75 = (4 \times 1.38 \times 10^{-23} \times 310 \times 25 \times 10^3 \times 5.985 \times 10^3)^{1/2}$

$e_{noise} = \mathbf{120\,\mu V}$

31. low-noise resistor - a resistor that exhibits low levels of thermal noise

32. 128.7 uV/1 Mohm equals approximately 129 pico amps
The noise current increases with the increase in temperature

33. $$\frac{e^2{}_n}{\Delta f} = kTR = (1.6x\,10^{-20})(20x\,10^3) = 3.2x\,10^{-16}$$

$e_n = 20\,\mu V \;\therefore \Delta f = 1.25\,MHz$

34. $$\frac{S}{N} = \frac{signal\ power}{noise\ power}$$

$$= \frac{(4V)^2/\acute{R}}{(0.48V)^2/\acute{R}} = \mathbf{69.44}$$

$S/N(db) = 10\ \log_{10} S/N$

$= 10\ \log_{10} 69.44$

$= \mathbf{18.42\,dB}$

35. $$\boldsymbol{NF} = 10\ \log_{10} \frac{S_i/N_i}{S_o/N_o}$$

$$= 10\ \log_{10} \frac{110}{69.44} = \mathbf{1.998\,dB}$$

$$NR = \frac{110}{69.44} = \mathbf{1.584}$$

36. $\boldsymbol{NF} = 10\ \log_{10}\frac{S_i}{N_i} - 10\ \log_{10}\frac{S_o}{N_o}$

$6\,dB = 25\,dB - 10\ \log\frac{S_o}{N_o}$

$S/N\ dB = 10\ \log\frac{S_o}{N_o} = 25dB - 6dB = \mathbf{19}\boldsymbol{dB}$

$S_o/N_o\ as\ a\ ratio\ =\ 10^{19/10} = 10^{1.9} = \mathbf{79.4}$

37. $NR\ =\ 5 + \frac{10-1}{50} + \frac{10-1}{50x1000}\ =\ 5.18$

$NF\ =\ 10\log NR\ =\ 10\log 5.18\ =\ \mathbf{7.143}\boldsymbol{dB}$

38. $NR_1 = antilog\ NF_1 = antilog\ 2.4\,dB = 1.74$

$NR_2 = antilog 6.5\,dB = 4.47$

$P_{G_1} = antilog 8\,dB = 6.31$

$P_{G_2} = antilog\ 40\,dB = 10{,}000$

$\therefore NR = 1.74 + \frac{4.47-1}{6}.31 = \mathbf{2.29} \qquad \therefore NF = 10\log 2.29 = \mathbf{3.6}\,\boldsymbol{dB}$

$P_{noise\ input} = kT\,\Delta f$

$= 1.38\times10^{-23}\times300\times\frac{\pi}{2}\times150\times10^3\ =\ \mathbf{9.75\times10^{-16}}\boldsymbol{W}$

$e_{noise\ input} = (4\ \ R\ \ P^{1/2}_{noise\ input} = \mathbf{19.8\,\mu}\boldsymbol{V}$

$NR = \frac{S_i/N_i}{S_i/N_i}\ and\ \frac{S_o}{S_i} = P_G = 10{,}000\times6.31 = 63{,}100$

$\therefore 2.29 = \frac{1}{63{,}100}\times\frac{N_o}{N_i} = \frac{N_o}{63{,}100\times9.75\times10^{-16}}$

$N_o = 2.29\times9.75\times10^{-16}\times63{,}100\ =\ \mathbf{1.41\times10^{-10}}\boldsymbol{W}$

$P = \frac{V^2}{R}\therefore e_{noise\ output} = (N_o\times R)^{1/2}$

$= (1.41\times10^{-10}\times300)^{1/2}\ =\ \mathbf{0.206}\ \boldsymbol{mV}$

39. $N = kT\,\Delta f\ =\ 1.38\times10^{-23}\times(25+30+60)\times2\times10^6\ =\ \mathbf{3.17\times10^{-15}}\,\boldsymbol{W}$

$NR = T_{eq}/T_0 + 1\ =\ 60/290 + 1 = \mathbf{1.21}$

$NF = 10\log NR = 10\log 1.21 = \mathbf{0.817}\,\boldsymbol{dB}$

40. Symptoms, Signal Tracing and Injection, Voltage and Resistance Measurements Substitution or check the AC connection, check fuses, check input/output connections, ask yourself if you forgot something also, check visual inspection and all of your senses, check power supplies, verify input and output signals

41. Good components can get damaged in the substitution process.

42. Voltages will cause incorrect resistance measurements. The power must be turned off and the component isolated.

43. complete failures, intermittent faults, poor system performance, induced failures

44. When tracing through a multiple stage circuit for a fault.

45. the answer should include at least two of the following issues
    - limitation of the electronics (eg. noise)
    - the bandwidth limitation of the communications channel

46. $Assume\ T = 27^oC$

$$At\ the\ input,\ e_{noise} = (4kT\Delta f\,R)^{1/2}$$

$$= (4 \times 1.38x10^{-23}(273+27) \times 200 \times 10^3 \times 2 \times 10^3)^{1/2} = \mathbf{2.574\mu V}$$

$$\therefore \frac{S_i}{N_i} = \frac{(1mV)^2}{(2.574V)} = 150.9 \times 10^3$$

$$NF = 10\log\frac{S_i/N_i}{S_o/N_o}$$

$$\frac{S_i/N_i}{S_o/N_o} = antilog\ 5/10 = 3.162$$

$$\therefore \frac{150.8 \times 10^3}{S_o/N_o} = 3.162$$

$$S_o/N_o = 47.73 \times 10^3$$

$$S_o = 1mV \times 100 = 100mV$$

$$\therefore (N_o)^2 = \frac{100mV)^2}{47.73x10^3} \qquad N_o = \mathbf{458\mu V}$$

47. Noise temperature measurements are more common and these are based more on the system rather than the device.

1. dc. 2kHz, 1498kHz, 1500 kHz, 1502kHz, and harmonics of the last three frequencies

2. 1498, 1500, and 1502kHz

3. The non-linear mixing of the carrier and intelligence frequencies.

4. The combination of the upper and lower sideband frequencies.

5. sideband - collections of all frequencies in that band
side frequency - this just refers to one frequency

6. the modulation is at 100%, usb = lsb

7. the carrier phasor represents the peak value of the sine wave
one full revolution represents 360 degrees.

8. refer to figure 2-11

9. refer to Figure 2-5

10. sideband splatter

11. $\%m = \frac{E_i}{E_c} \times 100\%$

$\%m = \frac{100V}{300V} \times 100\% = 33.3\%$

$\%m = \frac{200V}{300V} \times 100\% = 66.7\%$

$\%m = \frac{300V}{300V} \times 100\% = 100\%$

12. $A = 60V \quad B = 200V$

$\frac{B - A}{B + A} \times 100\% = \frac{200 - 60}{200 + 60} \times 100\% = 53.8\%$

13. $m = \frac{Ei}{Ec} \times 100\% = .5385$

$at\ 100\%, B = 260 \therefore Ec = 65Vpk \ \ Ei = 35Vpk$

14. This shown in the portion of section 2–2 entitled "Amplitude Modulation and Mixing in the Frequency Domain."

15. $E_{SF} = \frac{mE_c}{2} = \frac{0.75 \times 100V}{2} = 37.5V$

16. $$P_c = \frac{E^2{}_c}{2R} = \frac{(40V_{peak})^2}{2\times 50} = \mathbf{16W}$$

$$P_{LSB} = P_{USB} = \frac{m^2}{4}P_c = \frac{(0.7)^2}{4}\times 16 = \mathbf{1.96W}$$

Check：

$$= P_{LSB} + P_{USB} + P_C = 19.84$$

$$P_t = P_c\left(1 + \frac{m^2}{2}\right) = 19.92 \simeq 19.84$$

17. $$P_t = P_c\left(1 + \frac{m^2}{2}\right) \qquad 500 = P_c\left(1 + \frac{0.75^2}{2}\right)$$

$$P_C = \mathbf{390W}$$

$$\therefore P_{SB's} = 500 - 390 = \mathbf{110W} \qquad \therefore P_{USB} = P_{LSB} = \frac{110W}{2} = \mathbf{55W}$$

18. $$I_t = I_c\left(1 + \frac{m^2}{2}\right)^{\frac{1}{2}} \qquad 6.7 = 6.2\left(1 + \frac{m^2}{2}\right)^{\frac{1}{2}} \qquad m = \mathbf{0.579}\ \textbf{\textit{or}}\ \mathbf{57.9\%}$$

19. A high percentage of modulation is important so that the power to the sidebands is sufficient for a quality signal.

20. $$P_t = P_c\left(1 + \frac{m^2}{2}\right)$$

$$\mathrm{P_t / P_c} = \left(1 + \frac{1^2}{2}\right) = 1.5$$

$$\therefore P_c/P_t = \frac{1}{1.5} = \frac{2}{3}$$

$$\therefore \frac{P_{SB's}}{P_t} = \frac{1 - 2/3}{1} = \frac{1}{3} = \mathbf{33\frac{1}{3}\%}$$

21. $P_t = P_c = \left(1 + \frac{0.8^2}{2}\right) = 1kW\left(1 + \frac{0.8^2}{2}\right) = \mathbf{1.32kW}$

$$dB = 20\log\frac{V_1}{V_2} = 20\log\frac{147mV}{405mV} = \mathbf{51.2dB}$$

$$dBm = 10\ \log\frac{P_c}{10^{-3}W}$$

$$m_{eff} = (m_1^2 + m_2^2 + m_3^2 + ...)^{1/2}$$

$$Since\ \ m_1 = m_2 = m_3$$

$$0.8 = (3(m)^2)^{1/2} \quad \boldsymbol{m} = \mathbf{0.462}$$

22. From Table 1-3c, the peak amplitude of each harmonic is

$$1st \quad \frac{4A}{\pi} = \frac{4x20}{\pi} = \frac{80}{\pi}$$

$$2nd \quad \frac{4A}{3\pi} = \frac{80}{3\pi}$$

$$3rd \quad \frac{4A}{5\pi} = \frac{80}{5\pi}$$

$$4th \quad \frac{4A}{7\pi} = \frac{80}{7\pi}$$

The ms values are obtained by dividing by $\sqrt{2}$

$$Thus\ m = 2x\,80/\pi x\frac{1}{\sqrt{2}} = 0.72 \quad m_2 = 0.24, m_3 = 0.036, m_4 = 0.010$$

$$\therefore m_{eff} = (m_1{}^2 + m_2{}^2 + m_3{}^2 + m_4{}^2)^{1/2} = 0.77$$

23. $m = 1,\ \therefore\ P_{SBS} = \frac{1}{3}P_t$

$$\therefore\ P_{one\ sideband} = P_{SSB}$$

$$= \frac{1}{3}\times 1000\ W \times \frac{1}{2} = \mathbf{167\ \ \mathit{W}}$$

24. $121\ V_p \times 0.707 = 85.6\ V$

$$PEP = \frac{85.5^2}{50} = \mathbf{146\ W}$$

25. PEP - peak envelope power. This rating only occurs occasionally in time with voice transmission while a sinusoid transmission is constant.

26. ACSSB - Amplitude Compandored Single Sideband, includes a pilot carrier, speech signal is compressed at the transmitter and expanded at the receiver

SSB - Single Sideband, only one sideband is transmitted

SSBSC - the carrier and one sideband are suppressed

ISB - Independent Sideband, another name for twin-sideband suppressed carrier transmission. This involves the transmission of two independent sidebands.

27. Advantages of SSB over conventional AM
 - spectrum
 - less affected by fading
 - power savings
 - noise advantage

Disadvantage of SSB over conventional AM
 - SSB reception can be a problem, Donald Duck voice.

28. The main advantage of DSBSC is since there is a suppressed carrier, there is a significant power savings, so more power can be placed in the sideband that is carrying the intelligence.

29. The linear combination of the two signals will not produce the desired carrier and side-frequencies.

30. The upper and lower side-frequencies should be mirror images of each other.

31. a. $27{,}002{,}000\ Hz$
$27{,}000{,}000\ Hz$
$26{,}998{,}000\ Hz$

b. $P_c = \frac{E_c^2}{R}$ $10\ W = \frac{E_c^2}{50}\ \Omega$ $E_c = 22.36\ V$

$E_{c\ peak} = 22.36 \times 2 \times \sqrt{2} = 31.6\ V_p$

$m = \frac{E_i}{E_c}$

At $m = 20\%$

$0.2 = \frac{E_i}{31.6}$

$E_i = 6.32 V_p$

This varies from $31.6 + 6.32 = \mathbf{37.9 V_p}$ *to* $31.6 - 6.32 = \mathbf{25.3 V_p}$

At $m = 90\%$ $E_i = 0.9 \times 31.6 = 28.5 V_p$

This varies from $31.6 - 28.5 = \mathbf{3.14 V_p}$ *to* $31.6 + 28.5 = \mathbf{60.1 V_p}$

c. **at m = 0.2**

$$P_t = P_c = \left(1 + \frac{m^2}{2}\right) = 10\left(1 + \frac{0.2^2}{2}\right) = \mathbf{10.2\ W}$$

$\therefore P_{SB's} = 10.2 - 10 = 0.2 W$

$\therefore P_{USB} = P_{LSB} = \frac{0.2}{2} = \mathbf{0.1 W}$

$P = E^2/R$ $.1 = E_{SB}^2/50\Omega$ $E_{SB} = \mathbf{2.24 V}$

at m = 0.9

$$P_t = 10W\left(1 + \frac{0.9^2}{2}\right) = 14.05W$$

$\therefore P_{SB's} = 14.05 - 10 = 4.05 W$

$\therefore P_{USB} = P_{LSB} = \frac{4.05 W}{2} = \mathbf{2.025 W}$

$2.025 = E^2/50\Omega$ $E = \mathbf{10.06 V}$ *each sideband*

d. $P = I^2 R \quad 10W = I_c^2 \times 50\Omega \quad I_c = 0.447A$

$$\therefore At\ m = 0.2,\ I_t = 0.447\left(1 + \frac{0.2^2}{2}\right)^{1/2} = \mathbf{0.451}\,A$$
$$At\ m = 0.9,\ I_t = 0.447\left(1 + \frac{0.9^2}{2}\right)^{1/2} = \mathbf{0.530}\,A$$

32. An oscilloscope is primarily used to view the time domain components; the spectrum analyzer allows the frequency spectrum to be observed.

33. AM receivers use the carrier to tune in (lock) to the RF signal. A loss of carrier will make the receive circuits not work. The loss of one of the sidebands should not cause a problem.

34. One sideband is eliminated, the carrier is suppressed but can be used as a pilot carrier for the receiver to lock to.

35. $f_{DSB_1}(t) = (\cos\ \omega_i t)(\cos\ \omega_c t)$ (1)

Take the same carrier and intelligence and shift 90° before feeding into balanced modulator to get

$$f_{DSB_1}(t) = \sin\ \omega_i t\ \sin\ \omega_c t \qquad (2)$$

$$trig\ identity;\ \sin A\ \sin B = \frac{1}{2}[\cos(A-B) - \cos(A+B)]$$

$$\therefore equation\ 2 = \frac{1}{2}[\cos(\omega_c - \omega_i)t - \cos(\omega_c + \omega_i)t] \qquad (3)$$

$$trig\ identity;\ \cos A\ \cos B = \frac{1}{2}[\cos(A+B) - \cos(A-B)]$$

$$\therefore equation\ 1 = \frac{1}{2}[\cos(\omega_c + \omega_i)t + \cos(\omega_c - \omega_i)t] \qquad (4)$$

Add equation 3 to equation 4 to get

$$3 + 4 = \cos\ (\omega_c - \omega_i)t$$

which is SSB (the lower sideband in this case) **QED**

36. The first sections of the AM and SSB receivers are the same. The difference is the SSB receiver uses a 2nd IF and a BFO to tune into the sideband.

This would be the hardest part, modifying the AM receiver to tune into the sideband.

1. Angle modulation is the process of superimposing the intelligence signal on a high-frequency carrier so that its phase angle or frequency is altered as a function of the intelligence amplitude. The two sub-categories are: Phase modulation (PM) and Frequency Modulation (PM)

2. PM - the amount of phase change is proportional to the intelligence amplitude
   FM - the amount of frequency change is proportional to the intelligence amplitude

3. FM has superior noise performance
   FM can use low-level modulation
   Class C amplifiers can be used and hence more efficiency

4. FM suffers from undesired phase-shifting when used at frequencies below 30MHz.

5. improved noise performance ... and FM can use low-level modulation.

6. see Figure 3-1 for an example

7. Deviation constant defines how much the carrier frequency will deviate for a given modulating input voltage level. The units for deviation are expressed as [kHz/V].

8. $(a)\ f_{dev} = 50mV\,x\,500Hz/20mV = \mathbf{1.25kHz\ or\ \pm 1.25kHz}$

   $(b)\ rate = input\ frequency = \mathbf{1kHz}$

9. The amplitude of the intelligence is responsible for deviating the carrier frequency. The units for deviation are expressed as [kHz/V].
   The rate at which the carrier is deviated is controlled by the frequency of the intelligence.

10. $f_i = \mathbf{1\ kHz}$

    $f_c = \mathbf{90\ MHz}$

    $E_i = \frac{1.5\ kHz}{1.0\ kHz} \times 3\ V = \mathbf{4.5\ V}$

11. The rate at which the carrier is deviated is controlled by the frequency of the intelligence.

12. f = fc +/- Vi * k (kHz/V)
    where

    fc = FRM carrier frequency
    vi = amplitude of the intelligence signal
    k = deviation constant in units of kHz/V

13. modulation index equals the maximum carrier frequency shift divided by the intelligence frequency (see equation 3-3)

14. the amplitude and the frequency

15. refer to Figure 3-4, the frequency spectrum changes

16. $\delta = 15\ kHz$
$f_i = \mathbf{3\ kHz}$
$m_f = \frac{\delta}{f_i} = \frac{15}{3} = 5$
J_8 is last significant sideband (form Bessel Function Table)

$\therefore BW = \pm 8 \times 3\ kHz = \pm 24\ kHz = \mathbf{48\ kHz}$
$f_i = 2.5\ kHz$
$m_f = \frac{1.5}{2.5} = 6 \qquad J_9\ is\ significant.$
$\therefore BW = \pm 9 \times 2.5\ kHz = \pm 22.5\ kHz = \mathbf{45\ kHz}$
$f_i = 5\ kHz$
$m_f = \frac{15}{5} = 3 \qquad J_6\ is\ significant.$
$BW = \pm 6 \times 5\ kHz = \pm 30\ kHz = \mathbf{60\ kHz}$

17. The guard bands help minimize interference with adjacent channels. The broadcast channel is 200 kHz wide.

18. The maximum possible frequency deviation is +/– 75 kHz for FM broadcast stations. This deviation is defined by regulation as 100% modulation.

19. The center frequency is the frequency of the carrier when it is at rest. "At rest" implies that there is no modulating signal.

20. This refers to how much the FM channel deviates. The amount of deviation dictates the bandwidth allocation.

21. 60% of full permissible amount for broadcast FM.
60% of ± 75 kHz = **±45 kHz**

22. Double its previous swing.

23. Unchanged.

24. Same current as before since transmitter power does not change in FM.

25. $f_c = \dfrac{10^9}{2\pi} = \mathbf{159\ \ MHz}$

$f_i = \dfrac{10^4}{2\pi} = \mathbf{1.59\ \ kHz}$

$$P = \frac{\left(\frac{1000}{\sqrt{2}}\right)^2}{75\ \Omega} = \mathbf{6.67\,kW}$$

$m_f = 4 \quad \delta = m_f f_i = 4 \times 1.59\ \ kHz = \mathbf{6.37\,kHz}$

$BW \simeq 2(\delta_{\max} + f_{i\ \max})$

$= 2(6.37\ \ kHz + 1.59\ \ kHz) \simeq \mathbf{16kHz}$

26. $P_{J_2\ and\ higher} = 1000 - 9829 = \mathbf{171\ \ W}$

27. $DR = \dfrac{5\,kHz}{3kHz} = \mathbf{1.67,\ \ wideband}$

28. FM receivers are not sensitive to static.

29. The limiter stage removes any amplitude variations of the received FM signal before it reaches the discriminator.

30. Removal of some spikes cause a phase shift and thus frequency shift of the FM signal; this frequency shift can not be removed.

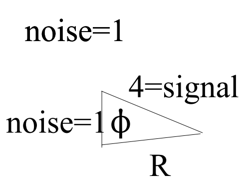
31. $\phi = \dfrac{35°}{57.3°/radian} = 0.61\ \ radians$

$\delta \simeq \times f_i$

$= 0.61 \times 5\ \ kHz$

$= \mathbf{3.05\ \ kHz}$

32. S/N = 4
Thus, worst case occurs when S and N are 90° out of phase.



$Sin\ \phi = \dfrac{1}{4} = 0.25$

$\phi = 14.47° = 0.253\ \ radian$

$\therefore \delta = 0.253 \times 15\ \ kHz = 3.79\ \ kHz \quad \therefore worst\ \ case$

$S/N_{output} = \dfrac{full\ \ deviation}{3.79\ \ kHz} = \dfrac{75\ \ kHz}{3.79\ \ kHz} = \mathbf{19.8:1}$

33. The narrowband transmission has limited bandwidth and as a result only the fist harmonic contains significant power. All other side frequencies have a reduced amplitude and are more susceptible to noise. The deviation of the carrier is small and there is limited range (dynamic range) from the intelligence to the small deviations resulting from noise.

34. The capture effect is an FM receiver phenomenon that involves locking onto the stronger of two received signals of the same frequency and suppressing the weaker signal.

35. The voice communication channels of radio communications typically require a limited bandwidth; therefore, the reduced carrier deviation has minimal impact on the overall noise.

36. See Figure 3-16 for a pre-emphasis circuit. Pre-emphasis circuits amplify the higher frequencies more than lower frequencies. This improves the noise reduction capability. The de-emphasis circuit returns the received signal back to the original values.

37. (a-h) refer to section 3-3 "FM is the Frequency Domain" for the answers to these questions
(i) pre-emphasis is incorporated to provide additional amplification of the higher frequencies that are more susceptible to noise.

38. The intelligence amplitude causes the frequency deviation, the intelligence frequency affects the rate the carrier is deviating.

39. In PM, the phase of the carrier varies with the modulating signal amplitude (mp).
In FM, the carrier phase is determined by the ratio of the intelligence signal amplitude to the intelligence frequency. This is the method used in the Armstrong indirect FM.

40. The deviations determine the modulation index, which in turn determines the significant sideband pairs. The bandwidth is computed by the sideband pairs and not deviation frequency. The deviation is not the bandwidth but it does have an effect on the bandwidth.

41. When $m_f = 2$

$$J_0 = 0.22$$
$$J_1 = 0.58$$
$$J_2 = 0.35$$
$$J_3 = 0.13$$
$$J_4 = 0.03$$

$$J_0(carrier) = 0.22^2 \times 1\ kW = 48.4\ W$$
$$J_1 = 0.58^2 \times 1\ kW \times 2\ SB's = 672.8\ W$$
$$J_2 = 0.35^2 \times 1\ kW \times 2 = 245.0\ W$$
$$J_3 = 0.58^2 \times 1\ kW \times 2 = 33.8\ W$$
$$J_4 = 0.58^2 \times 1\ kW \times 2 = 1.8\ W$$
$$Total\ power = 1002.0\ W \simeq 1000\ W\ \ \boldsymbol{QED}$$

42. It can be shown, using Carson's rule, that deviation exceeding +/- 75 kHz will result in a FM bandwidth exceeding the 200 kHz channel spacing.

1. see Figures 4-9 and 4-10.

2. The capacitor in series with the inductor swamps out the transistor's internal capacitances thereby negating transistor variation and increasing stability.

3. A Pierce crystal oscillator is provided in Fig. 4-13. The crystal has a fixed resonant frequency.

4. *There are* 2.592×10^6 *second per month* $(60 \times 60 \times 24 \times 30)$

$$\therefore \pm 15\, s/month$$

$$= \pm \frac{15}{2.592 \times 10^6}$$

$$= \pm 5.787 \times 10^{-6} = \pm \mathbf{5.787}\, \boldsymbol{ppm}$$

5. Inductors - store energy in the surrounding magnetic field
capacitor - stores energy between the plates
(Q) quality factor - ratio of the energy stored to the energy lost

6. resonance - when $X_C = X_L$

7. $f = 100\,MHz \quad L = 6mH \quad R = 1.2k$

$$Q = \frac{\omega L}{R} = \frac{2\pi(100\,MHz)(6x10^{-3})}{1.2x10^3} = 3.14x10^3$$

$$D = \frac{1}{Q} = 0.318x10^{-3}$$

8. $f = 100\,MHz \quad C = .001\mu F \quad R = .7x10^6$

$$Q = \frac{\omega C}{G} = \frac{2\pi(100x10^{-6}}{\frac{1}{.7x10^{-6}}} = 4.398x10^5 \qquad D = \frac{1}{Q} = 2.27x10^{-6}$$

9. *At* 100 *MHz*

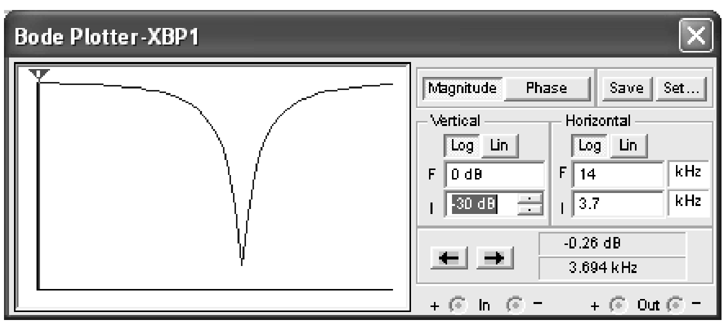
$$Z_{ind}=R+jX_L$$
$$=1.2\times10^3\times j2\pi\times10^8\times6\times10^{-3}$$
$$=1.2\times10^3\times j37.7\times10^5 \simeq \boldsymbol{j37.7\times10^5}$$

$$Z_{cap}=R\| -jX_C$$
$$=0.7\times10^6\| -j\frac{1}{2\pi\times10^8\times0.001\times10^{-6}}$$
$$\simeq0.7\times10^6\| -j1.592\,\Omega$$

$$Z_{TOT}=Z_{ind}+Z_{\cap}$$
$$=j37.7\times10^5-j1.592\,\Omega \simeq \mathbf{37.7}\ \boldsymbol{M\Omega}$$

$$f_r=\frac{1}{2\pi\sqrt{LC}}=\frac{1}{2\pi(6\times10^{-3}\times0.001\times10^{-6})^{1/2}}=\mathbf{65}\boldsymbol{kHz} \quad At\ f_r,\ Z\simeq R_{ind}=\mathbf{1200\ \Omega}$$

10. At 4KHz , e out ~ 0.96V at 6KHz e out ~ 0.8V



11. see Fig. 4-17

12. as Q increases the filter becomes more selective
the limiting factor is the resistance factor (see equation 4-5)

13. $$Q = \frac{f_r}{BW} = \frac{10.7\times10^6}{200\times10^3} = \mathbf{53.5}$$

14. $$f_r = \frac{1}{2\pi\sqrt{LC}} \;=\; 10.7\times10^6 = \frac{1}{2\pi(L\times0.1\times10^{-9})^{1/2}}$$

$$\therefore\; L = \mathbf{2.21\mu H}$$

$$Q = \frac{X_L}{R} = \frac{2\pi\times10.7\times10^6\times2.21\times10^{-6}}{R} = 53.5$$

$$\uparrow\; from\; Prob.\mathbf{8}$$

$$R = \frac{2\pi\times10.7\times10^6\times2.21\times10^{-6}}{53.5} = \mathbf{2.78\;\Omega}$$

15. $$Z_{res} = Q^2R = 60^2\times5\;\Omega = \mathbf{18\;k\Omega}$$

16. $$f_r = \frac{1}{2\pi\sqrt{LC}} \;=\; \frac{1}{2\pi(27\times10^{-3}\times0.68\times10^{-6})^{1/2}} \;=\; \mathbf{1175 Hz}$$

$$Q = \frac{X_L}{R} = \frac{2\pi\times7{,}148\times10^3\times27\times10^{-3}}{4} = \mathbf{49.8}$$

$$Z_{\max} = Q^2R = (49.8)^2\times4\;\Omega = \mathbf{23.6\;Hz}$$

$$BW = \frac{f_r}{Q} = \frac{1{,}175\;Hz}{49.8} = \mathbf{23.6\;Hz}$$

$$f_{lc} \simeq f_r - \frac{BW}{2} \;=\; 1{,}175 - \frac{23.59}{2} \;\simeq\; \mathbf{1163\;Hz}$$

$$f_{hc} \simeq f_r + \frac{BW}{2} \;\simeq\; \mathbf{1187\;Hz}$$

17. constant-k filters - capacitance and inductive reactive resistance made equal to some constant k.
m-derived filters - use a tuned circuit in the filter to provide nearly infinite attenuation at a specific frequency

18. above 100 kHz - use LC
below 100 kHz - use RC

19. at high frequencies the leads exhibit stray inductance and capacitance

20. number of RC or LC sections in a filter
Note: There is also a mathematical relationship for filters that uses the poles term in filter circuits.

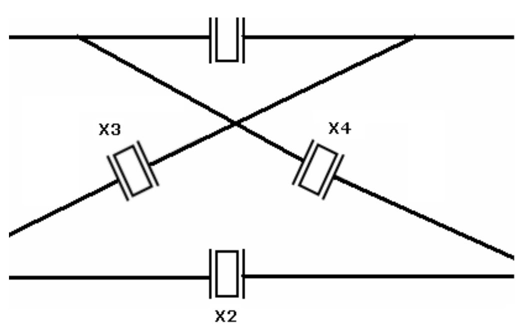
21. they use a constant-k value for the inductive and capacitive reactance values

22. see Fig. 4-21

23. The crystal holder capacitance Cp shunts the crystal and offers a path to other frequencies. This problem is minimized by placing an external variable capacitance in the circuit. [see Fig. 4-21(b)]

24. they are made from quartz crystal

25. This is an example of a bandpass lattice filter. Crystals X1 and X2 are series resonant while X3 and X4 are parallel resonant. The center frequencies are at the required sideband.



26. The big advantage is stability.

27. They use a piezoelectric effect just as crystals do. See problem 28 for the discussion of the shape factor.

28. The ratio of the 60db to 6db bandwidth is called the shape factor.

29. The 3dB ripple amplitude is describing the peak-to valley variations.

30. The electrical energy is converted to mechanical variations and then back to electrical variations. The mechanical filter has a resonant frequency. They provide excellent rejection characteristics, are rugged, small, and have a high Q.

31. SAW filters are typically used in high frequency applications that are not commonly used in SSB transmission.

32. differential inputs (+ / -) and a double side-band output

33. see Fig. 4-27 and the related discussion

34. The LIC provides superior performance because of the matched components.

35. 100 dB, The difference is with the 10k feedback resistor (pin 14) and the compensating capacitor (pin 12).

36. The SSB output requires the use of a filter to remove one of the sidebands.

37. See Figure 4-29. The difference between the input frequency and the PLL VCO frequency generates an error voltage. The error voltage output level and the rate of change are representative of the intelligence riding on the input FM signal.

38. Free-running - this is the nominal frequency of the PLL
Capture - the point where the VCO begins to change frequency
Locked or tracking - the point where the VCO changes frequency to match the input.

39. Capture range $\approx 2 \times 20$ kHz = **40 kHz**
lock range $\approx 2 \times 150$ kHz = **300 kHz**

40. $f_R = 1\ MHz \quad N = 61$

$f_0 = f_r \times N = 1\ MHz \times 61 = \mathbf{61\ MHz}$

41. The output frequency of the synthesizer in Figure 4-32 is limited to the maximum frequency of the programmable divider. The synthesizer in Figure 4-34(a) allows narrower channel spacing and faster lock-time. Figures 4-34(b) and (c) are subject to noise and have wide channel spacing.

42. The circuit in Figure 4-35 overcomes the problem of high-speed programmable division. The operation of this circuit is discussed in the Two-Modulus Dividers section.

43. $f_R = 1\ MHz$

$A = 26 \quad M = 28 \quad N = 4$

$f_0 = (NM + A) \times 1\ MHz$

$f_0 = \mathbf{138\ MHz}$

44. The phase accumulator generates a phase increment of the output waveform based upon its input. The input phase determines the frequency of the output waveform. Translating phase information is accomplished by means of a ROM look-up table. The digital output of the NCO is converted to an analog signal via the D/A.

45. Maximum output frequency is about 40% of 60 MHz $\quad$ 0.40 × 60 MHz = **24 MHz**

$$frequency\ resolution = \frac{f_{clk}}{2^N} = \frac{60\,MHz}{2^{28}} = 0.223\,Hz$$

1. base modulation (Fig. 5-2)
   collector modulator (Fig.5-4)

2. low-level modulation - in an AM transmitter, the intelligence is superimposed on the carrier and the modulated waveform is amplified before reaching the antenna.

3. high-level modulation - in an AM transmitter, the intelligence is superimposed on the carrier at the last point before the antenna.

4. high-level modulation is preferred for high-power transmission
   low-level modulation is less expensive and used for low-power applications

5. neutralizing capacitor - a capacitor that cancels feedback signals to suppress self-oscillation

6. at tuned frequencies parasitic oscillations prevent amplification
   self-oscillation is a problem for all RF amplifiers; it can at the tuned frequency or at a higher frequency.

7. parasitic oscillations are undesirable high-frequency oscillations

8. the feedback signal is in phase with the signal being amplified

9. see Fig. 5-4

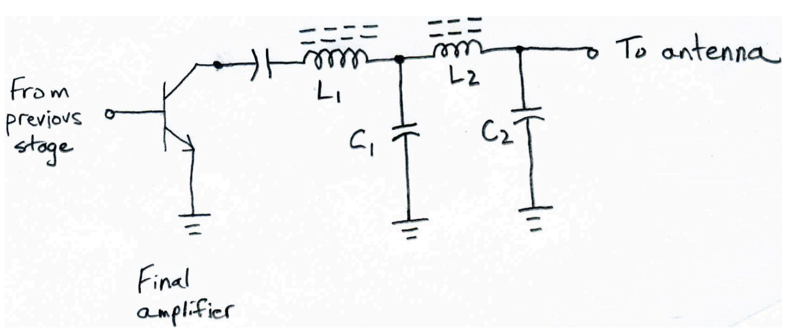
10. the advantage of class C amplification is efficiency

11. the crystal maintains the high accuracy of the carrier frequency required by the FCC.

12. see Figure 5-1

13. the buffer amplifier provides a high impedance load for the oscillator to minimize drift. It also provides enough gain to sufficiently drive the modulation amplifier.

14. One method is shown below:



The L1–C1 and L2–C2 combinations create a "double-pi" filter network that matches the final amplifier output impedence to that of the antenna and that also filters out unwanted harmonics. The L and C values are frequency-dependent. (The pi filter derives its name from its resemblance, in schematic form, to the Greek letter pi, π).

15. The antenna coupler is necessary so that the transmitter output impedance is matched to the antenna.

16. $dB = 20\log\frac{147mV}{405mV} = 51.2dB$

17. The tune-up procedure is used to place the transmitter on the air. The tuning coils are typically adjusted to about 1/2 of their values. The coils are then adjusted so that reliable oscillation is achieved and maximum power is obtained.

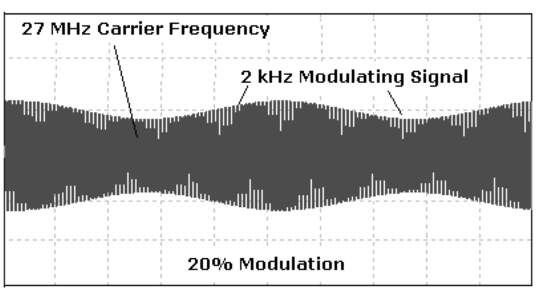
18. see Fig. 5-7(c)

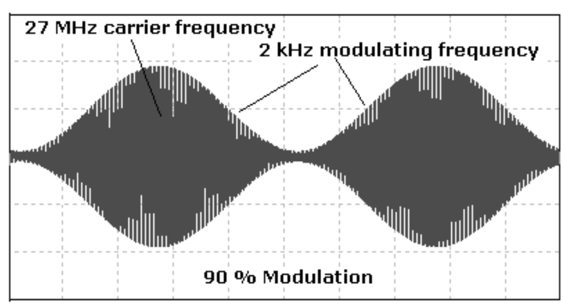
19. The trapezoidal measurement allows easy observation of over-modulation, under-modulation, and improper phase relationships.

20. This is showing the RF spectrum of an AM signal. The carrier frequency is 960 kHz and the modulating frequency is 2kHz. The percentage of modulation is 100% (refer to equation 2-9). The carrier voltage is 1 Volt.

21. spurs are undesired frequency components of a signal usually having to do with the harmonics.

22.





23. The carrier is 5.4 divisions above the -20 dBm noise floor. At 10 dB per division, carrier power is 54 dB above the noise floor or +34 dBm

$$dbm = 10\log\frac{P_c}{10-3}$$

$$let x = \frac{P_c}{10^3} \quad 3.4 = \log x$$

$$\therefore 10^{-3.4} = x \quad x = 2.51 x 10^3 \quad \therefore P_c = 2.51 x 10^{-3} = 2.51 W$$

The first two spurs are ± 2.3 divisions from the carrier. Thus, 2.3 divisions × 5 kHz=11.5 kHz
∴50.0034 MHz ± 11.5 kHz = **50.0149 MHz** and **49.9919 MHz**

The second two are ±4.6 divisions from the carrier.
Thus, ± 23 kHz is **50.0264 MHz** and **49.9804 MHz**
Power of the ± 11.5 kHz spurs is down 2.6 divisions form the carrier.

2.6 div. × 10 dB/div. = 26 dB

$$10\log\frac{2.51}{P} = 26dB \quad \log\frac{2.51}{P} = 2.6 \quad P = 6.3mV$$

Similarly P of ± 23 kHz spurs ≈**1 mW**

24. The dummy antenna is used for testing the transmitter off-air. The dummy antenna is basically a resistive load that absorbs the radiating signal.

25. $THD = \sqrt{V_2^2 + V_3^2 + .../V_1}$

$$V_1 = 50mV \times 60 = 3V$$

$$THD = \sqrt{(0.035^2) + (0.027)^2 + (0.019)^2 + (0.011)^2 + (0.005)^2/3}$$

$$THD = \sqrt{0.00082033} = 0.02864 = 2.864\%$$

$$The relative harmonic distortion is 20\log\frac{3V}{0.035} = 38.66 dB$$

26. THD without V_6 is 7.348% or 0.07348
with V_6 is 7.416% or 0.07416

$$\% error = \frac{.07416 - 0.07348}{0.07416} = 0.0091 = 0.91\%$$

27. $f_{carrier} = 3.102\ MHz - 2\ kHz = \mathbf{3.1\ MHz}$

28. Phase advantages
   - greater ease of switching from one sideband to the other
   - SSB can be generated directly
   - lower intelligence frequencies can be economically used since high Q filtering is not necessary

   The filter method is already firmly entrenched in many systems.

29.
$$Q = \frac{2.9\ MHz\left(\log^{-1}\dfrac{40\ dB}{20}\right)^{1/2}}{4\times 200\ Hz}$$
$$= \frac{2.9\ MHz(1\times 10^2)^{1/2}}{800} = \mathbf{36{,}250}$$

30.
$$Q = \frac{200\ kHz\left[\log^{-1}\dfrac{40\ dB}{20}\right]^{1/2}}{4\times 200\ Hz}$$
$$= \frac{200\ kHz(1\times 10^2)^{1/2}}{800} = \frac{200\times 10^3\times 10}{800} = \mathbf{2500}$$

31. The carrier is a single frequency where the audio signal covers a wide range of frequencies.

32. Refer to Figure 5-14.

33. Refer to Figure 5-15. A reactance modulator is designed so that its input impedance has a reactance that varies as a function of the amplitude of the applied input voltage.

34. Crosby systems use direct FM generation with an AFC.

35. The system typically requires some AFC (Automatic Frequency Control) circuit.

36. $2kHz\times 2\times 3\times 4 = \mathbf{48\ kHz}$

37. see Figure 5-16

38. A discriminator is the opposite of a VCO in that it provides a dc level output based on the frequency input.

39. see Figure 5-19

40. The mixer output changes the center frequency without changing the deviation. The multiplier increases to deviation.

41. The circuitry is typically called a pump chain.

42. The amplified audio signal frequency modulates a crystal oscillator. The variable capacitance of the varactor diodes provides approximately +/- 200 kHz deviation (see section 5-4)

43. referring to Figure 5-23
pre-emphasis - amplifies the high frequencies
matrix network - generates the L+R and L-R audio signals
delay network - this is added to the L+R so that the L+R and L-R signals are in phase
master oscillator - generates the 19 kHz pilot tone
frequency doubler - doubles the frequency of the 19 kHz signal to 38 kHz
balanced modulator - provides a double sideband output and shifts the L-R signal up to (23-38) kHz and (38-53)kHz.

44. This is explained in section 5-5 Stereo FM. The stereo FM signal is more prone to noise. The net result is stereo FM has about 20dB less S/N than monophonic FM.

45. Frequency division multiplexing is the simultaneous transmission of two or more signals on one carrier, each having its own separate frequency range.

46. It is still FM (Frequency Modulation). The signal has simply been shifted in frequency.

47. The matrix network is used to generate the L+R and L-R audio signals. Adder circuits (summing amplifiers) and an inverter are used to create the L+R and L-R signals.

48. FM stereo has about 20dB less S/N compared to monophonic FM. Stereo reception can be changed to monophonic to improve reception.

1. sensitivity - the minimum input RF signal to a receiver required to produce a specified audio signal at the output.

   selectivity - the extent to which a receiver can differentiate between the desired signal and other signals.

   These are important because they determine the requirements for the input level. They also determine how much the input signal is above the noise floor and how well the desired signal is selected.

   typical units for sensitivity range in the millivolts to nanovolts for more sophisticated receivers

2. a receiver that is overly selective can result in a lack of fidelity because part of the intelligence is not included (filtered out)

3. see Figure 6-1

4. At 550 kHz

$$f=\frac{1}{2\pi\sqrt{LC}}$$
$$550\times10^{3}=\frac{1}{2\pi\sqrt{25\times10^{-6}C}}$$
$$C=\mathbf{3.35}\boldsymbol{nF}$$

At 1550 kHz

$$C=\mathbf{0.422}\boldsymbol{nF}$$
$$Q=\frac{f_r}{BW}+\frac{1000\ kHz}{10\ kHz}=\mathbf{100}$$
$$BW=\frac{f}{Q}=\frac{1550\ kHz}{100}=\mathbf{15.5}\ \boldsymbol{kHz}$$

At 550kHz

$$BW=\frac{550\ kHz}{10}=\mathbf{5.5}\ \boldsymbol{kHz}$$

5. See Figure 6-2

6. The superheterodyne receiver contains intermediate-frequency transformers.

7. dc
   1.1 MHz
   1.1 MHz ±2kHz
   1.555 MHz
   2.655 MHz
   2.655 MHz ±2kHz
   455 kHz
   455 kHz ±2kHz

   } accepted by IF amp and harmonics of the above frequencies

8. first detector - the mixer stage in a superheterodyne receiver that mixes the RF signal with a local oscillator signal to form the IF signal.

9. The key is to make the LO frequency track with the circuits that are tuning in the incoming radio signal so that the difference is a constant frequency, the IF.

10. The intermediate frequency is 300 kHz; ∴ a 1600 kHz signal mixed with the 1300 kHz (local oscillator) would also yield an output equal to the IF (1600 kHz -1300 kHz = 300 kHz). Therefore, the image frequency is **1600 kHz.**

11. When tuned to 20 MHz:
    LO = 10.7 MHz +20 MHz = **30.7 MHz**
    Image frequency = 30.7 MHz + 10.7 MHz = **41.4 MHz**
    When tuned to 30 MHz:
    LO = 10.7 MHz + 30 MHz = **40.7 MHz**
    Image frequency = 40.7 MHz +10.7 MHz = **51.4 MHz**
    Therefore, LO range = **30.7 to 40.7 MHz**
    Image frequency range = **41.4 MHz to 51.4 MHz**

12. See Figure 6-9

13. The tuned circuit attenuates the possible image frequencies.

14. This depends on the receiver but in the case of a multistage RF section the defective section can be bypassed keeping in mind that the receiver selectivity can be affected.

15. self oscillation is minimized and neutralization is not required.

16. the mixers are referred to as converters and first detectors generating the sum and difference frequencies generating the output IF frequency.

17. The IF amplifiers operate within a fixed bandwidth thereby providing better selectivity and gain control.

18 Image frequency is 1 MHz + (2 × 455 kHz) = **1.91 MHz**

$$P_{in} = \frac{V^2}{R} = \frac{(21\mu V)^2}{50\ \Omega} = \mathbf{8.82\ pW}$$

$$dBm = 10\ \log\frac{P}{1\ mW} = \frac{8.82\ pW}{1\ mW} = \mathbf{-80.5\ dBm}$$

$$P_{out} = -80.5 + 6.5 + 3 + (3\times24) - 4 + 13 = \mathbf{10\ dBm}$$

$$10\ dBm = 10\ \log\frac{P_{out}}{1\ mW}$$

$$\frac{P_o}{1\ mW} = 10 \qquad \therefore P_{out} = \mathbf{10\ mW}$$

19.

$$81\,dB = 10\ \log\frac{x}{0.55\times10^{-9}}$$

$$8.1 = \log\frac{x}{0.55\times10^{-9}}$$

$$\frac{x}{0.55\times10^{-9}} = 10^{8.1} = 1.26\times10^{8} \qquad x = \mathbf{0.0692\,W}$$

20. Dynamic range - the dB difference between the largest tolerable receiver input level and its sensitivity level.

21. 1 MHz +/- 1 kHz, 1 MHz
for USB only 1MHz + 1 kHz

22. minor drifts in the BFO frequency can cause serious problems with SSB reception. Small shifts can make the voice sound like Donald Duck.

23. The BFO should be set to 400 kHz

24. The product detector is a balanced modulator that is used to recover the intelligence in an SSB signal. The low pass filter allows only the audio (low frequencies) components to pass.

25. BFO = 1 MHz

26. It is used to recover the intelligence by converting the frequency changes to voltage amplitude variations.

27. New FM receivers have sufficient frequency stability.

28. see Fig. 6-14

29. LO = 96.5 MHz to 10.7 MHz = **107.2 MHz**
Image Frequency = 107.2 MHz +10 MHz = **117.9 MHz**

30. In FM, it is necessary to amplify the small input voltages to get the signal up to a sufficient level for mixing. At 1 GHz and beyond, transistor noise is increasing while the gain is decreasing. It is more advantageous to feed the incoming FM signal directly to a diode mixer to step it down to a lower frequency.

31. local oscillator re-radiation - undesired radiation of the local oscillator through a receiver's antenna. The RF amplifier helps isolate the receiving antenna from the local oscillator radiation.

32. A square-law device has an output signal at the input frequency and a smaller distortion component at 2 times the frequency. Other devices have many more distortion components.

33. The major advantage of FETs is that they have an input/output square law relationship.

34. The RFC is used to keep the signal frequency from appearing on the power supply.

35. In FM receivers, the limiter removes unwanted amplitide variations.

36. see Figure 6-16

37. The resistor Rc limits the dc collector supply voltage. As soon as the input is large enough, the output will be clipped (the desired effect).

38. **Sensitivity** - minimum input RF signal to a receiver required to produce a specified output. **Quieting Voltage** - the minimum FM receiver input voltage that begins the limiting process. **Limiting Knee Voltage** - same as quieting voltage

39.
$$100\ dB = 20\ \log\frac{300\ mV}{sensitivity}$$
$$5 = \log\frac{300\ mV}{s}$$
$$10^5 = \frac{300\ mV}{s}$$
$$s = \mathbf{3\ \mu V}$$

40. The advantage is the image frequency is almost totally suppressed. Image frequency for the 1st IF = (37.7 +10>7) MHz = 48.4. MHz Image frequency for single conversion is 28 MHz.

41. VHF crystal filters are now available for IF circuitry and are economically attractive. Additional advantages include better image suppression and less tuning range requirement. Figure 6-10 and 6-11 provide example block diagrams.

42.

lowest
to
↓
highest

$$f_{LO} = 3\ MHz + 40.525\ MHz = \mathbf{43.525\ MHz}$$
$$f_{LO} = 30\ MHz + 40.525\ MHz = \mathbf{70.525\ MHz}$$

43.

$$f_{image} = f_{LO} + f_{IF}$$
$$f_{IF} = 455 \ kHz$$
$$f_{LO} = 1180 \ kHz + 455 \ kHz = 1635 \ kHz$$
$$f_{image} = 1635 \ kHz + 455 \ kHz = \mathbf{2090 kHz}$$

$$\text{image rejection (dB)} \cong 20 \log\left[\left(\frac{f_i}{f_s} - \frac{f_s}{f_i}\right)Q\right]$$

$$= 20 \log\left[\left(\frac{2090}{1180} - \frac{1180}{2090}\right) 90\right] = \mathbf{40.7 \ dB}$$

44. see Figure 6-21 and the text discussion for 6-21 (a) - (g)

45. Advantages
- handle high power
- acceptable distortion levels
- efficient
- provide a usable dc voltage for the AGC circuits

Disadvantages
- reduced Q and selectivity
- no amplification

46. Synchronous detection
- low distortion
- ability to follow fast modulation waveforms
- ability to provide gain

The received modulated signal is mixed with a local oscillator. The result is the extracted intelligence and higher frequencies that are removed with filters.

47. See Figure 6-26 and the accompanying discussion. Slope detection is not widely used in FM receivers because the slope characteristic of a tank circuit is not linear, especially in wideband FM.

48. Refer to Figures 6-27 and 6-28 and the related discussion.

49. The Foster-Seeley discriminator is shown in Figure 6-27 and the ratio detector is shown in Figure 6-29. The Quadrature Detector is shown in Figure 6-30.

50. Refer to Figure 6-29 and the related discussion.

51. Foster-Seeley offers excellent linear response to wideband FM signals but responds to undesired amplitude variations. The ratio detector does not respond to amplitude variations and thereby minimizes the required limiting befeore detection.

52. a) and b) see Figure 6-18
c) see Figure 6-16
d) see Figure 6-27

53. The full discussion is provided in section 6-5 in the Quadrature Detector section.

54. The PLL's input phase comparator compares the input signal and the output of the PLL's VCO. This difference is used to develop an error signal proportional to the difference between the two.

55. Refer to Figures 6-32 and 6-33.
L+R is added to L-R to yield 2L
L+R is added to -(L-R) to yield 2R
The levels of the 2L and 2R signals are then dropped to L and R

56. SCA - Subsidiary Communication Authorization, this is often used to transmit music programming for subscription service.

57. $74.5\,kHz - 67\,kHz = 7.5\,kHz$

$67.0\,kHz - 59.5\,kHz = 7.5\,kHz$

58. $$s = -174\,dBm + NF + 10\ \log\ \Delta f + \frac{S}{N}$$
$$= -174\,dBm + 8\ dB + 10\ \log\ 200{,}000 + 15dB = \mathbf{-98\,dbm}$$

59. The 1dB compression point is where the input/output relationship has just reached a level 1 dB down from the ideal linear response. From Figure 6-37, the 1 dB compression point is approximately -10 dBm.

60. The third order intercept point is slightly greater than +20 dBm.

61. $$dynamic\ range \simeq \frac{2}{3}[3rd\ order\ intercept\ minus\ noise\ floor]$$
$$= \frac{2}{3}[20\ dBm - (-98\ dBm)]$$
$$= \mathbf{78.7\ dB}$$

62. $$-96 = -174\,dBm + NF + 10\log(10\,MHz)$$
$$NF = \mathbf{3\,dB}$$

63. $$SINAD = 10\log\frac{S+N+D}{N+D} = 10\log\frac{15.7}{0.015} = 30.19\,dB$$

64. The ratio of the signal + noise + distortion power out to the output signal + noise power,

65. Delayed AGC does not provide any gain reduction until some arbitrary signal level is attained and therefore has no gain reduction for weak signals.

66. Auxiliary AGC causes a step reduction in receiver gain at some arbitrary high value of received signal thus preventing very strong signals from overloading a receiver. An example circuit is provided in Figure 6-44(a).

67. This is called variable bandwidth tuning. A block diagram is provided in Figure 6-45. The need for this is because the bandwidth varies for different types of transmissions.

68. The output of Mixer 1 is (2050 - 2250) Hz. (2050-2100) Hz is passed to Mixer 2. The output of Mixer 2 is (550-600) Hz. The system bandwidth drops to 50Hz.

69. The noise limiter is employed to silence the receiver for the duration of a noise pulse. For the circuit in Figure 16-46, impulse noise will cause the AGC voltage to instantaneously increase. This increases the anode voltage on D2, thus turning it off and blocking the audio from entering the audio amplifier.

70. Metering provides a visual indication of received signal strength. It can also aid with troubleshooting.

71. The squelch circuit quiets the receiver in the absence of a carrier.

72. Quieting and Muting, Figure 6-47 shows a squelch system in block diagram form. When no signal is present, the AGC voltage is high, turning on Q1 which removes the audio signal from Q2. This turns off the audio out from the collector of Q2. The five different methods for providing quelch are: 1) Fixed RF level threshold, 2) Variable level control, 3) Pilot tone control, 4) Digital code control signal and, 5) Microprocessor controlled algorithm.

73. EMI creates undesired amplitude variations that can affect FM reception and destroy AM reception.

74. An ANL is employed to silence the receiver for the duration of a noise pulse.

75. The receiver must provide for a minimum received signal level to guarantee that the output will meet the desired specifications.

76. Assuming that the AM signal is modulated with some low frequency intelligence then the intelligence (in the IF) can be recovered but if the AM signal contains only a high frequency carrier then only the unmodulated IF signal will be recovered.

77. Superheterodyne receivers provide constant selectivity over a wide range of received frequencies. The bulk of the amplification takes place in the IF stages at a fixed frequency enabling the use of frequency selective circuits.

78. When $f_{received}$ is minimum (4 MHz), the tuning capacitors are maximum. Thus, assume C=325 pF for LO and RF stages when receiving a 4 MHz signal.

For the RF stage,

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$4\ MHz = \frac{1}{2\pi(L\times 325\times 10^{-12})^{1/2}}$$

$$L = \mathbf{4.87\ \mu H}$$

For local oscillator, f=5.8 MHz (4 MHz +1.8 MHz)

$$5.8\ MHz = \frac{1}{2\pi(L\times 325\times 10^{-12})^{1/2}}$$

$$L = \mathbf{2.32\ \mu H}$$

At 10 MHz, the inductors stay the same, but for the RF

$$10\times10^{6}=\frac{1}{2\pi(4.87\times10^{-6}C)^{1/2}}$$
$$L=\mathbf{52\ pF}$$

For the local oscillator,

$$11.8\times10^{6}=\frac{1}{2\pi(2.32\times10^{-6}\times C)^{1/2}}$$
$$L=\mathbf{78.5\ pF}$$

79. Yes, noise reduction is important. The noise reduction should aid with FM quieting.

80. The limiter provides an amplitude output. The constant amplitude eliminates its need for AGC.

81. Refer to Fig. 6-33.

82. Up conversion produces an IF signal higher in frequency than the original RF signal. This provides better image frequency suppression and less tuning range requirements.

83. The dynamic range can be improved by using a low-noise pre-amplifier with high gain. However, to maintain a high dynamic range, use only the amplification needed. Examples 6-13 to 6-15 demonstrate how dynamic range can be improved.

84. It is common to test a receiver's IMD using two test frequencies. Examples of this are provided in Figures 6-38 and 6-39. IMD testing of a receiver is most critical.

85.
$$NR_1 = \log^{-1}\frac{6\,dB}{10} = 3.98$$
$$NR_2 = \log^{-1}\frac{8\,dB}{10} = 6.31$$
$$P_{G_1} = \log^{-1}\frac{20\,dB}{10} = 100$$
$$NR = 3.98+\frac{6.31-1}{100} = 3.98+0.0531 = 4.0331$$
$$NF = 10\ \log\ 4.51 = 6.056\,dB$$
$$S = -174\,dBm+6.056\,dB+53\,dB+15\,dB = \mathbf{-99.94\,dBm}$$
$$\textit{The new 3rd order intercept is } +20\,dBm-20\,dbm = 0\,dBm$$
$$\textit{dynamic range} \simeq \frac{2}{3}[0\,dBm-(-99.94\,dBm)] = \mathbf{66.96\,dB}$$

1. Baseband means that the signal is transmitted at its base frequency with no modulation.

2.

3. This is typical of a digital system being carried over an analog channel.

4. By using an ADC - analog-to-digital converter.

5. Transmitters operate on a very low duty cycle. Time intervals between pulses can be filled with samples of other messages.

6. Refer to Figure 7-1 and the related discussions.

7. A simple way to generate PWM is to use a 565 PLL. (See Figure 7-3.)

8. See Figure 7-3

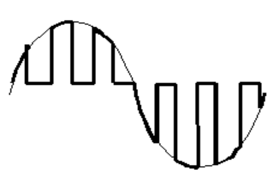
9. See Figure 7-5

10. Acquisition time is the amount of time it takes the hold capacitor to reach its final value.

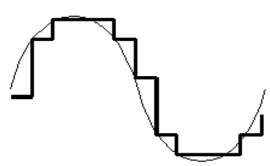
11. Aperture time is the time that the S/H circuit must hold the sampled voltage.

12. 1 nF

13.



Natural Sampling



Flat-top Sampling

14. $f_s = 2 \times 15\,kHz = \mathbf{30\,kHz}$

15. Mixer, (sin A) × (sin B) frequencies are generated by the sampling process.

16. Dyamic range = 6.02 dB/Bit × 12 bits = 72.24 dB

17. Resolution refers to the accuracy of the digitizing system in representing a sampled signal. This can be obtained by increasing the number of quantization levels (increase the number of binary bits) or increasing the sample frequency.

18. $$\textit{number of bits} = \frac{48\,dB}{6.02\,dB/Bit} \approx \mathbf{8\ bits}$$

19. The sampled signal is segmential into different voltage levels, each corresponding to a different binary number.

20. Linear PCM - each quantile interval has the same step size.
Non linear PCM- each quantile interval step-size may vary in magnitude.

21. digital companding - the quantile intervals are varied to improve the weak signal's S/N
analog amplitude companding - process of volume compression before transmission and volume expansion after detection.

22. *use equation* 7–6

$$V_{out} = \frac{V_{\max} \times \ln\,(1 + \mu\ V_{in}/V_{\max})}{\ln\,(1 + \mu)}$$

$$for\ V_{in} = 0 \qquad \frac{10 \times \ln\,(1 + (100)(0)/10)}{\ln\,(1 + 100)} = 0$$

$$for\ V_{in} = .1 \qquad \frac{10 \times \ln\,(1 + (100)(.1)/10)}{\ln\,(1 + 100)} = 1.5$$

$V_{in} = 1$ $\quad V_{out} = 5.2$
$V_{in} = 2.5$ $\quad V_{out} = 7.06$
$V_{in} = 5$ $\quad V_{out} = 8.52$
$V_{in} = 7.5$ $\quad V_{out} = 9.38$
$V_{in} = 10$ $\quad V_{out} = 10$

23. Dmin, also called the Hamming distance, is the distance between logical states.

24. By adding bits.

25. *a*) $D_{min} = 2$

$$errors\ detected = D_{min} - 1 = 1$$

$$errors\ corrected = \frac{D_{min}}{2} - 1 = \frac{2}{2} - 1 = 0$$

b) $D_{min} = 5$

$$errors\ detected = D_{min} - 1 = 5 - 1 = 4$$

$$errors\ corrected = \frac{1}{2}(D_{min} - 1) = \frac{1}{2}(5 - 1) = 2$$

26.
```
 110001010
 010000010
 ---------
 100001000
```
(2) *distance* = 2

27. Error detected = D_{min} - 1
(a) 6
(b) 9

28. Ethernet

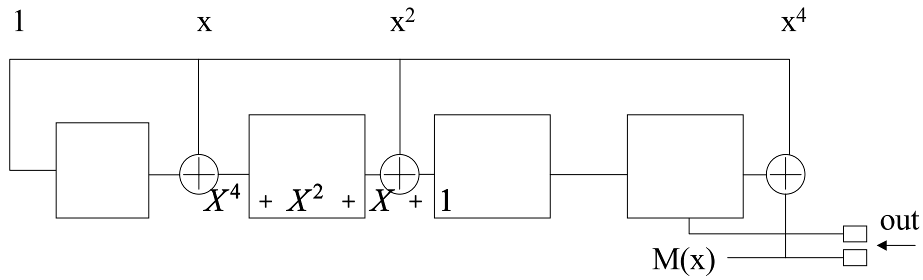
29. A code in which the message and the block check code are transmitted as separate parts within the same transmitted code.

30. n - length of the transmitted code
k - length of the message

31. The code generated when creating the CRC transmit code. This code is added to the message to create the full transmit code.

32. The feedback paths to each XOR gate are determined by the coefficient for the generating polynomial. A “1" indicates a feedback path, a “0" means no feedback.

33.



34.

```
        11
1101√101001
     1101
     ----
      1110
      1101
      ----
       111
```

$111 = BCC$

35. Syndrome - same as the BCC which is the value left in the CRC dividing circuit after all data have been shifted in.

36. a) No errors detected
b) errors detected

NOTE: This assumes that the registers in the CRC generating circuit were reset to all logical zeros prior to generating the code.

37. Received data errors can be corrected.

38. CD Players. The forward error correction ability of Reed-Solomon codes allows blocks of defects (eg. a bad scratch) to be corrected.

39. recursive

40. non-recursive

41. fourth order

42. first order filter, recursive

43. (a) 2^{nd}-order Bandstop filter:

(b) 4^{th}-order Bandpass filter:

44. CRC codes can effectively catch 99.95% of transmission errors. The generating and decoding circuitry can easily be implemented in high speed applications.

45. $f_s \geq 2 \times 10\,kHz \geq 20\,kHz$

$$number\ of\ bits = \frac{72\,dB}{6.02\,dB/Bit} = 11.96 \rightarrow 12\ bits$$

46.

$$3\ bit\ produces\ 2^3 = 8\ quantile\ intervals$$

$$resolution = \frac{1V}{8} = .125\,V$$

$$quantization\ error = \frac{.125}{2} = 0.625\,V$$

1. A type of transmission where a continuous sinusoidal waveform is interrupted to convey information. The carrier is turned on/off to convey information.

2. The AGC will have problems with the carrier turning on/off. In two-tone modulation, the carrier is always being transmitted.

3. Output frequencies are 21 MHz +/- 300 Hz and 21MHz +/- 700 Hz
   The bandwidth required = 2 x 700 Hz = 1400 Hz.

4. FSK is a form of FM in which the modulating wave shifts the output between two pre-determined frequencies. Methods of generation include a VCO and modifying the oscillating frequency of a tank circuit.

5. one technique is to use a PLL and use the error signal to indicate the data change.

6. the incoming data cause the phase of the carrier to phase-shift a defined amount

7. $M = 2^n$, number of allowable phase states
   n = the number of data bits needed to specify the phase state

8. The +/- sin $\omega_c t$ signals are input into 1 of 2 selectors. The binary data input is used to select the phase.

9. The received BPSK signal is input to a coherent carrier recovery circuit which produces a sin $\omega_c t$ signal. The recovered carrier is mixed with the BPSK input The output of mixer is filtered through a low-pass filter and the result is a +/- 1/2 term that indicates the phase.

10. A recovered carrier frequency is used as an input to a mixer to recover the data.

11. The recovered carrier is fed to two phase detector circuits. One side has a 90^o phase-shift. The outputs of the phase detectors are fed through low-pass filters. The I and Q data is output from the low-pass filters.

12. See Figure 8-22 and 8-23. The QAM system uses a four-level baseband stream providing a 16 state QAM constellation in a limited bandwidth.

13. The output signal must contain both amplitude and vector information.

14. It is used for diagnosing the performance of a digital modulation system. It allows for the immediate observation of the effects of filters, circuits, or antenna adjustments.

15.

	1	1	0	1
0	0	0	1	1
-sin	-sin	-sin	+sin	+sin

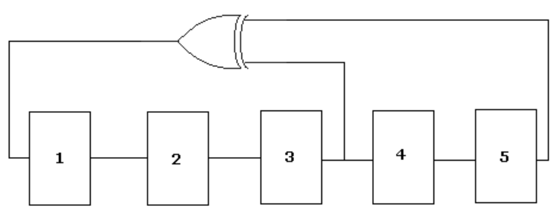
16. A PN sequence is a pseudo random sequence. It is noise-like because the sequence appears to be random like noise.

17. The RF signal is randomly spread over a range of frequencies in a noise-like manner.

18. (a) pn sequence length = 2^4 -1 = 15
(b) pn sequence length = 2^9 - 1 = 511
(c) pn sequence length = 2^{23} - 1 = 8388607

19. This indicates that the PN code has a length of 2^n - 1 where n is the number of shift registers.

20.



21. The data is transmitted by a carrier that is switched in frequency in a pseudorandom fashion.

22. The time each carrier spends at a specific frequency.

23.

Shift #	SR0	SR1	SR2
0	1	0	1
1	1	1	0
2	1	1	1
3	0	1	1
4	0	0	1
5	1	0	0
6	0	1	0
7	1	0	1

24. A pseudorandom sequence to break-up the message into chips. The chips successfully modulate fractions of the bit, typically using a phase-shift technique. The receiver multiplies the incoming signal to recover the original modulated digital signal. This enables many signals to be multiplexed over one communications channel.

25. When two spread spectrum transmitters momentarily transmit at the same frequency.

26. The pseudorandom digital sequence used to spread the signal.

27. See Figure 8-37 and 8-40.

28. $$spreading = \frac{1x10^6}{56x10^3} \approx 17\ 86$$

29. See Figure 8-44.

30. Flash OFDM uses a fast hopping technique to transmit each symbol over a different frequency.

31. D - T - V

D	0 1 0 0 0 1 0 0
T	0 1 0 1 0 1 0 0
V	0 1 0 1 0 1 1 0

32. Both the analog and digital signals share the same channel bandwidth.

33. The digital data rate for AM HD radio is 36 kbps which produces a signal with comparable quality to the current analog FM.

34. The digital data rate for FM HD radio is 96 kbps which produces a near CD quality audio signal.

35. a) hybrid AM – see Fig. 8-46
b) hybrid FM - see Fig. 8-47

36. OFDM

37. The data is transmitted over fixed carrier frequencies therefore only one system can transmit at a time.

38.

Shift #	SR0	SR1	SR2
0	1	1	1
1	0	1	1
2	0	0	1
3	1	0	0
4	0	1	0
5	1	0	1
6	1	1	0
7	1	1	1

no changes with a seed value of 0 0 0.

39. The answer should include the following: unique PN codes for each transmitter and receiver, hits cause very little loss of signal quality, other signals appear as noise

1. Most telephone network voice connections are analog and the data speeds are limited.

2. Received voice signal (millivolts)
transmitted voice signal(1 to 2 Vrms)
ringing signal (90 Vrms)

3. Subscriber lifts the handset, a switch is closed providing a dc loop current between tip and ring. Telco senses the off-hook condition and responds with a dial-tone. At this point, the subscriber dials the desired number.

4. Phones use pulse dialing and dual-tone multi-frequency (DTMF)

5. PBX - Private Branch Exchange, the primary function is switching one telephone line to another.

6. **B**attery feeding **O**vervoltage protection **R**inging **S**upervision
Coding **H**ybrid **T**esting

7. Cable resistance and transmission line effects

8. Loaded cable - cable with added inductance every 6000, 4500, or 3000 feet.

9. The “C2" line is an improved line. The limits between (500 - 2800) Hz are +1 dB to -3 dB. From 300 to 500 Hz and 2800 to 300 Hz the C2 limits are +2 dB and -6 dB.

10. The signal is attenuated and distorted when carrying over long distances.

11. Attenuation distortion is the difference in gain at some frequency with respect to a reference tone of 1–4 Hz.

12. Delay distortion happens when various frequency components of a signal are delayed by different amounts during transmission. The delay distortion is caused by the transmission line’s inductive and capacitive components.

13. Refer to Figure 9-6 and the related discussion.

14. Modems enable the transmission of digital data over analog phone lines. Phone lines are widely available.

15. This maps the use of the telephone network, 9:00-11:00 AM, 2:00-4:00PM.

16. Erlangs or hundred-call seconds.

17. A situation in a telephone switching office when calls are unable to reach their destination

18. Grade of service (B) = $\dfrac{number\ of\ calls\ lost}{number\ of\ calls\ offered}$ $or\ B = \dfrac{traffic\ lost}{traffic\ offered}$

19. The grade of service is verified using traffic scanning devices. The lower the number the higher the grade of service.

20. Customer calling patterns are recorded. This provides data for establishing toll rates, developing contingencies for network failures, forecast future demands and project capital expenditures.

21. Synchronous - implies that the transmit and receive data clocks are locked together (example computer - printer)
Asynchronous - implies that the transmit and receive clocks are not locked together and the data must provide start and stop information.

22. Protocol - a set of rules to make devices sharing a channel observe orderly communication procedures

23. Binary coding systems are generally more efficient than other systems and provide better noise immunity . A possible disadvantage is the complexity of implementing a fully digital solution but this is becoming less of an issue.

24. Coding - transforming messages or signals in accordance with a definite set of rules.
Bit - unit of information required to allow proper selection of one out of two equally probable events.

25. NRZ - see Table 9-1, 0-low and 1 - high
RZ - same limitations and disadvantages of NRZ, includes RZ-unipolar, RZ-bipolar RZ-AMI (see Fig. 9-9 and Table 9-2)
Phase Coded Binary - see Table 9-3
Multilevel Binary - see Table 9-4

26. The plots of 1 1 0 1 0 are provided in the first five bits of Figure 9-9 for each format.

27. The bipolar pulse +/- which reduces the DC component. Unipolar codes pulse in one direction and have a dc component.

28. The bi-phase codes are considered to be self-synchronizing or self-clocking. The data stream transitions relative to the clock interval.

29. TDM is a technique used to transport data from multiple sources over the same data channel.

30. Guard times are time added to the TDMA frame to allow for the variation in data arrival.

31. See Figure 9-11

32. See Table 9-5

33. 24 telephone calls

$$\begin{aligned} 24\ channels\ x\ 64 kbps/channel &= 1.536 Mbps \\ +\ framing\ bits &= 8 kbps \\ \hline Total\ Rate &= 1.544 Mbps \end{aligned}$$

34. fractional T1 - a term used to indicate that only a portion of the data bandwidth of a T1 line is being used.

35. Point-of-presence - the point where the users connect their data to the communications carrier.

36. The CSU/DSU provides the data interface to the communications carrier providing framing and line management.

37. The data are divided into small segments called packets. They are held for short periods of time at switching centers and therefore transmitted in near real-time.

38. Frame relay is a packet switching network designed to carry data traffic over Telco. Frame relay operates on the premise that the data channel will not introduce bit error thereby the need for overhead bits is minimized.

39. ATM is a cell relay technique, all stations are constantly transmitting cells.

40. ISDN is physically “in band” and logically “out of band”. SS7 is both physically and logically “out of band.

41. Layers 1-3.

42. Layers 1-7.

43. Layer 7, ISUP, communicates directly with MTP 3, SCCP, TCAP, and OAM.

44. IAM (starts the call), ACM (the phone is ringing), ANM (the called party picks up the phone), REL (either the called or calling party hangs up the phone), and RLC (the voice trunk is available for another call).

45. A protocol analyzer.

46. A number that identifies the switch nearest to the caller.

47. A number that identifies the switch nearest to the called party.

48. A number that identifies the trunk used for the SS7 message.

49. 35, someone hangs up the phone.

1. 802.11b - 11 Mbps 802.11a - 54 Mbps 802.11g - 54 Mbps

2. 5.8 GHz and 2.5 GHz

3. because of its improved NLOS characteristics

4. Frequency assignments differ, data rates differ but the main difference is the WiMax unit only has to compete once to gain entry into the network.

5. Uplink – TDMA, Downlink – TDM
The uplink is TDMA so any WiMax unit can get access to the network. The downlink is TDM to make sure time sensitive data is delivered on time.

6. the 2.4 GHz ISM band.

7. Bluetooth has three operating classes.

Bluetooth Output Power Classes

Power Class	Maximum Output Power	Operating Distance
1	**20 dBm**	**~ 100 m**
2	**4 dBm**	**~ 10 m**
3	**0 dBm**	**~ 1 m**

8. an ad hoc network of up to eight Bluetooth devices.

9. used by Bluetooth to discover other Bluetooth devices or to allow itself to be discovered.

10. it is used to establish and synchronize a connection between two Bluetooth devices.

11. refers to the reflection of the radio waves striking the RFID tag and reflecting back to the transmitter source.

12.
    1. means of powering the tag
    2. frequency of operation
    3. communication protocol

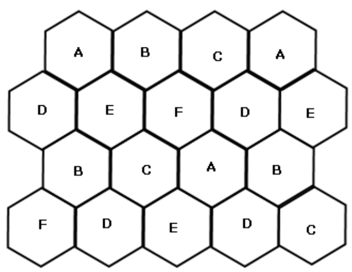
13. power is provided by rectifying the RF energy transmitted by the reader that strikes the RF tag antenna.

14. the two dipoles of the dual dipole antenna are oriented at 90° angles to each other which means that tag orientation is not critical

15.
1. can incorporate wireless Ethernet connectivity
2. can incorporate location capability
3. the unit is always turned "on"

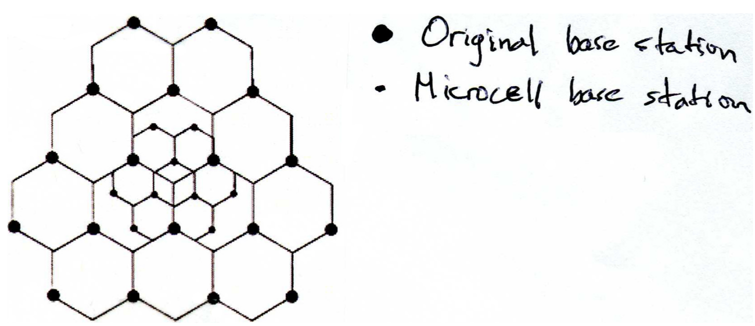
16. LF – 125/134 kHz, HF - 13.56 MHz, UHF – 860-960 MHZ and 2.4 GHz

17.



18. Frequency reuse is the process of using the same carrier frequency in different cells that are graphically separated. Cell splitting results from reducing the size of the coverage area.

19. A split-cell system is one in which congested cells are subdivided into smaller cells called microcells. If each microcell base station is placed halfway between those serving larger cells, as shown in the figure below, then the system will retain its original hexagonal geometry, albeit scaled down to accommodate four times as many cells as before. With the appropriate reduction in transmitter power and antenna height, the microcells can be integrated into the system without the need for modification to the system's frequency reuse plan. The most commonly used reuse plans (N = 4, N = 7, or N = 12) could continue to be employed without the need for a system retune.



20. Mobile unit samples all received "set-up" channels and selects the strongest signal. The mobile units synchronize the data streams and tunes to the assigned channel to place the call. While in operation, the mobile unit monitors for a change in a cell site.

21. As first discussed in Question 19, a cell-splitting configuration preserves the original channel reuse plan because the underlying system geometry is unaffected. Therefore, the channel-reuse plan established for macrocells can also be used in split-cell systems with each split cell base station operating at reduced power and with lower antenna height. The optional configurations are clusters of radio-frequency channels, N, established by the relation

$$N = i^2 + ij + j^2,$$

where i and j each represent the number of cells traveled in one direction (i) and then in a direction oriented 60° counter-clockwise (j) before the channel group is reused. From the above expressions, the optimal values for the clustered channels, both before and after cell-splitting, are N = 4, N = 7, N = 12, or N = 19.

22. Rayleigh fading is the rapid variation in signal strength received by mobile units in urban environments. Digital systems provide significant improvement.

23. $5280\,ft/mi \times 40\,mi/hr \times hr/3600\,\text{sec} = 58.67\ ft/\text{sec}$

$58.67\,ft/\text{sec} \times 12\,in/ft \times 0.0254\,m/in = 17.8\ m/s$

$$\lambda = \frac{c}{f} = \frac{3\times10^8\ m/s}{840\,MHz} = 0.357m \quad \lambda/2 = 0.179m \quad \frac{17.88\,m/s}{0.179\,m} = \mathbf{100\,\textit{fades}/sec}$$

24. $$2\ dB = 10\ \log\frac{P}{0.7} \quad 0.2 = \log\frac{P}{0.7}$$

$$10^{0.2} = \frac{P}{0.7} \quad P = \mathbf{1.11\ W}$$

25. The base station communicates with the mobile user. The switch collects calls from many base stations and places the calls into the PSTN. The PSTN routs the calls to the switch nearest the called party location.

26. GSM and CDMA.

27. 30 KHz.

28. $\pi/4$ DQPSK

29. ETSI

30. GMSK

31. 8

32. 6

33. Equalizing filter.

34. Rake receiver.

35. It is like a lighthouse. It constantly looks for users.

36. Code 0, which is the Pilot Signal.

37. It is the synchronizing signal.

38. SCH

39. TIA

40. CDMAone

41. Walsh codes.

42. PN offset.

43. The system noise level increases.

44. GPS satellites provide the frequency reference. The frequency is 1.575 GHz and the power level is about –140 dBm.

45. Unmodulated carrier that leaks through to the output signal. The specified level is that it be at least 25 dB below the carrier signal.

46. Signals that interfere with: GPS signal, uplink, and downlink.

47. $F_{out} = n F_1 \pm mF_2$

48. Rusty fences and piles of rusty metal.

49. a) Span is 15 MHz, across the entire display, for both photos.
b) Power for the vertical photo and time for the lower photo.
c) 3 MHz
d) 87

50. a) Horizontal is time and vertical is frequency.
    b) -3.75 MHz.
    c) About 1.5 MHz KHz.

51. The WAP standard has been developed to bridge the gap between mobile communications, the Internet, and corporate Intranets.

52. confidentiality, integrity, authentication, non-repudiation, availability of the network

53. It is a guarantee that any modification to the data set can be detected.

54. An interfering signal is transmitted over the same channel thereby disrupting or slowing down communication.

55. passive – bad guy is just listening
    Active – the bad guy is disrupting the communication link.

56. internal – protection is often put in place to protect against external threats but not necessarily against inside attacks.

57. to prevent eavesdropping

58. the secret code used in the encryption algorithm to both create and decode the message

1. ASCII - American Standard Code for Information Interchange
   EBCDIC - Extended Binary-Coded Decimal Interchange Code

2. 5 - 0 1 1 0 1 0 1
   a - 1 1 0 0 0 0 1
   A - 1 0 0 0 0 0 1
   STX - 0 0 0 0 0 1 0

3. 5 - 0 1 0 1 1 1 1 1
   a - 0 0 0 1 0 0 1 0
   A - 0 0 0 1 0 0 1 1
   STX - 0 0 1 0 0 0 1 0

4. The Gray code is based on the relationship that only one bit in a binary word changes for each binary step.

5. The Gray code is used in telemetry and systems with slowly changing data.

6. RS 232 is an EIA standard. It is still used in many applications but it is slowly being replaced by USB.

7. RED +5 Brown - Ground Yellow - Data Blue - Data

8. Upstream

9. Handshaking is flow control.

10. USB supports up to 480 Mbps Firewire supports up to 800 Mbps

11. See Figure 11-6, Type A is upstream, which connects to the computer. Type B is downstream and connects to the peripheral.

12. A network of users that share computers in a limited area.

13. BUS - an older style of hardwired topology but the concept applies to modern wireless networks. TOKEN-RING - passes a token for control of the network. STAR - a central hub or switch interconnects the networking devices.

14. Ethernet is best described as carrier sense multiple access with collision detection (CSMA/CD).

15. The Ethernet frame structure is provided in Figure 11-17. The MAC address is 12 hexadecimal characters made up of the vendor code and vendor assigned board ID.

16. A broadcast is defined by all 1's in the address.

17. See Figure 11-19

18. See Figure 11-20 and the related discussion.

19. See Table 11-5

20. LAN - Local Area Network (limited geographic area), MAN - Metropolitan Area Network (metro area), WAN - Wide Area Network (regional, national, worldwide)

21. OSI - see Figure 11-21 and the related discussion

22. Bridges - use MAC addressing to interconnect LANs
    Routers - use layer 3 addressing to interconnect networks

23. Developed from ARPANET, uses TCP/IP addressing, provides extensive worldwide inter-connectivity.

24. IP addresses are divided into five classes. Classes A, B, C are used to route data over the Internet, Class D is used for Multicasting, and Class E is an experimental range.

25. Many sites are available. Keyword for the student's search include cellular, wireless, and PCS.

26. IP telephony is the use of routing telephone traffic over a data network.

27. QoS issues are very important when considering telephone service; key issues include reliability (uninterrupted service), 911 service, etc.

28. ADSL - Asymmetric DSL provides data rates up to 1.544 Mbps upstream and up to 8 Mbps downstream.

29. Cable modems use the high bandwidth of the cable television systems to provide data rates from (128 kbps to 10 Mbps) upstream to (10 to 30 Mbps) downstream. A technique called ranging is used by the modem to determine the time it takes for data to travel to the cable head-end.

30. V.92/V.90 uses asymmetric operation, analog (customer-to Telco) and digital (ISP-Telco-customer).

31. The advantage is a standardized digital interface.

32. See Table 11-7

33. DMT is an industry standard that uses multiple subchannel frequencies to carry the data.

34. You can expect significant data loss without the equalization.

35. Handshaking is not actually a standard protocol but rather a way to describe that both ends of the communication line recognize each other and know how to exchange data.

36. You need to know the point of presence.

1. A transmission line is defined as the conductive connections between the system elements that carry signal power. The effects of carrying a signal over wire are very complex and these effects vary greatly with frequency.

2. Two-wire, Open wire, Twisted Pair, Unshielded Twisted Pair, Shielded Twisted Pair, Coaxial lines, Balanced and Un-balanced lines (see section 12-2)

3. Flexibility of solid dielectric, expense of rigid coaxial lines

4. To keep moisture out.

5. In computer networks.

6. A category describing the performance specification for the cable.

7. NEXT - a measure of crosstalk or signal coupling.

8. PSNEXT - a measure of the total crosstalk for all four wire-pairs.

9. Unbalanced line - signal is carried in one wire and the other is at ground.
   Balanced line - same current flows in each wire but 180° out of phase.

10. The noise on each line of the balanced cable is 180° out of phase. The signals cancel when added together. Today, the common signal to both lines is removed by a differential amplifier. The common signals are rejected.

11.

$$10\log\left(\frac{.011\,\mu W}{5\,mW}\right) = \mathbf{-56.6\,dB}$$

12. See Figure 12-9

13. This is the input impedance exactly matched to its characteristic impedance called Zo, (see Equation 12-1)

14.

$$Z_0 = \sqrt{\frac{L}{C}} = \left(\frac{4\times10^{-9}}{1.5\times10^{-12}}\right)^{1/2} = \mathbf{51.6\Omega}$$

15.

$$Z_0 = \sqrt{\frac{L}{C}}$$

$$50\Omega = \left(55\times\frac{10^{-9}}{C}\right)^{1/2}$$

$$C = \frac{55\times10^{-9}}{(50)^2} = \mathbf{22\,pF/m}$$

16. Connect the transmission line to the impedance bridge and read to measurement.

17. If D increases, Zo increases (refer to Equation 12-9)

18. This problem assumes that d increases therefore Zo decreases. (Refer to Equation 12-9)

19. The surge impedance of a two-wire transmission line depends on the ratio of the distributed inductance and capacitance in the line.

20.

$$a.\quad Z_0 \simeq 276\ \log\frac{2D}{d} = 276\ \log 6 = \mathbf{215\ \Omega}$$

$$b.\quad Z_0 \simeq \frac{138}{\sqrt{\epsilon}}\ \log\frac{D}{d} = \frac{138}{\sqrt{1}}\ \log 1.5 = \mathbf{24.3\Omega}$$

$$c.\quad Z_0 = \frac{138}{\sqrt{\epsilon}}\ \log\frac{D}{d} = \frac{138}{\sqrt{2.3}}\ \log 2.5 = \mathbf{36.2\ \Omega}$$

21. Copper losses - at high frequencies the losses are due primarily to the skin effect
Dielectric losses - proportional to the voltage across the dielectric, increasing with frequency.
Radiation or induction losses - these can be greatly reduced by terminating the line with a resistive load equal to Zo and properly shielding the line.

22.

$$P = i^2R$$

$$10\,kW = 4.8^2R \qquad R = 434\ \Omega$$

$$P_{trans} = 5^2\times434\Omega = 10.85\,kW$$

$$Thus,\ P_{loss}\ in\ line = 10.85\,kW - 10\,kW = \mathbf{850\ W}$$

23. Surge impedance - another name for characteristic impedance.

24. This derivation is provided in equations 12-12 to 12-19.

25. Velocity $\approx 3 \times 10^8$ meters/second

26.

$$for\ RG\text{-}8A/U\quad delay/ft = 1.475\,ns\ (Ex\ 12\text{-}3)$$

$$\therefore \frac{5\ ns}{1.475\ ns/ft} = \mathbf{3.39\,feet}$$

27. This is the ratio of the actual velocity to the velocity in free space.

28.

$$v_p = = \frac{d}{\sqrt{LC}} = \frac{20x10^3 m}{\sqrt{7.5x10^{-12}}} = 7.3x10^9 m/s$$

29.

$$f = 500\,GHz \qquad \therefore \lambda = \frac{7.3x10^9 m/s}{500x10^9 cycles/second} = .0146\,m$$

30.

$$\frac{20ft.}{600ft./\text{sec}} = \mathbf{33.3\,ms}$$

31. Non-resonant line - one of infinite length or that is terminated with a resistive load equal in ohmic value to its characteristic impedance. The length is not critical and the voltage and current waves move in phase with one another.

32.

$$P = i^2 R$$
$$Z_0 = 500\Omega = Z_L\ (if\ properly\ matched)$$
$$\therefore Z\ seen\ at\ the\ input = Z_0 = Z_L = 500\Omega$$
$$P = 3^2 \times 500\ \Omega = \mathbf{4.5\,kW}$$

33. Figure 12-15 shows the wave travel. The waveform plotted at any point is a duplicate of the source signal.

34. Resonant line - a transmission line terminated with an impedance that is not equal to its characteristic impedance. Reflected waves are generated by the impedance mismatch. See Figures 12-17 and 12-18.

35. See Figure 12-17

36. See Figure 12-18

37. Standing waves - waveforms that apparently seem to remain in one position, varying only in amplitude.
SWR - another name for voltage standing wave ratio, the ratio of the maximum or minimum voltage on a line.
Characteristic impedance - the input impedance of a transmission line either infinitely long or terminated in a pure resistance equal to its characteristic impedance.
Standing waves are minimized by impedance matching.

38. Refer to the text discussion for Figure 12-19 in section 12-6.

39.

$$f = \frac{1}{T} = \frac{1}{1\times10^{-6}} = 1\ MHz$$

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}\ m/s}{1\times10^{6}} = \mathbf{300\ m}$$

40.

$$\lambda = \frac{c}{f} = \frac{186{,}000\,mi/\sec}{950\,kHz} = 0.1958\,mi\ \ (=360°)$$

$$\therefore 120° = \frac{360°}{3} = \frac{0.1958}{3} = 0.06526\,mi = \mathbf{345\,ft}$$

41.

$$\textit{reflection coefficient}\quad \Gamma = \frac{E_r}{E_i}\ ,\ \Gamma = \frac{Z_L - Z_o}{Z_L + Z_o}$$

42.

$$VSWR = \frac{E_{\max}}{E_{\min}},\ VSWR = \frac{I_{\max}}{I_{\min}}\quad VSWR = \frac{1+|\Gamma|}{1-|\Gamma|},\quad VSWR = \frac{Z_o}{R_L}\ \ or\ \ \frac{R_L}{Z_o}$$

43. A mismatched line leads to a higher VSWR

44. Minimize the VSWR

45. They are 180º out of phase causing cancellation of the reflections.

46.

$(a)\ \Gamma = \frac{150-50}{150+50} = \frac{1}{2} = 0.5$

$(b)\ \lambda = \frac{v}{f} = \frac{2.07x10^8 m/s}{2.27x10^6 Hz} = 91.19m \quad 75ft. = 22.86 meters$

$electrical\ \ length\ \ is \frac{22.86m}{91.19 meter/wavelength} = .25\lambda$

$(c)\ SWR = \frac{150}{50} = 3$

$(d)\ P_{load} = 200 - 50 = 150W$

47.

$Z'_o = \sqrt{600x70} = 204.9\Omega$

48. Using the Smith chart, we first normalize the load impedance (call it point A)

$$z_L = \frac{Z_L}{Z_o} = \frac{50 + j75}{75} = 0.666 + j1$$

Read the location from the WTG scale at A. The load is located at 0.1425λ. We must travel 675 degrees from the load towards the generator. The distance traveled in wavelengths is

$$\frac{675}{369} = 1875\ wavelengths$$

We add the two together to get the input, Point B on the Smith chart.

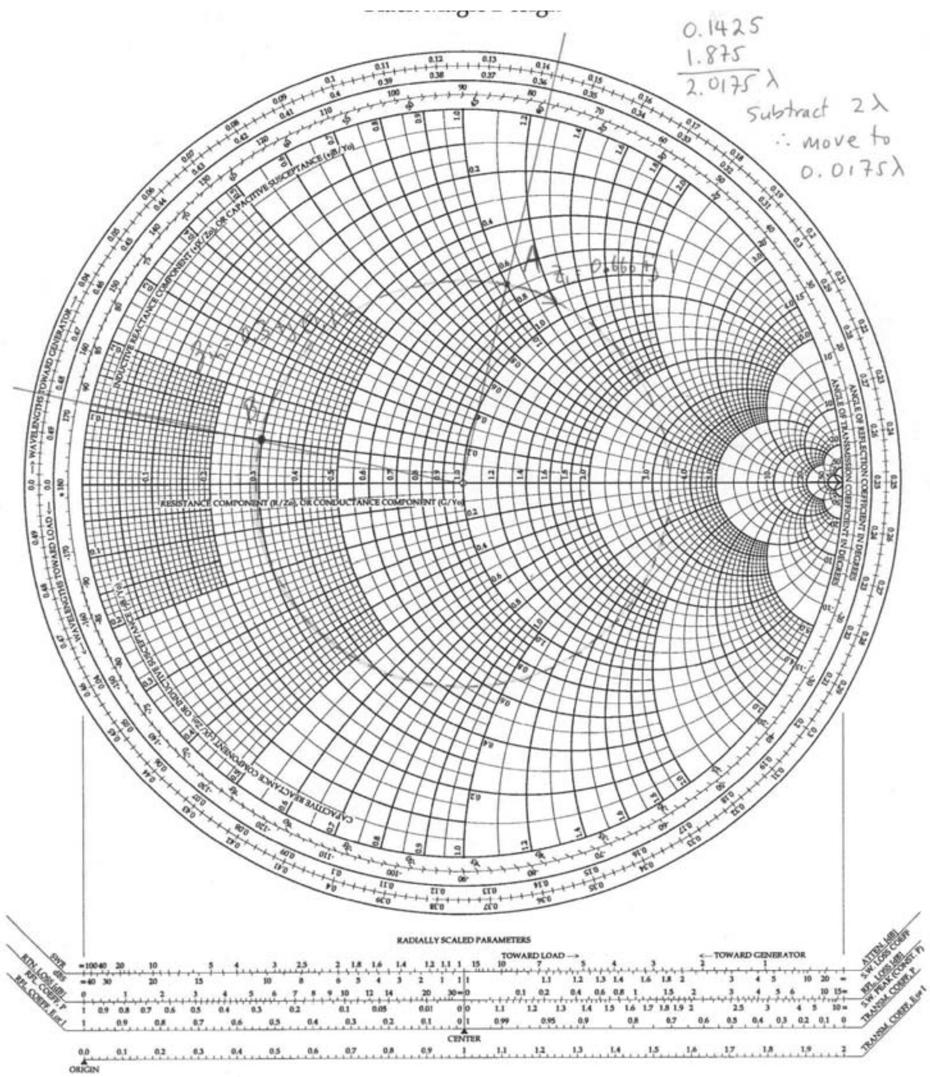
$$0.1425\lambda + 1.875\lambda = 2.0175\lambda$$

The normalized impedance read at Point B is

$$Z_{in} = 0.3 + j0.1$$

Thus, the input impedance is

$$Z_{in} = z_{in}Z_o = (0.3 + j0.1)75 = 22 / 5 + j7.50\ \Omega$$


0.1425
1.875
2.0175 λ
subtract 2λ
∴ move to
0.0175λ
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
RADIALLY SCALED PARAMETERS
TOWARD LOAD →
← TOWARD GENERATOR
CENTER
ORIGIN

$$j := \sqrt{-1}$$

The load impedance is $Z_L := 50 + j\cdot 75\,\Omega$

The characteristic impedance is $Z_o := 75\,\Omega$

The line was previously found to be 1.875λ long, compute the electrical length

$$\beta L := 2\cdot\pi\cdot 1.875$$

Use Eq. 11-30

$$Z_{in} := Z_o\cdot\frac{Z_L + j\cdot Z_o\cdot\tan(\beta L)}{Z_o + j\cdot Z_L\cdot\tan(\beta L)} \qquad Z_{in} = 22.5 + 7.5i\,\Omega$$

Now work it using Eq. (12-30)

The results are the same. Ordinarily the Smith chart is not read with sufficient precision to yield exact answers.

49. Using the Smith chart, first normalize the impedance. For the purposes of this problem assume that $Z_o = 50\ \Omega$ (simply because the only Smith chart handy is a normalized one). Call the impedance location Point A. (The Smith chart is presented on the next page.)

$$z_L = \frac{Z_L}{Z_o} = \frac{62.5 - j90}{50} = 1.25 - j1.8$$

Construct a line through the center of the chart and Point A. Extend it the same distance in the opposite direction. Read the normalized admittance at Point B.

$$y_L = 0.26 + j0.37$$

$$\frac{1}{62.5 - j\cdot 90} = 5.206\times 10^{-3} + 7.496i\times 10^{-3} \quad \text{S}$$

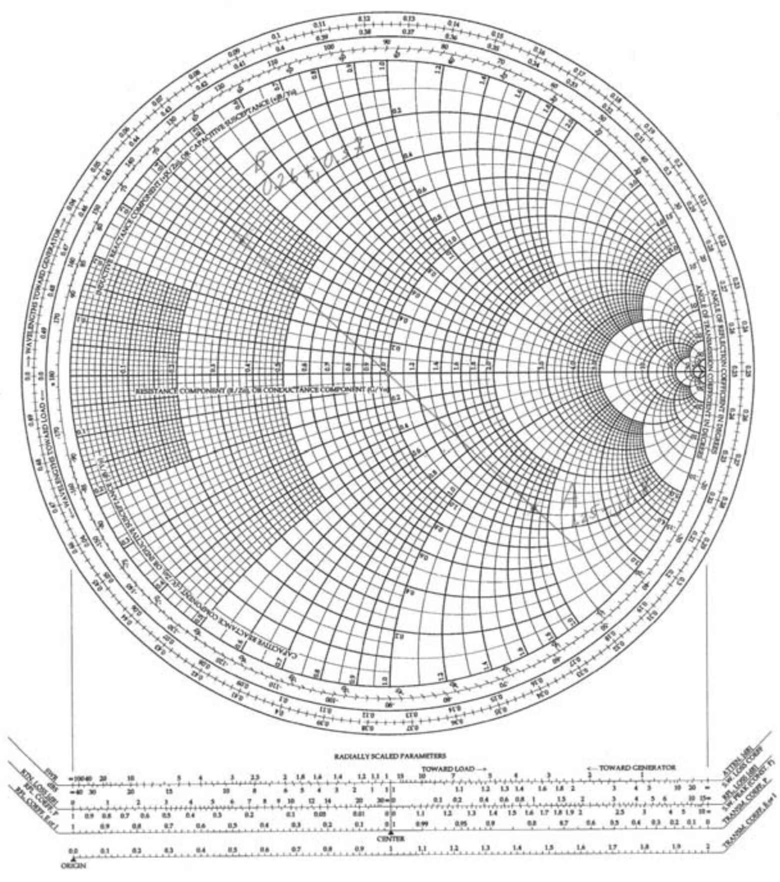
Determine the admittance by multiplying by the characteristic admittance.

$$Y_L = y_L\, Y_o = \frac{y_L}{Z_o} = \frac{0.26 + j0.37}{50} = 0.0052 + j0.0074 \quad S$$

Now compute the admittance directly by taking the reciprocal of the impedance (in this case we don't need to assume a value of characteristic impedance).

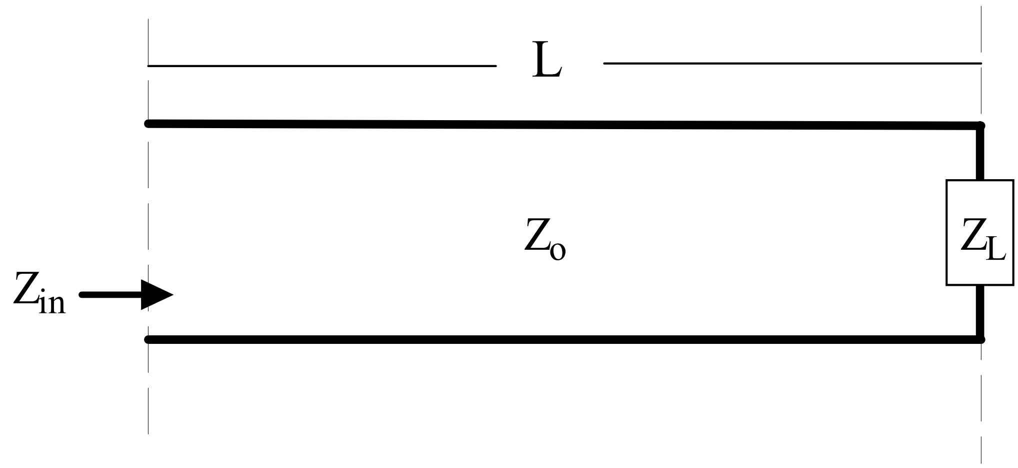
The analytical result is slightly different.

$$Y_L = 0.005206 + j0.007496 \quad S$$



Problem 12-49

50. Find the input impedance of a 100-Ω line, 5.35 λ long, and with $Z_L = 200 + j\,300\ \Omega$.



The load impedance is $Z_L := 200 + j \cdot 300\ \Omega$ $\qquad j := \sqrt{-1}$

The characteristic impedance is $Z_o := 100\ \ \Omega$

The line is specified to be 5.35λ long, compute the electrical length

$$\beta L := 2 \cdot \pi \cdot 5.25$$

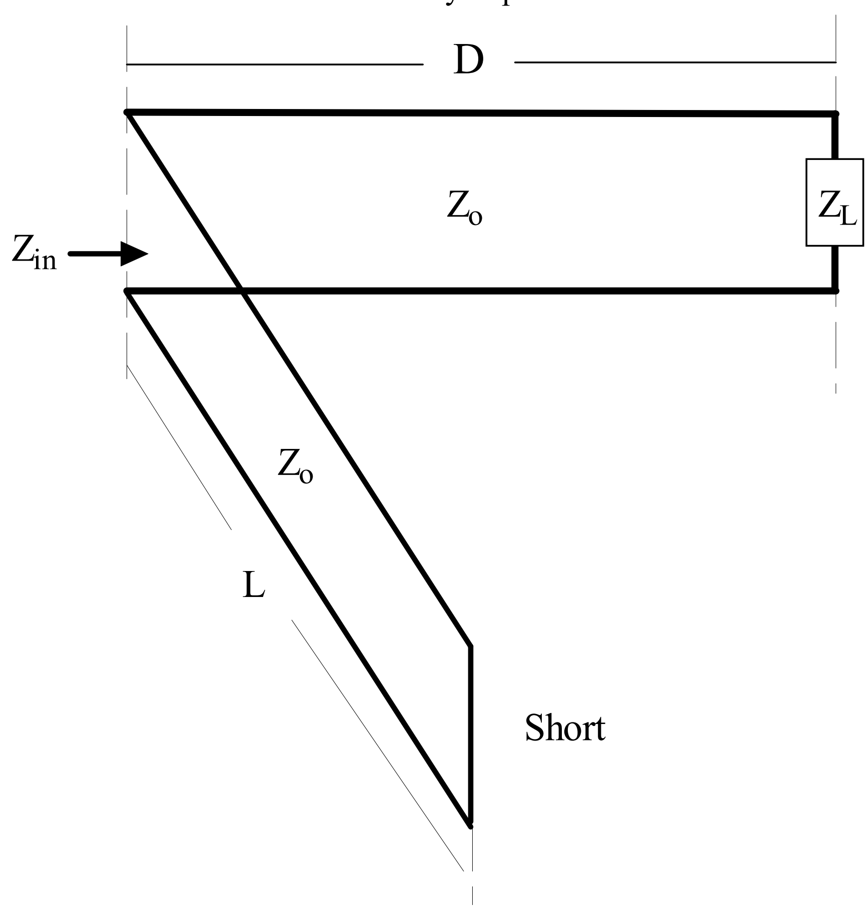
Use Eq. 11-30

$$Z_{in} := Z_o \cdot \frac{Z_L + j \cdot Z_o \cdot \tan(\beta L)}{Z_o + j \cdot Z_L \cdot \tan(\beta L)} \qquad Z_{in} = 15.385 - 23.077i\Omega$$

51. The characteristic impedance of the transmission line must match the transmitter's output impedance to prevent energy from being reflected back into the transmitter, possibly causing damage to the final amplifier stages. Also, maximum power is coupled to the line when line and transmitter impedances are equal (maximum power transfer theorem). For this reason, transmitters are designed to have output impedances equal to those of commonly used transmission lines (most often 50 ohms for radio-frequency systems).

52. Stub tuning makes use of lengths of transmission line to act as inductors and/or capacitors. As shown in Figure 12-33 in the text, transmission-line sections less than, equal to, or greater than one-quarter wavelength behave alternately as series or parallel LC networks or as capacitances or inductances. The reactive properties of such components can be used, either in series or (more often) in parallel to "tune out" or cancel unwanted reactances by adding an opposite-type reactance in series or admittance in parallel. This is to cause a complex load to act purely resistive, and if the resistance is equal to that of the source and transmission line impedances, then a good match is achieved, thereby minimizing reflections.

53. The antenna load on a 150-Ω transmission line is 225 - j 300 Ω. Determine the length and position of a short-circuited stub necessary to provide a match.



First the analytic solution

$Z_o := 150 \quad \Omega \qquad R_L := 225 \quad \Omega \qquad X_L := -300 \quad \Omega$

Now, if the load of impedance Z_L is to be matched Z_o line using a stub of impedance Z_o
Let the distance from the load to the stub be D and the length of the stub be L

$$T_1 := \frac{-X_L + \sqrt{X_L^{\,2} - (Z_o - R_L)\cdot\left[\frac{(R_L^{\,2} + X_L^{\,2})}{Z_o} - R_L\right]}}{Z_o - R_L} \qquad T_1 = -9.05$$

$$T_2 := \frac{-X_L - \sqrt{X_L^{\,2} - (Z_o - R_L)\cdot\left[\frac{(R_L^{\,2} + X_L^{\,2})}{Z_o} - R_L\right]}}{Z_o - R_L} \qquad T_2 = 1.05$$

First Solution

$$D_1 := \frac{\mathrm{if}(\mathrm{atan}(T_1) > 0, \mathrm{atan}(T_1), \mathrm{atan}(T_1) + \pi)}{2\cdot\pi} \qquad D_1 = 0.268 \quad \lambda$$

Second Solution

$$D_2 := \frac{\mathrm{if}(\mathrm{atan}(T_2), \mathrm{atan}(T_2), \mathrm{atan}(T_2) + \pi)}{(2\cdot\pi)} \qquad D_2 = 0.129 \quad \lambda$$

Now find the stub lengths corresponding to the two solutions

$$Y_L := \frac{1}{R_L + j \cdot X_L} \qquad Y_o := \frac{1}{Z_o}$$

The input susceptance of the line Zo without the stub attached. Solutions 1 and 2

$$\beta D1 := 2 \cdot \pi \cdot D_1$$

$$B_1 := \mathrm{Im}\left(Y_o \cdot \frac{Y_L + j \cdot Y_o \cdot \tan(\beta D1)}{Y_o + j \cdot Y_L \cdot \tan(\beta D1)}\right) \qquad B_1 = -0.011 \quad \mathrm{S}$$

$$\beta D2 := 2 \cdot \pi \cdot D_2$$

$$B_2 := \mathrm{Im}\left(Y_o \cdot \frac{Y_L + j \cdot Y_o \cdot \tan(\beta D2)}{Y_o + j \cdot Y_L \cdot \tan(\beta D2)}\right) \qquad B_2 = 0.011 \quad \mathrm{S}$$

For a ***short-circuited*** stub we find the lengths as

$$L_1 := \frac{\mathrm{if}\left(\mathrm{atan}\left(\frac{Y_o}{B_1}\right) > 0, \mathrm{atan}\left(\frac{Y_o}{B_1}\right), \mathrm{atan}\left(\frac{Y_o}{B_1}\right) + \pi\right)}{(2 \cdot \pi)} \qquad L_1 = 0.415 \quad \lambda$$

$$L_2 := \frac{\mathrm{if}\left(\mathrm{atan}\left(\frac{Y_o}{B_2}\right) > 0, \mathrm{atan}\left(\frac{Y_o}{B_2}\right), \mathrm{atan}\left(\frac{Y_o}{B_2}\right) + \pi\right)}{(2 \cdot \pi)} \qquad L_2 = 0.085 \quad \lambda$$

Now use the Smith chart. Normalize the impedance. Call it Point A.

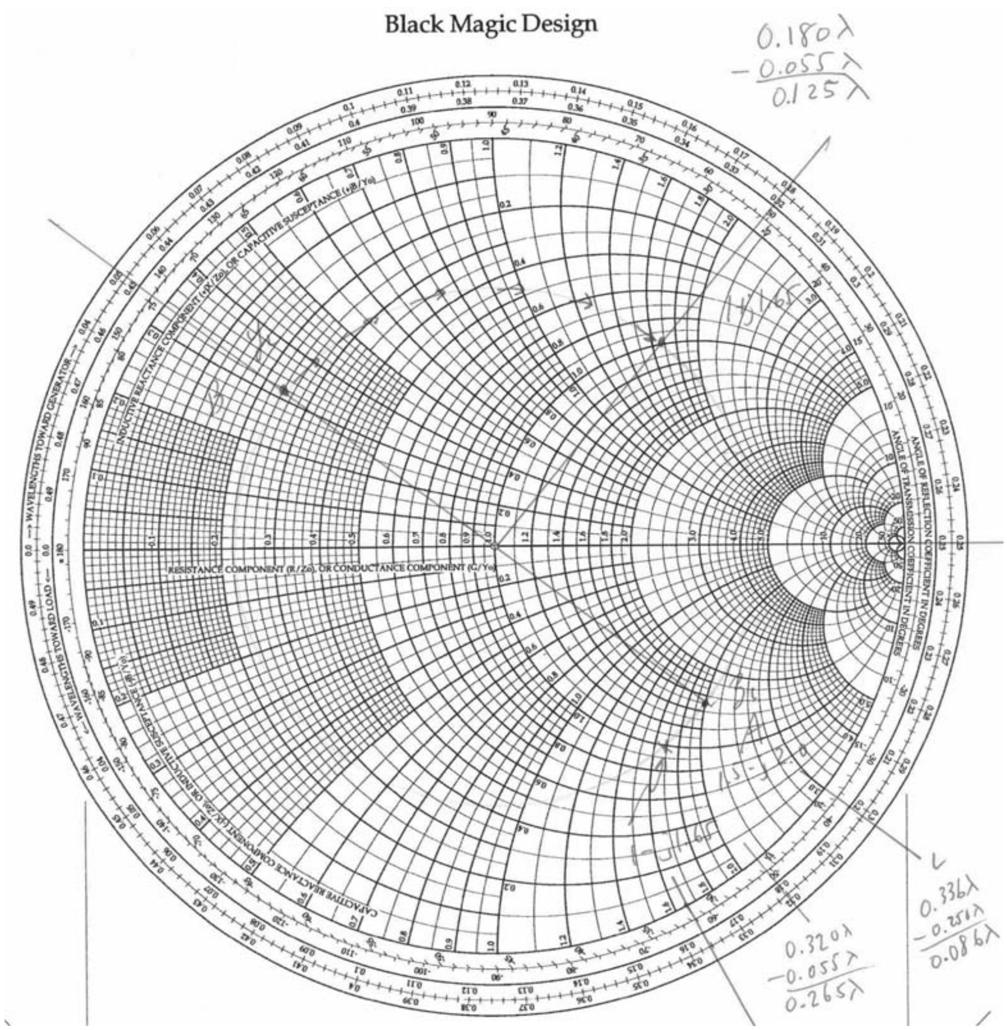
$$z_L = \frac{225 - j300}{150} = 1.5 - j2.$$

Convert to admittance. Call it Point B. Then transform to Point C, 1 + j 1.65. This corresponds to the second analytical solution above.

From the Smith chart.

D = 0.180 - 0.055 = 0.125 λ

L = 0.336 - 0.250 = 0.085 λ



54. Repeat Problem 53 for a 50-Ω line and an antenna of 25 + j 75 Ω. First the analytical solution

$Z_o := 50 \quad \Omega \qquad R_L := 25 \quad \Omega \qquad X_L := 75 \quad \Omega$

Now, if the load of impedance Z_L is to be matched Z_o line using a stub of impedance Z_o. Let the distance from the load to the stub be D and the length of the stub be L

$$T_1 := \frac{-X_L + \sqrt{X_L^{\,2} - (Z_o - R_L)\cdot\left[\frac{(R_L^{\,2} + X_L^{\,2})}{Z_o} - R_L\right]}}{Z_o - R_L} \qquad T_1 = -0.764$$

$$T_2 := \frac{-X_L - \sqrt{X_L^{\,2} - (Z_o - R_L)\cdot\left[\frac{(R_L^{\,2} + X_L^{\,2})}{Z_o} - R_L\right]}}{Z_o - R_L} \qquad T_2 = -5.236$$

First Solution

$$D_1 := \frac{\mathrm{if}(\mathrm{atan}(T_1) > 0, \mathrm{atan}(T_1), \mathrm{atan}(T_1) + \pi)}{2\cdot\pi} \qquad D_1 = 0.396 \quad \lambda$$

Second Solution

$$D_2 := \frac{\mathrm{if}(\mathrm{atan}(T_2) > 0, \mathrm{atan}(T_2), \mathrm{atan}(T_2) + \pi)}{(2\cdot\pi)} \qquad D_2 = 0.28 \quad \lambda$$

Now find the stub lengths corresponding to the two solutions

$$Y_L := \frac{1}{R_L + j\cdot X_L} \qquad Y_o := \frac{1}{Z_o}$$

The input susceptance of the line Zo without the stub attached. Solutions 1 and 2

$$\beta D1 := 2\cdot\pi\cdot D_1$$

$$B_1 := \mathrm{Im}\left(Y_o\cdot\frac{Y_L + j\cdot Y_o\cdot\tan(\beta D1)}{Y_o + j\cdot Y_L\cdot\tan(\beta D1)}\right) \qquad B_1 = -0.045 \quad \mathrm{S}$$

$$\beta D2 := 2\cdot\pi\cdot D_2$$

$$B_2 := \mathrm{Im}\left(Y_o\cdot\frac{Y_L + j\cdot Y_o\cdot\tan(\beta D2)}{Y_o + j\cdot Y_L\cdot\tan(\beta D2)}\right) \qquad B_2 = 0.045 \quad \mathrm{S}$$

For a ***short-circuited*** stub we find the lengths as

$$L_1 := \frac{\mathrm{if}\left(\mathrm{atan}\left(\frac{Y_o}{B_1}\right) > 0, \mathrm{atan}\left(\frac{Y_o}{B_1}\right), \mathrm{atan}\left(\frac{Y_o}{B_1}\right) + \pi\right)}{(2\cdot\pi)} \qquad L_1 = 0.433 \quad \lambda$$

$$L_2 := \frac{\mathrm{if}\left(\mathrm{atan}\left(\frac{Y_o}{B_2}\right) > 0, \mathrm{atan}\left(\frac{Y_o}{B_2}\right), \mathrm{atan}\left(\frac{Y_o}{B_2}\right) + \pi\right)}{(2\cdot\pi)} \qquad L_2 = 0.067 \quad \lambda$$

Now use the Smith chart. Normalize the impedance. Call it Point A.

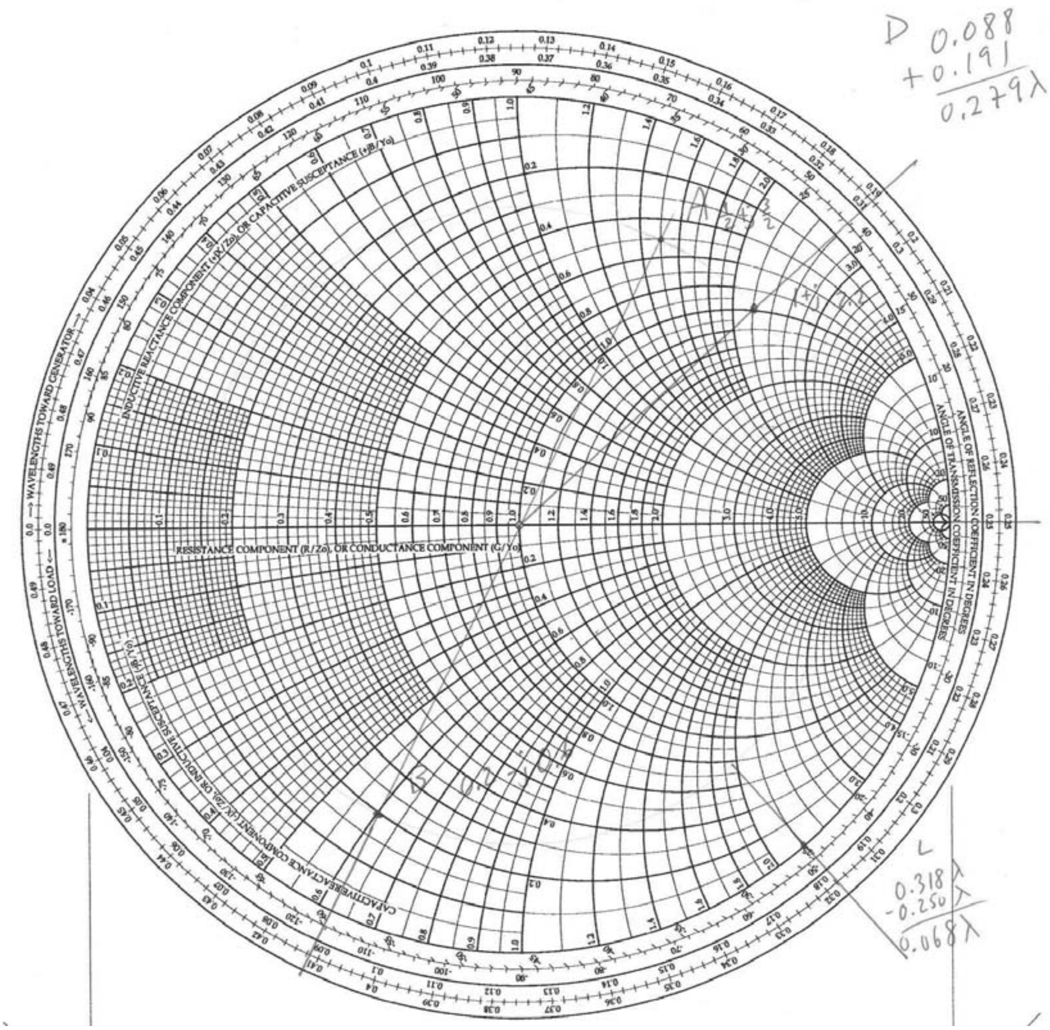
$$z_L = \frac{25 + j75}{50} = 0.5 + j1.5$$

Convert to admittance. Call it Point B. Then transform to Point C, 1 + j 2.2. This corresponds to the second analytical solution above.

From the Smith chart.

D = 0.088+ 0.191 = 0.279 λ

L = 0.318 - 0.250 = 0.068 λ



55. Given $L := 2 \times 10^{-9}$ H $Z_o := 50$ Ω

$f := 10^9$ Hz $\omega := 2 \cdot \pi \cdot f$ $\omega = 6.283 \times 10^9$

$X := \omega \cdot L$ $X = 12.566$ Ω

For a short-circuited line $Z_{in}^{SC} = jZ_o \tan(\beta d)$

Find the distance d required for the short-circuited line to look like a 2 nH inductance at 1 GHz. Equate the inductive reactance to the input impedance and solve for d. Assume the line has a dielectric.

$\lambda := \frac{3 \cdot 10^8}{f}$ $\lambda = 0.3$ meters

$d := \mathrm{atan}\left(\frac{X}{Z_o}\right) \cdot \frac{\lambda}{2 \cdot \pi}$ $d = 0.012$ meters

56. Given $C := 50 \times 10^{-12} F$ $Z_o := 50$ Ω

$f := 500 \cdot 10^6$ Hz $\omega := 2 \cdot \pi \cdot f$ $\omega = 3.142 \times 10^9$

$X := \frac{-1}{\omega \cdot C}$ $X = -6.366$ Ω

For a short-circuited line $Z_{in}^{SC} = jZ_o \tan(\beta\ d)$

Find the distance d required for the short-circuited line to look like a 2 nH inductance at 1 GHz. Equate the inductive reactance to the input impedance and solve for d. Assume the line has an dielectric.

$\lambda := \frac{3 \cdot 10^8}{f}$ $\lambda = 0.6$ meters

$$d := \text{if}\left(\text{atan}\left(\frac{X}{Z_o}\right) > 0, \text{atan}\left(\frac{X}{Z_o}\right), \text{atan}\left(\frac{X}{Z_o}\right) + \pi\right) \cdot \frac{\lambda}{2 \cdot \pi}$$

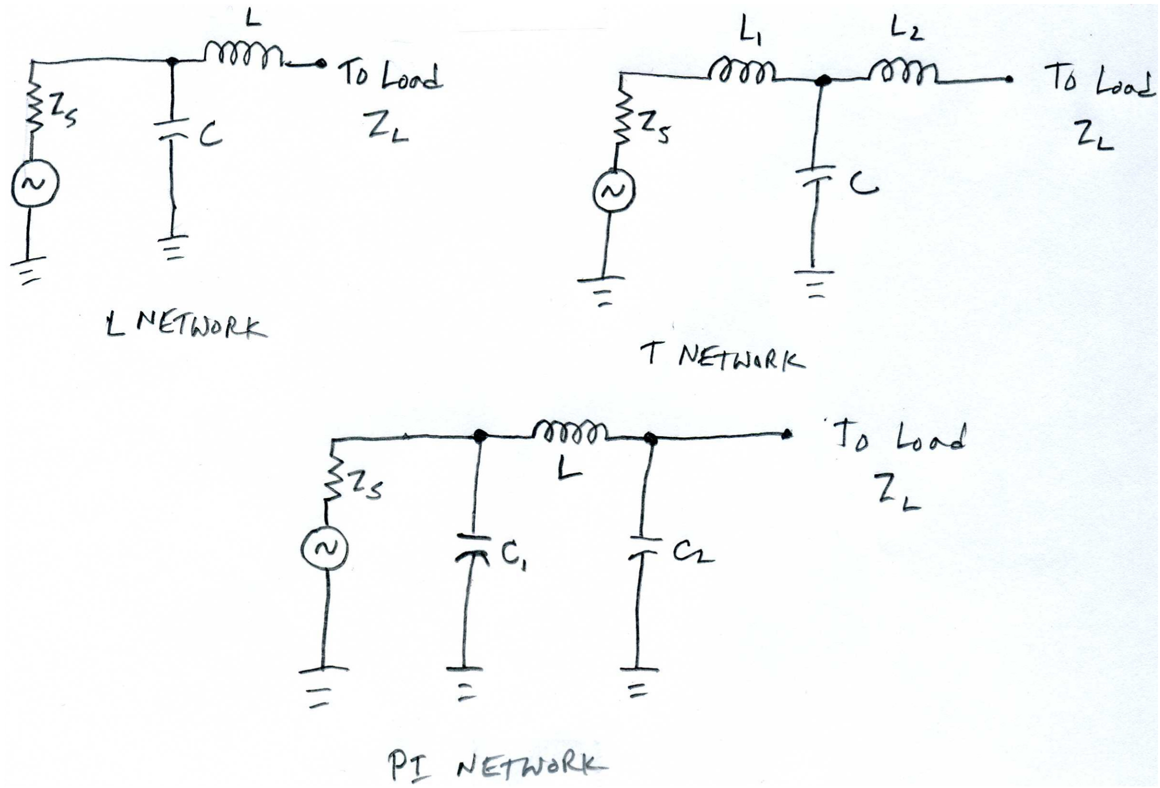
$d = 0.288$ meters

57. The two types of baluns are transformer-type, as shown in Figure 12-8 of the text, and transmission-line type, as shown in Figure 12-34. The purpose of a balun is to couple an unbalanced line (with one conductor at ground potential) to a balanced line (where both conductors are at an equal impedance from ground).

58. Harmonic radiation is best suppressed through the use of spectrally pure signal sources and output filters.

59. Harmonic radiation is prevented through the use of output filters at the final stages of transmitters. The output filter shown as the answer to Question 14 in Chapter 5 is one example. Other steps are to use linear amplifiers to the greatest degee possible and to use spectrally pure oscillators for the generation of radio-frequency signals.

60. In most cases, some form of impedance matching as well as output filtering is required. The most common impedance-matching networks are LC networks that also provide output filtering. Transformers and baluns are also used. The LC networks can be L networks, T networks, or pi networks. An example of each is shown below.



61. A slotted line is a section of coaxial line or waveguide into which a lengthwise slot has been cut into the outer conductor or waveguide wall. A pickup probe inserted into the slot effectively acts as a small antenna and couples a signal whose magnitude is proportional to the voltage between the conductors (or within the waveguide) at the point of insertion. The probe is movable and generally rides in a carriage along a calibrated scale. With this arrangement, the probe is used to measure he voltages of the standing-wave pattern as a function of distance. Knowledge of the standing-wave pattern allows for determination of characteristics including VSWR, generator frequency, and unknown load impedance.

62. Time-domain reflectometry (TDR) is a technique for determining transmission line characteristics and impedance mismatches. A short-duration pulse is applied to the line under test. The TDR instrument determines the distance to the fault by measuring the time a pulse takes to travel down the line and return to the source. Distance is calculated based on the known propagation velocity (velocity factor) for the cable unter test.

63. The pulse has traveled a total distance of $(2.1 \times 10^8 \text{ m/s})(0.731 \times 10^{-3} \text{ s}) = 153.51$ km. This distance represents both the incident (forward) and reflected distances traveled, so the fault is located one-half the calculated total distance, or 76.755 km, from the generator. Because the reflected voltage pulse is equal in magnitude but of opposite polarity to that of the incident pulse, two conclusions can be drawn. First, no energy has been absorbed by the load, so the line is either completely open-circuited (infinite impedance) or completely short-circuited (zero impedance). Second, the phase inversion of the voltage pulse is an indication of a short-circuited line for the reasons illustrated in Figure 12-18.

64.

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{80-50}{80+50} = \mathbf{0.231}$$

$$E_F = E_i(1+\Gamma) = 10\ V(1+0.231) = \mathbf{12.3\ V}$$

$$E_F = E_i + E_r$$

$$E_r = E_F - E_i = 12.3 - 10 = \mathbf{2.3\ V}$$

65. Internal resistance of voltage source, E_{bb}, is assumed to be equal to the characteristic impedance of the transmission line represented by the lumped *L* and *C* values of the transmission line represented in Figure 12-12. Steps are as follows: (a) Close switch S_1. (b) Voltage of E_{bb} divides equally between internal resistance of source and characteristic impedance of line. (c) Applied voltage to line causes current flow through inductor L_1 because there is a potential difference between points *a* and *c*, causing the magnetic field around the inductor to expand. (d) At maximum potential difference between points *a* and *c*, equal to one-half E_{bb}, the magnetic field around inductor L_1 collapses, causing current to flow into capacitor C_1, charging it to one-half E_{bb}. (e) Capacitor C_1 discharges, causing current to flow into L_2, and process repeats until all *L* and *C* combinations are alternately charged and discharged. Because the line represented in Figure 12-12 was assumed to be infinitely long, current continues to flow through the line. The ratio of applied voltage to current determines the characteristic impedance of the line.

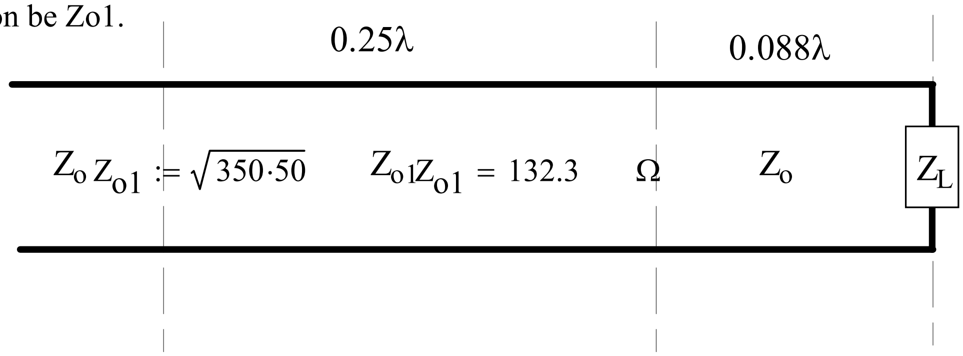
66. A line of 1.75λ, line one of any odd-numbered fractions of a wavelength, will exhibit a phase inversion of voltage and current as viewed by the generator. In other words, it will behave similarly to a single quarter-wavelength section of line. The voltage maximum/current minimum predicted at the open-ended line will appear as a short (minimum voltage/maximum current) at the generator. Therefore, the voltage/current relationship seen by the generator will be similar to that pictured in Figure 12-21 (a) for a quarter-wavelength section, perhaps with some attenuation in amplitude because of the length of the line. For a short-circuited line, the voltage and current seen by the generator will be similar to that pictured in Figure 12-21 (b).

67. A one-sixteenth wavelength section of transmission line is free from transmission-line effects because there is no significant change in voltage or current variation at any point along its length. The line's characteristic impedance is determined by the ratio of voltage to current, and lines that are electrically very short at the frequencies of the signals applied to them appear as constant impedances.

68. Match a load of 25 + j 75 Ω to a 50-Ω line using a quarter-wavelength of matching section. Repeat this problem for Z_L = 110 - j 50 Ω.

$$Z_L := 25 + j\cdot 75 \quad \Omega \qquad\qquad Z_o := 50 \quad \Omega$$

First transform until the load impedance is real. The first time it is real is when the distance between the load and the matching section is 0.088 wavelengths. At this point the equivalent load impedance is 350Ω, Let the characteristic impedance of the matching section be Zo1.

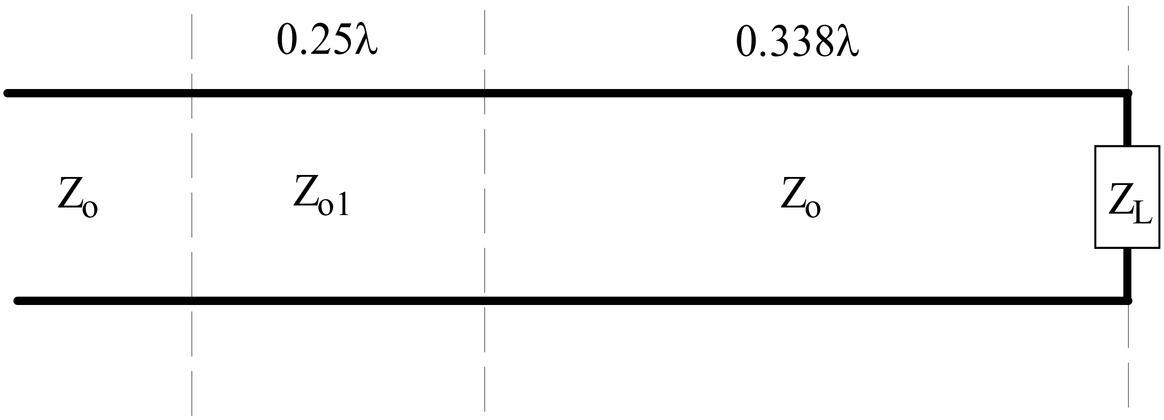


(0.088 + 0.25 = 0.338λ)

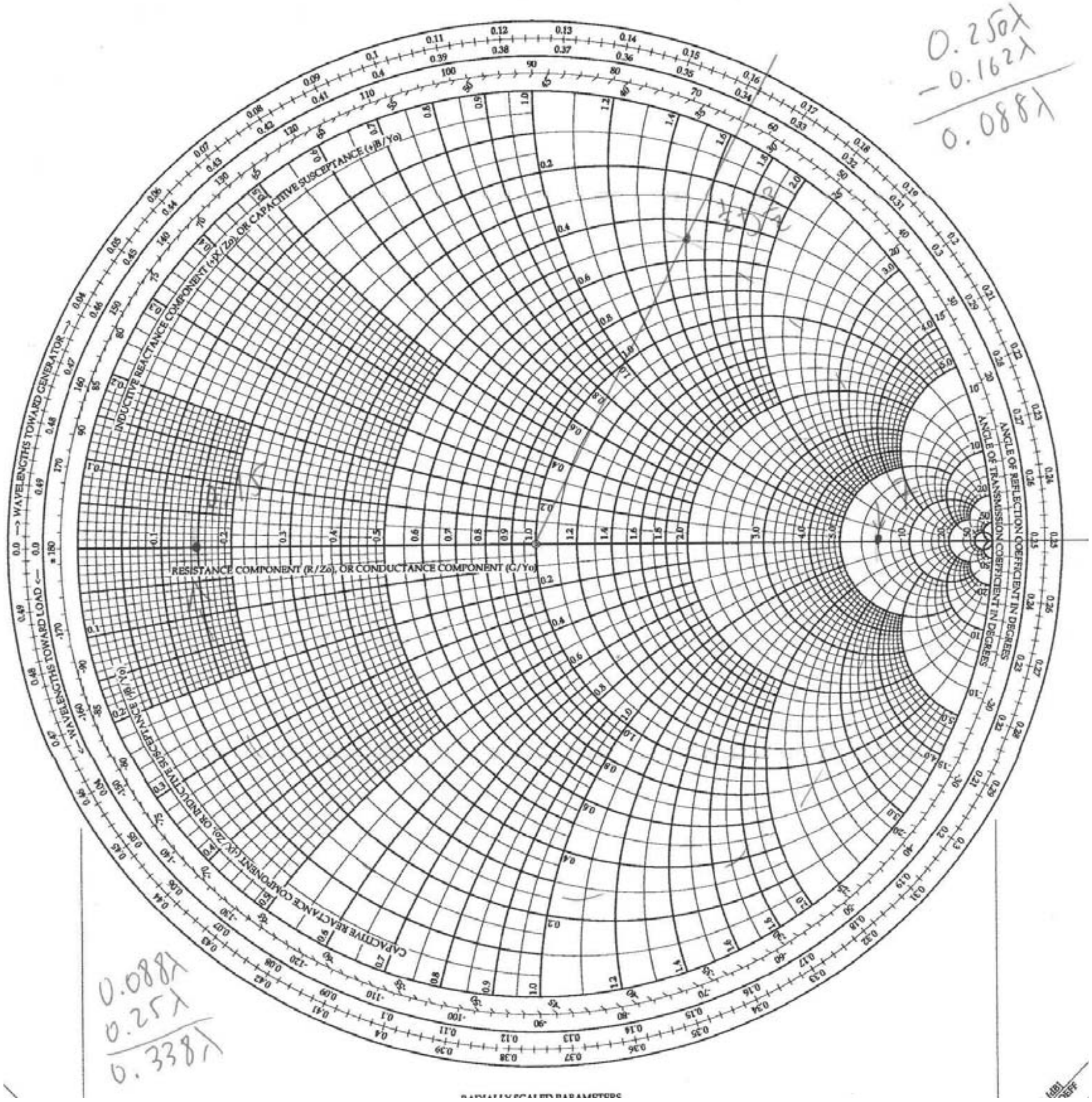
The second solution is the second time the load transforms to a real value.

At the second point, the equivalent load impedance is 7.5Ω.

$$Z_{o1} := \sqrt{7.5\cdot 50} \qquad\qquad Z_{o1} = 19.4 \quad \Omega$$



0.25λ
0.338λ
Zo
Zo1
Zo
ZL

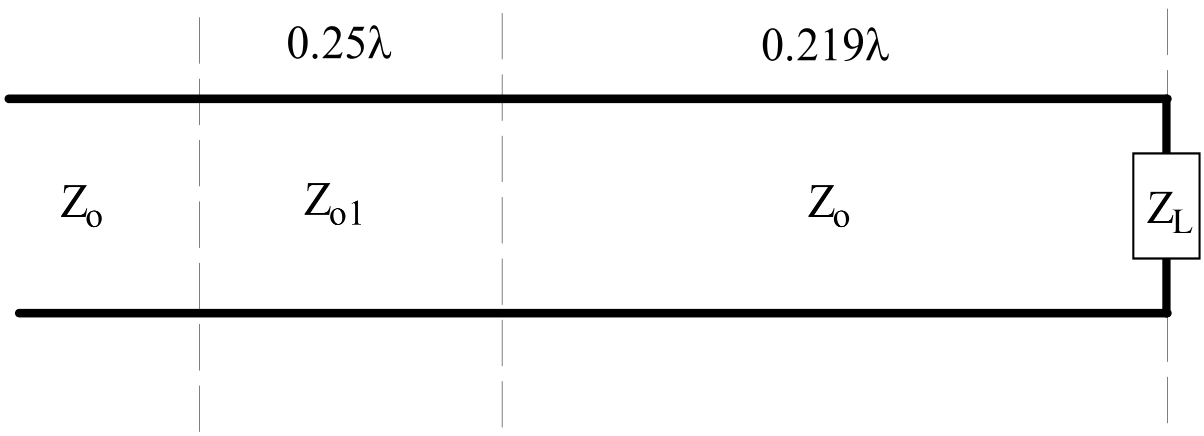

0.250λ
−0.162λ
0.088λ
0.088λ
0.25λ
0.338λ
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
CAPACITIVE REACTANCE COMPONENT (−jX/Zo), OR INDUCTIVE SUSCEPTANCE (−jB/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES

Now the other impedance.

$Z_L := 110 - j \cdot 50 \quad \Omega \qquad Z_o := 50 \quad \Omega$

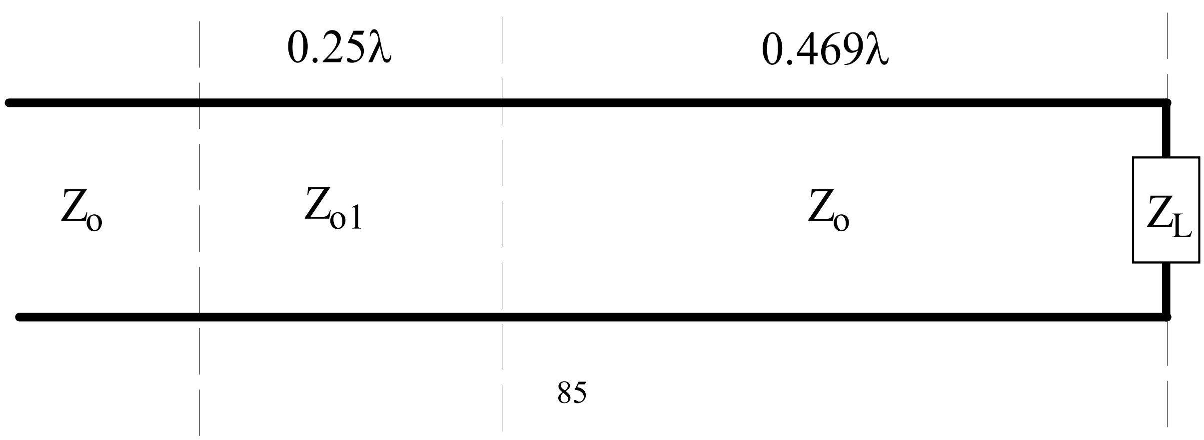
First transform until the load impedance is real. The first time it is real is when the distance between the load and the matching section is 0.219 wavelengths. At this point the equivalent load impedance is 18.5Ω, Let the characteristic impedance of the matching section be Zo1.

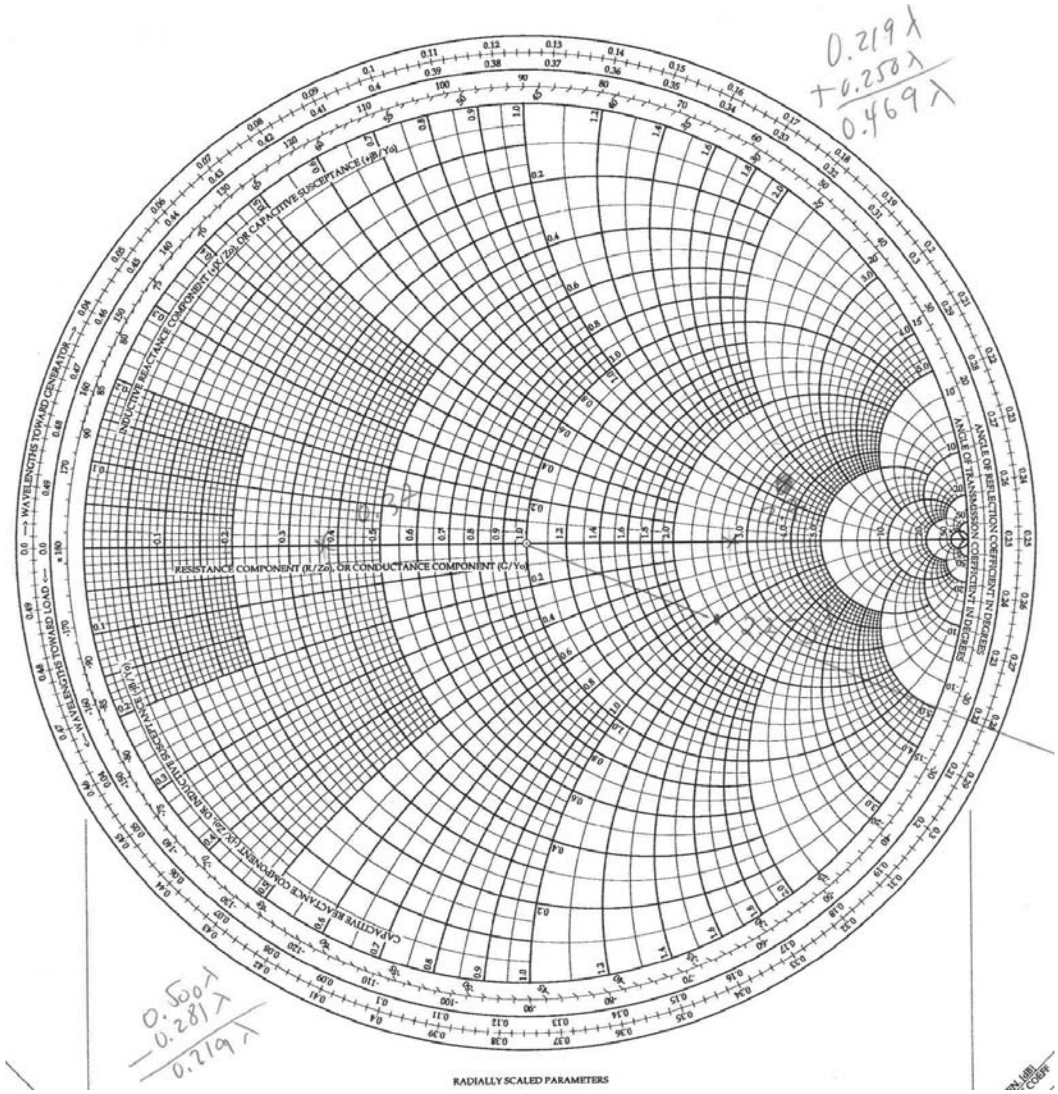
$Z_{o1} := \sqrt{18.5 \cdot 50} \qquad Z_{o1} = 30.4 \quad \Omega$



The second solution is
At the second point, the equivalent load impedance is 135Ω (0.219+0.25 = 0.469 λ).

$Z_{o1} := \sqrt{135 \cdot 50} \qquad Z_{o1} = 82.2 \quad \Omega$




0.219λ
+0.250λ
0.469λ
0.500λ
−0.281λ
0.219λ
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS

1. The antenna converts electrical energy to electromagnetic energy.

2. Light waves and radio waves differ in frequency but both travel at the speed of light.

3. Electric field and magnetic field, these fields exist with any current carrying conductor and they create an electric field and are radiated.

4. These describe the direction of the electric field of an electromagnetic wave.

5. The electric field (E) and the magnetic field (H) which are perpendicular to each other.

6. Wavefront - a plane joining all points of equal phase in a wave.

7.
$$\wp = \frac{P_t}{4\pi r^2} = \frac{10\ W}{4\pi[22\times10^3\ mi\times1.609\times10^3\ m/mi]^2} = \mathbf{6.35\times10^{-16} W/m^2}$$

8.
$$\wp = \frac{P_t}{4\pi r^2} = \frac{20\ W}{4\pi[22\times10^3\ mi]^2} = \mathbf{1.27\times10^{-15} W/m^2}$$
$$P = \wp\times A = 1.27\times10^{-15}\times1600 = \mathbf{2.03\times10^{-12}\,W}$$

9.
$$\mathscr{E} = \frac{\sqrt{30P_t}}{r} = \frac{\sqrt{30\times1\times10^3}}{20\times10^3} = \mathbf{8.66\,mV/m}$$
$$At\ 50\,km,\ \mathscr{E} = \frac{\sqrt{30\times1\times10^3}}{50\times10^3} = 3.464\,mV/m$$
$$dB = 20\log\frac{8.66}{3.464} = \mathbf{7.96\ dB}$$

10.
$$R = \frac{V^2}{P}\ and\ \mathfrak{Z} = \frac{\mathscr{E}^2}{\wp}$$
$$but\ \mathscr{E} = \frac{\sqrt{30P_t}}{r}\ and\ \wp = \frac{P_t}{4\pi r^2}$$
$$\therefore \mathfrak{Z} = \frac{30P_t}{r^2}\times\frac{4\pi r^2}{P_t} = 120\pi = \mathbf{377\Omega}$$
$$\mathfrak{Z} = \sqrt{\frac{\mu}{\epsilon}}$$
$$\mu = 1.26\times10^{-6}$$
$$\epsilon = 8.85\times10^{-12}$$
$$\mathfrak{Z} = \left(\frac{1.26\times10^{-6}}{8.85\times10^{-12}}\right)^{1/2} = \mathbf{377\Omega}$$

11. Inversely proportional to the square of its distance.

12. This is the degree of magnetism of a material in response to a magnetic field.

13. Radio waves are reflected by conductive material such as metal or the Earth's surface.

14. The radio wave is refracted as shown in Figure 13-4. Refraction occurs when waves pass from a medium of one density to another medium with a different density.

15. Diffraction - the phenomenon whereby waves traveling in straight paths bend around an obstacle. A shadow zone is an area following an obstacle that does not receive a wave by diffraction.

16. It is the ratio of the reflected electric field intensity divided by the incident intensity.

$$\rho = \frac{\epsilon_r}{\epsilon_i}$$

17. Refraction - is the bending of a wave

18. Shadow zone - an area following an obstacle that does not receive a wave by diffraction

19. Ground wave, space wave, and sky wave

20. Ground wave - a wave that travels along the Earth's surface

21. Changes in terrain have a negative impact on ground waves, dry terrain has poor conductivity, salty water is a good conductor.

22. Attenuation of ground waves is directly related to the surface impedance of the Earth. This impedance is a function of conductivity and frequency. The ground losses increase rapidly with increasing frequency.

23. ELF (30 to 300) Hz is used for submarine communications.

24. Space-wave propagation consists of direct and ground reflected space waves. A direct wave travels from antenna to antenna while a reflected wave bounces off a surface such as the earth.

25. Sky waves are radiated in a direction that strike the ionosphere, reflect to the ground and bounce back and so on. This produces skipping.

26. Refer to Figure 13-9.

27. Skip distance is affected by solar disturbances.

28. Critical frequency - the highest frequency that will be returned to the earth when transmitted vertically under given ionospheric conditions
Critical angle - the highest angle with respect to a vertical line at which a radio wave of a specified frequency can be propagated and still returned to the earth from the ionosphere.
Maximum Usable Frequency - the highest frequency that is returned to the earth from the ionosphere between two specific points on earth.

29. The optimum working frequency is one that provides the most consistent communication while the MUF defines the maximum usable frequency.

30. Tropospheric propagation, 350 MHz to 10 GHz, and most VHF frequencies behave the same.

31. Frequencies below 30 Mhz.

32. The skip zone occurs for a given frequency, when propagated at its critical frequency. The skip distance is the minium distance from the transmitter to the skywave that can be returned to Earth (due to the density of the atmosphere).

33. The reflection causes a 180^{o} phase shift of the skywave.

34. See Figure 13-14. The signal is reflected beyond the Earth's horizon enabling reliable communications up to 400 miles. It provides for reliable links in deserts, mountain regions, and between islands.

35. Diversity is used to select the best received signal using multiple receivers to provide a summed receive signal.

36. Space diversity - comprising two or more receiving antennas separated by 50 λ or more. Frequency diversity - transmission of the same information on different frequencies. Angle diversity - transmission of the same information at two or more more slightly different angles.

37. Skipping - the alternate refracting and reflecting of a sky-wave signal between the ionosphere and the earth's surface.

38. Fading - variation in signal strength that may occur at the receiver over a period of time.

39. Frequencies above the critical frequency will continue on out into space.

40. Satellite communications involves the use of a satellite to relay a signal from an uplink on earth, amplify the signal and translate the frequency using a transponder and re-transmit the signal back to earth.

41. GEO - Geosynchronous orbit satellites, fixed location of 22,00 miles above the earth, these satellites have a long delay time due to the distance traveled.
LEO - Low Earth Orbit satellites, small signal delay, location not fixed.

42. VSAT - see page 487
MSAT - a mobile satellite system

43. Frequency division multiple access - operates on different frequencies based on which channel is available. TDMA uses one carrier for the communication link, selectivity is accomplished in time rather than in frequency, and is well suited for digital communications.

44. This answer will vary based on geographic location.

45. Azimuth = 169.64° Elevation = 48.73

46. GPS satellites transmit two signals, a coarse acquisition (C/A) signal transmitted on 1575.42 MHz, which is available for civilian use, and a precision code (P-code), transmitted on 1227.6 MHz and 1575.42 MHz, which are for military use only.

47. using the on-line calculator, distance ≈ 38298 km, round trip delay ≈ .25549 seconds.

48. refer to figure 13-17, **perigee** - closest distance of the orbit to earth and **apogee** - farthest distance of the orbit from earth.

49. altitude – 485 miles orbital period – 100 minutes and 28 seconds
66 satellite using near polar-orbit

50. NF(dB) = 10 log (100/290 + 1) = 1.29 dB

51. 28.65 K (using http://web.nmsu.edu/~jbeasley/Satellite/)

52. 204.4 dB (using http://web.nmsu.edu/~jbeasley/Satellite/)

53. The uplink transmit power is 4.5 W. Both the uplink and downlink C/N are well within limits specified in the problem.

54. EMI has differing symptoms.

55. $d \simeq \sqrt{2h_t} + \sqrt{2h_r} = \sqrt{2 \times 500} + \sqrt{2 \times 20} = \mathbf{37.9\,mi}$

$110\% \times 37.9 = 41.7$

$41.7 = \sqrt{2 \times 500} + \sqrt{2 \times h_r}$

$h_r = 51.2 ft$

$height\ increase = 51.2 - 20 = \mathbf{31.2\,ft}$

56. The skip distance is how far away a received signal is obtained. The skip zone defines the region where no signal is received, found or reflected.

57. This varies with frequency. You can expect variations from day to night and with solar activity.

1. The transmit antenna must be vertically polarized. The receive antenna must also be vertically polarized.

2. $d = \frac{V}{\mathscr{E}} = \frac{2.7\,V}{25\,mV/m} = \mathbf{108\ m}$

3. $P \propto \mathscr{E}1^2$

$\therefore \mathscr{E} \propto \sqrt{P}$

$P_{change} = 2$

$\therefore \mathscr{E}$ *is increased by* $\sqrt{2}$ *or* 1.414 *or* **141% *change***

$dB\ change\ =\ 20 \log 1.414\ =\ \mathbf{3\,dB}$

4. $\epsilon\ =\ \frac{\sqrt{30\,P_t}}{r}$

$at\ 200\ mi\ =\ \frac{10\,V/m}{2}\ =\ \mathbf{50\,\mu V/m}$

5. $P \propto i^2$

$\therefore P = \left(\frac{1}{2}\right)^2 P_{original}\ =\ 0.25$

$\mathscr{E} \propto \sqrt{P_t}$

$\therefore \mathscr{E} \propto \sqrt{0.25}\ \mathscr{E}_{original}$

$\therefore \mathscr{E} \propto 0.5\ \mathscr{E}_{original}$ *or* **50%**

6. Field intensity - this is measured in terms of the field strength which is inversely proportional to the distance from the transmitter.

7. Polarization - the direction of the electric field of a given electromagnetic radiated signal.

8. This refers to the fact that an antenna will work equally well for transmit and receive given adequate power boundaries.

9. Refer to Figures 14-2 and 14-3. The half-wavelength dipole is comprised of two quarter-wave sections. The total length of the two sections is ½ λ.

10. See Figure 14-2.

11. See Figure 14-2 and Figure 14-14 in the text for illustrations of the voltage and current relationships in a half-wavelength dipole and a quarter-wave grounded antenna, respectively. The voltage and current waves for a full-wavelength antenna (center-fed)

would appear in each of the half-wavelength sections on either side of the generator as though they were composed of two quarter-wavelength sections laid end-to-end. Moving one-quarter wavelength (i.e., half-way) from each end toward the center, one would see a current maximum and voltage minimum, and at the center feed point the distribution would again be current minimum/voltage maximum, as was the case for the half-wave dipole. The principal difference in this case, however, is that the polarity of the voltage wave in each half-wavelength section would change (equal positive and negative polarities in each half), which in turn would have an effect on the energy distribution from the antenna.

12. The impedance value for the half-wave dipole varies from about 2500 Ω at the open ends to 73 Ω at the source ends.

13. The reception of the induction field requires that the receive antenna be close to the transmit antenna. For practical purposes, it does not radiate a field.

14. See Figure 14-6.

15. The angular separation between the half-power points on an antenna's radiation pattern.

16. $$Power\ to\ antenna = 100 - 50 = 950\,W$$

$$ERP = P \times G_{ant} = 950\,W \times 3 = \mathbf{2850\,W}$$

17. $$P_r = \frac{P_t G_t G_r \lambda^2}{16\pi^2 d^2} = \frac{5 \times \frac{1.64}{2} \times \left(\frac{3 \times 10^8}{225 \times 10^6}\right)^2}{16\pi^2 (100 \times 10^3)^2} = \mathbf{7.57\,pW}$$

$$V = (P \times R)^{1/2}$$

$$V = (7.57 \times 10^{-12} \times 73\,\Omega)^{1/2} = \mathbf{23.5\,\mu V}$$

18. An antenna with a gain of 4.7 dBi has a gain of (4.7 - 2.15) dBd = 2.55 dBd, which is less than 2.6 dBd.

19. The size of the antenna below 2 MHz is physically too large.

20. A half-wave dipole has an approximate physical length of one-half wavelength of the applied frequency

$$\lambda = \frac{3x10^8\,m/s}{100x\,10^6\,cycles/second} = 3\,meters \quad \therefore \frac{2}{3}\lambda = 2\,meters$$

21. $\lambda = \dfrac{3 \times 10^8}{90.7 \times 10^6} = 3.3m / cycle \qquad \dfrac{\lambda}{2} = 1.653m$

$R > \dfrac{2(1.653)^2}{3.3} = 1.653m$

22. $\lambda = \dfrac{3 \times 10^8}{4.1 \times 10^9} = .073m$

$D = 10m \qquad R > \dfrac{2(10)^2}{.073} = 2733.3m$

23. near field region - less than 2D/λ from the antenna
far-field region - region greater than 2D/λ from the antenna.

24. Radiation resistance - the portion of an antenna's input impedance that results in power radiated into space.

25. $P \propto i^2$
$\therefore P = 2.77^2 \times P_{original} = \mathbf{7.67}$

26. For a given power, if antenna current increases , the effect is as if the radiation resistance decreases.

27. The value falls steadily to a minimum value of 70Ω at a height of λ/2 above ground. The value rises and falls by several ohms.

28. The ground has an effect on the radiation resistance

29. $\eta = \dfrac{R_r}{R_r + R_d} = \dfrac{73}{73+5} = \dfrac{73}{78} = .936 = \mathbf{93.6\%}$

30. (a) Physical length - this affects the radiation resistance, also the physical length ~ 85% of the electrical length.
(b) electrical length - determined from λ = speed of light / frequency
(c) polarization - the direction of the electric field of a given electromagnetic field
(d) diversity reception - using multiple antennas with different heights and angles to provide a choice for obtaining the best signal
(e) corona discharge - luminous discharge of energy by an antenna from ionization of the air around the surface of the conductor

31. The physical length can be approximated to be about 95% of the calculated electrical length.

32. Antenna length is an issue and the resulting impedance. A properly matched antenna will look resistive.

33. $$\lambda = \frac{c}{f} = \frac{3\times 10^{8}\,m/s}{1250\,x\,10^{3}\,cycles/second} = 240\,meters/cycle$$
$$405ft = 123.45\,meters\ \therefore\ \frac{123.45}{240} = .51435\,\lambda$$

Electrical length = 0.95 x 240 = 2238 meters
physical length = 123.45/228 =~ .54 λ

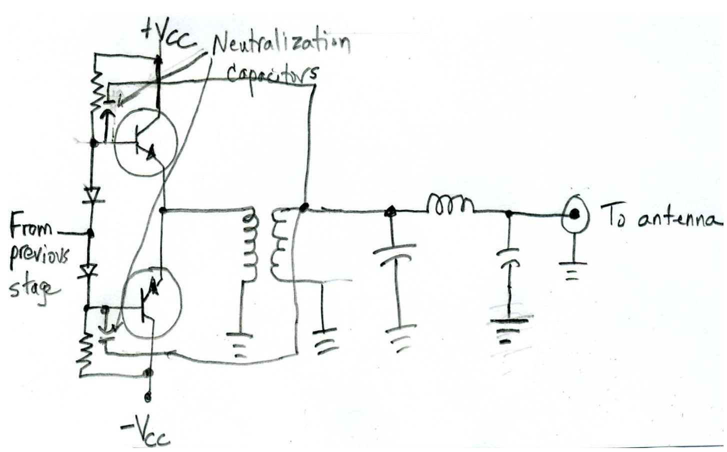
34. $$\lambda = \frac{c}{f} = \frac{3\times 10^{8}\,m/s}{1.1\,MHz} = 272.7\,m$$
$$\therefore\ \lambda/2 = \mathbf{136\,m}$$

35. The antenna feed line is a transmission line. A resonant feed line is not widely used; it is inefficient and length is critical, however impedance is not an issue.

36. A non-resonant feed line is more widely used, it has negligible standing waves and its operation is practically independent of its length.

37. Delta-match - impedance matching device that spreads the transmission line as it approaches the antenna. It is convenient to use when the transmission line does not have a characteristic impedance sufficiently low to match a center-fed dipole.

38. Many methods are available. A very basic method is shown below (note that high-power designs will most likely use MOSFETs or vacuum tubes as the active elements):



39. See Figure 14-13(b)

40. $Z_0 = \sqrt{Z_0 R_L} = \sqrt{75 \times 300} = \mathbf{150\,\Omega}$

41. See Figure 14-13(c) and the related discussion.

42. The monopole (vertical) antenna.

43. $P = I^2R$

44. The monopole (vertical) type antenna requires a conducting path to ground and the half-wave dipole does not.

45. See Figure 14-16. Yes the reciprocity theorem applies.

46. Image antenna - the simulated λ/4 antenna resulting from the Earth's conductivity with a vertical antenna.

47. The ground plane would be the roof of the car (assuming the roof top is a conductive surface). If the whip antenna is placed on the bumper, it distorts the radiation patterns and increases the directivity of the antenna.

48. They provide the ground plane if the actual Earth ground can not be used. Bad reflections will result in poor radiation.

49. The series inductor tunes out the capacitive appearance of an antenna so the antenns appears resistive.

50. The antenna becomes highly capacitive.

51. By adding a loading coil to the antenna.

52. The resonant frequency would increase.

53. Top loading enables maximum possible radiation.

54. The loading coil can be used to compensate for the fact that the vertical antenna is not a full quarter wavelength.

55. A parasitic element is located λ/4 behind the dipole. The parasitic element reflects the waves doubling the signal propagated in that direction.

56. (a) driven element - an antenna element that is excited through a transmission line.
(b) parasitic elements - not electrically connected
(c) reflector - the parasitics that effectively reflects energy from the driven element
(d) parasitic element - effectively directs energy in the desired direction.

57. $ERP = P \times Gain = 500 \times \log^{-1} 7\,dB = 500 \times 5 = \mathbf{2500\ W}$

58. (a) F/B = 7 - (-3) = 10 dB (b) F/B = 18 - (5) = 13 dB

59. See Figure 14-20

60. See Figure 14-21, any combination of half-wave elements are excited by a connected transmission line. This results in a more directed antenna.

61. See Figure 14-22, a group of half-wave elements is mounted vertically. This arrangement provides greater directivity in both the vertical and horizontal planes.

62. Refer to Figure 14-23 and the drawing at the intersection of the phase difference = 0 and the spacing = ½ λ.

63. This is accomplished using a vertical array.

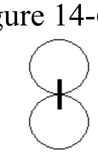
64. The changes in the ionized layers of the atmosphere will change the sky-wave coverage (refer to Figure 13-9).

65. Phased array - combination of antennas in which there is control of the phase and power of the signal applied to each antenna resulting in a wide variety of possible radiation patterns.

66. A parasitic array is developed when one or more of the elements in an antenna is not driven.

67. A log-periodic antenna is a special case of a driven array, good gain over an extremely wide range of frequencies. The longest and shortest dipoles are a half-wavelength for the upper and lower frequencies.

68. (a) horizontal half-wave dipole (see Figure 14-5)
(b) vertical half-wave dipole (see Figure 14-6)
(c) monopole (vertical) loop antenna



(d) horizontal loop antenna (see Figure 14-25)
(e) vertical antenna (see Figure (14-14)

69. It is bi-directional. see Figure 14-25

70. Ferrite loop antennas are found in most AM receivers. The large number of loops wound around a ferrite core serves to greatly increase the effective diameter of the loops. It enables the reception of lower frequencies using a small antenna.

71. The radiated resistance is 288Ω. It offers relatively broadband operation. The folded dipoles provide a high input impedance for Yagi-Uda antennas.

72. A smooth surface can be obtained (see Figure 14-27). Phase arrays can be built into the wings of the aircraft, the phase arrays provide for a directive radiation pattern.

73.
a. *Since beamwidth is* $36°$, *at* $18°$ *either side of maximum gain, the gain should be* $3\,dB$ *down, or*

$$14\,dB - 3\,dB = \mathbf{11\,dB}$$

b. $BW = 185 - 55 = \mathbf{130\,MHz}$

c. $F/B = 14\,dB - (-8\,dB) = \mathbf{22\,dB}$

d. $185\,MHz$ *is at the bandwidth frequency; thus the power gain will be* $3\,dB$ *down from the maximum*

$$14\,dB - 3\,dB = \mathbf{11\,dB}$$

74. Bandwidth specifies the usable frequencies, beamwidth describes the radiation pattern.

75. The shape of the different types of antennas focus the RF signal and provide gain.

76. See Figure 14-28.

77. These antennas are highly directive. See Figure 14-29, equation 14-7, and Example 14-6.

78. Refer to Figure 14-29.

79.
$$A_p \simeq 6\left(\frac{P}{\lambda}\right)^2$$

$$\lambda = \frac{c}{f} = \frac{3\times10^8\,m/s}{4.3\times10^9} = 6.977\,cm$$

$$A_p \simeq 6\left(\frac{160\,ft\times 12\,in/ft\times 2.54\,cm/in}{6.977\,cm}\right)^2 = 2.93\times10^6$$

$$ERP = P_{out}\times A_p = 10\,W\times 2.93\times10^6 = \mathbf{29.3\,MW}$$

$$beamwidth \simeq \frac{70\lambda}{D} = \frac{70\times 6.977\,cm}{4{,}877\,cm} = \mathbf{0.10°}$$

80. $beamwidth \approx \dfrac{70\lambda}{D}$

$0.5° = 70 \times \dfrac{3 \times 10^8}{18 \times 10^9} \div D$

$D = 2.33\,m$

$A_p \approx 6\left(\dfrac{D}{\lambda}\right)^2 = 6\left(\dfrac{2.33}{3 \times 10^8/18 \times 10^9}\right)^2 = 117{,}600$

$dB = 10\log 117{,}600 = \mathbf{50.7\ dB}$

81. Radome - a low-loss dielectric material used as a cover for a microwave antenna. It is used for protecting the antenna from the environment.

82. Zoning - a fabrication process that allows a dielectric to change a spherical wavefront into a plane wave. See figure 16-4.

83. fr = 1.3 Ghz BW ≈ 10% of fr = 130 Mhz.

84. $beamwidth \approx \dfrac{70\lambda}{D} = 1.1° \quad f = 4\,Ghz \quad \lambda = .075$

$D = \dfrac{(70)(.075)}{1.1} = 4.772 \quad A_p \approx 6\left(\dfrac{D}{\lambda}\right)^2 = 6\left(\dfrac{4.772}{0.75}\right)^2 = 24297.5\ \ (43.8\,dB)$

85. focal length = D / 16h = 5 / (16)(1.2) = .26 meters

86. $\lambda = \dfrac{3x10^8\,m/s}{14x10^9\,Hz} = .0214 meter$

$Ap(dB) = 10\log\ 6[\dfrac{D}{\lambda}]^2 = 20\log\ 6[\dfrac{10}{.0214}] = 68.95dB$

87. $(a) beamwidth = \dfrac{70\lambda}{D} = \dfrac{70(.0214)}{10} = .1498^o$

$(b) beamwidth = \dfrac{70\lambda}{D} = \dfrac{70(.075)}{10} = .525^o$

The beamwidth is narrower as the wavelength gets smaller.

88. $A_e = k\pi(\frac{D}{2})^2 = 0.6\pi(\frac{3}{2})^2 = 4.24m^2$

89. $dB = 20\log\frac{V_1}{V_2} = 20\log\frac{147}{405} = \mathbf{51.2\ dB}$

90. You need to know the TX output power and the antenna gain.

91. Notes to instructor:

1. Because of an author oversight, the log-periodic antenna description in the text is incomplete, and more information is necessary to produce a final design. In Figure 14-24, the spacing and lengths of the elements defined by τ also create the angle represented by α in the antenna sketch associated with this problem. The dimensions D_1, D_2, and so forth, represent the distances between each of the elements and the apex of the angle enclosing them. This angle α is typically about 30°, and, from trigonometry,

$$\frac{L_1}{2D_1} = \tan\frac{\alpha}{2}.$$

An $\alpha = 30°$ is used in the following calculations.

2. An effective log-periodic design calls for a wider bandwidth than the expected frequency range. Therefore, the frequency range 50–220 MHz was initially selected in the following solution to enclose fully the 54–216-MHz VHF TV frequency band.

3. The following solution produces dimensions in meters. To determine dimensions in feet use the expression 468/*f*MHz in step 1.

Design Steps:

1. Determine length of half-wave dipoles at lowest and highest frequencies

$$\text{L} = \frac{142.5}{50} = 2.85\text{m for 50 MHz}$$

$$\text{L} = \frac{142.5}{220} = 0.647\text{m for 220 MHz}$$

2. Determine distance D_1 between first two dipoles:

Assuming $\alpha = 30°$, so

$$D_1 = \frac{L_1}{2\tan\frac{\alpha}{2}}$$

$$= \frac{0.647}{2\tan 15°}$$

$$= 1.2\text{m}$$

3. Using relation $\tau = \frac{L_1}{L_2} = \frac{L_2}{L_3} = \frac{L_3}{L_4} \ldots$, determine length of each dipole section.

$$L_2 = \frac{L_1}{\tau}$$

$$= \frac{0.647}{0.7}$$

$$= 0.924\text{m}$$

$$L_3 = \frac{L_2}{0.7}$$

$$= \frac{0.924\text{m}}{0.7}$$

$$= 1.32\text{m}$$

$$L_4 = \frac{1.32\text{m}}{0.7}$$

$$= 1.885\text{m}$$

$$L_5 = \frac{1.885\text{m}}{0.7}$$

$$= 2.69\text{m}$$

$$L_6 = \frac{2.69\text{m}}{0.7}$$

$$= 3.84\text{m}$$

Length L_6 is significantly larger than necessary, and because we initially assumed a lower frequency of 50 MHz rather than 54 MHz, we can stop with a 5-element beam because the length L_5 produces a dipole with a half-wavelength frequency of 52.9 MHz.

4. Determine remaining distances between elements:

$$D_1 = 1.2\text{m} \qquad \tau = \frac{D_1}{D_2} = \frac{D_2}{D_3} \;\ldots\; \text{etc.}$$

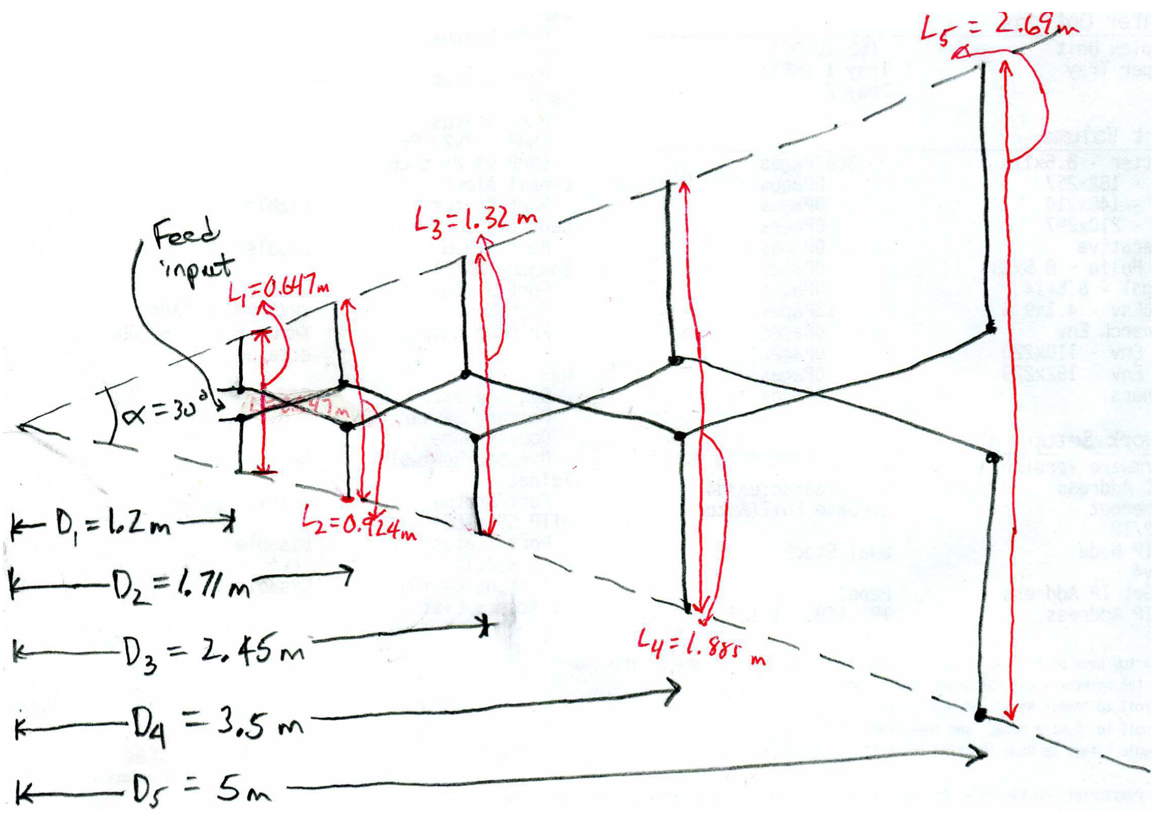
$$\tau = 0.7$$

$$D_2 = \frac{1.2\text{m}}{0.7} = 1.71\text{m}$$

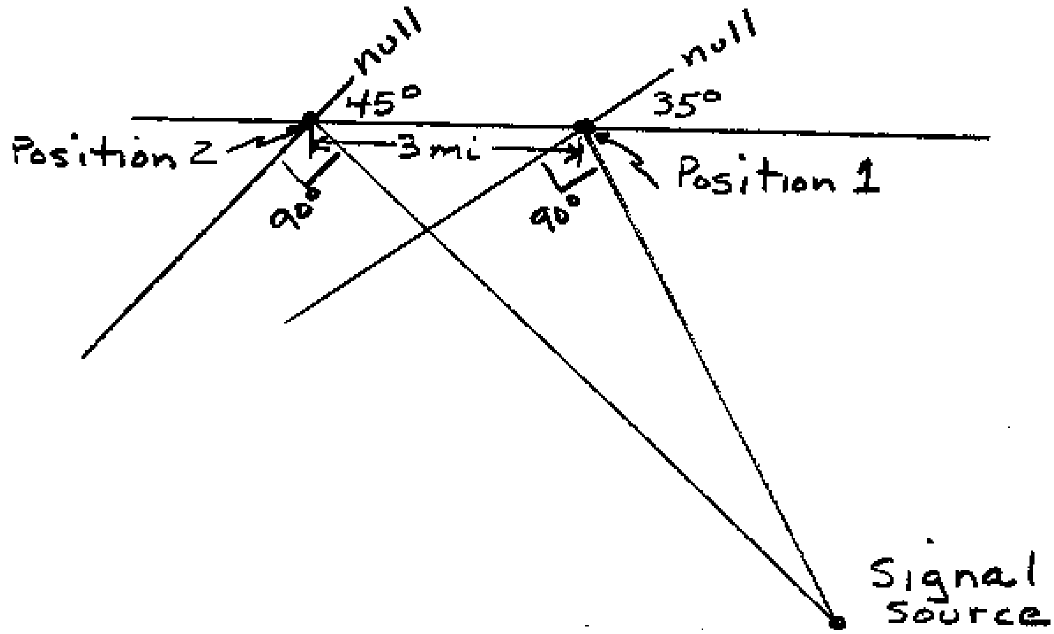
$$D_3 = \frac{1.71\text{m}}{0.7} = 2.45\text{m}$$

$$D_4 = \frac{2.44\text{m}}{0.7} = 3.5\text{m}$$

$$D_5 = \frac{3.5\text{m}}{0.7} = 5\text{m}$$



92.



1. Factors should include:
   (1) initial cost and long-term maintenance
   (2) frequency band
   (3) selectivity and privacy
   (4) reliability and noise characteristics
   (5) power level

2. Waveguide - a medium that guides a wave, generally it is a transmission line, hollow metal tube or pipe, that conducts electromagnetic waves through its interior.

3. The coaxial transmission line has high attenuation at high frequencies, the waveguide has minimal loss at the same frequencies.

4. TE - Transverse electric, TM - transverse magnetic, the wave that is propagated by a waveguide is electromagnetic and therefore has an E-field and an H-field. If no component of the E-field is in the direction of propagation, we say that it is the TE mode. TM is the mode whereby the magnetic field has no component in the direction of propagation.

5. TE - Transverse electric, TM - transverse magnetic, the wave that is propagated by a waveguide is electromagnetic and therefore has an E-field and an H-field.

6. TE_{10}, the most "natural" one for operation. It has the lowest cutoff frequency.

7. This defines the range of sizes of waveguide that can be used for a given length.

8.
$$\lambda_{co} = 2a = 2 \times 2\,cm = 4\,cm$$
$$f_{co} = \frac{c}{\lambda_{co}} = \frac{3 \times 10^8\,m/s}{0.04\,m} = \mathbf{7.5\,GHz}$$

9. Refer to question 4.

10. $a = \lambda/2$ (TE_{10})   a for TE_{20} = 2 half-wavelengths

11.

$$\lambda = \frac{c}{f} = \frac{3\times10^8 m/s}{10\times10^9} = 3\,cm$$

$$\cos\theta = \frac{\lambda}{2a} \qquad a = 0.9'' = 2.28\,cm$$

$$= \frac{3\,cm}{4.56\,cm}$$

$$\therefore\ \theta = -48.46°$$

$$\frac{V_g}{c} = \sin\theta$$

$$V_g = \sin 48.86°\times3\times10^8 m/s = 2.26\times10^8 m/s = \mathbf{2.26\times10^8\, m/s}$$

$$\lambda_g/\lambda = \frac{\lambda}{\sin\theta}$$

$$\lambda_g = \frac{\lambda}{\sin\theta} = \frac{3\,cm}{\sin 48.86°} = \mathbf{3.98\,cm}$$

$$\sqrt{V_p\times V_g} = C$$

$$(2.26\times10^8\times V_p)^{1/2} = 3\times10^8$$

$$V_p = (3\times10^8)^2 over 2.26\times10^8 = \mathbf{3.98\times10^8\, m/s}$$

12. The wave that travels in a waveguide propagates down the guide at less than the velocity of light. This is called the group velocity. In Smith chart calculations, the group velocity should be used when making moves, not the free-space wavelength.

13. The cross-sectional area of a circular waveguide must be more than double that of a rectangular guide.

14. The cross-sectional area of a circular waveguide must be more than double that of a rectangular guide. Circular waveguide can be rotationally symmetrical which means it can be rotated with no electrical disturbance.

15. ridged-waveguide: Advantage - allows operation at lower frequencies for a given set of outside dimensions; Disadvantage - expensive to manufacture

16. See Figure 15-10, outside section is covered with a soft dielectric such as rubber, inside has spiral wound ribbons of brass or copper.

17. The main advantage is in applications where space is at a premium.

18. Operating frequency and the choice of dielectric. At high frequencies the current tends to flow only on the surface of the conductor . Coaxial cable will have a significant loss at high frequencies which reduces its power handling capacity.

19. The purpose of the waveguide is to carry the guided wave from point A to point B. Be careful of dents, dings, twists, or severe bends. Also keep the waveguide pressurized to keep out contaminants.

20. Abrupt changes in the waveguide path will cause disruptions in the waves.

21. See Figure 15-12 and the related discussion.

22. Slide - screw tuner [see Figure 15-14(a)]. The effect of the protruding object is to produce shunting reactance across the guide.
Double-slug tuner [see Figure 15-14(b)]. This tuner provides for the adjustment of the longitudinal position of the slugs aand the spacing between them.

23.

$$Z_0 = \frac{\Im}{\sqrt{1-(\lambda/2a)^2}} = \frac{\Im}{\sin\theta} = \frac{377\Omega}{\sin 68.26°} = \mathbf{405\Omega} \;\; QED$$

24.

$$\lambda = \frac{c}{f} = \frac{3\times10^8 m/s}{8\,GHz} = 3.75\,cm$$
$$\cos\theta = \frac{\lambda}{2a} = \frac{3.75\,cm}{4.56\,cm} = 0.8224$$
$$\theta = \cos^{-1}0.8224 = 34.68°$$
$$Z_0 = \frac{\Im}{\sin\theta} = \frac{377\Omega}{\sin 34.68°} = \mathbf{663\Omega}$$
$$at\ f = 10\,GHz \qquad Z_0 = \mathbf{501\Omega}$$
$$at\ f = 12\,GHz \qquad Z_0 = \mathbf{450\Omega}$$

25. See Figure 15-15 (a) fill the end of the waveguide with graphited sand; (b) high resistance rod; (c) use a wedge of resistive material

26. Flap attenuator - attenuation is accomplished by inserting a thin card of resistive material through a slot in the top of the guide [see Figure 15-16(a)]
vane attenuator - attenuation is provided by changes in the sides, minimum (vanes are close to the side walls), maximum (vanes are in the center)

27. See Figure 15-17, a directional coupler consists of two pieces of waveguide with one side common to both guides and with two holes in the common side.

28.
$$coupling = 10\log\frac{P_{in}}{P_{out}} = 10\log\frac{70\,mW}{0.35\,mW} = \mathbf{23\,dB}$$

29. Capacitive coupling (Probe - see Figure 15-18) the probe is excited by an RF signal setting up an electric field. The probe is in the center of the waveguide and $\lambda/4$ from the short-circuited end.

30. Inductive (loop) coupling [see Figure 15-19], the current flow in the loop sets up magnetic field inside the guide.

31. Slot (aperture) coupling [see Figure 5-20], slot A is at an area of the maximum E-field, slot B is at an area of the maximum H-field, slot C is at an area of the maximum E and H-field and is a form of electromagnetic coupling.

32. (a) as frequency increases, the size decreases
(b) TE - Transverse electric, TM - transverse magnetic, the wave that is propagated by a waveguide is electromagnetic and therefore has an E-field and an H-field. If no component of the E-field is in the direction of propagation, we say that it is the TE mode. TM is the mode whereby the magnetic field has no component in the direction of propagation.
(c) Probe, loop, and aperture coupling is used
(d) The wave that travels in a waveguide propagates down the guide at less than the velocity of light. This is called the group velocity. In Smith chart calculations, the group velocity should be used when making moves, not the free-space wavelength.

33. Cavity resonators are metal-walled chambers filled with devices for admitting and extracting electromagnetic energy.

34. Resonant cavity walls are made of highly conductive material [see Figure 15-21]. Resonant mode occurs at frequencies for which the distance between end plates is a half-wavelength or multiples of half-wavelengths.

35. Waveguide - a medium that guides a wave, generally it is a transmission line, hollow metal tube or pipe that conducts electromagnetic waves through its interior

36. See Figure 15-22, the movement of the disk may be calibrated in terms of frequency.

37. Cavity volume, cavity inductance, cavity capacitance.

38. A radar uses reflected waves to determine the direction and distance of a target.

39. Radars typically use high power and operate at high frequencies, coaxial cable high loss at high frequencies.

40. (a) Target - the object struck by the radar's radio waves
(b) Echo - part of the returning radar energy collected by the antenna and sent to the receiver
(c) Pulse repetition rate - number of pulses transmitted per second
(d) Pulse repetition time - the time from the beginning of one pulse to the beginning of the next
(e) Pulse Width - the duration of the time in transmitting energy
(f) Rest Time - the time between pulses
(g) Range - the time it takes for a pulse of energy to travel to a target and return

41.

$$range_{(mi)} = \frac{\Delta t}{12.36} = \frac{167}{12.36} = \mathbf{13.5\,mi}$$

$$range_{(meters)} = 150\ \Delta t = 150 \times 167 = \mathbf{25{,}050\,m}$$

42.

$$range_{(mi)} = \frac{\Delta t}{12.36} = \frac{123}{12.36} = \mathbf{10\,mi}$$

43. Double Range Echoes are produced when the reflected beam makes a second round trip.

44. A target too close will return an echo before the transmitter turns off, masking the echo.

45. Long duty cycles allow the transmitter output components to be physically much smaller. A short pulse is advantageous for seeing closely spaced objects.

46.

$$PPR = 900$$

$$PRT = \frac{1}{900} = 1.11\,ms$$

$$duty\ cycle = \frac{PW}{PRT} = \frac{1\mu s}{1.11 ms} = 0.09\%$$

$$Peak\ Power = \frac{P_{avg}}{duty\ cycle} = \frac{18\,W}{0.0009} = \mathbf{20\,kW}$$

47. Refer back to the basic radar block diagram section

48.

$$fd = \frac{2V\cos\theta}{\lambda}, \theta = 0^o, \lambda = \frac{3x10^8}{1.024x10^{12}} = 0.29297\,meters$$
$$\therefore v = \frac{fd\lambda}{2\cos\theta} = 40.28\,m/s \;\; which \;\; equals \;\; 90.11\,mph, \;\; yes, \; a\ ticket\ will\ be\ issued..$$

49. Doppler Effect is the phenomenon whereby the frequency of a reflected signal is shifted if there is a relative motion between the source and the reflecting object. A common use is for measuring the speed of objects in sports.

50. Doppler radars are always on, hence the term continuous wave (CW).

51. Refer to Figure 15-27 and the related discussion.

52. A dielectric waveguide is a waveguide with just a dielectric (no conductors) used to guide electromagnetic waves. Advantage - easy to manufacture; Disadvantage - higher loss

53. $t\ h + h - c \;=\; 0.16 - 0.006 \;=\; 0.154\,in$

$$Z_o \;=\; \frac{60}{\epsilon}\ln\left(\frac{4t}{0.67\,\pi\, b\left(0.8 + \frac{c}{h}\right)}\right) \;=\; \frac{60}{\epsilon}\ln\left(\frac{4\times 0.154}{0.67\,\pi\times 0.1\left(0.8 + \frac{0.006}{0.08}\right)}\right) \;=\; 41.4\ln 3.34 \;\approx\; \mathbf{50\Omega}$$

54. See Figure 15-28

55. Check that the line is pressurized; check flanges; look for evidence of arcing; inspect for worn components, cracking, and corrosion.

56. Make sure joints are properly fitted.

57. The most likely problems are with joints or other flanges.

58. Refer to Figure 15-32, connect the power meter to the reflected coupler.

59.

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{9\,GHz} = \mathbf{3.33\,cm}$$

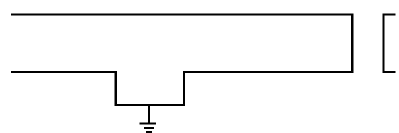
$$\cos\theta = \frac{\lambda}{2a} = \frac{3.33\,cm}{2\times4.5\,cm} = 0.3704$$

$$\therefore \theta = 68.26°$$

$$V_g = \sin\theta\times C = \sin 68.26°\times3\times10^8\,m/s = \mathbf{2.79\times10^8\,m/s}$$

$$\lambda_g = \frac{\lambda}{\sin\theta} = \frac{3.33\,cm}{\sin 68.26°} = \mathbf{3.59\,cm}$$

$$\sqrt{V_p\times V_g} = C$$



$$V_p = \frac{(3\times10^8\,m/s)^2}{2.79\times10^8\,m/s} = \mathbf{3.59\times10^8\,m/s}$$

$$z_L = \frac{Z_L}{Z_0} = \frac{350+j100}{405} = 0.864+j0.247$$

Plot z_L *on Smith Chart and read* $SWR = \mathbf{1.38}$

Plot z_L *on Smith Chart and move* $\frac{4\,cm}{\lambda_g} = \frac{4}{4.961}$

$$z \simeq 1.3 - j0.2$$

$$\therefore Z_{4\,cm\,from\,load} = Z_0\times z = 405(1.3-j0.2) = \mathbf{527 - j81\,\Omega}$$

60. See Figure 15-13, yes, the receive signal can be sent to the transmitter without affecting the transmit signal.

61. $$\text{max. } unamb.\ range = \frac{PRT}{12.2} = \frac{400}{12.2} = \mathbf{32.8}\,mi.$$

62. See Figure 15-32 and the related discussion.

1. See Figure 16-1, modulator, connector, optical fiber, light detector.

2. (1) bandwidth (2) immunity to electrostatic interference (3) elimination of crosstalk (4) security (5) lower signal attenuation

3. Refractive index - ratio of the speed of light in free space to its speed in a given material.

4.

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}}{5.7\times10^{14}} = \mathbf{526\,nm}$$

5. $NA = (n_1^2 - n_2^2)^{1/2} = (1.52^2 - 1.31^2)^{1/2} = \mathbf{0.77}$

6.

$$\theta = \sin^{-1}\frac{1.0}{1.33} = \mathbf{48.7°}$$

7. Infrared light - the electromagnetic waves just below the frequencies in the visible spectrum.

8. See Table 16-1

9. See Table 16-1

10. See Figure 16-5

11. Pulse dispersion - a broadening of received pulse width because of the multiple paths taken by the light. This limits the maximum distance and data rates.

12. Multimode - fibers with cores of about 50 to 100 μm that support many waveguide modes; light takes many paths.

13. Graded-index fiber was developed to overcome the pulse dispersion problem. Core sizes of 50 and 62.5 μm are commonly used and both have 125 μm cladding.

14. Single mode fibers are used in high data rate and/or long distance systems.

15. Core diameters of 7 to 10 μm are typical. The cladding size is 125 μm.

16. Mode field diameter is the actual guided optical power distribution diameter.

17. The wavelength at which the material dispersion and waveguide dispersion cancel one another.

18. short-range sensors (on the manufacturing floor) and in short data lengths.

19. attenuation and dispersion

20. scattering, absorption, macro-bending, micro-bending

21. dispersion - broadening of a light pulse as it propagates through a fiber strand

22.

$$95\,ps/(nm\,km) \times 18\,nm \times 1.5\,km$$
$$= \mathbf{2.565\,ns/km}$$

23. chromatic, polarization, and modal

24. acts like an equalizer, canceling dispersion effects and yielding close to zero dispersion in the 1550 nm region

25. Refer to Table 16-6

26. The diode laser is basically an optical oscillator. When forward biased, a large number of free holes and electrons are created near the junction. The collision of holes and electrons produce a photon of light. At some point, a density level is reached where the release of one photon can trigger several more. The wavelength is determined by the materials used.

27. Dense Wavelength Division Multiplex incorporates the propagation of several wavelengths in the 1550 nm range of a single fiber.

28. A laser in which the fundamental wavelength can be shifted a few nanometers, ideal for traffic routing in DWDM systems.

29. An in-line passive device that allows optical power to flow in one direction only.

30. reduce the signal level

31. isolators, attenuators, branching devices, splitters, couplers

32. They are used to convert the transmitted light back into an electrical signal.

33. DFB - a more stable laser suitable for use in DWDM systems

34. VCSEL - lasers with the simplicity of LEDs and the performance of lasers.

35. axial misalignment, angular misalignment, air gap, rough surface, numerical aperture differences, core-size differences, core concentricity or offset, core ellipticity

36. Fusion splicing is a long-term method and should always be used if the cost is justified.

37. SC, ST, MT-RJ

38. The ends on mechanical splices must be polished. Connections with air gaps require the use of index matching gel.

39. GENERAL RULE - do not splice single mode and multimode together. In an emergency, small-to-larger core splicing results in minimal insertion loss, larger-to-smaller core splicing results in significant insertion loss and an increase in reflected power.

40. link distance, bit-rate, received signal level

41. Long-haul - intercity or interoffice class of system, high bit-rate, high channel density, high reliability, redundant

42. RSL - received signal level

43. Accounts for the system degradation due to addition of link splices, added losses due to wear and tear, misalignment, and repairs.

44. The fiber length can exceed the cable run by .5% to 3% due to the construction of the loosely enclosed fiber in the buffer tubes.

45.

$$10\,km \times .4\,dB/km = \mathbf{4\,dB}$$

46. cable losses, splice losses, connector losses, losses due to splitters, couplers, WDM devices, patch panels, etc.

47. environment, exposure factors, pulling tensile, bend radius

48. OTDR - optical time-domain reflectometer, sends a light pulse down the fiber and measures the reflected light which provides some measure of performance for the fiber.

49. A- dead zone
B- begins useful trace info
C- splice
D- termination at the fiber end
E- end of the fiber

50. speed, decreasing cost of fiber, increasing data capacity

51. FTTC - fiber to the curb   FTTH - fiber to the home

52. OC-192 is a high speed (~10 Mbps) connection

53. The fiber uses high-speed dedicated connections that provide high bit-rates over increased distances.

54. FDDI - fiber distributed data interface uses two counter-rotating rings to increase data throughput.

55. The average distance between stations can not exceed 200 meters, therefore the distance to the last stage can not exceed 208 meters.

56 .

$$NA = (n_1^2 - n_2^2)^{1/2} = (1.515^2 - 1.49^2)^{1/2} = \mathbf{0.274}$$
$$\lambda_c = 2\pi a n_1 \sqrt{2\Delta}$$
$$\Delta = \frac{1.515 - 1.49}{1.515} = 0.017$$
$$\lambda_c = 2\pi \times 1 \times 10^{-6} \times 1.515\sqrt{2 \times 0.017} \div 2.405 = \mathbf{1.73\,\mu m}$$

57.

$$P = P_t \times 10^{-Al/10} = 225 \times 10^{-6} \times 10^{\frac{-0.35 \times 20}{10}} = 225 \times 10^{-6} \times 10^{-0.7} = \mathbf{44.9\,\mu W}$$

58.

$$Loss = 3.2\,dB \times 1.8 + (0.8 + 2 + 2)\,dB = \mathbf{10.56\,dB}$$
$$10.56 = 10 \log \frac{P_{in}}{3\,\mu W}$$
$$P_{in} = \mathbf{34.1\ \mu W}$$

59.

Transmit power output		$2\,dBm$	
losses			
2 connections	$2.0\,dB$		
3 splices	$1.5\,dB$		
Cable $20\,km \times .35\,dB/km$	$7.0\,dB$		
Pigtail	$6.65\,dB$		
Total losses		$\underline{17\,dB}$	
Received Signal Power			$\mathbf{19\,dB}$
Margins			
operational margin	$3\,dB$		
maintenance margin	$\underline{3\,dB}$		
Total Margin			$\underline{\mathbf{6\,dB}}$
Design Receive Signal Level			$\mathbf{-25\,dB}$

minimum RSL $(-33\,dB)$
maximum RSL $-22\,dBm$ *but the system provides* $-19\,dBm$

$\therefore$ *a* $3\,dB$ *attenuator will be needed.*

Laboratory Solutions Manual for

Electronic Communications

A Systems Approach

Experiment 1: Decibel Measurements in Communications

Procedure

Part I: Measuring the Insertion Loss Provided by Passive Resistive Attenuator Circuits

1. 773.5 mV

   -0.017 dB (~0 dB)

2. dB level measured at the attenuator input: ~0 dB

   dB level measured at the attenuator output: -20 dB

   insertion loss (output – input): 20 dB

3. Table 1-1

R2	R3	R4	Input level (dB)	Output level (dB)	Insertion loss (dB)
230	230	685	~0	-6.95	6.95
69	69	258	* 4.5	-8.18	8.18
588	588	12	0	-40	40
312	312	422	0	-10	10
563	563	38	0	-30	30

* Ask the students why the input level does not equal 0 dBm. This is not a 600-ohm attenuator; therefore 0.774 V does not equal 0 dBm for this input/output impedance combination.

4. Table 1-2

R2	R3	R4	Input resistance (ohms)
230	230	685	605.28
69	69	258	255.19
588	588	12	599.88
312	312	422	600.5
563	563	38	599.8

Questions

1. Multisim uses peak-to-peak (p-p) voltages in its simulations; however, dBm calculations rely on root-mean-square (rms) values. Therefore, multiply 2.188 V by 0.3535 to obtain the rms voltage of 773.5 mV rms, which is 0 dBm in a 600-ohm system. (Alternatively, the p-p voltage can be halved to obtain 1.094 V p, and this result can be multiplied by 0.707 to achieve the same result for the rms value.) The 0-dBm result is obtained by rearranging the formula $P = V^2 \quad R$ to solve for V: $V = \sqrt{PR} = \sqrt{(0.001W)(600\Omega} = 773.5$ mVrms.

2. The question is intended to address the issue of loading presented by test equipment. Students should articulate in the interview setting that when generator and measuring-instrument impedances are matched (i.e., a 600-ohm generator output applied to an equivalent system impedance), then effectively a series circuit has been set up and the generator output divides equally between source and load impedances. Therefore, the voltage seen across the load (the system) will be one-half the output from the generator (a 6-dB reduction). For this reason, many measuring instruments used in level-setting applications have switchable impedance settings: in the "bridge" mode, the instrument presents a high enough impedance to the system under test so as not to appear as an additional, parallel load, whereas in the "terminate" mode, the impedance of the measuring instrument is made equal to the system impedance to permit levels to be set with the measuring instrument itself acting in place of the load. The levels will remain set properly when the measuring instrument is subsequently removed and replaced with the equivalent-impedance load.

   Yes, generators can and often do have impedances other than 600 ohms. Those for radio-frequency work are most often 50 ohms, while video equipment usually has 75-ohm impedance. The intent of the question is to make students aware that the "dBm" designation is used with different system impedances and is, therefore, dependent on context: in audio work, 600 ohms is the most often encountered value; however, the "dBm" designation is appropriately encountered in other types of systems as well. The 0-dBm voltage in each of these cases will be different for the reason described in Question 1, so an instrument calibrated to read dB values in one context will not be accurate for other system impedances unless the instrument itself has an adjustable impedance feature.

3. An attenuator reduces signal voltage levels by a specific amount, usually expressed in dB. As an example, 6 dB attenuators will have a voltage output of one-half the input voltage.

4. (a) Voltage gains/losses do not necessarily equate to changes in power level because power is the product of voltage and current, and both quantities will be affected by changes in impedance. For example, an increase in voltage accompanied by a reduction in current will produce the same power as before. Thus, if there is an impedance mismatch, the decibel gain or loss must be modified by the square root of the input and output impedances to produce an accurate result.

(b) Effectively, the resistances (or impedances) cancel. Because decibel relationships for voltage and current are derived from those for power levels, then setting the impedances equal to each other will cause them to cancel out completely; unequal impedances modify the decibel formulas for voltage or current in the manner shown in Section 1-2 of the text. Put another way, power is independent of impedance because, for a constant impedance, an increase in voltage (say) will be accompanied by a decrease in current sufficient to hold power constant.

5. Power has increased by a factor of 4, while voltage has doubled.

6. Gain is output level minus input level: -24 dBm – (-47 dBm) = 23 dB. Gains or losses are always expressed in dB units because one relative value is being compared with another relative value, but these values are not with respect to an absolute reference. The gain is not expressed as "23 dBm" because such a statement would indicate that the power output is 200 mW (i.e., 23 dB above 0 dBm or 1 mW) rather than the true output of 4 microwatts indicated by -24 dBm.

7. The voltage gain is also 6 dB. (Note: students will tend to answer 12 dB based on the entries shown in Table 1-2. Have them do sample calculations assuming a system impedance of 1 ohm so that they see for themselves that voltage doubles even as power increases by a factor of four, thus confirming the statement that power scales as the square of voltage or current.)

8. The feed input resistance to the STL is 600 ohms. The levels for each source must be set with the source terminated; therefore, yes, the position of the switch is important. This is an example of level-setting with equipment set to "terminate" versus "bridged" mode discussed in the answer to Question 2.

9. No, the input to the STL feed is already terminated in 600 ohms.

10. Yes, the +8-dBm level is obtained relative to a 600-ohm load; therefore, a 600-ohm termination resistor must be used when setting the level.

Experiment 2: Waveforms in the Time and Frequency Domains

Procedure

Part I: Analyzing a Sine Wave with the Multisim Spectrum Analyzer

4. (d) Table 2-1

Minimum end frequency	Minimum resolution frequency
100 kHz	97.656 Hz
455 kHz	444.336 Hz
108 MHz	105468.75 Hz
433 MHz	422821.156 Hz

Part II: Spectral Analysis of a Square Wave

6. Table 2-2

Harmonic	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
Frequency (kHz)	1	2	3	4	5	6	7	8	9	10	11	12	13
dB value	20.25	*	8.55	*	2.12	*	1.4	*	0.7	*	-0.4	*	-1.2
Harmonic	Fund.		1^{st} odd		2^{nd} odd		3^{rd} odd		4^{th} odd		5^{th} odd		6^{th} odd

* Even-numbered harmonics should have very low amplitudes (close to or equaling zero) for a square wave.

Note: the dB values will vary depending on the exact point where the measurement is made on the spectrum analyzer. Make sure the students set the cursor close to each harmonic frequency when making a measurement. It might be easier for the student to measure the first harmonic with the cursor and then to approximate the 3^{rd} through 13^{th} harmonic measurements relative to the first. The spectrum analyzer has a dB/div setting specified on the control panel to help with the measurement. ***The answers provided are only an approximation. Make sure the dB value for each harmonic is decreasing.***

Part III: Spectral Analysis of a Triangle Wave

8. Table 2-3

Harmonic	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
Frequency (kHz)	1	2	3	4	5	6	7	8	9	10	11	12	13
dB value	16.8	*	-3.5	*	-11.7	*	-19	*	-22.5	*	-24.6	*	-27
Harmonic	Fund.		1st odd		2nd odd		3rd odd		4th odd		5th odd		6th odd

* Even harmonics should be at very low amplitudes, as predicted by the Fourier series expression for a triangle wave shown in Table 1-3(e) of the text.

Part IV: FFT Math Simulation

13. The student should see a display similar to that of the virtual spectrum analyzer display of step 4 and Figure 2-7. The oscilloscope is acting as a frequency-domain instrument as a result of the FFT math functionality built into the instrument.

14. The student should see a display similar to that produced for step 5 and table 2-2.

Questions

1. The spectral content of a sine wave is just the fundamental frequency; therefore, only one frequency is expected. The function generator is set to 1 kHz, so only a 1-kHz component is expected.

2. (a) The first harmonic (which is the fundamental) has the greatest amplitude (dB) value: 20.25 dB.
   (b) The third harmonic is 11.7 dB down (20.25 dB – 8.55 dB) = 11.7 dB).
   (c) The seventh harmonic is 18.85 dB down (20.25 – 1.4 dB = 18.85 dB).

3. (a) Again, the fundamental (first harmonic) has the greatest value: 16.8 dB.
   (b) The 5th harmonic is 28.5 dB down from the first harmonic. (16.8 dB – (-11.7 dB) = 28.5 dB).
   (c) The 11th harmonic is 41.4 dB down from the first harmonic (16.8 dB – (-24.6 dB) = 41.4 dB.)

4. A pure sine wave will have spectral content only at the fundamental frequency (first harmonic). The presence of energy at any harmonic other than the fundamental is evidence of harmonic distortion.

5. The square wave should show evidence of harmonic energy at the fundamental and the odd harmonics (3rd, 5th, 7th, and so forth). Therefore, the table the student completes as part of the lab assignment should show little or no amplitude for the even harmonics; however, there should be entries associated with the odd harmonics, which is where the spikes on the screen should be visible. The frequencies of the displayed harmonics can be determined by moving the slider at the bottom of the spectrum analyzer display horizontally and reading the frequency at any desired point.

Experiment 3: Introduction to Spectrum Analysis

Note to instructor: This experiment was written around the Rigol DSA-815 spectrum analyzer, and some answers below are specific to that instrument; however, any spectrum analyzer will work. Modify the frequency ranges and calculated results as necessary to match the specifications of the analyzers in your student laboratories.

Procedure

Part I: Introduction to Spectrum Analyzer Operation

1. Answers may vary. For the Rigol DSA-815:

   Impedance: 50 ohms

   Maximum RF input: + 20 dBm

   Maximum dc voltage input: 50 VDC

2. Assuming a maximum 20-dBm input with a 50-ohm system impedance,

   (a) +20 dBm is 100 mW or 0.1 W.

   (b) V = $\sqrt{PR}$ = $\sqrt{(0.1W)(50\Omega)}$ = 2.24 Vrms.

   (c) 2.24 V × 2.828 = 6.334 V p-p

3. Student answers may vary; however, the Rigol instrument defaults to the following values upon power-up:

   Reference level in dBm: 0 dBm

   Vertical scale factor in dB/div: 10 dB/div

   Center frequency in MHz: 750 MHz

   Span in MHz or GHz: 150 MHz

   Resolution bandwidth (RBW): 1 MHz.

4. See Figure 5-2 for a representative display from the Rigol instrument, including the locations of each reading.

6. (c) The display should update more slowly than it did with wider resolution bandwidths, but the "spikes" associated with each frequency component should appear narrower as well.
   (d) The display should update more quickly but with wider frequency spikes.

Part II: Spectral Composition of Sine and Square Waves

8. (c) Answers may vary, but a typical value at maximum attenuation (minimum signal out) would be about -55 dBm.
   (d) Again, assuming -55 dBm, the power would be 3.16 nW.
   (e) With a 50-ohm system impedance, the voltage would be 397.5 μV.

10. What is the center frequency now? <u>1 MHz</u>

    Each major division in the horizontal direction represents a frequency change of <u>100 kHz</u>.

    What are the second and third harmonics of the applied signal? <u>1 MHz and 1.5 MHz</u>.

    Are frequency components present at these frequencies? Ideally, there should be no harmonics for a pure sine wave. The presence of visible harmonics is an indication of harmonic distortion. *(Note: emphasize to students that these harmonics may be 30 to 50 dB down from the fundamental; just because they are visible on the analyzer display does not necessarily make them important.)*

    If so, record the reduction in decibels of the harmonics with respect to the fundamental: <u>Answers will vary, but harmonics are typically at least 30 dB down from the fundamental, if not more</u>.

11. Predict the frequencies at which the first two harmonics would be seen: <u>1.5 MHz and 2.5 MHz</u>. (Note: these are the first two odd-numbered harmonics, or the third and fifth harmonics of the fundamental.)

    Are the harmonics displayed: <u>Yes</u>

    What are their frequencies: <u>Should be close to predicted values</u>.

13. Fundamental: <u>-10 dBm</u>

    first significant harmonic: <u>-19.6 dBm</u>

    second significant harmonic: <u>-24.25 dBm</u>

    By how many decibels is the first displayed harmonic reduced in power from the fundamental? <u>9.6 dB</u>. The second displayed harmonic from the first? <u>4.65 dB [-19.6 dB – (-24.25 dB) = 4.65 dB].</u>

Part III: Spectral Composition of Amplitude-Modulated Signals

14. Predict where the upper and lower side frequencies would be seen if the modulating signal is a 1-kHz sine wave: 499 kHz and 501 kHz.

16. What is the modulation percentage? 100%.

17. How far apart in frequency are the side frequencies above and below the carrier? The side frequencies should be 1 kHz on either side of the carrier.

    Does this result agree with your prediction from step 14. Yes. What are the amplitudes of the side frequencies in dBm? -6 dBm (assuming 0-dBm carrier and 100% modulation; in any event, the side frequencies should be 6 dB below carrier at full modulation.)

    How many decibels below the amplitude of the carrier are the side frequencies? 6 dB (again, assuming 100% modulation).

18. Reduce the amplitude of the modulating signal. Does the carrier amplitude change? No. Carrier amplitude always remains constant, regardless of modulation level or absence of modulation.

19. Carrier: No change (0 dBm)

    Side frequency (upper): -12 dBm (12-dB reduction from carrier)

    Side frequency (lower): -12 dBm (12-dB reduction from carrier)

20. From the spectrum analyzer display, what is the bandwidth of the modulated signal? 2 kHz

Questions

1. No, a DMM could not determine the rms voltage of a 500-kHz signal accurately. DMMs have maximum -3-dB bandwidths of 2 to 5 kHz at most, so higher-frequency signals will be excessively attenuated.

2. Narrower resolution bandwidths (RBWs) such as 100 Hz will cause the display to be updated (refreshed or drawn) more slowly than would wider RBW's, such as 300 Hz or 1 kHz. At the same time, however, the narrow RBWs permit the identification and resolution of closely spaced signals. The widths of the "spikes" of each signal component drawn on the screen are narrower at 100-Hz RBW than they are at the other settings, further permitting the identification of signal components spaced nearby.

3. A pure sine wave should have no harmonic content, so no harmonics of the 500-kHz sine wave should be present. Most likely, some harmonic content will be visible, which is an indication of spectral impurities (harmonic distortion content) of the signal provided by the source.

4. Square wave produce energy at the odd harmonics of the fundamental. Therefore, harmonics should appear at 1.5 MHz (the third harmonic of the 500-kHz fundamental, and the first odd harmonic), and at 2.5 MHz (the fifth harmonic, or second odd harmonic).

5. The amplitude of the third harmonic should be 1/3rd the fundamental, and the fifth harmonic 1/5th the fundamental, as predicted by the Fourier series equation shown in Table 1-3(d). For the third harmonic, the power would be $(1/3)^2$ or 1/9, and for the fifth harmonic $(1/5)^2$ or 1/25 the power resident in the fundamental. The observed reduction in amplitude is expressed in decibel terms on the spectrum analyzer, necessitating a conversion from voltage (amplitude) to power quantities. Thus, the expected reduction in decibels from fundamental to third harmonic is 10 log (1/9) = -9.5 dB, and for the fifth harmonic the expected reduction is 10 log (1/25) = -13.9 dB. These results comport very closely with the observed amplitudes on the spectrum analyzer display.

6. No, the carrier amplitude does not vary as the percentage of modulation is varied, but the side-frequency amplitudes do vary. This result confirms that all useful information resides within the side frequencies, not the carrier.

7. The side frequency amplitudes were reduced by 6 dB when the modulation percentage was reduced from 100% to 50%, which in turn caused a reduction to ¼ the power because power scales as the square of voltage: $(1/2)^2 = ¼$. Because all information is carried within the sidebands in AM and because sideband power reduces as the square of amplitude, this result predicts that the information-carrying capability falls off quickly as the modulation percentage decreases. Table 2-1 in the text provides a comparison of the power levels in carrier and sidebands at both 100% and 50% modulation percentages.

8. Bandwidth can be determined by subtracting the observed frequency of the lower sideband from that of the upper sideband. The modulating signal frequency can be determined from the spacing of either the upper or lower sideband from the frequency of the carrier; i.e., if the side frequencies appear 1 kHz above and below the carrier, then the intelligence frequency is 1 kHz. The rule for bandwidth (BW) in an AM system is that BW = $2f_i$, where f_i is the highest intelligence frequency. Thus, an f_i of 1 kHz produces a BW of 2 kHz, an f_i of 5 kHz produces a 10-kHz BW, and so on.

9. Student should recognize that an oscilloscope is a time-domain instrument and that a spectrum analyzer is a frequency-domain instrument. Typical troubleshooting situations for an oscilloscope would involve determining whether a signal is present (such as a clock signal from an oscillator) and for a spectrum analyzer would involve identifying the presence of potentially interfering frequency components created as the result of system operation.

Experiment 4: Upconversion and Downconversion

Procedure

6. Table 4-1 Calculated Signals Generated for a Mixer; When F_2 = 20 MHz and F_1 = 21 MHz (–20 dBm).

#	FREQUENCY (MHz)	*m*	*n*	ORDER	* CALC. POWER (dBm)	MEASURED WITH −20 dBm INPUT AT 21 MHz
1	1	1	1	2	−26	
2	2	2	2	4	−38	
3	20	1	0	1	—	
4	21	0	1	1	−20	
5	22	1	2	3	−32	
6	23	2	3	5	−44	
7	19	2	1	3	−32	
8	39	3	1	4	−38	
9	41	1	1	2	−26	
10	43	1	3	4	−38	
11	59	4	1	5	−44	
12	61	2	1	3	−32	
13	62	1	2	3	−32	
14	64	1	4	5	−44	
15	81	3	1	4	−38	
16	82	2	2	4	−38	
17	83	1	3	4	−38	
18	101	4	1	5	−44	
19	102	3	2	5	−44	
20	104	1	4	5	−44	

Questions

1. The highest-output signals, other than the input signals themselves, should be those from second-order products ($f_1 + f_2$ or $f_1 - f_2$).

2. $f_1 + f_2$ and $f_1 - f_2$.

3. $f_1 + 2f_2$, $f_1 - 2f_2$, $2f_1 + f_2$, $2f_1 - f_2$.

4. At least one of the third-order products will appear in the passband of the signals of interest. These undesired products can be impossible to identify as being distinct from desired signals and, therefore, impossible to filter out. This problem can occur with all odd-order products, but because third-order products produce the highest amplitudes, they are of most immediate concern to receiver designers.

5. Dynamic range speaks to the linear operating range of the receiver. Operation outside this range (such as by overdriving the receiver input) will create intermodulation products, including the third-order products identified in the previous question.

6. No, anything exhibiting nonlinear behavior will act as a mixer. The device does not have to be active (i.e, one requiring an external power source) to function as a mixer. Diodes act as mixers, as do transistors or amplifiers driven into nonlinear operation. The essential characteristic is that there is nonlinear operation.

7. Yes, non-electronic devices can act as mixers. Even a rusty fence-post presents a point-contact rectifying junction, and in the presence of a high enough voltage field (i.e., in the immediate vicinity of a high-power transmitter at a communications installation) it can create undesired mixing products. As long as nonlinearities are present, mixing will occur.

Experiment 5: Frequency Modulation: Spectrum Analysis

Procedure

Part I: Determination of Deviation Constant

6. Results will vary. A typical value for deviation constant would be 10 kHz/V. The relationship should be linear, as depicted on the student-drawn graph.

Part II: Determination of Reference Carrier Amplitude

7. (a) Z = <u>50</u> ohms.

   (b) V_{rms} = <u>223.6</u> mV

   (c) V_{p-p} = <u>632.4</u> mV

8. (d) Reference level (dBm): <u>0 dBm</u>

   Vertical scale factor (dB/div): <u>10 dB/div</u>

   Center frequency (kHz): <u>200 kHz</u>

   Span (kHz): <u>10 kHz</u>

   Resolution bandwidth (RBW) in Hertz: <u>300 Hz</u>

   (e) Amplitude of 200-kHz carrier will be approximately 6 dB below the reference level.

Part III: FM Signal Analysis

12. Sketch should be similar to Figure 5-2.

13. Carrier amplitude initially decreases as an increasing number of sideband pairs becomes visible. These sideband pairs increase in amplitude as the modulating signal amplitude is increased.

14. Sketch should show carrier in center and pairs of side frequencies, each spaced 1 kHz apart, on either side of the carrier.

15. The frequency spacing of the sidebands also increased to 1.5 kHz.

17. From the display, determine by how many dB the amplitude of one of the two sidebands (either upper or lower) has been reduced from the reference level and write it here: <u>-7.1</u> dB (approx)

18. Expression should initially read -7.1 = 20 log $\frac{V_2}{V_1}$

$$\frac{-7.1}{20} = \log \frac{V_2}{V_1}$$

$$10^{(-7.1/20)} = \frac{V_2}{V_1}$$

$V_2/V_1 = 0.441$

19. Are the numbers the same? Yes

20. J0: <u>-1.3</u> dBm normalized amplitude: <u>0.22</u>

J1: <u>-4.7</u> dBm normalized amplitude: <u>0.58</u>

J2: <u>-9.1</u> dBm normalized amplitude: <u>0.35</u>

J3: <u>-17.7</u> dBm normalized amplitude: <u>0.13</u>

22. Answers will vary depending on calculated deviation constant; peak-to-peak voltage displayed on oscilloscope should be the voltage that produces ±2.4 kHz of deviation with a 1-kHz modulating signal.

Bessel nulls should be seen at modulation indices of 2.4, 5.5, and 8.65.

25. Results will vary depending on equipment used; however, typical errors caused by nonlinearities in low-cost function generators are on the order of 10%.

Questions

1. The displayed amplitude is reduced by 6 dB because the input impedance of the analyzer and the output impedance of the function generator are equal (most likely 50 ohms), whereas the input impedance of the oscilloscope is 1 megohm or higher. With the analyzer in place, the applied signal divides equally between the generator impedance and that of the analyzer; therefore causing the applied signal to be reduced by one-half, or a 6-dB voltage reduction. The oscilloscope did not load down the signal produced by the generator, but the analyzer did.

2. The separation of each side frequency component from the next is equal to the intelligence frequency. Thus, a sine-wave modulating signal of 1 kHz would produce side frequency components separated by 1 kHz from each other.

3. Most likely, there are nonlinearities in the voltage-controlled frequency capability of the function generator that cause the deviation constant to vary from its calculated or experimentally determined value. Variations on the order of 10% are typically seen with low-cost function generators.

4. For an intelligence frequency of 1 kHz and deviation also of 1 kHz, Carson's rule predicts bandwidth to be 2(1 + 1) or 4 kHz. The Bessel function determination for a modulation index of 1.0 includes three pairs of significant sidebands, one each above and one each below the carrier and separated by 1 kHz from the next, for a predicted bandwidth of 6 kHz. The Carson's rule approximation includes about 98% of the total power. Limiting the bandwidth to that predicted by Carson's rule would involve reducing either the maximum deviation or the highest intelligence frequency, thus possibly affecting intelligibility or (in the case of deviation) the improvement in signal-to-noise ratio seen at the receiver output (Section 3-5).

5. Licensed systems will include a modulation monitor or percentage modulation indicator showing the amount of deviation. These indicators must be periodically calibrated. One way to do so is to use a 1-kHz sine wave modulating signal and to increase deviation to ±2.405 kHz, then to ±5.5 kHz and then to ±8.65 kHz while viewing the spectrum analyzer display. The carrier should be absent when the modulation indicator displays these deviation values. If so, the indicator can be trusted to display deviation (or modulation percentage) accurately, and from these values the occupied bandwidth can be approximated using Carson's rule or determined more precisely with the table of Bessel functions.

6. (a) Modulation index is 3 kHz/2 kHz, or 1.5. Therefore, according to Table 3-1, the carrier and the first four sets of sidebands are significant.

J_0 (carrier): $(0.51)^2 \times 1$ kW = 260.1 W

J_1: $(0.56)^2 \times 1$ kW = 313.6 W

J_2: $(0.23)^2 \times 1$ kW = 52.9 W

J_3: $(0.06)^2 \times 1$ kW = 3.6 W

J_4: $(0.01)^2 \times 1$ kW = 0.1 W

(b) The total power is the sum of the carrier power plus that of the sideband pairs. Therefore, the power calculated in step (a) for each sideband must be doubled and then added to the carrier power to determine the total power:

260.1 + 2(313.6 + 52.9 + 3.6 + 0.1) = 1000.5 W.

(c) The total power should be equal to that of the unmodulated carrier, demonstrating that in the presence of modulation, FM systems distribute power among carrier and sidebands rather than have the sideband power add to that of the carrier, as is the case for AM. The slight overage shown in part (b) is a result of rounding errors. For other situations, any calculated power less than that of the unmodulated carrier is most likely accounted for as being power residing in side frequencies considered insignificant in the Bessel table.

(d) Because there are four significant sidebands, and each is separated by 2 kHz from the next, and the sidebands extend both above and below the carrier, the total bandwidth is 16 kHz. This predicted bandwidth is significantly more than that for an AM transmission (4 kHz).

(e) The Carson's rule approximation for bandwidth is 2(2 kHz + 3 kHz) = 10 kHz, versus the Bessel determination of 16 kHz from part (d). The significantly narrower bandwidth predicted by Carson's rule does not take into account the small (but not insignificant, in the case of high-power systems) power residing in the outermost sidebands.

Experiment 6: Radio-Frequency Amplifiers and Frequency Multipliers

Procedure

Part I: Clamping Circuits

3. At what Vin does Vout no longer have the same dc offset: 0.8 V (approx).

4.

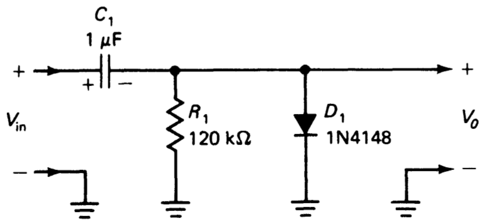
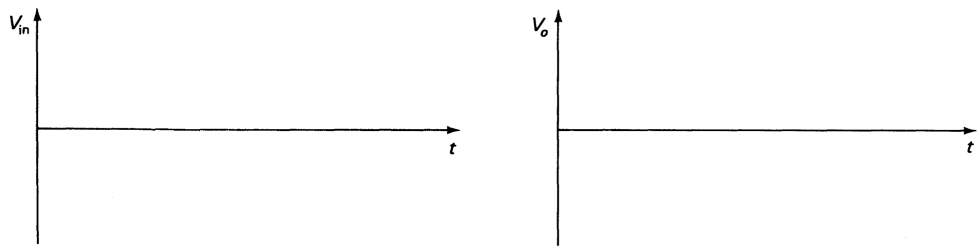
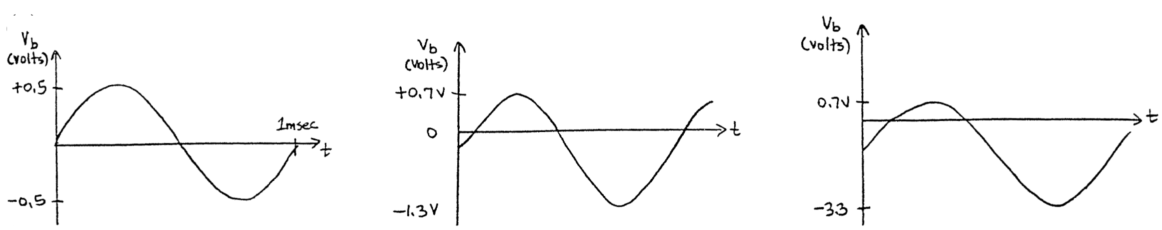


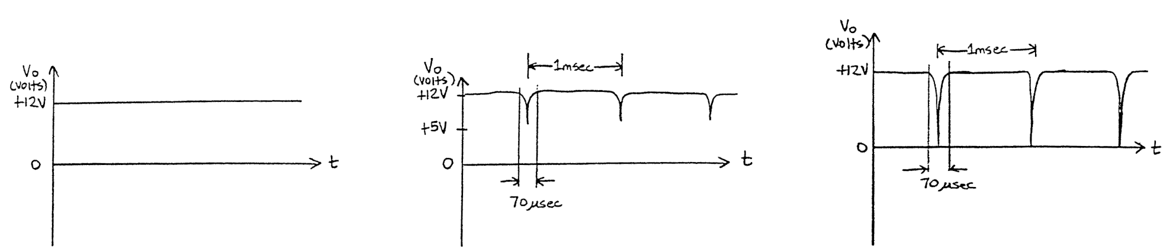
FIGURE 6-2



6.



7.



This amplifier has a gain greater than unity.

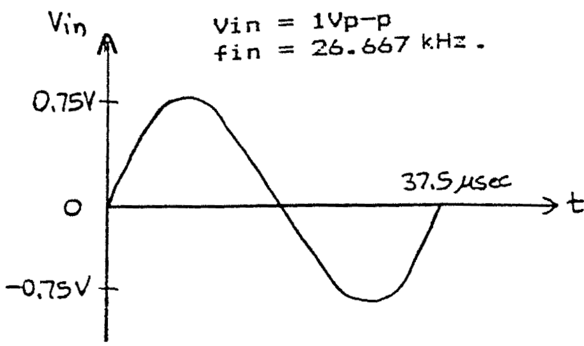
8. (d) $V_{in} = 1\ V_{p\text{-}p}$; $\%D = \dfrac{0}{1\ \text{msec}} = 0\%$, $I_{avg} = 0$

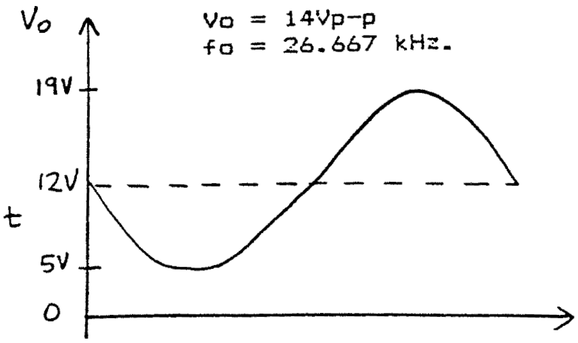
$V_{in} = 2\ V_{p\text{-}p}$; $\%D = \dfrac{70\ \mu\text{sec}}{1\ \text{msec}} = 7\%$, $I_{avg} = 7\%\ I_{max}$

$V_{in} = 4\ V_{p\text{-}p}$; $\%D = \dfrac{70\ \mu\text{sec}}{1\ \text{msec}} = 7\%$, $I_{avg} = 7\%\ I_{max}$

Part II: Tuned Class C Amplifier

9. Resonant frequency is 27.105 kHz.

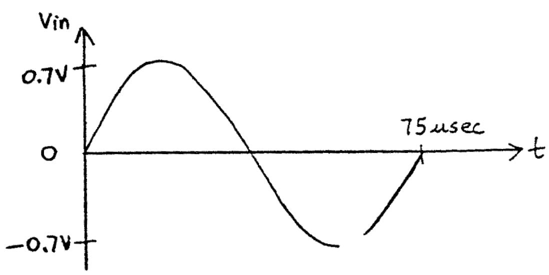




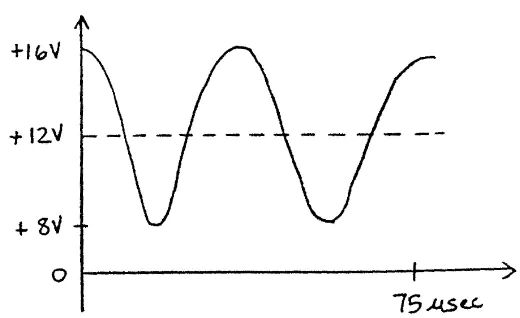
10. f_{upper} = 27.135 kHz; f_{lower} = 26.310 kHz; BW = 27.135 kHz – 26.310 kHz = 825 Hz *(Note: some variation is expected because of variations in the Q values of the inductors used for the experiment.)*

11. $Q = \dfrac{f_r}{BW} = \dfrac{26.667 kHz}{825 Hz} = 32.32.$

12.



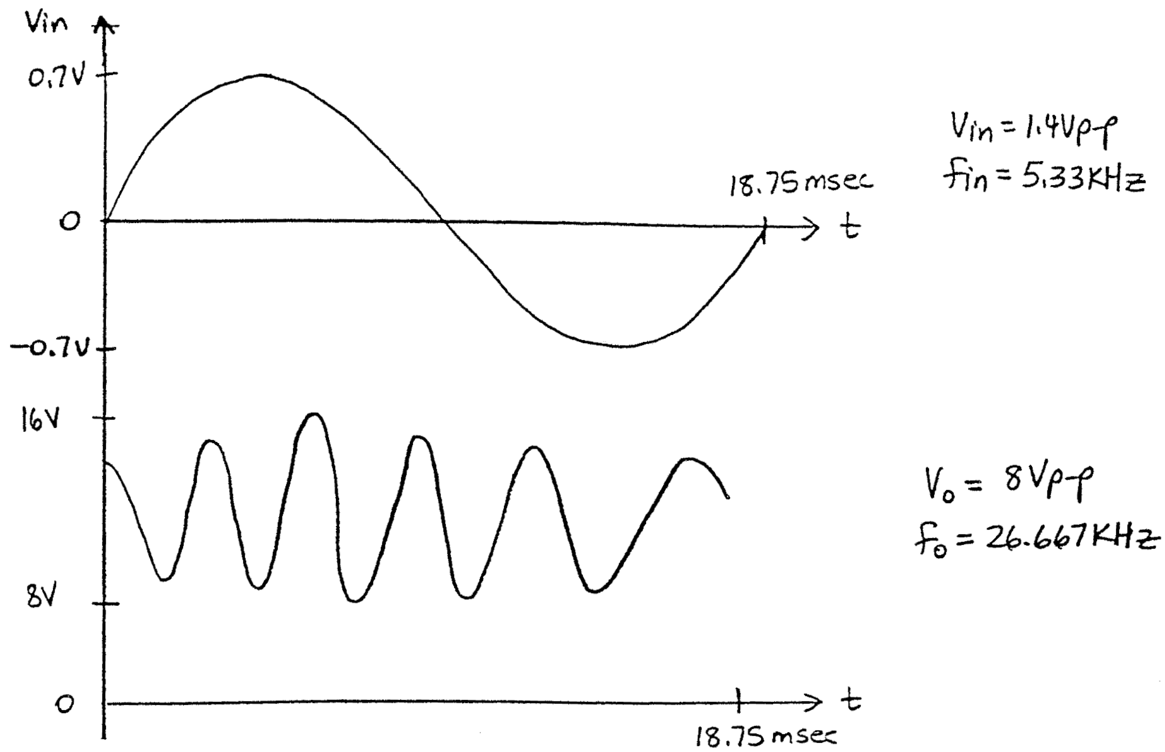
f = 13.333 kHz
V_{in} = 1.4 $V_{p\text{-}p}$



f = 26.667 kHz
V_o = 8 $V_{p\text{-}p}$

13. Solution to Table 6-1:

TYPE	V_{in} (V_{p-p})	f_{in} (kHz)	V_o (V_{p-p})	f_o (kHz)
×3	1.4	8.889	8.0	26.667
×4	1.4	6.667	8.0	26.667
×5	1.4	5.333	8.0	26.667



Questions

1. No, the clamping action would not be visible if the oscilloscope input coupling is set to ac because the dc blocking capacitor at the scope input would remove any average voltage (i.e., dc component). With ac coupling, the display will always appear centered about the 0-V reference.

2. Figure 4-6 (b) in the text shows the load-line diagram for class-C operation. In Figure 4-6(a), the additional negative voltage, $-V_{BB}$, applied to the base of the transistor keeps it turned off until the input signal reaches a peak amplitude of $V_{BB} + V_{BE}$, at which time the transistor becomes forward-biased and remains so for the positive peak of the input sine wave. This brief on-time interval produces a burst of energy at the collector, which, when applied to a tank circuit, can be used to recreate higher-amplitude sine waves as a result of the flywheel effect.

3. V_{out} would not vary as a result of amplitude variations seen at V_{in}. In other words, the class C amplifier cannot be used in AM transmitters employing low-level modulation because the output tank circuit will recreate a sine-wave carrier of constant amplitude, thus removing any variations in carrier amplitude created as the result of modulation. Class C amplifiers are extremely useful because of their high efficiencies (often 75% or more), which is their principal advantage over class A or B amplifiers. For this reason, class C amplifiers are often found in high-power applications, such as FM broadcast transmitters (where amplitude variations in the modulated signal are undesired) and in AM broadcast transmitters employing high-level modulation.

4. The frequency tripler has a tank circuit that is resonant at three times the input frequency, thus producing the largest output at the third harmonic of the input. This action can also be explained with a frequency-domain analysis by recognizing that the output of the class C amplifier is rich in harmonic content as the result of nonlinear operation. The output contains a tuned circuit to select the third harmonic of the input, which is among the many harmonics present at the amplifier output. The tuning action provided by the tank circuit gives rise to the term "tuned amplifier" for class C operation, implying that the amplifier has an operating bandwidth determined by the Q of the tuned circuit.

5. The output amplitudes get progressively smaller at higher harmonics. The effect in the time domain is shown in the sketch produced for step 12 (Figure 6-9). Note in particular that every other cycle of the output has the higher amplitude. This effect becomes particularly pronounced at higher harmonics. For example, at the ×5 value from step 13 and Table 6-1, the highest amplitude occurs with every fifth cycle. This result implies the presence of distortion as a reduction in output amplitude at higher harmonics. For this reason, practical systems primarily rely on doublers and triplers, with higher multiples obtained by using several stages of multiplication. (For example, ×6 multiplication can be obtained with a tripler followed by a doubler, or vice versa.)

Experiment 7: Colpitts RF Oscillator Design

Procedure

1. $V_E = V_{CC} - V_{CE} = 10 - 5.5 = 4.5$ V
$V_B = V_B + V_{BE} = 4.5 + 0.5 = 5.0$ V

$$R_1 = R_2 = \frac{V_B}{I_{R_2}} = \frac{5\text{ V}}{0.1(3.75 \times 10^{-3})} = 13.3\text{ k}\Omega\text{; use }12\text{ k}\Omega$$

$$R_E = \frac{V_E}{I_E} = \frac{4.5\text{ V}}{3.75\text{ mA}} = 1.2\text{ k}\Omega$$

2. $$A_v = \frac{R_c \| R_L}{r_e'} \cong \frac{R_4}{r_e'}$$

$$r_e' \cong \frac{25\text{ mV}}{I_E} = \frac{25\text{ mV}}{3.75\text{ mA}} = 6.67\ \Omega$$

$$A_v = \frac{R_4}{r_e'} = \frac{680\ \Omega}{6.67\ \Omega} = 102$$

Let $A_v B = 10$
$102\,B = 10$
$B \approx 0.1$

$$f_r = \frac{1}{2\pi\sqrt{L_2 C_T}} \text{ so } C_T = \frac{1}{4\pi^2 f^2 L_2} = \frac{1}{4\pi^2(1.8 \times 10^6)^2(8.2 \times 10^{-6})}\text{, so } C_T = 953\text{ pF}$$

Let $C_1 = 1000$ pF, $C_2 = .01\ \mu$fd

Then $$C_T = \frac{(1000\text{ pF})(.01\ \mu\text{fd})}{1000\text{ pF} + .01\ \mu\text{fd}} = 909\text{ pF} \approx 953\text{ pF}$$

$$B = \frac{C_1}{C_2} = \frac{1000\text{ pF}}{.01\ \mu\text{fd}} = 0.1$$

$$A_v B = \frac{V_f}{V_1} = \frac{116\text{ mV}}{20\text{ mV}} = 5.8$$

3.

Measured	Calculated
$V_{BE} = 0.63$ VDC	$V_{BE} = 0.5$ VDC
$V_{CE} = 5.69$ VDC	$V_{CE} = 5.5$ VDC
$V_E = 4.40$ VDC	$V_E = 5.0$ VDC

4. frequency = 1.960 MHz

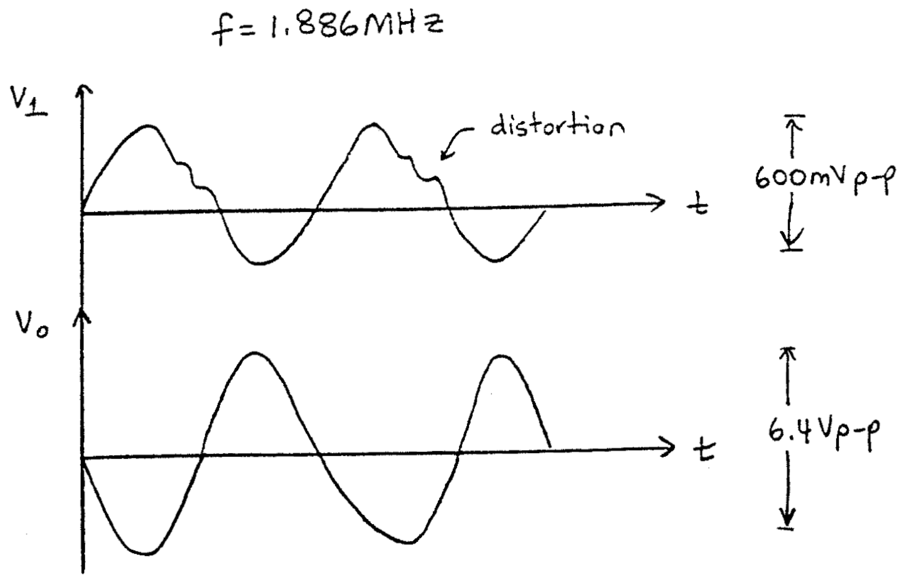
5.

	Amplitude	Frequency	Phase
V_1	20 $mV_{p\text{-}p}$	1.887 MHz	0 degrees (ref)
V_c	690 $mV_{p\text{-}p}$	1.887 MHz	180 degrees
V_f	116 $mV_{p\text{-}p}$	1.887 MHz	0 degrees

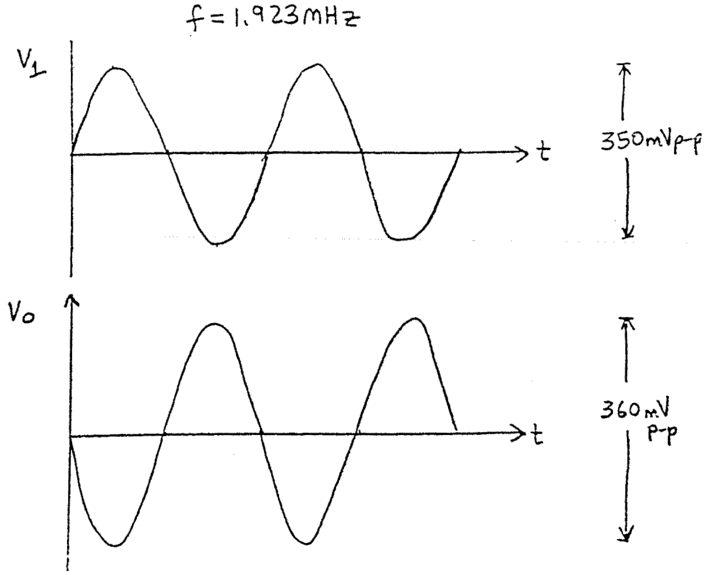
6. $$A_vB = \frac{V_f}{V_1} = \frac{116\ \text{mV}}{20\ \text{mV}} = 5.8$$

7. No changes are necessary

8. Using 10:1 probes: obvious distortion noted.



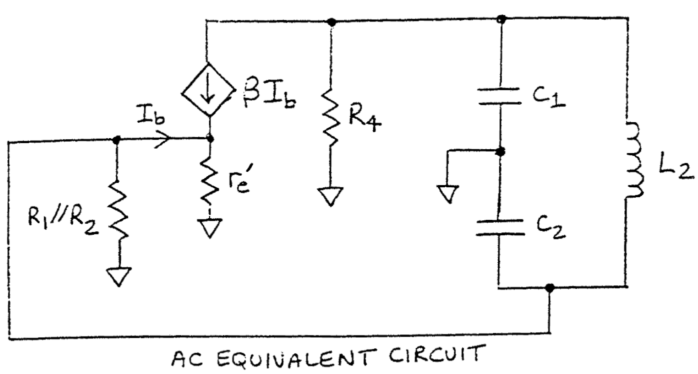
9. An emitter resistance of 33 ohms is added. This removes all visible distortion.



If r_e is increased to 39 ohms, all oscillations cease. No waveforms are observed at V_1 and V_0.

Questions

1.



2. The inverting amplifier has a voltage gain of approximately 100 and provides phase inversion. The tank circuit resonant at a frequency of oscillation is determined by its internal inductance and capacitance values. It also provides voltage attenuation due to the arrangement of the feedback capacitors, C_1 and C_2, in a voltage-divider configuration. Since the function of the two feedback capacitors is connected to ground, there is a 180 degree phase-shift of the signal within the feedback network. This phase inversion along with the inverting amplifier configuration insures that positive feedback is being employed. Since the loop gain (A_v x B) exceeds unity and the total phase shift around the loop is zero degrees, the circuit oscillates when the loop is closed. As unbypassed emitter resistance of 33 ohms is added so that the loop gain *slightly* exceeds unity, which produces an undistorted output waveform. Without this resistor, the loop gain is set too high and obvious distortion results in the output waveform.

Experiment 8: Hartley RF Oscillator Design

Procedure

2.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$L = \frac{1}{4\pi^2 f^2 C} = \frac{1}{4\pi^2(7.82 \times 10^{-6})^2 C} = 7.82\ \mu\text{H}$$

$$n_{\text{total}} = 100\sqrt{\frac{L}{135}} = 100\sqrt{\frac{7.82}{135}} = 24 \text{ turns}$$

Let $B = 0.21$

$$B = \frac{\text{turns before tap}}{\text{total turns}} = \frac{n_1}{n_{\text{total}}}$$

$$0.21 = \frac{n_1}{24}$$

$$n_1 = 5 \text{ turns}$$

$$n_2 = n_{\text{total}} - n_1 = 24 - 5 = 19 \text{ turns}$$

$$R_p = \frac{619.2\ \text{k}\Omega\ \text{turns}^2}{(n_{\text{total}})^2} = \frac{619.2 \times 10^3}{(24)^2} = 1.075\ \text{k}\Omega$$

Let $A_v B \cong 1.05$

$$A_v(0.21) = 1.05$$

$$A_v = 5$$

$$r_e' \cong \frac{25\ \text{mV}}{I_E} = \frac{25\ \text{mV}}{3.75\ \text{mA}} = 6.67\ \Omega$$

$$R_4 = 15 r_e' = 15(6.67) = 100\ \Omega$$

$$A_v \cong \frac{R_3 \| R_p}{R_4}$$

$$5 = \frac{R_3 \| R_p}{100}$$

$$R_3 \| R_p = 500\ \Omega$$

$$R_3 \| 1.075\ \text{k}\Omega = 500\ \Omega$$

$$\frac{R_3(1075)}{R_3 + 1075} = 500$$

$$1075\, R_3 = 500\, R_3 + 537500$$

$$575\, R_3 = 537500$$

$$R_3 = 934\ \Omega$$

Let $R_3 = 1\ \text{k}\Omega$

3. $$V_{CC} = I_E R_3 + V_{CE} + I_E R_4 + I_E R_5$$
$$15 = (3.75 \times 10^{-3})(1 \times 10^3) + 6 + (3.75 \times 10^{-3})(100) + (3.75 \times 10^{-3})R_5$$
$$R_5 = 1.3\ \text{k}\Omega$$
$$\text{let } R_5 = 1.2\ \text{k}\Omega$$
$$V_B = I_E(R_4 + R_5) + V_{BE}$$
$$V_B = (3.75 \times 10^{-3})[100 + 1.2\ \text{K}] + 0.5$$
$$V_B = 5.38\ \text{V}$$
$$V_B = I_2 R_2 \approx \left[\frac{1}{10} I_E\right] R_2$$
$$5.38 = \frac{1}{10}(3.75 \times 10^{-3}) R_2$$
$$R_2 = 14.35\ \text{k}\Omega$$
$$\text{let } R_2 = 15\ \text{k}\Omega$$
$$R_1 = \frac{V_{CC} - V_B}{\frac{1}{10}(3.75 \times 10^{-3})} = \frac{15 - 5.38}{\frac{1}{10}(3.75 \times 10^{-3})} = 25.65\ \text{k}\Omega$$
$$\text{let } R_1 = 27\ \text{k}\Omega$$

6.

Measured	**Calculated**
$V_{BE} = 0.639$ V	$V_{BE} = 0.5$ V
$V_{CE} = 7.141$ V	$V_{CE} = 6.0$ V
$V_E = 4.469$ V	$V_E = 4.88$ V

No alterations are necessary.

7. With frequency set for maximum possible amplitudes at V_c and V_f and a phase difference of 180 degrees. Frequency = 1.754 MHz.

8.

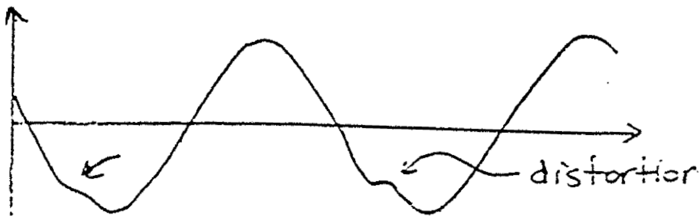
	Amplitude	**Frequency**	**Phase**
V_1	20 $mV_{p\text{-}p}$	1.754 MHz	0 degrees (ref)
V_c	65 $mV_{p\text{-}p}$	1.754 MHz	180 degrees
V_f	35 $mV_{p\text{-}p}$	1.754 MHz	0 degrees

9. $$A_v B = \frac{V_f}{V_1} = \frac{35\ \text{mV}}{20\ \text{mV}} = 1.75$$

10. With the loop closed: V_f and V_1 are the same voltage.

	Amplitude	Frequency	Phase
V_1/V_f	1.85 $V_{p\text{-}p}$	1.754 MHz	0 degrees (ref)
V_c	3.40 $V_{p\text{-}p}$	1.754 MHz	180 degrees

The waveform, V_c, shows no distortion. However, there is a slight amount of distortion visible in V_1V_f.

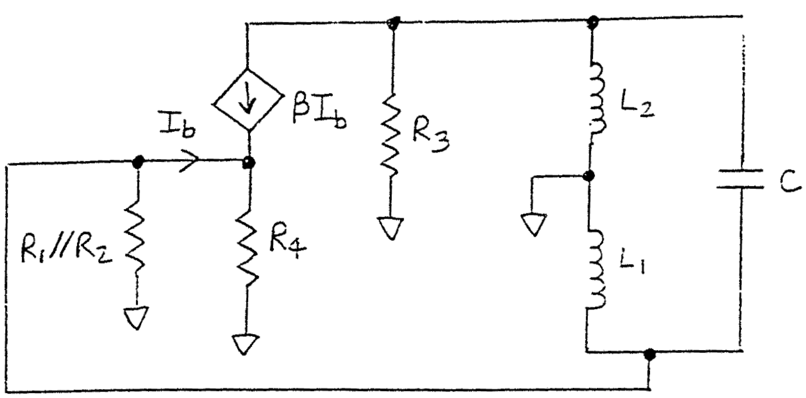


This distortion disappears when R_4 is increased to 150 ohms. If R_4 is increased to 180 ohms, oscillations disappear due to $A_vB < 1$.

11. Final design values are those calculated in step 1 except for R_4, which is set at 150 ohms.

Questions

1.



AC EQUIVALENT CIRCUIT

2. The inverting amplifier has a voltage gain of approximately 5 and provides phase inversion. The tank circuit resonates at a frequency of oscillation determined by its internal inductance and capacitance values. It also provides voltage attenuation due to the feedback inductors, L_1 and L_2, being configured in a voltage divider circuit. Since the junction of the two inductors is connected to ground, phase inversion occurs within the feedback path. This phase inversion and the inverting amplifier ensure that positive feedback is being employed. Since the loop gain (A_vB) exceeds unity and the total phase shift around the loop is zero degrees, the circuit will oscillate when the loop is closed. The final value of R_4 determines that the loop gain *slightly* exceeds unity, which guarantees an undistorted output waveform. Otherwise, obvious distortion occurs.

Experiment 9: Principles of Nonlinear Mixing

Procedure

Part I: Bandpass Filter Characterization

1 (a) Output voltage one-half the input is a 6-dB voltage reduction. From the figure, the lower frequency (where output is attenuated by 6 dB from maximum at 455 kHz) appears at approximately 449.5 kHz, and the upper frequency appears at 460.5 kHz.
(b) One-tenth the input voltage is 20 dB of voltage attenuation. The lower 20-dB down frequency is approximately 448 kHz, and the upper 20-dB down frequency is approximately 462 kHz.
(c) This is 40 dB of attenuation. Lower frequency: 447 kHz; upper frequency: 463 kHz.
(d) Frequencies below 446.5 kHz and above 463.5 kHz are attenuated by more than 45 dB.

2. $V_{in} = 1\ V_{p-p}$

$V_{out} = 0.8\ V_{p-p}$

V_{out} is less than V_{in} because of the insertion loss of the filter.

Insertion loss = 20 log (0.8 V/1 V) = -1.94 dB, within manufacturer specifications.

3. Measured values should be close to those predicted in step 1.

Part II: The Mixer

6. Voltage: <u>700</u> mV

Frequency: <u>455</u> kHz

7. a. V: 700 mV F: 455 kHz

b. V: 100 mV F: 455 kHz

c. V: 100 mV F: 455 kHz

d. V: 200 mV F: 455 kHz

e. V: 200 mV F: 455 kHz.

f. V: 40 mV F: 455 kHz.

Note: All voltages given above and for question 6 are peak-to-peak.

Questions

1. Tests similar to the ones carried out in Part I may be conducted as part of an acceptance-testing program for filters supplied by a new vendor, wherein a representative sample is tested to verify compliance with manufacturer specifications. The measurements could be automated through the use of an automated test equipment (ATE) environment or with a spectrum analyzer/tracking generator combination to sweep through the frequencies of the filter passband and stopband.

2. This unwanted difference-frequency component is exactly equal to the desired intermediate-frequency component and would, therefore, be impossible to differentiate and remove through filtering.

3. The largest amplitudes are associated with the fundamental frequencies, f_1 and f_2, followed by those of the second-order products and then the third-order products. Higher-order harmonics have lower amplitudes than fundamentals, as predicted by the Fourier series relationships shown in Table 1-3 of the text.

4. The amplitude of the ($f_1 + 2f_2$) output signal was approximately 8 dB below the sum or difference frequency component. To keep these “extra” frequency component amplitudes to a minimum, two suggestions would be to make sure the mixer stage is not overdriven, and/or to use a square-law device such as an FET as the mixer.

5. The other third-order products are $f_1 - 2f_2$, $2f_1 + f_2$, $2f_1 - f_2$.

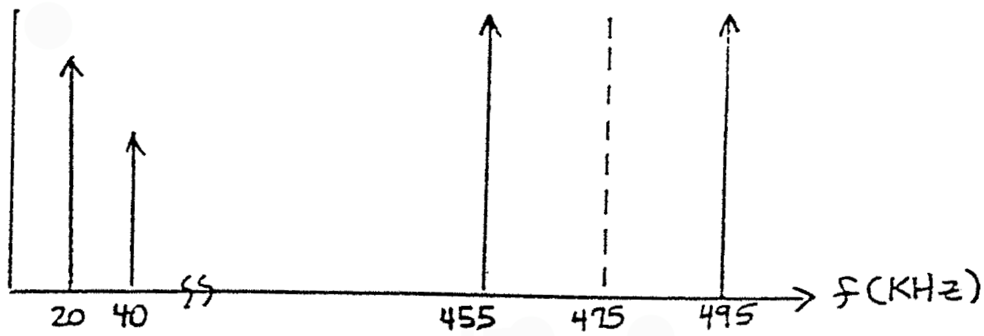
6. Third-order products are of particular concern because at least one of the four frequency combinations identified in questions 4 and 5 will invariably fall within the passband of the frequencies of interest, thus making it impossible to remove by filtering. The same result will be obtained with all odd-order mixing products; however, third-order products will produce the highest amplitudes, thus making them the products of most immediate concern.

Experiment 10: Sideband Modulation and Detection

Procedure

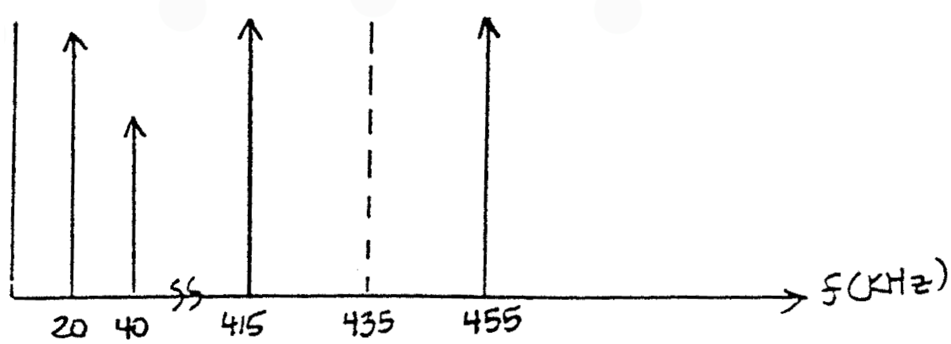
1. (a) Assuming the RF carrier at 475 kHz is suppressed by the balanced modulator:

f_i = 20 kHz $f_c - f_i$ = 455 kHz
$2f_i$ = 40 kHz $f_c + f_i$ = 495 kHz



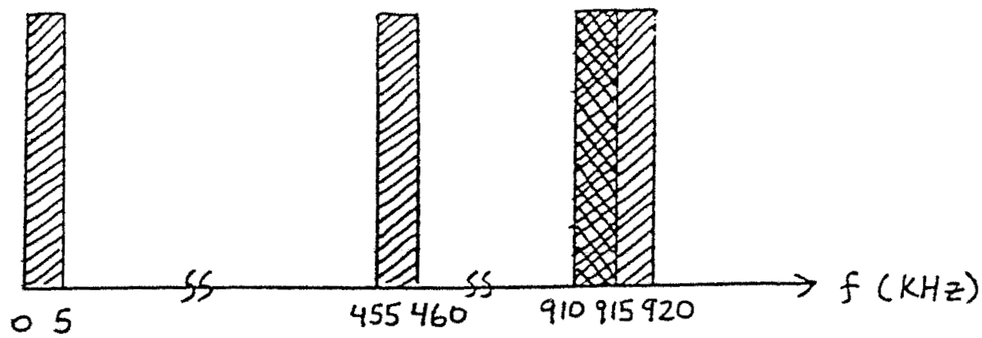
(b) Assuming the RF carrier at 435 kHz is suppressed by the balanced modulator:

f_i = 20 kHz $f_c - f_i$ = 415 kHz
$2f_i$ = 40 kHz $f_c + f_i$ = 455 kHz



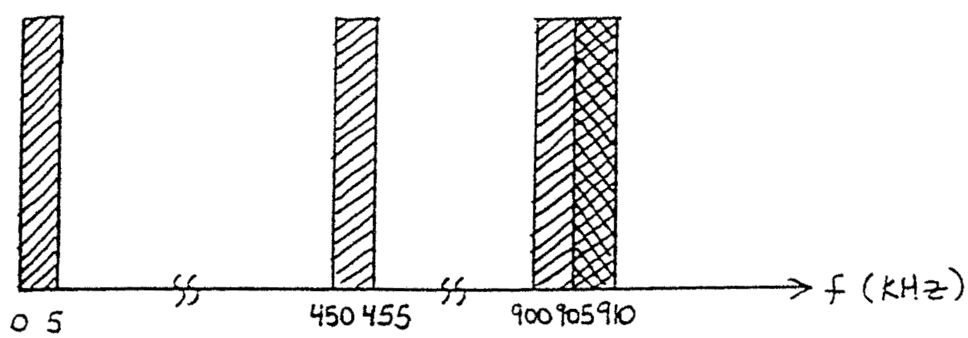
(c) Assuming the RF carrier at 455 kHz is suppressed by the balanced modulator:

$f_i = 455 - 460$ kHz $\qquad f_c - f_i = 0 - 5$ kHz
$2f_i = 910 - 920$ kHz $\qquad f_c + f_i = 910 - 915$ kHz



(d) Assuming the RF carrier at 455 kHz is suppressed by the balanced modulator:

$f_i = 450 - 455$ kHz $\qquad f_c - f_i = 0 - 5$ kHz
$2f_i = 900 - 910$ kHz $\qquad f_c + f_i = 905 - 910$ kHz

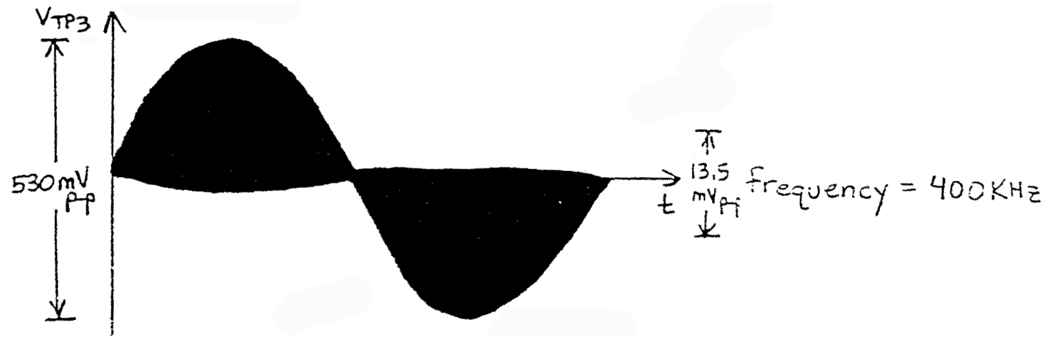


(e) Only the difference frequencies produced by mixing action would be passed by the filter:

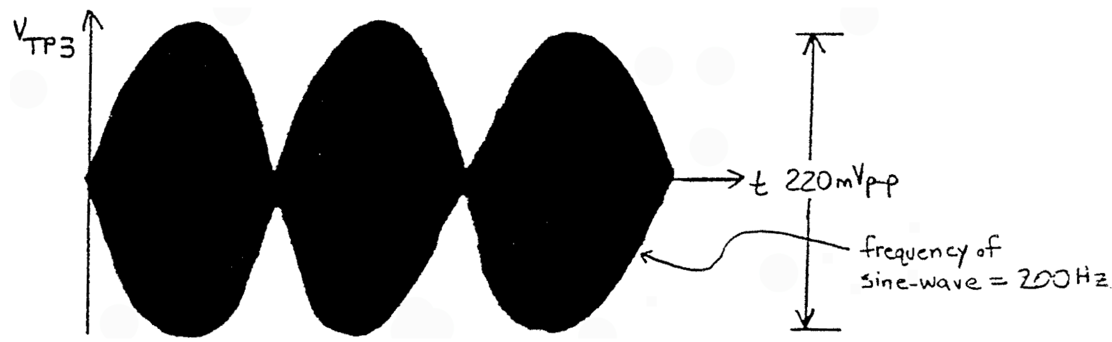
$f_c - f_i = 0 - 5$ kHz

2. The output voltage at TP_3 was reduced to 0 V by adjustment of R_2.

3.

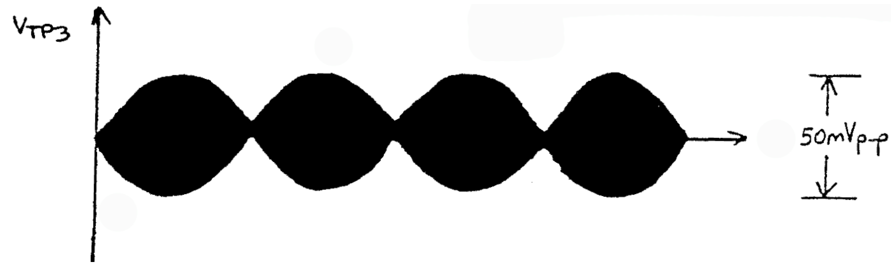


4. By resetting the carrier signal to 450 $mV_{p\text{–}p}$ and the intelligence signal to 300 $mV_{p\text{–}p}$, the following display was obtained at TP_3:

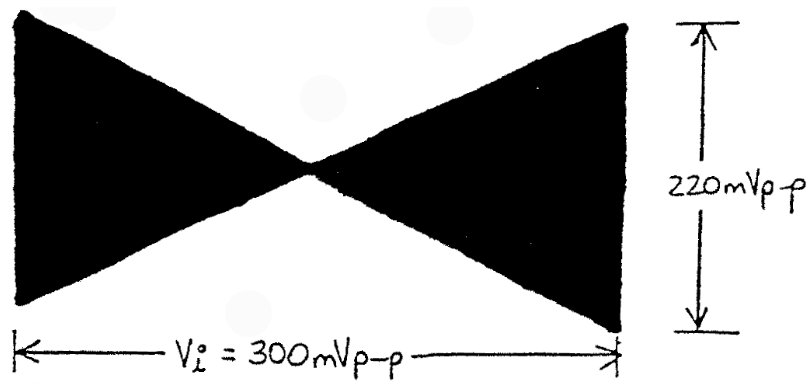


5. With R_{10} set to 47 Ω, there is more amplification in the balanced modulator, which produces an output signal which shows distortion (flat-topping).

With R_{10} set to 1 kΩ, there is less amplification in the balanced modulator, which produces an output signal which shows a very small particle.



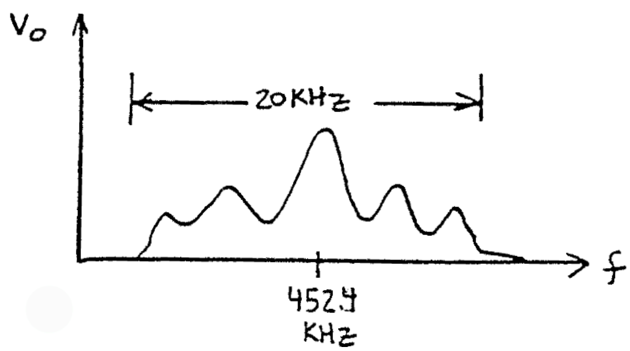
6.



If R_2 is adjusted, one triangle becomes larger than the other. This unbalanced display shows the presence of a carrier in the double-sideband signal.

7. RF generator frequency = 432.4 kHz
intelligence frequency = 20 kHz
upper sideband frequency = 452.4 kHz

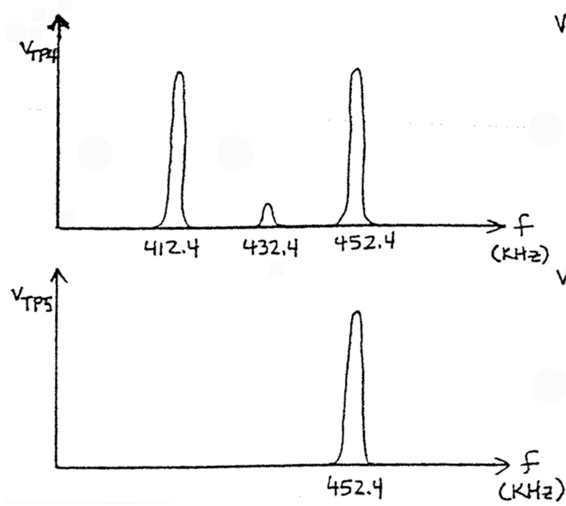
V_o peaks at approximately 150 $mV_{p\text{-}p}$. Be careful: The ceramic filter will peak at three frequencies within its bandpass. Make sure that you peak on the center frequency, which is its biggest peak.



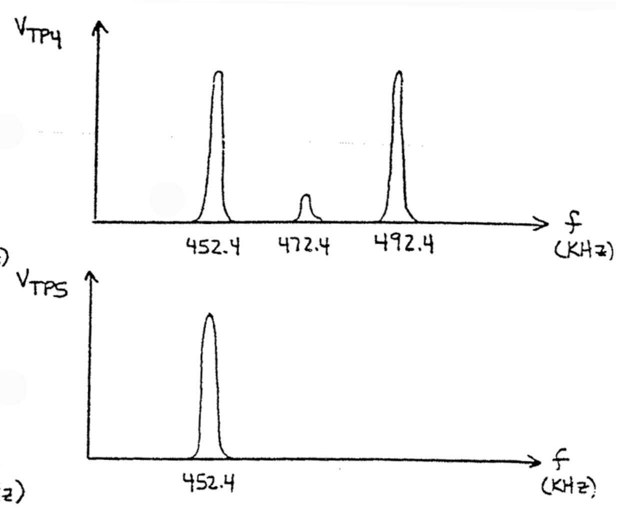
8. RF generator frequency = 472.4 kHz
intelligence frequency = 20 kHz
lower sideband frequency = 452.4 kHz

Spectral displays:

Step 6 settings

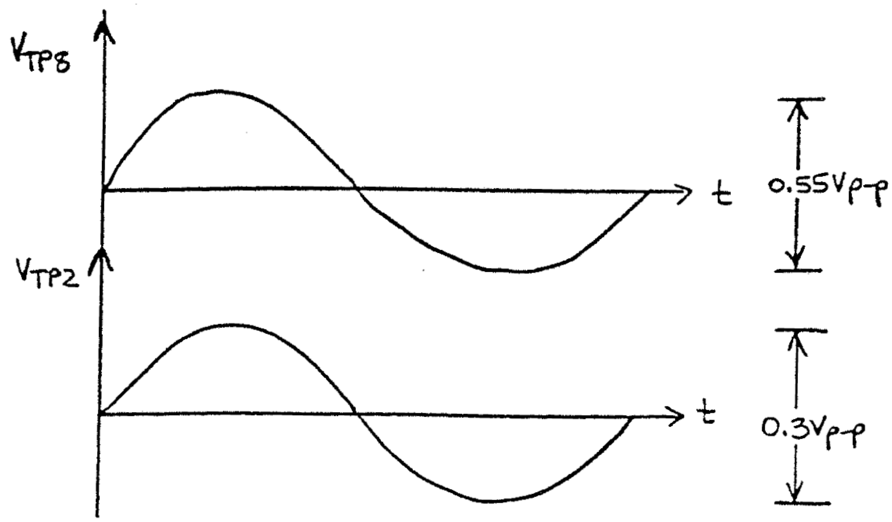


Step 7 settings

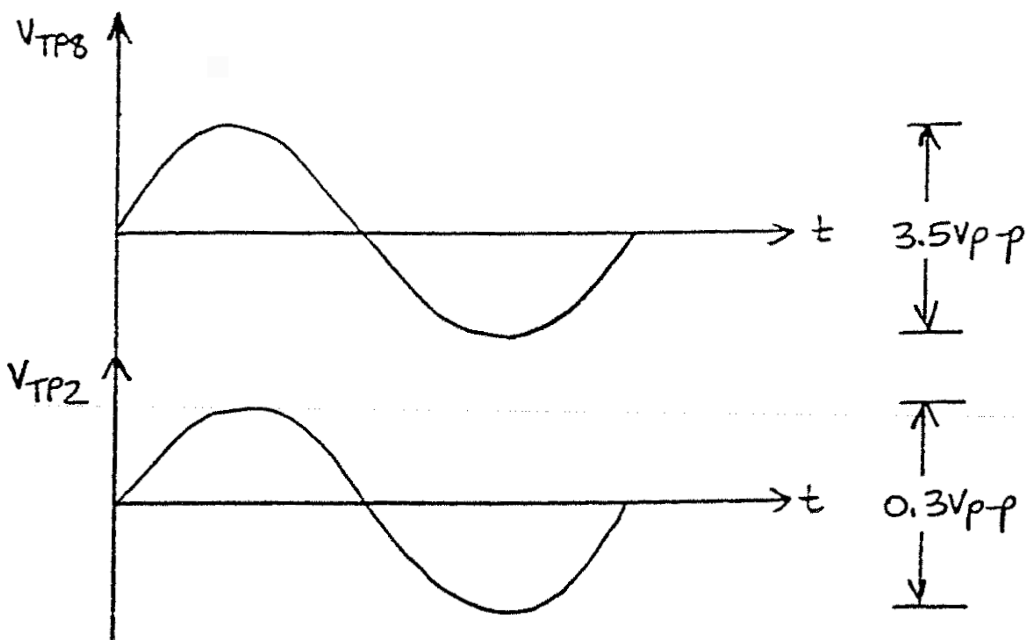


9. When the product detector is added, it loads down the carrier signal considerably. Also, the carrier voltage needs to be increased to make the detector work well. A suitable carrier amplitude is approximately 3.5 $V_{p\text{-}p}$. The carrier signal will appear quite noisy at this point, so average the noise out in making your measurement.

At an RF generator frequency at 432.4 kHz:

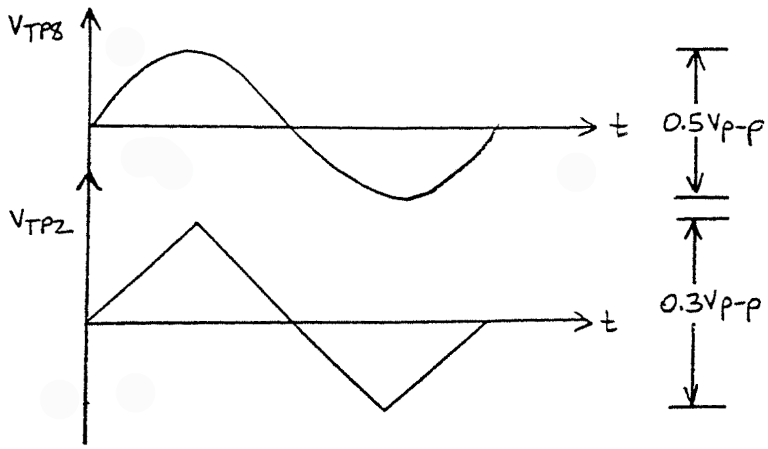


10. At an RF generator frequency of 452.4 kHz:



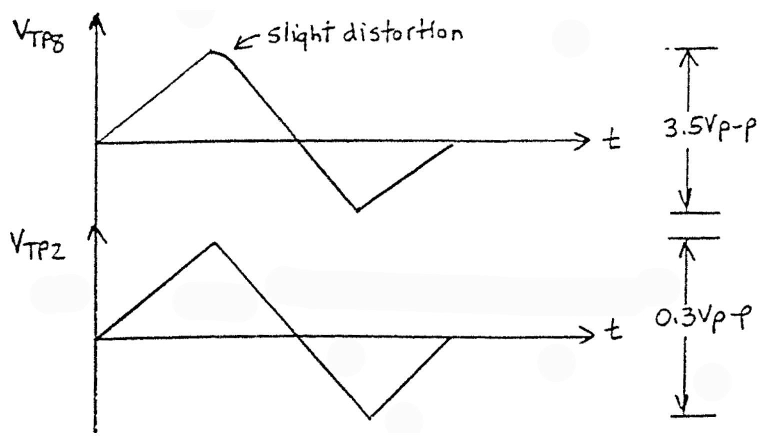
11. When the RF generator is set at either 432.4 kHz or 472.4 kHz, the waveforms given in step 9 result.

12. When the RF generator is set at either 432.4 kHz or 472.4 kHz, the following waveforms result:

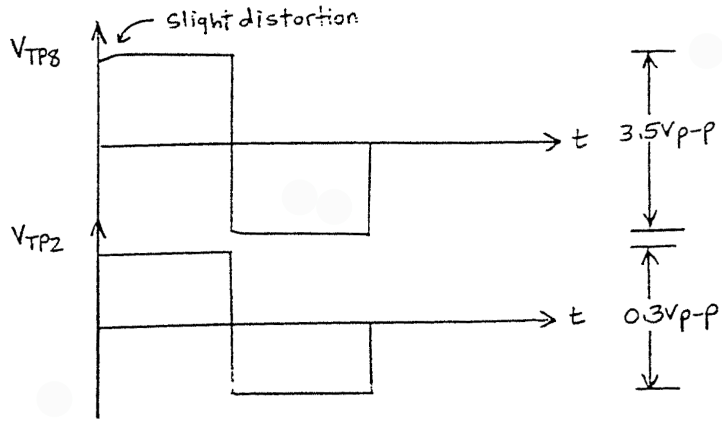


If a square wave is used instead of a triangle wave, the output signal still looks sinusoidal.

13. When the RF generator is set at 452.4 kHz:

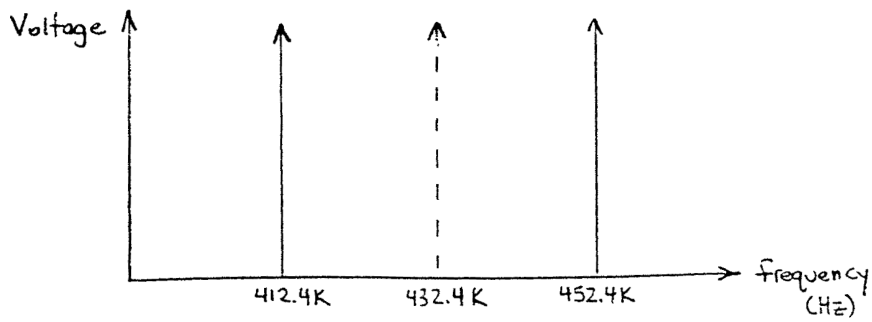


14. When the RF generator is set at 452.4 kHz:

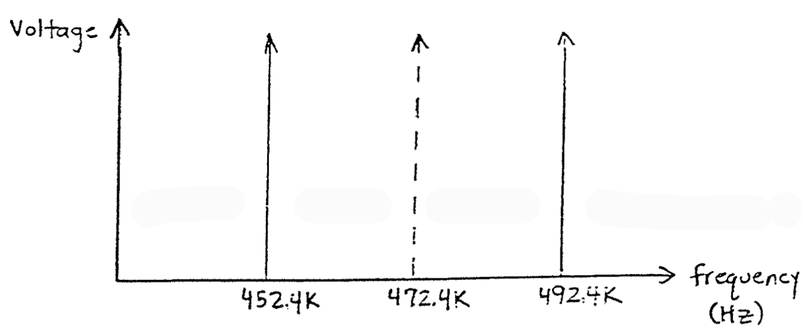


Questions

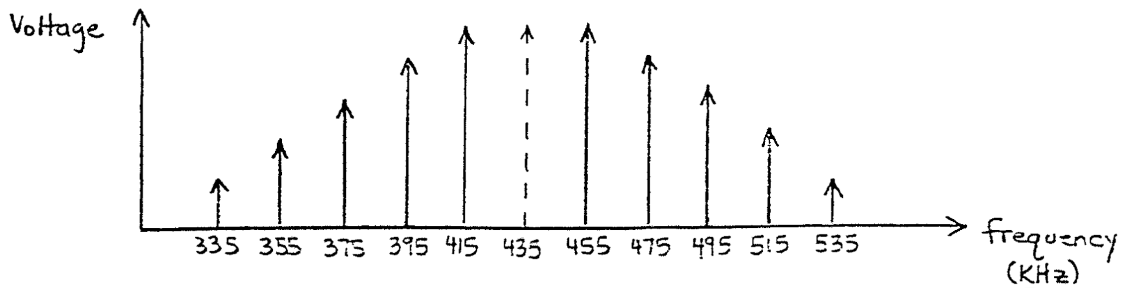
1. In step 7, the only frequency contained in the DSB-SC output signal of the balanced modulator that was close to the resonant frequency of the ceramic filter was the upper sideband signal at approximately 455 kHz. Thus, a sinewave at approximately 455 kHz was produced at the filter's output.



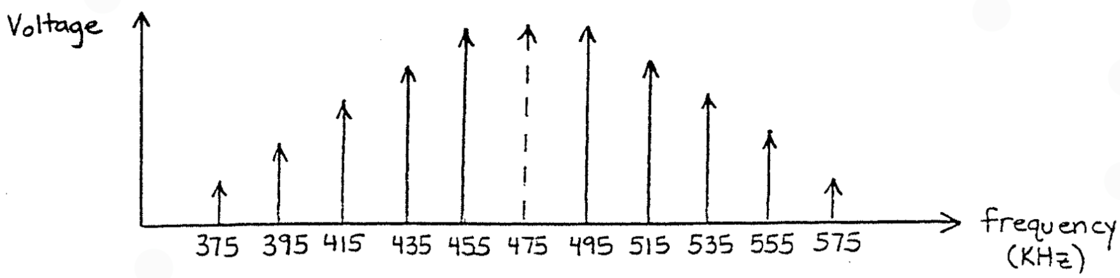
In Step 8, the only frequency contained in the DSB-SC output signal of the balanced modulator that was close to the resonant frequency of the ceramic filter was the lower sideband signal at approximately 455 kHz. Thus, a sinewave at approximately 455 kHz was produced at the filter's output.



2. For either a square-wave or a triangle-wave, the frequency spectra consist of only odd harmonics. Thus, the output of the balanced modulator will be a DSB-SC signal which contains many upper and lower sidebands that are positioned on either side of the carrier frequency. The difference between each sideband frequency and the carrier frequency corresponds to each successive harmonic of the intelligence signal. Since the intelligence signal is at 20 kHz and if the carrier frequency is approximately 435 kHz, the following spectra results:

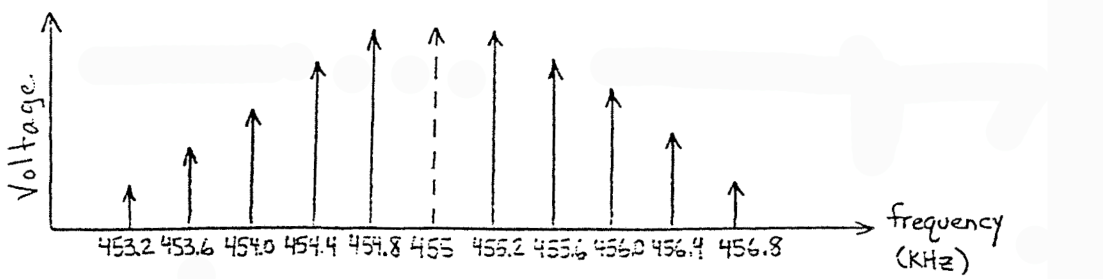


Similarly, if the carrier frequency is reset to 475 kHz, the following spectra result:

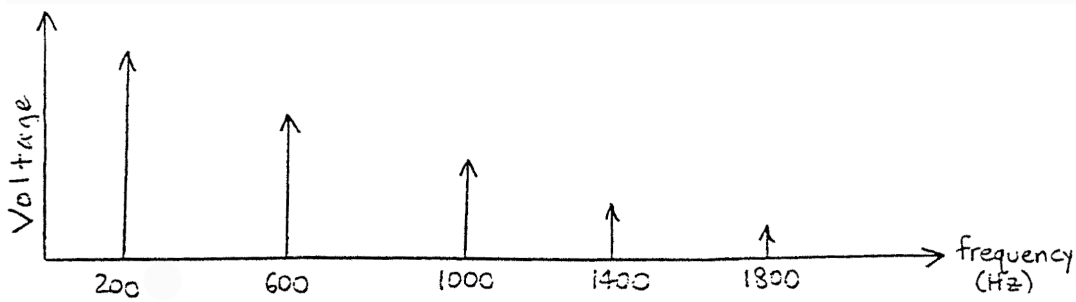


Notice that in either of the above two cases only one frequency component ends up being near the pass-band of the ceramic filter. Thus, the SSB product detector produces only one difference frequency in its output signal. This frequency is small enough to pass through the low-pass filter that is in the product detector. This frequency is simply the difference between the carrier frequency (435 kHz or 475 kHz) and the ceramic filter output signal (455 kHz). The difference frequency of 20 kHz passes through the low pass filter and produces a clean 20 kHz sinewave at the output.

3. If the frequency of the square wave or triangle wave is reduced to 200 Hz, again the output of the balanced modulator will be a DSB-SC signal which contains many upper and lower sidebands that are positioned on either side of the carrier frequency. Again, the difference between each sideband frequency and the carrier frequency corresponds to each successive harmonic of the intelligence signal. With the carrier frequency set at 455 kHz, the following spectra result:



Since the ceramic filter has a bandwidth of approximately 50 kHz, most of the spectral content of the DSB-SC signal is passed by the filter. The SSB product detector mixes this DSB-SC signal with the carrier frequency of 455 kHz and produces difference frequencies that resemble the original intelligence frequency:



Since most of the original harmonics are retained in the output spectra, the output signal closely resembles the triangle or square wave input.

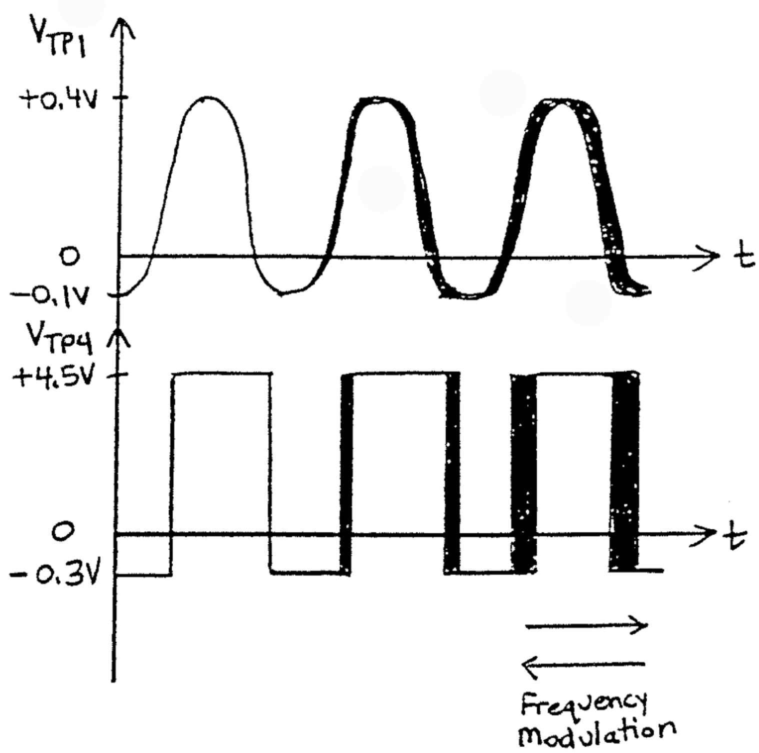
Experiment 11: FM Detection and Frequency Synthesis Using PLLs

Procedure

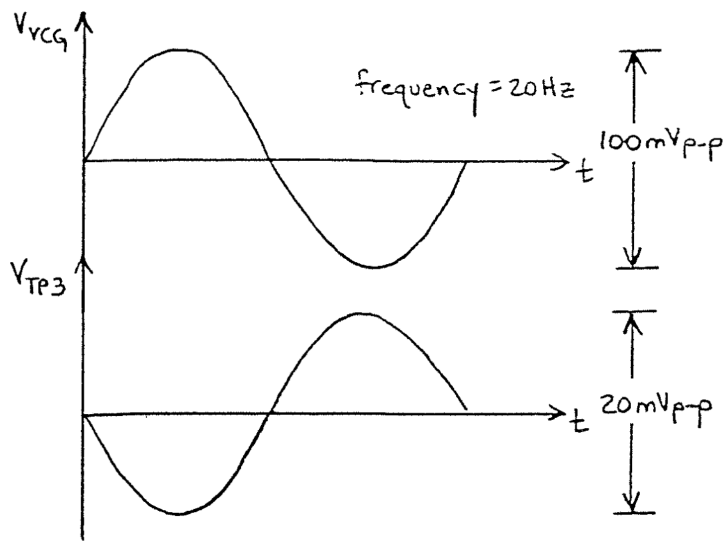
1. Free-running frequency = 55.5 kHz

2. VCO locks up and is set at 55.5 kHz.

3.



4.

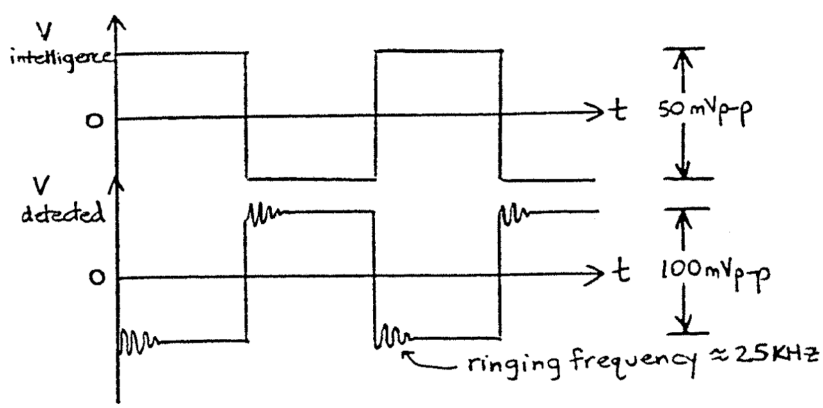


5. Increasing and decreasing the intelligence signal causes the detected signal to also increase and decrease, and it causes the amount of frequency deviation of the FM signal to also increase and decrease.

6. Increasing the amplitude of the carrier has no effect on the amplitude of the detected signal and has no effect on the VCO's output FM signal. When the amplitude of the carrier exceeds 15 $V_{p\text{–}p}$, the detected signal suddenly disappears, due to the PLL being overdriven.

7. At an approximate frequency of 1.9 kHz, the detected output waveform suddenly breaks into random amplitude variations. This critical frequency is dependent on the amplitude of the intelligence signal. When the intelligence frequency exceeds this critical frequency, the intelligence signal is varying too rapidly for the PLL to be able to follow.

8.



9. Free-running frequency = 64.9 kHz.

10. f_c = 64.9 kHz with f_{gen} = 253.5 Hz. N = 256.02
duty cycle at PT_{11} = 50%

Tracking Range:	Capture Range:
$f_{t\ max}$ = 101.5 kHz	$f_{c\ max}$ = 75.9 kHz
$f_{t\ min}$ = 28.0 kHz	$f_{c\ min}$ = 60.15 kHz

11. Duty cycle at TP_{11} = 2.1 div/5.8 div = 36.2%

f_c = 64.9 kHz with f_{gen} = 333 Hz N = 194.89

Tracking Range:	Capture Range:
$f_{t\ max}$ = 94.3 kHz	$f_{c\ max}$ = 74.8 kHz
$f_{t\ min}$ = 40.0 kHz	$f_{c\ min}$ = 61.6 kHz

12. f_c = 64.9 kHz with f_{gen} = 398.5 Hz N = 162.86

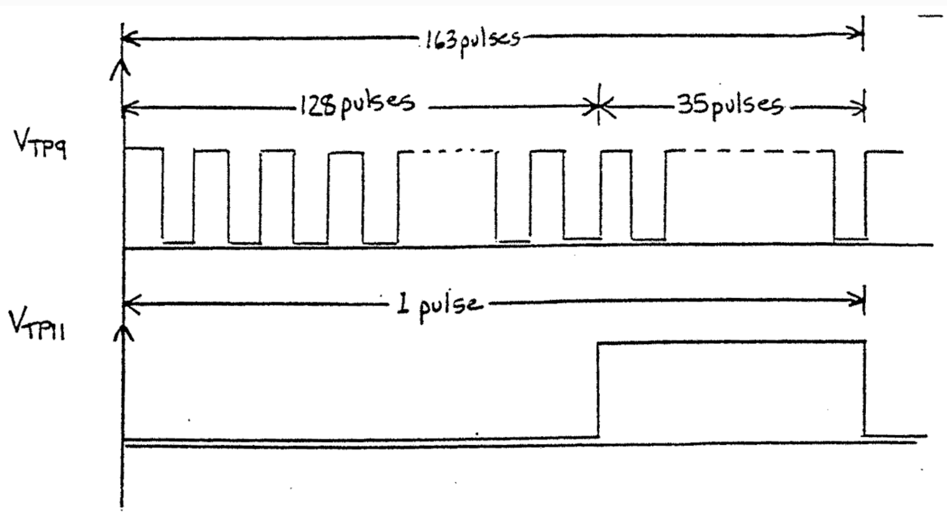
Tracking Range:	Capture Range:
$f_{t\ max}$ = 84.3 kHz	$f_{c\ max}$ = 73.3 kHz
$f_{t\ min}$ = 50.7 kHz	$f_{c\ min}$ = 62.7 kHz

a.

TP_8	TP_7	TP_6	TP_5	TP_4	TP_3	TP_2	TP_1	TP_0
1	0	1	0	0	0	0	1	1

10100011 in binary is 163 decimal; thus, N = 163.

b. After a very careful use of the delayed sweep functions on the oscilloscope:



duty cycle = 35 pulses/163 pulses = 21.5%

13. A decimal 139 is equal to 10001011 in binary. Thus, set test points TP_8, TP_4, TP_2, and TP_1 high using numbers J_1, J_2, J_3, and J_4. Connect J_1 to TP_1, J_2 to TP_2, J_3 to TP_4, and J_4 to TP_8.

f_c = 64.9 kHz with f_{gen} = 466.5 Hz N = 139.12

Tracking Range:	Capture Range:
$f_{t\ max} = 74.0$ kHz	$f_{c\ max} = 71.3$ kHz
$f_{t\ min} = 61.8$ kHz	$f_{c\ min} = 62.8$ kHz

Questions:

1. As long as the PLL remains in its tracking range, it will follow any frequency changes that occur in the signal driving its phase detector input. If an FM signal is applied to the phase detector input, the PLL will follow any instantaneous deviation in frequency. As the PLL follows these deviations in frequency, the phase detector produces an error voltage that has an amplitude that varies directly proportional to the amount of deviation. For an FM signal, the amount of frequency deviation varies directly proportional to the instantaneous amplitude of the intelligence signal. It therefore can be concluded that the error voltage produced by the PLL's phase detector must be an exact replica of the original intelligence signal.

2. The phase detector responds to variations in frequency of its input signal, not changes in amplitude. Thus, the PLL functions as an FM detector, not an AM detector.

3. If a digital MOD counter is placed between the output of the VCO and the control input of the phase detector, the PLL will lock up only if the frequency of the input signal is equal to the frequency of the output signal of the counter. This will happen only when the input signal of the PLL is set at $1/N$ times the frequency of the VCO output signal. Thus, the PLL locks up only when the VCO output signal's frequency is exactly N times the input signal. Thus, a frequency multiplier circuit results.

   In applications where more than one frequency needs to be selected, one oscillator circuit's frequency can be multiplied up to an assortment of new frequencies by merely changing the value of N in the MOD-counter. This can be easily done by changing some switches to change some logic levels within the digital counter. The PLL's negative feedback keeps each synthesized frequency stable. This is less expensive than using multiple crystal oscillators for creating multiple frequencies that are stable.

Experiment 12: Generating FM from a VCO

Instructor note: this experiment illustrates many concepts also covered in experiment 5 and is included to illustrate these concepts in an alternate form for those seeking a shorter experiment or for those without the equipment needed to perform Experiment 5.

Procedure

1. Measure and record the rms voltage of the 100 KHz signal at the first J_0 null (x=2.4) : 18 mv

2. Measure and record the rms voltage of the 100 KHz signal at the 2nd J_0 null (x=5.5) : 29 mv

3. Measure and record the rms voltage of the 100 KHz signal at the 3rd J_0 null (x=8.7) : 46 mv

4. Calculate the AC voltage for x=5.0 : 26 mv

	J #	Voltage, from page 213 of textbook	Calculated (dB)	Measured (dBm)	Measured minus calculated values
Ref	J_N	1 (Reference)	0 (Reference)	-20 dBm	No modulation
1	J_0	-.18	-14.9 dB	-35 dBm	-0.1
2	J_1	-.33	-9.63 dB	-30 dBm	-0.37
3	J_2	.05	-26 dB	-45 dBm	1.0
4	J_3	.36	-8.87 dB	-30 dBm	-1.13
5	J_4	.39	-8.17 dB	-30 dBm	-1.83
6	J_5	.26	-11.7 dB	-32 dBm	-0.3
7	J_6	.13	-17.7 dB	-38 dBm	-0.3

Table 5A-1. Calculations and Measurements for VCO Project. (Bessel Functions for x=5)

Questions

1. A dc voltage applied to a voltage-controlled oscillator (VCO) determines its frequency of operation. The VCO can be tuned (shifted in frequency) by varying the input voltage. Within the VCO, the dc voltage varies the capacitance of a varactor diode, which acts as a variable capacitor and is part of the frequency-determining stage (parallel resonant circuit) of the VCO. Varactor diodes are normally reverse-biased, and a higher bias voltage decreases diode capacitance by widening the depletion region formed at the junction of p- and n-type semiconductor materials, effectively pushing the conductive plates of the capacitor farther apart. Conversely, lowering the dc voltage applied to the varactor narrows the depletion region, causing the conductors to move closer together and increasing the capacitance.

2. The carrier disappeared but the side frequencies were still present. This is the carrier null or Bessel null condition. This result shows that, in FM, the power of the unmodulated carrier is distributed among the carrier and sidebands in amounts determined by the modulation index. In contrast, AM systems show increased power in the presence of modulation; that is, the power in the sidebands adds to the carrier power, and the carrier power is unvarying.

3. The answer is the same as that for Experiment 5, Question 5.

4. This is a blocking capacitor. Any dc voltages present will affect the varactor capacitance, so these must be set in accordance with the design specifications of the Minicircuits module.

5. See Section 3-4 for a discussion of direct versus indirect FM. This experiment is an example of direct FM in that the VCO frequency can be changed by varying the dc voltage applied to it: if the control voltage is caused to vary at an audio rate, the VCO frequency will vary in a like manner. Indirect FM means that a stage subsequent to the VCO is modulated, causing the instantaneous phase angle of the carrier to respond in accordance with the modulating signal. Indirect FM is phase modulation, so an integrator (low-pass filter) is needed to cause the carrier deviation to be sensitive only to modulating signal amplitude, not frequency.

6. A modulator stage subsequent to the VCO (such as the reactance modulator discussed in Section 5-4 of the text) would need to be added.

Experiment 13: Pulse Amplitude Modulation

Test Equipment Used:

OWON DS7102V Oscilloscope
BK PRECISION 4012A function generator
Amprobe 34XR-A Multimeter
CSI5505S Power supply

Procedure

Part I: PAM Modulator

For an ASTABLE Oscillator, we have the following:

$$f = \frac{1.44}{(R1 + 2R2) \times C}$$

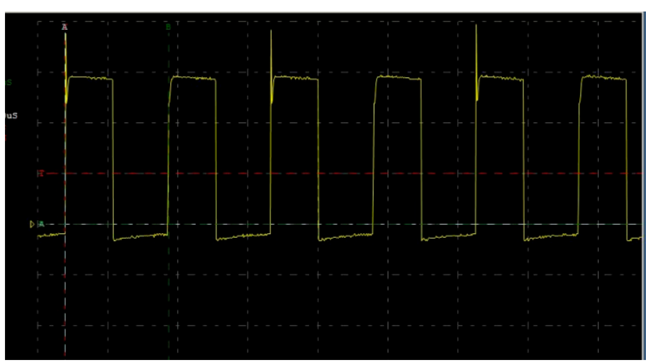
For the minimum value of resistance corresponding to the pot turned to the minimum position we choose R1 = 0 and R2 = 10 k.

$$= 1.44 / (0 + 2 * 10{,}000) * 2.2 * 10^{-9}) = 32{,}795 \text{ Hz}$$

For the maximum value of frequency corresponding to the pot turned to the maximum position we choose R1 = 10 k and R2 = 10 k.

$$= 1.44 / (10{,}000) * 2.2 * 10^{-9}) = 65{,}590 \text{ Hz}$$

2.



Frequency ___33 kHz_____ Amplitude _________2.5 V______

4.

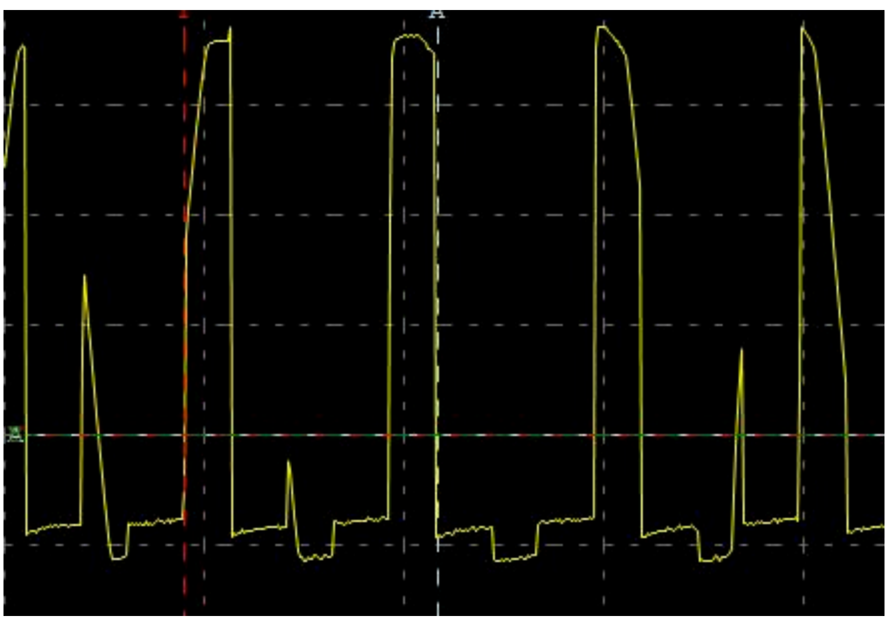
Note that the lab doesn't specify the input amplitude. It was arbitrarily selected to be 3 V. Determine the frequency and amplitude of the two signals and record the data below. In the case of the PAM signal, estimate the frequency of the overall envelope of the signal.

Input Frequency _____3 kHz___ PAM Frequency _______3 kHz_____________

Input Amplitude ____3 V____ PAM Amplitude _________4 V___________

DC Offset ______~1.5 V______________

5.



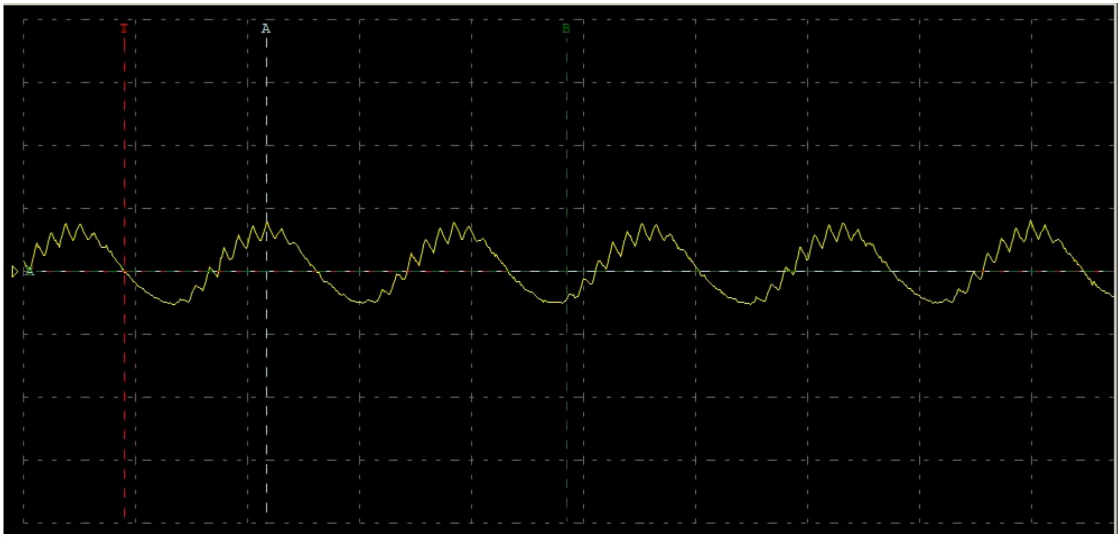
6. Input Frequency ____20 kHz____ PAM Frequency ______20 kHz________

Input Amplitude ____1.5 V___ PAM Amplitude ______2.5 V________

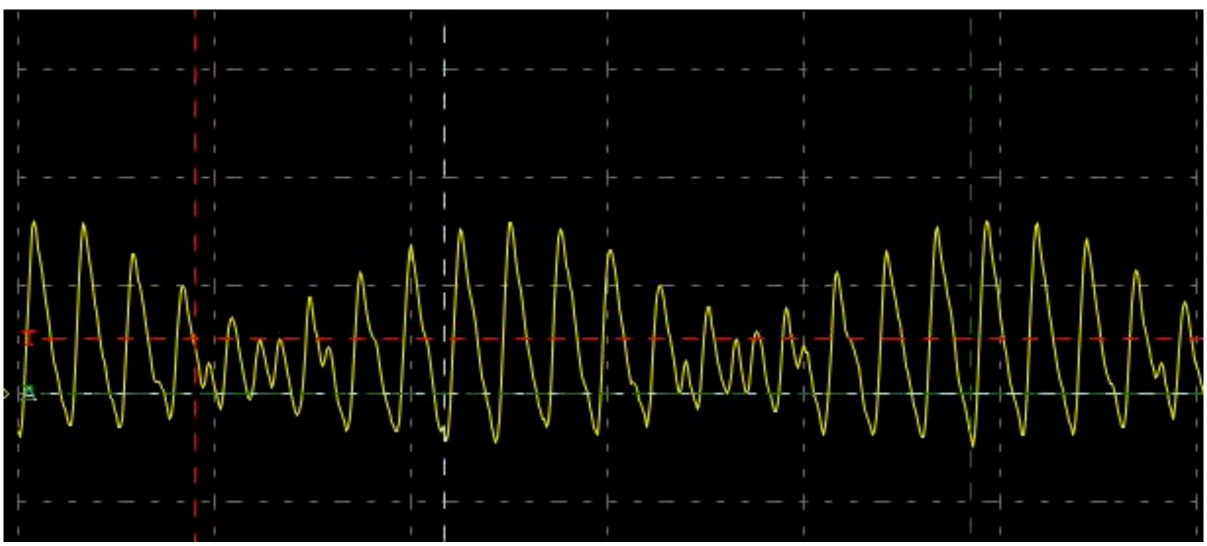
DC Offset _______1.5 V______

Part II: PAM Demodulation

8. 3 kHz



20 kHz : Note you should observe substantial aliasing in this signal. Also the amplitude of this signal is decreased because of the low pass filter.



9. This is somewhat subjective, but the criteria set put this at about ¼ the Nyquist frequency.

$f_{\max}$ = ______4KHz________

10. Solutions will look roughly the same except that the number of samples will be doubled, which will result in a demodulated signal with twice the resolution as before. Note that the maximum frequency will not increase appreciably, as the maximum frequency is limited by the attenuation of the low pass filter.

Questions

1. How does the input frequency compare to the PAM frequency? Should these values be the same? Why or why not?

   a. These frequencies are the same.
   b. Yes, they should be the same since this is an amplitude modulation scheme so we preserve the frequency in the modulated signal.

2. How does the amplitude of the input signal compare to the PAM amplitude? Should these values be the same? Why or why not?

   The amplitude of the PAM signal is not the same as the input amplitude. Since the transistor is being used to chop the function input, it is only providing the positive leg of the input, with the exception of the ~0.7-V drop across the base-emitter junction of the transistor.

3. Was there a DC offset between the PAM signal and the input signal? Explain where this would come from.

   The diode and capacitor across the transistor act as a positive clamp to raise the voltage above 0 V so that, for very small signals, a negative signal can be reproduced.

4. What is the cutoff frequency of the low pass filter used? What impact does this have on the signal?

   a. $F = 1 / 2\pi RC = 1 / 2\pi * 10\text{ k} * 10\ \mu\text{F} = 1591\text{ Hz}$
   b. Signals above 1.59 kHz are attenuated by 3 dB or decreased in power by 50% or voltage by 70%. In practice this means that the signal is smoothed by the action of the filter.

5. Why is the observed voltage of the demodulated signal lower than the input signal?

   The low pass filter is attenuating the signal and the attenuation gets larger at higher frequencies.

6. What impact does aliasing have on the demodulation of the signal?

   For high frequencies, the demodulated signal does not match the input signal so that the original signal cannot be reconstructed.

7. What is the highest data frequency possible for this circuit? How does this compare to the Nyquist frequency? What are the limits of the Nyquist criteria?

   a. In practice the highest usable frequency is 4 kHz. The Nyquist frequency is approximately 16 kHz, so the usable frequency is as much limited by the single pole low pass filter.
   b. The Nyquist criteria sets a limit, but the anti-aliasing filter has a cutoff that is far below the Nyquist limit.

8. What would be the impact of doubling the carrier frequency?

   Doubling the carrier frequency would double the Nyquist frequency, but doesn't solve the problem of attenuation caused by the anti-aliasing filter. In order to achieve a higher signal rate, you would need to move to an active anti-aliasing filter.

Experiment 14: Time-Division Multiplexing

Test Equipment Used:

OWON DS7102V Oscilloscope
BK PRECISION 4012A function generator
Amprobe 34XR-A Multimeter

Procedure

Part I: Pulse Width Modulation

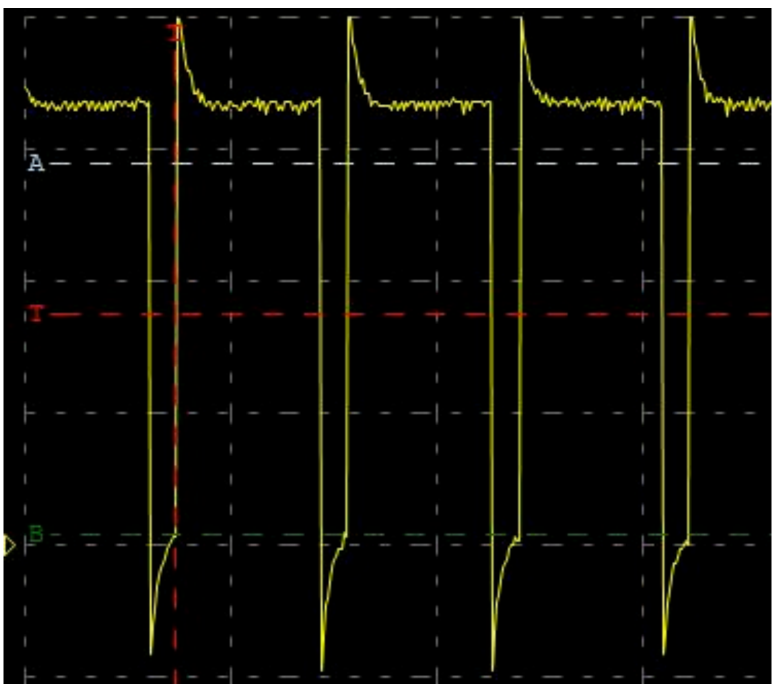
3. Maximum Pulse Width = __500__________ ms

Minimum Pulse Width = _1500___________ ms

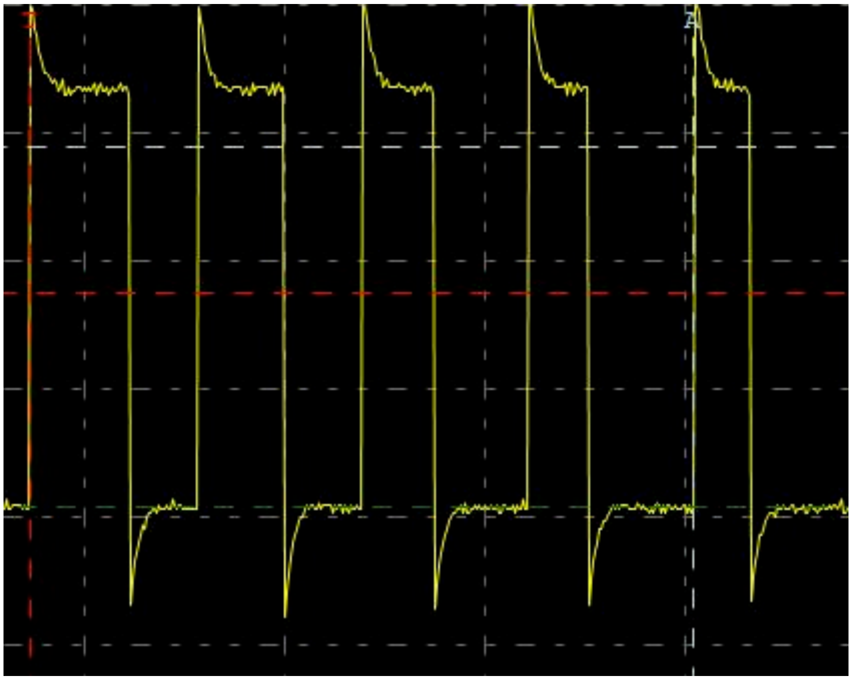
Range = ___1000_________ ms

4. ms / V = ___1000 ms / 5 V_= 200 ms/V__________

5.

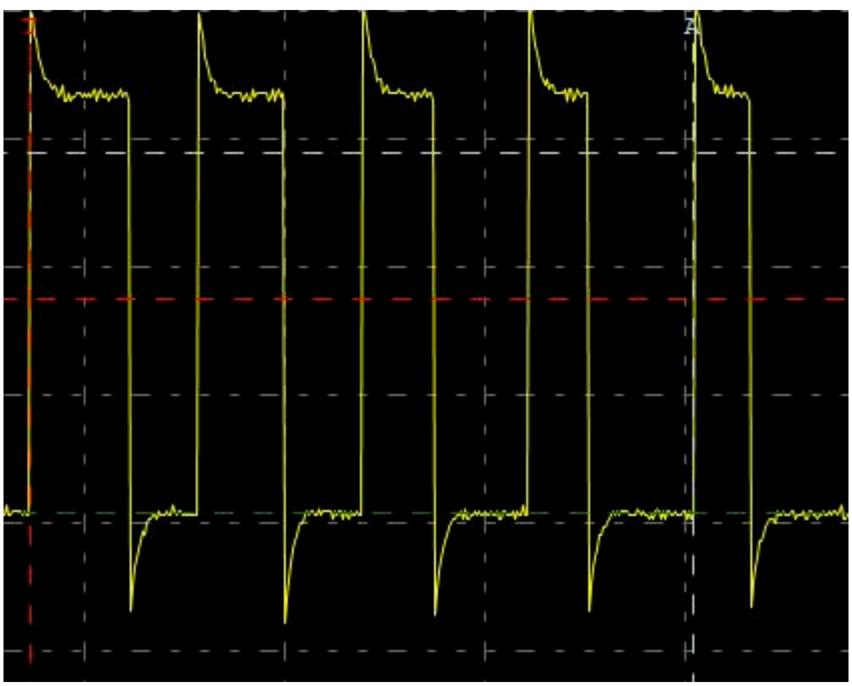


6. Use a time base of 1 ms.



7. Time = ___1650______ ms

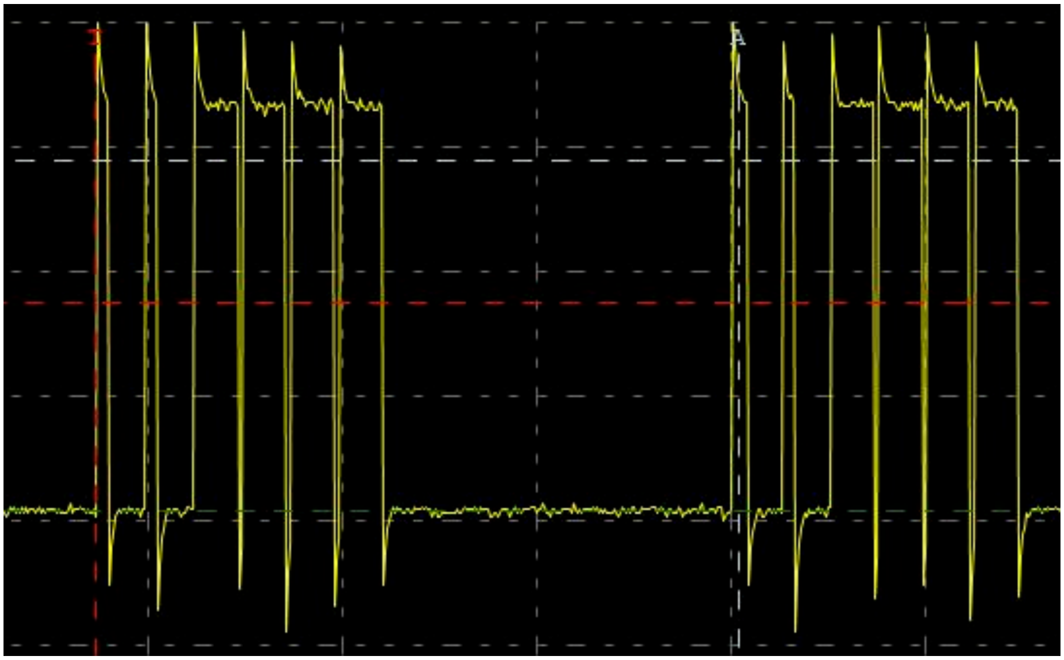
8. Use a time base of 1 ms



Note that while it is not clear from the above picture, the signal is now showing aliasing as the 500-Hz input is much faster than the sampling frequency.

Part II: Time-Division Multiplexing

10.



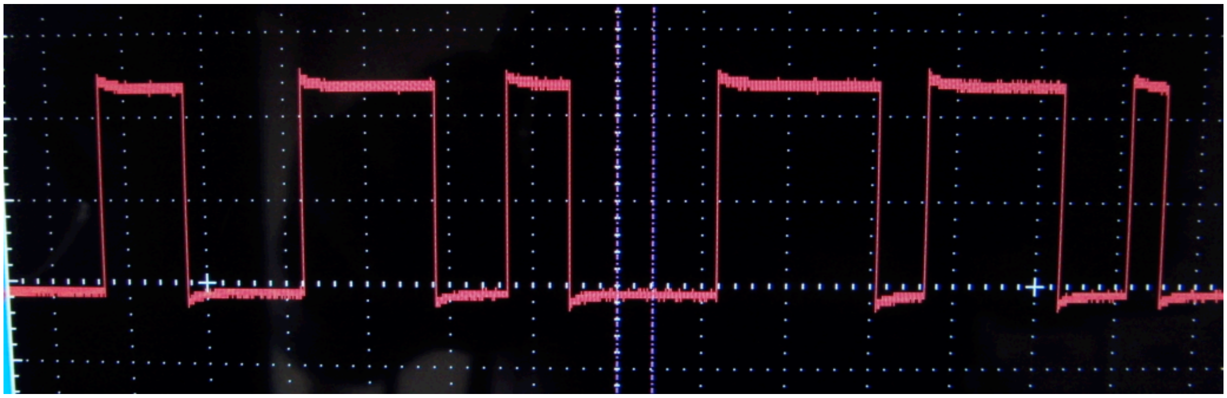
There should be 6 pulses, each with a width of about 700 μs. There will be slight variations because of differences in potentiometers and approximate center settings.

11.

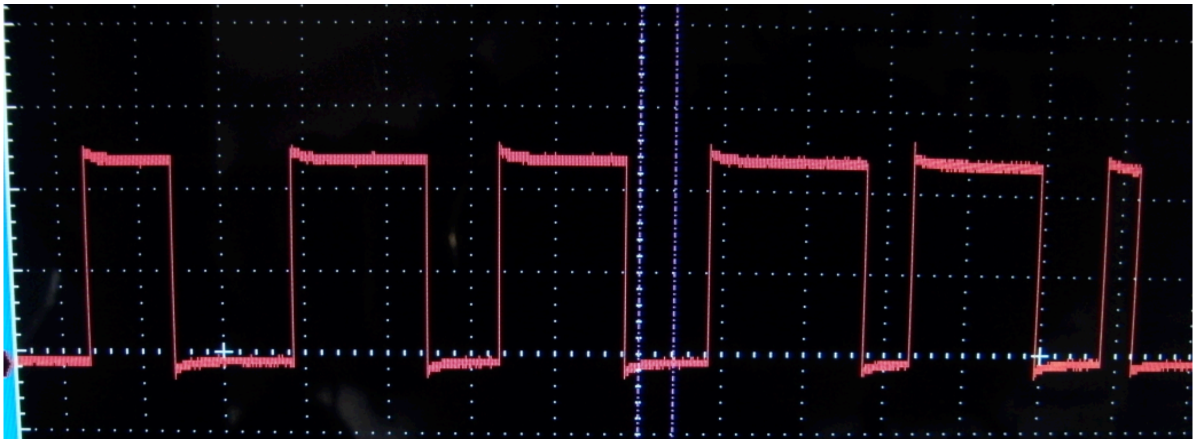
Potentiometer #	Voltage (V)	Measured Pulse Width (ms)
1	1.5	530
2	2.9	800
3	.8	390
4	3.5	950
5	2.9	800
6	0*	62

*The value of 62 μs can't be achieved! The minimum is ~200 μs.

12.



13.



Note that the first two pulses will be varying in frequency in sync with the time varying input amplitude.

Questions

Part I:

1. What are the main limitations of the PWM system used in this experiment? What are the limitations on the frequency of the analog signal that can be reliably encoded?

   a. The PWM signal has a period of 1650 μs, which limits the data rate to 606 Hz, which means that only 606 values can be sent per second. This is relatively slow for transmitting information. Also, only one signal is being sent over the line, so one cable is required for each signal.
   b. If the signal changes faster than the sample rate of the ADC, then the details of the signal will be lost. Since the PWM is being generated every 1650 μs, this corresponds to a frequency of $1/1650 * 10^{-6} = 606$ Hz. The signal must change at most at half this rate for the signal to be reconstructed. Students may choose to discuss the Nyquist sampling theorem here if it has been covered.

2. What could you change to increase the frequency of the analog signal that can be encoded as a PWM signal?

   Answer: Decrease the sampling time from 1650 μs to something smaller. This has the advantage of increasing the sampling frequency. However, it decreases the μs/V so that there is less resolution in the sampled signal.

3. Provide a brief explanation of how TDM can be used to send more than one channel of information over one cable.

   Answer: Each information signal accesses the entire channel bandwidth for a fraction of the available time. For instance if there are three signals, each one would use the channel for one-third the time.

4. What are the main limitations of the time division multiplexer system investigated in this experiment?

   Answer: Only six signals can be encoded in this scheme. In addition the channel must be held in a state to mark the start of each TDM signal. Thus the total time between each intelligence signal being repeated is quite long (on the order of 20 ms, which means that it is only good for slowly changing signals).

5. Explain the tradeoffs in encoding more signals on a TDM system with respect to the maximum frequency of the analog signal that can be encoded.

   Answer: More signals means that more time is required for each signal to be sent again. More signals means that the maximum frequency of the signals decreases. However, the duration of each intelligence signal can be decreased at the price of decreased resolution.

Experiment 15: Pulse-Width Modulation and Detection

Procedure

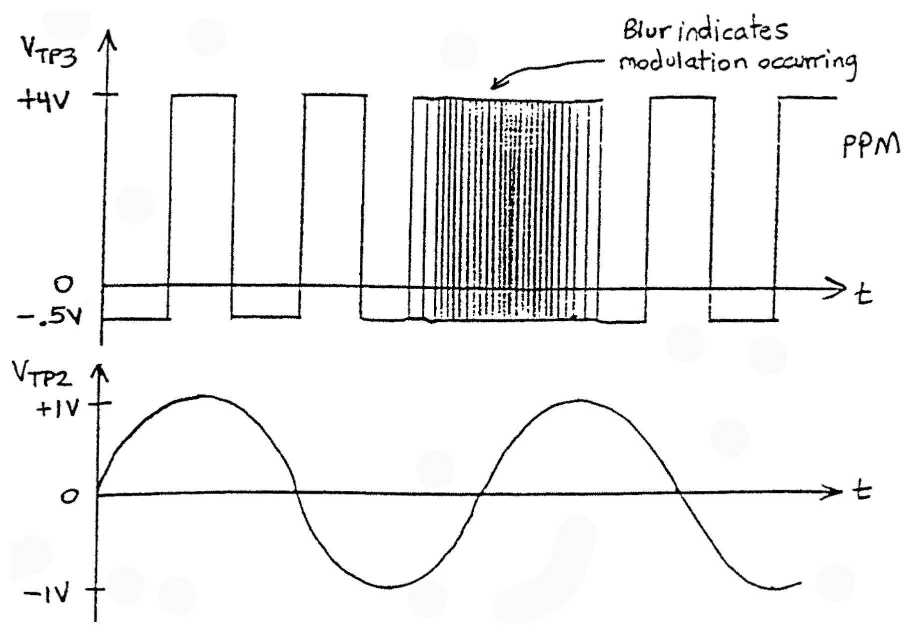
1. $f_0 = \frac{1}{3.7\,R_2C_6} = \frac{1}{3.7(3\text{ k}\Omega)(0.0047\ \mu\text{fd})} = 19.168\text{ kHz}$

2. At TP_3, the frequency is set at 15 kHz.
   At TP_7, the amplitude is set at 3.5 V.

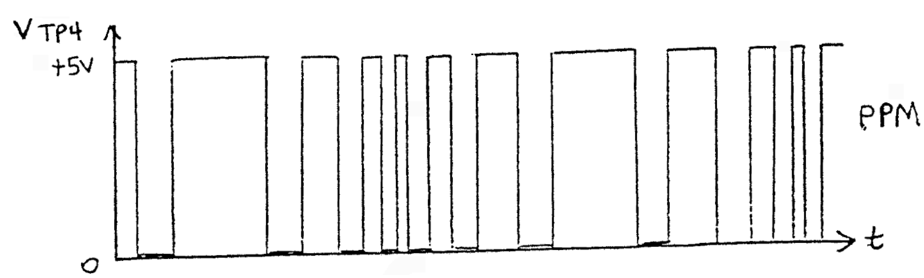
3. The capture and tracking ranges are observed to be identical (no hysteresis):

   f_{min} = 8.33 kHz
   f_{max} = 20.83 kHz

4.

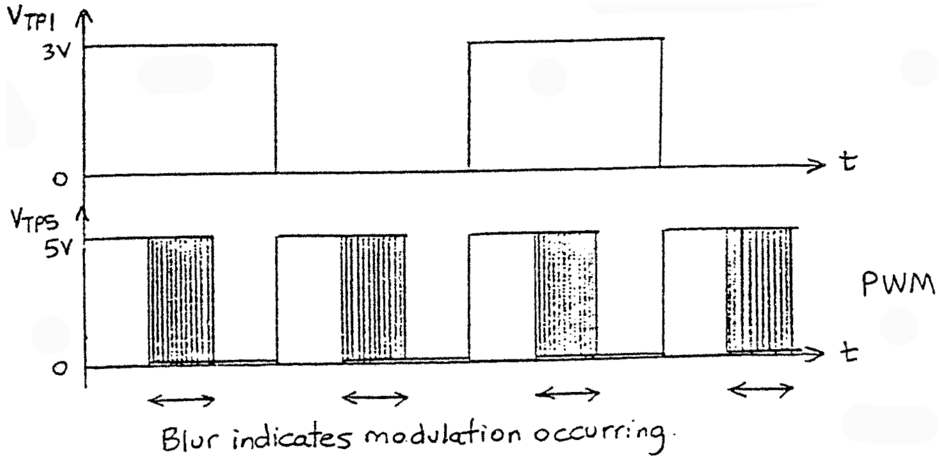


5.

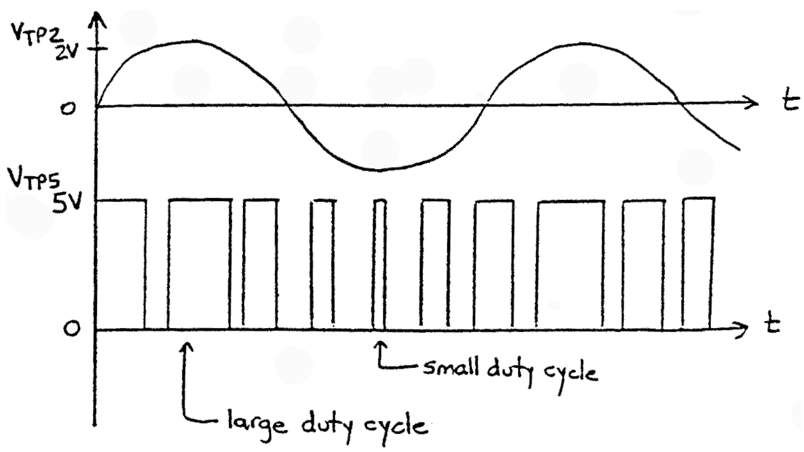


6. $f_{carrier}$ = 13.51 kHz

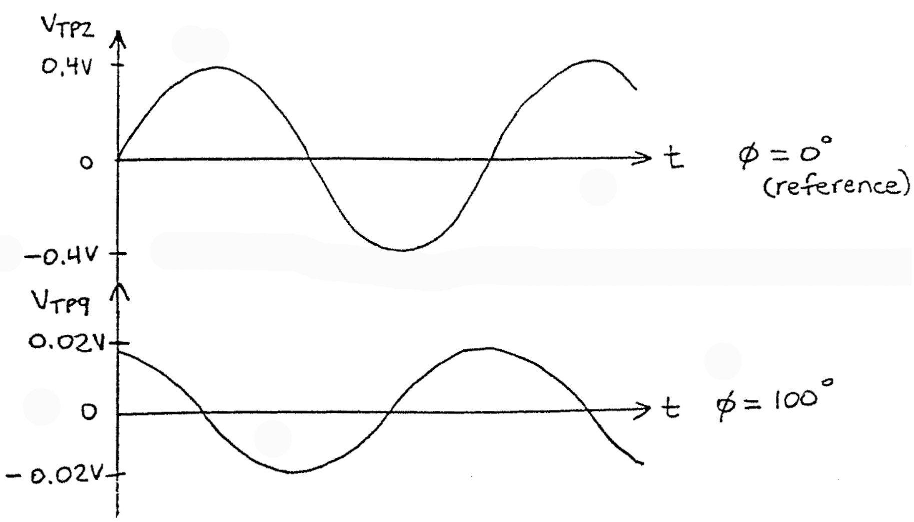
7.



8.

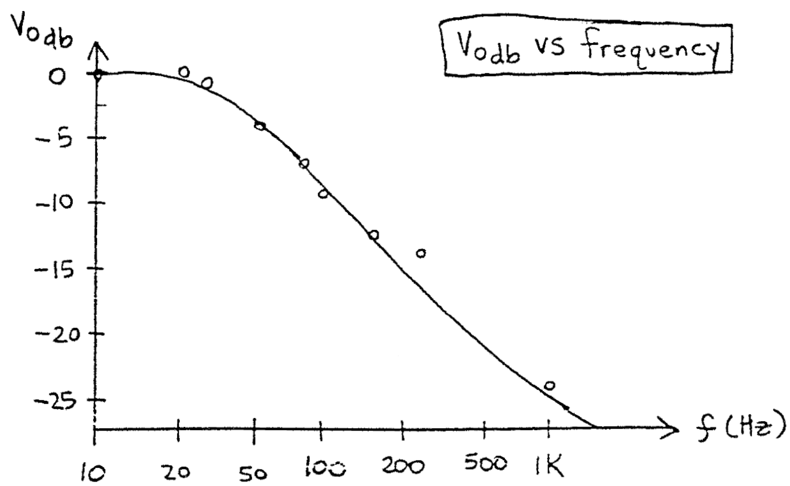


9-10. With carrier adjusted to a 2 volt amplitude positive-going square wave at a frequency of 12.04 kHz and with an intelligence signal of 800 m $V_{p\text{-}p}$ amplitude at a frequency of 200 Hz:



11. The TP_9 waveform stays fairly clean (no substantial noise or distortion), but its frequency response is quite limited:

Frequency (Hz)	TP_2 Voltage (mV_{p-p})	TP_9 Voltage (mV_{p-p})	TP_9 Voltage (dB)
10	800	200	0
20	800	200	0
30	800	170	−1.40
50	800	120	−4.40
80	800	84	−7.54
100	800	70	−9.12
150	800	48	−12.40
200	800	40	−13.98
500	800	12	−24.44



12. Intelligence signal: $V_{max} = 1\ V_{p\text{-}p}$
$V_{min} = 0\ V_{p\text{-}p}$

Carrier signal: $V_{max} = 2.5\ V$
$V_{min} = 1.5\ V$

Questions

1. The 565 PLL is adjusted so that the carrier frequency is in the middle of its tracking range. Therefore, when a 15 kHz carrier signal is applied at TP_1, the PLL immediately locks up causing a 15 kHz square wave to be produced at the VCO output. When the intelligence signal is applied to the reference input of the VCO, it causes the VCO's output signal to shift its phase with respect to the reference phase by an amount directly proportional to the amplitude of the intelligence signal. This fits the definition of pulse-position modulation. Since the original 15 kHz RF carrier pulse and the resulting PPM signal are fed into an Exclusive-Or gate, its output will be high only during the time when the carrier pulse and the PPM signal are at different logic states. Since the two signals are synchronized by the PLL, the Exclusive-Or output signal will be high only during the time of phase difference between the carrier pulse and the PPM pulse. This creates PWM.

2. The complex waveform at the output of the 1496 balanced modulator exhibits a dc offset that varies as a function of the phase difference between its two inputs. Thus, if the two input signals are the PWM signal and the original carrier pulse, the amplitude of the dc component will follow the phase difference variations and produce a replica of the original intelligence signal. A low-pass filter (R_2, C_{13}, and C_{14}) must be employed to filter out all of the other high frequency signals produced by mixing action in the balanced modulator. The output of the low-pass filter will then be a replica of the original intelligence signal.

3. The maximum intelligence frequency cannot exceed 30 Hz in this design without severe amplitude reduction occurring in the recreated intelligence signal at the output of the PWM detector.

Experiment 16: Introduction to Analog-to-Digital Conversion (ADC) and Digital-to-Analog Conversion (DAC)

Test Equipment User:

OWON DS7102V Oscilloscope
BK PRECISION 4012A function generator
Amprobe 34XR-A Multimeter
CSI5505S Power supply

Procedure

Part I: Analog to Digital Conversion (ADC) and Simple Pulse-Code Modulation (PCM)

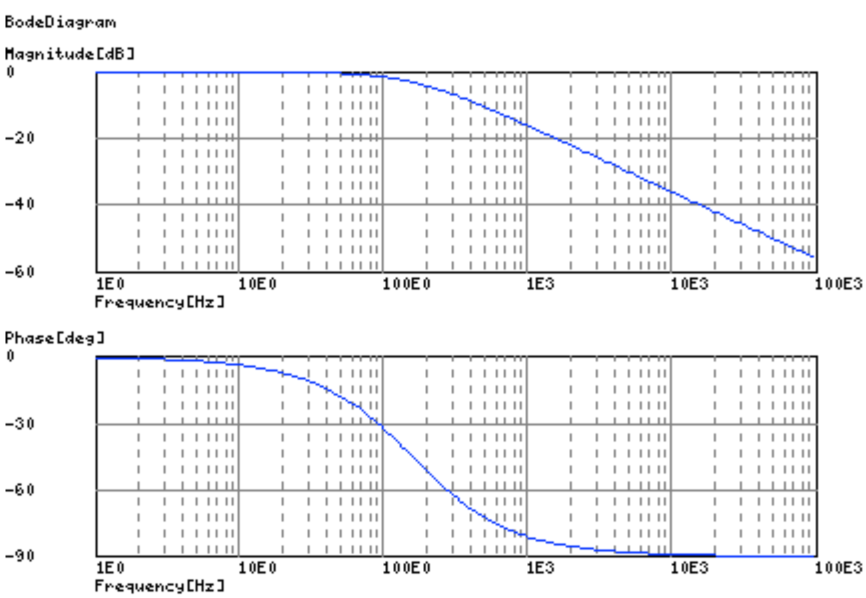
1. This is a low-pass filter with R = 10 k and C = 100 nF.

   For a low pass filter F = 1 / 2pRC = 159.15 Hz

   The transfer function is:

$$G(s)=\frac{1000}{s+1000}$$

   This has a pole at ~160 Hz, which again means that the cutoff frequency is ~160 Hz. The Bode plot is shown below:



4. V_{in} (00000000) = ______0______ V dc

V_{in} (01000000) = ______1.25______ V dc

V_{in} (10101001) = _____3.31_______ V dc

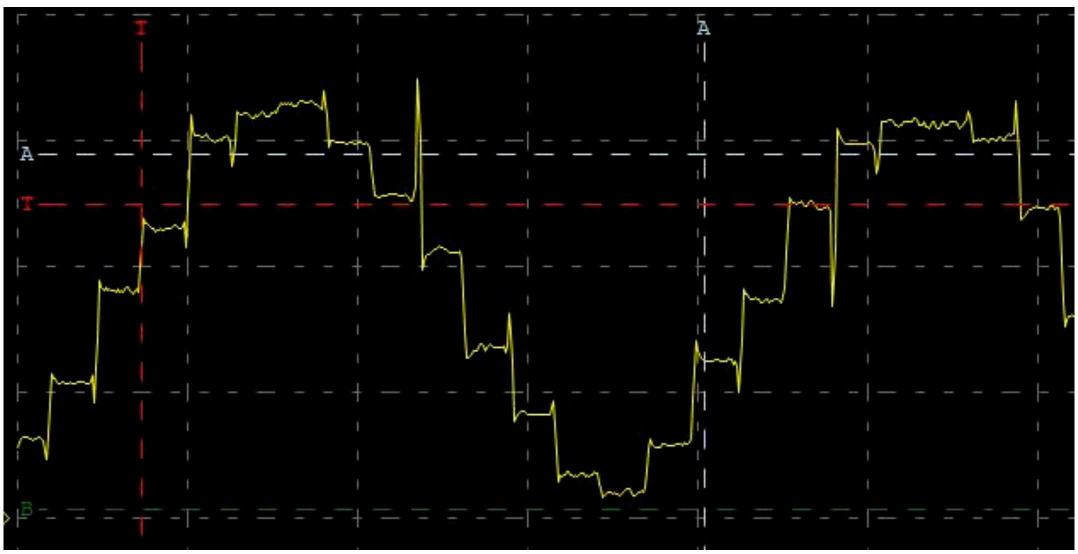
5. resolution = _______0.2________V dc

6. Need a 3.75-V maximum amplitude. Since the signal is centered at 1 V, it will need to go 2.75 V above the point at which it is centered to reach a 3.75-V amplitude, so the peak to peak amplitude will be twice 2.75 V, or 5.5 V.

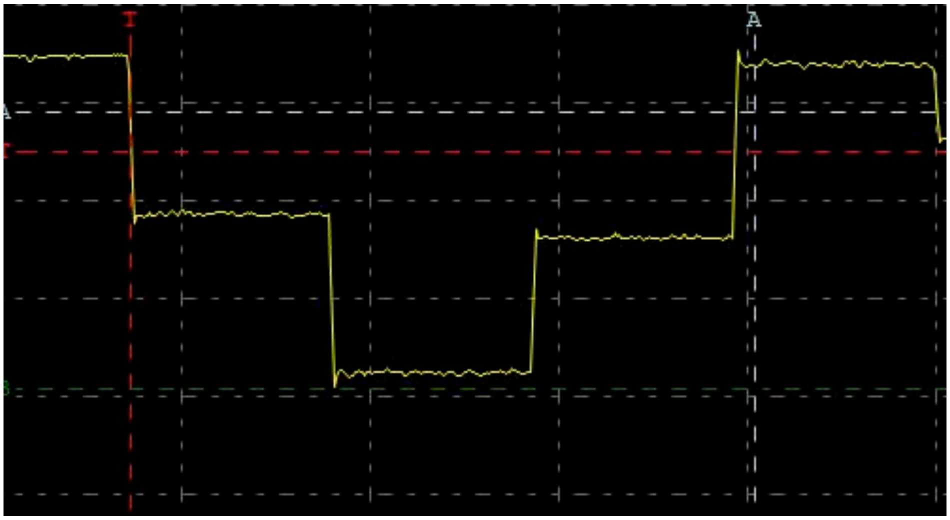
V_{in} (max) = _____5.5___ Vp-p dc

Part II: Digital to Analog Conversion (DAC)

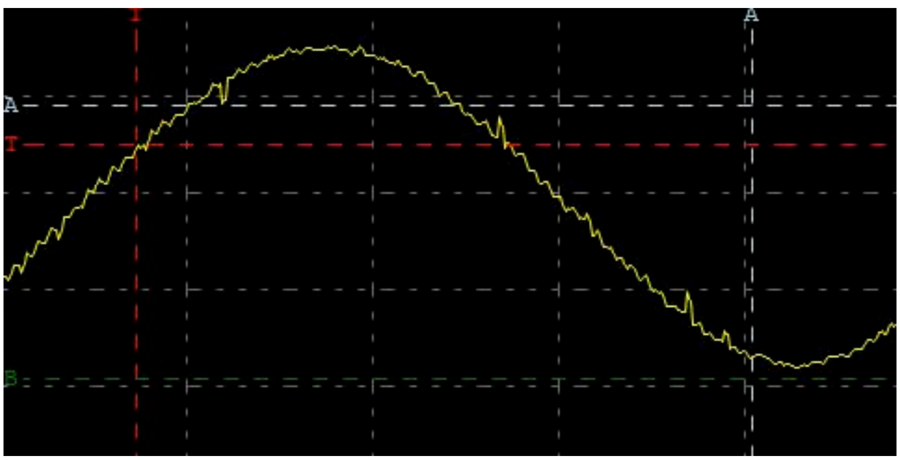
8.



9.

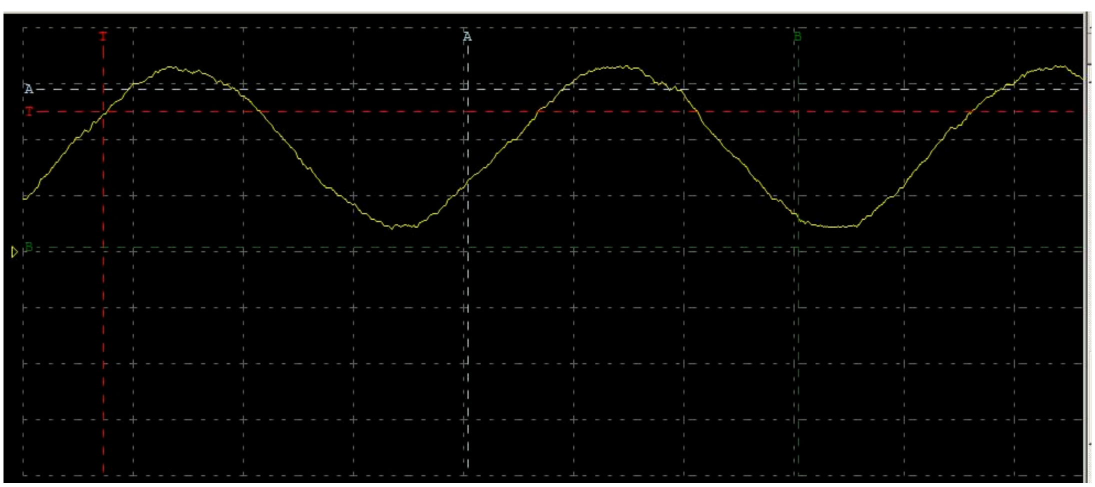


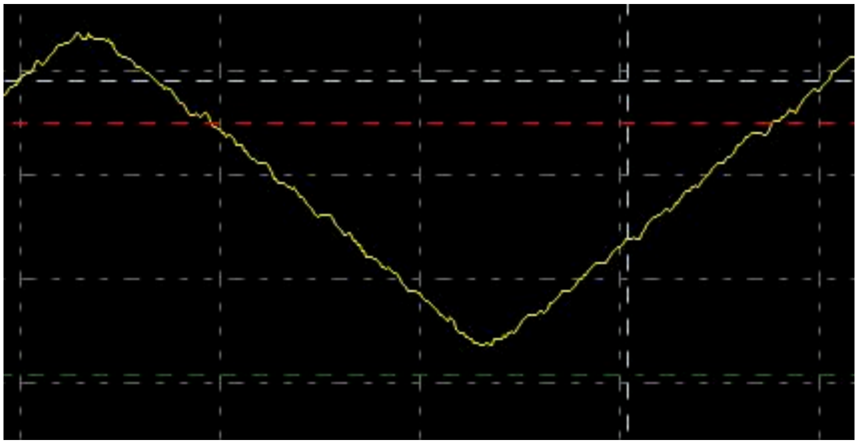
100 Hz Sampling rate



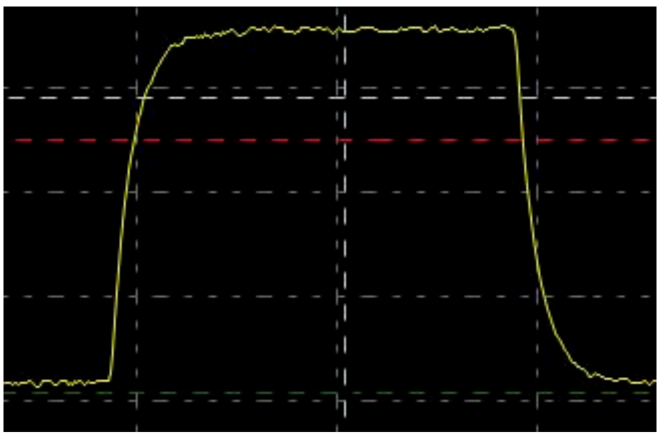
2 kHz Sampling Rate.

11.



12. 

Triangle Wave



Square Wave

13. Maximum Frequency = ______2000______ Hz

Sampling Frequency = ______8000______ Hz

Note these numbers are approximate. The maximum theoretical sampling speed is 10 kHz, but 8 kHz is a more practical attainable maximum. At an 8-kHz sampling rate there are 4 samples in a 2-kHz signal. In addition, there is a low-pass filter in place, which is also limiting the practical maximum frequency. This is a worthwhile place to have a discussion of the Nyquist sampling theorem and its practical limits.

Questions

1. What would have been the resolution of the ADC in step 4 if only 6 bits were used in the encoding and decoding schemes? Explain why.

   Answer: Six-bit words give a range of values from 0 to 63. Therefore, the maximum voltage of 5 V would be encoded as decimal 63. So each voltage step would be 5V / 63 = ~ 0.08V.

2. What would the LEDs display if you didn't include the DC offset on the input signal in step 5?

   Answer: The LEDs would be blank the entire time the signal amplitude was below 0 V. Since the signal has a peak-to-peak amplitude of 2 V, its maximum positive amplitude would be 1 V. Since the resolution is 0.02V, this would correspond to a decimal value of 1 / 0.02 = ~ 50, which is binary 00110010.

3. If only 6 bits were used in the encoding and decoding schemes, would the DAC output signal appear more or less distorted in steps 2 and 3? Explain why.

   Answer: The signal would appear more distorted because the minimum step size would now be 0.08 V instead of 0.02 V. The signal would take on a staircase-like appearance because the voltage would have to change by four times as much (compared with the 8-bit scheme) in order for the display to change.

4. How important is it that the clock rate is set high in the encoding of the digital data? What are the limitations of the clock?

   Answer: The clock rate sets the limit on the frequency of the signal that can be reproduced by the DAC. If the signal frequency is close to or greater than the clock rate, then the signal will not be reproduced accurately; instead, you will observe an aliased version of the signal. The effect is similar to what happens when a wagon wheel appears to spin backward as a result of light passing through the spokes.

   The clock is limited by the hardware of the microcontroller to about 8 kHz.

5. What are the limitations of using a low-pass filter to shape the output of the DAC?

   Answer: The low-pass filter limits the frequency that the DAC can reproduce to low-frequency signals. It also distorts the shape of the square wave and of other rapidly changing signals.

Experiment 17: Pulse Code Modulation and Serial Data Protocols

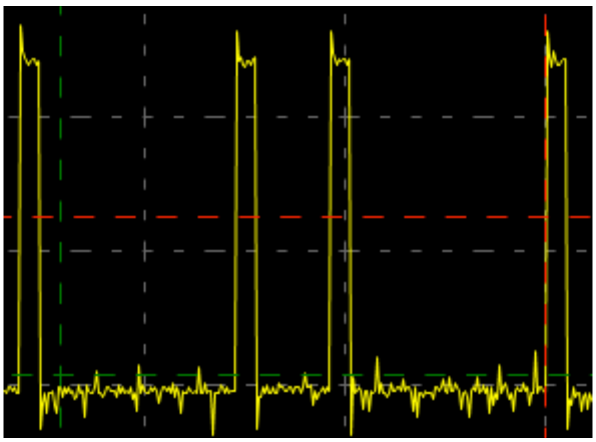
Test Equipment Used:

OWON DS7102V Oscilloscope
BK PRECISION 4012A function generator
Amprobe 34XR-A Multimeter
CSI5505S Power supply

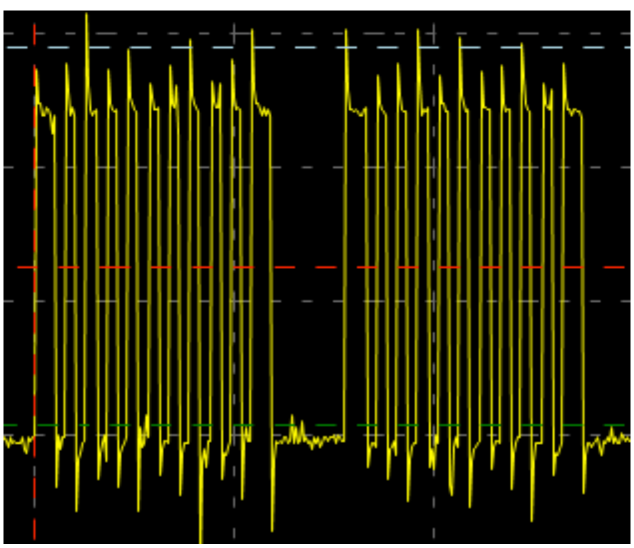
Procedure

Part I: PCM and ASCII

3.



4.



5. Start Bit Pulse Width = ____1000________ ms

Stop Bit Pulse Width = ___10000_________ ms

6. High Data Bit Pulse Width = _____500_______ ms

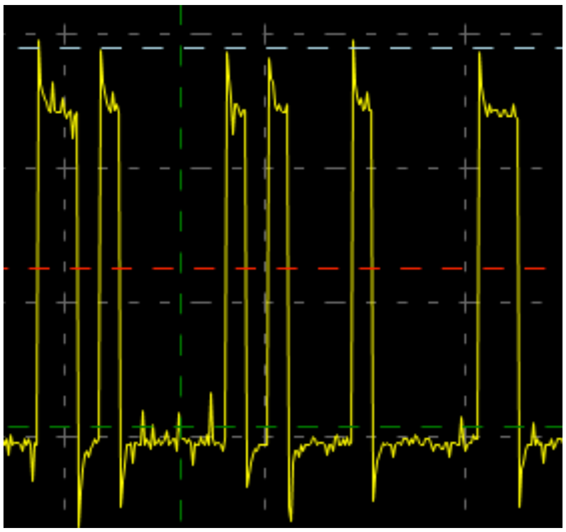
Data Pulse Period = _____1000_______ ms

7. Period between PCM words = ______16______ ms

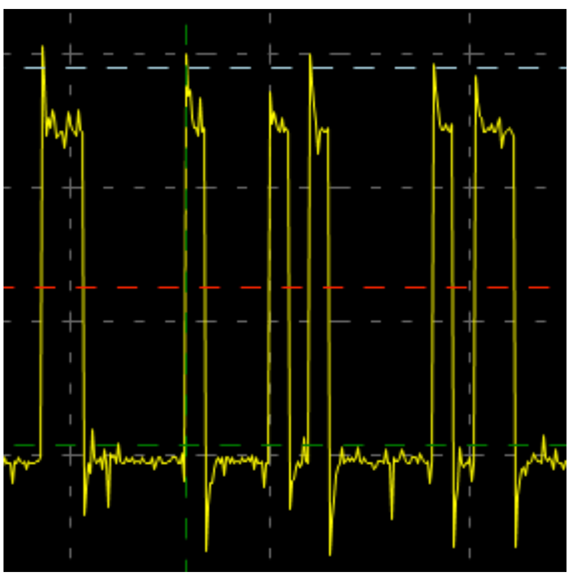
Data Rate = _____62.5_______ words / s

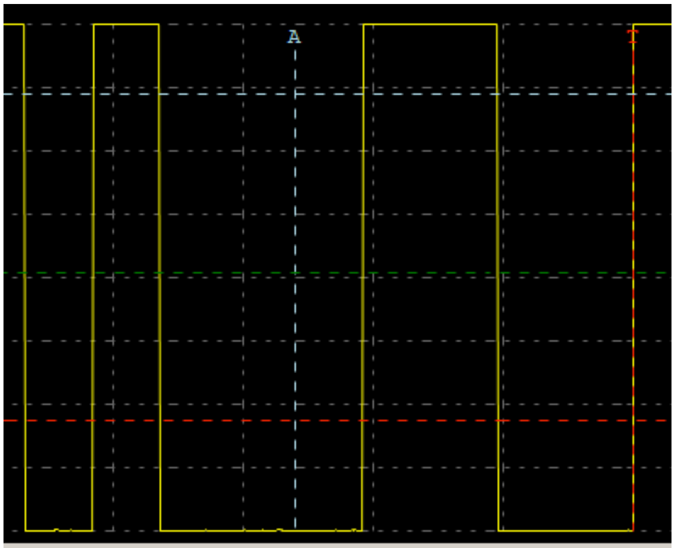
Data Rate = _____562.5_______ baud

8.



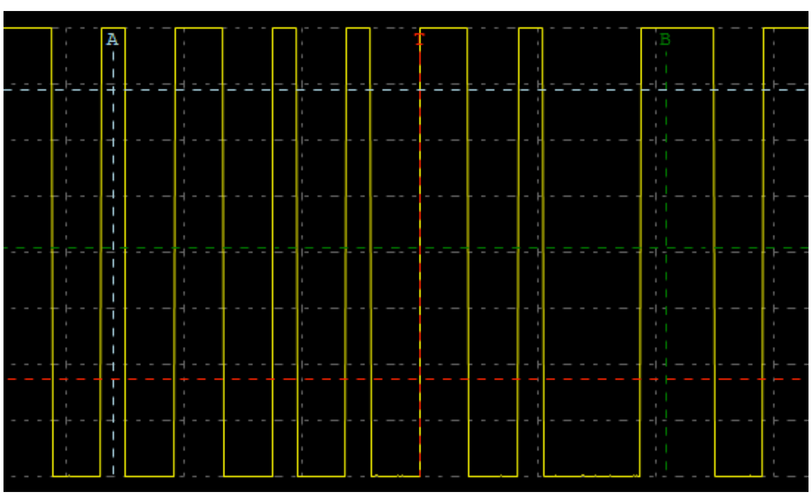
9.



11. 

12.

Number	Decimal	Binary
0	48	00110000
1	49	00110001
2	50	00110010
3	51	00110011
4	52	00110100
5	53	00110101
6	54	00110110
7	55	00110111
8	56	00111000
9	57	00111001

13. 

14. V_{in} (max) = ______2.2______ Vp-p dc

Part II: Digital to Analog Conversion

16. V_{in} = _____2.5_____ V dc

V_{DAC} = _____2.5_____ V dc

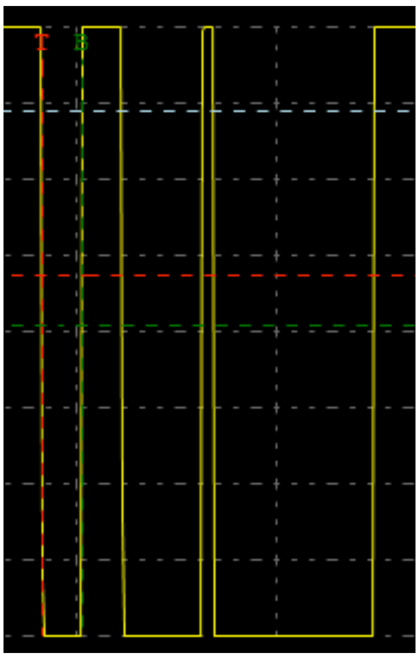
17. $T_{CS\ 1}$ = ___3300_ ms

$T_{CS\ 1\&2}$ = _____125___ ms

18. $f_{CLK\ 1}$ = ___1000_______ kHz

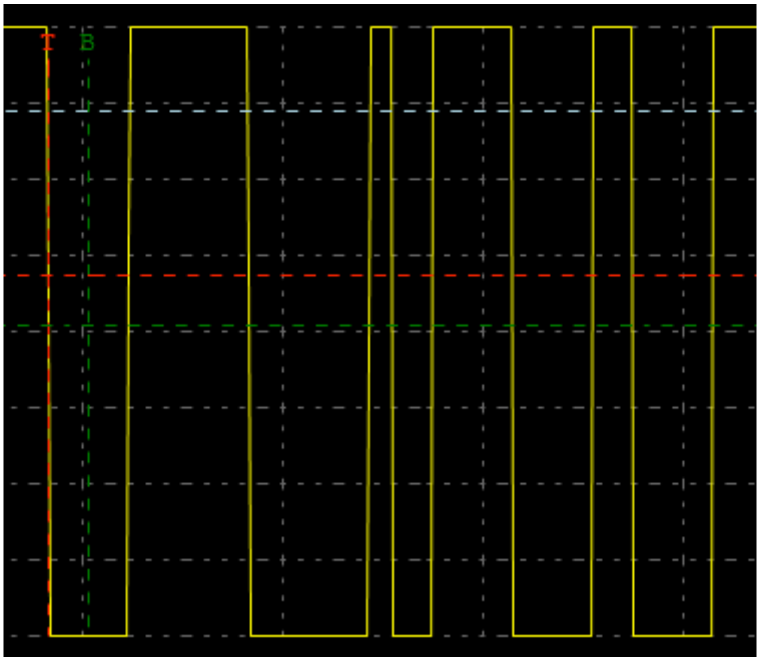
$f_{CS\ 1\&2}$ = __1000________ kHz

19.

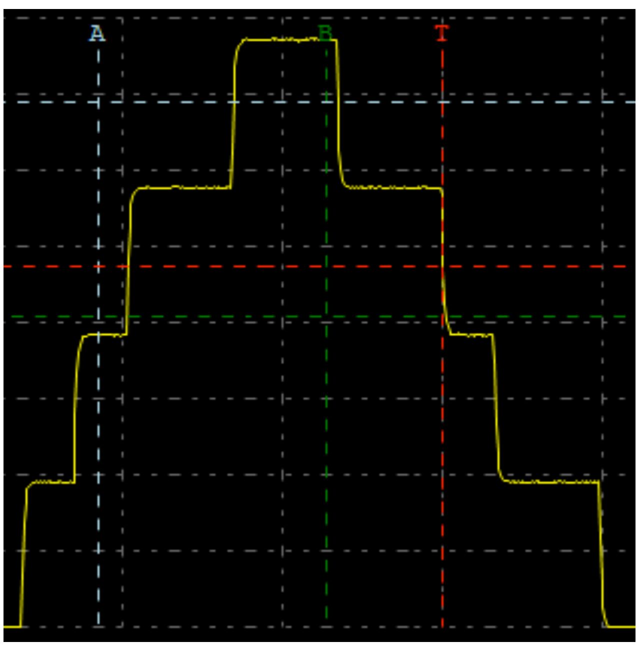


20. Resolution = _______1.22________ mV / Interval

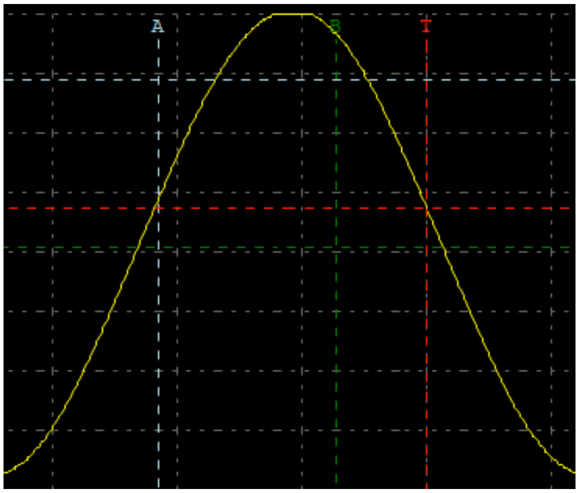
21.



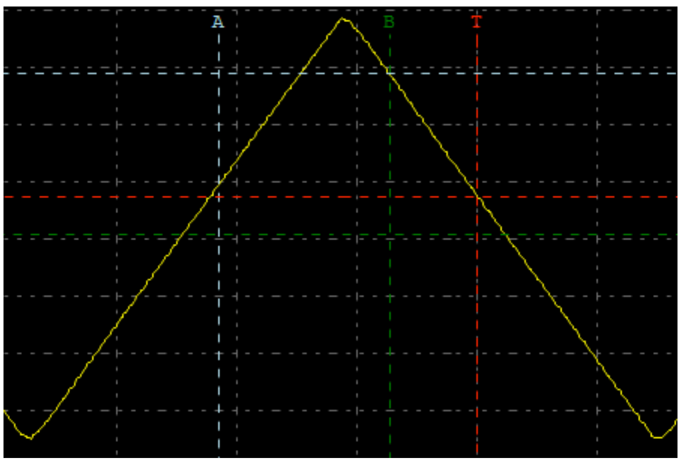
22.

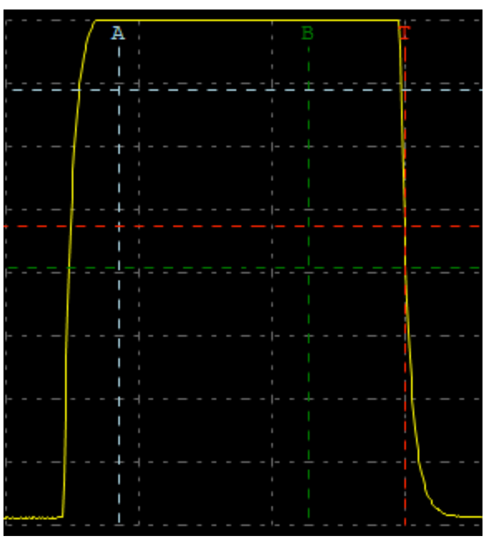


23.



24.





25. The answers below are approximate and students' values should vary within 20%

Maximum Frequency = _____2000_______ Hz

Sampling Frequency = _____8000_______ Hz

Questions

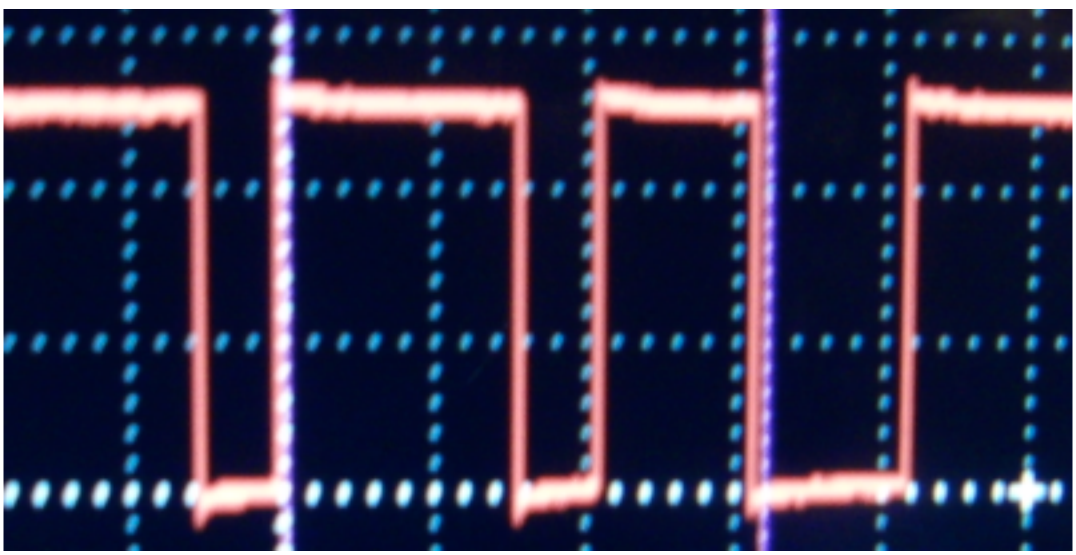
Part I:

1. Why are STOP and START bits necessary in a digital protocol? Describe a case where they both may not be required.

   Answer: Without the use of a Start bit, the sending and receiving systems would not know where one character ends and another begins. Stop bits are used to give the system time to catch up. The brief pause, typically 1 to 2 bit times, gives the receiver a change to synchronize with the transmitter.

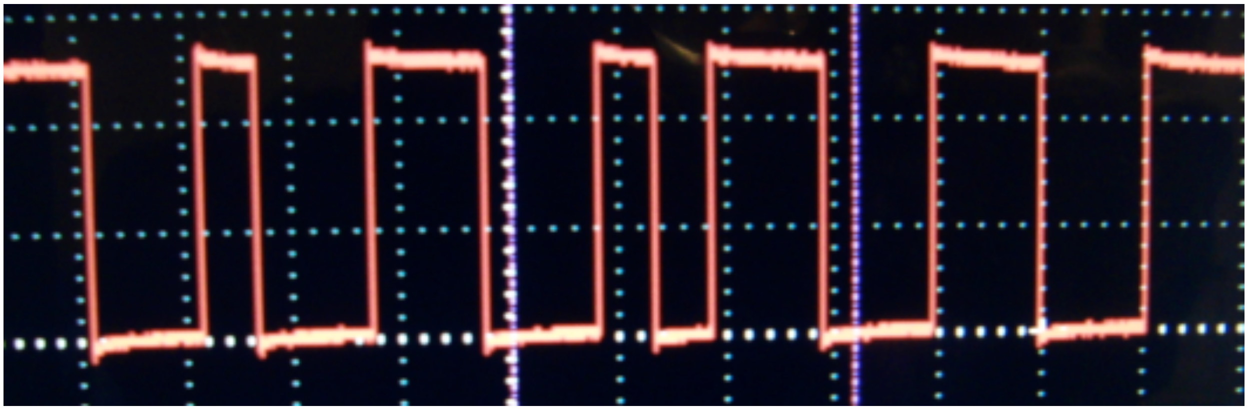
   A synchronous transmission protocol doesn't require stop bits.

2. Draw the TTL ASCII representation for the number 7. Label your diagram and explain how it is decoded.



   Read as 00110111. This corresponds to the number 55 in decimal, which is ASCII for the number 7.

3. Draw the TTL ASCII representation for the number 23. Label your diagram and explain how it is decoded. Explain the bit order of the two numbers.



Read as 00110011 00110010. This corresponds to decimal 51 50. ASCII 51 is 3 and ASCII 50 is 2. Read right to left this is 23.

Part II:

4. Calculate the frequency associated with the CS pin when the "Mode 1" and "Mode 2" buttons were pressed. How does this frequency compare to the maximum frequency and sampling frequency that you determined in step 11?

   a. The period (T) of the CS pin is 125 μs. Since the frequency is 1/T, the CS pin is running at 8 kHz.
   b. The frequency of the CS pin matches the sampling frequency. However, the maximum frequency is necessarily less as multiple samples are required to avoid aliasing.

5. Was the serial data measured in steps 6-9 characterized as being MSB first or LSB first? Why?

   a. ASCII uses a least significant bit protocol. This means that the pulses are read in reverse of the English-language convention (that is, they are read from right to left rather than from left to right), but in machine order the data are decoded sequentially.

6. How important is it that the clock rate is set high in the encoding of the digital data? What are the limitations of the clock?

   a. Many clock cycles are required to encode a single value. The faster that values can be encoded, the higher the frequency of the signals that can be represented.
   b. The DAC is being clocked at 1 MHz. The limitations of this system are in the encoding side, since the encoding runs at 8 kHz and the decoding side can run at 1 MHz / 16 bits per sample = 62.5 kHz.

Experiment 18: Frequency Shift Keying Modulation and Demodulation

Test Equipment Used:

OWON DS7102V Oscilloscope
BK PRECISION 4012A function generator
Amprobe 34XR-A Multimeter
CSI5505S Power supply

Instructor Note: Improved results can be obtained by substituting a 10-nF (0.01 µF) capacitor for the 100-nF (0.1 µF) capacitor shown between pins 1 and 2 of the 555 timer in Figure 18-4. All results in this solution key assume use of the 10-nF capacitor.

Procedure

Part I: FSK Modulation

1. For an ASTABLE Oscillator, we have the following:

$$f = \frac{1.44}{(R1 + 2R2) \times C}$$

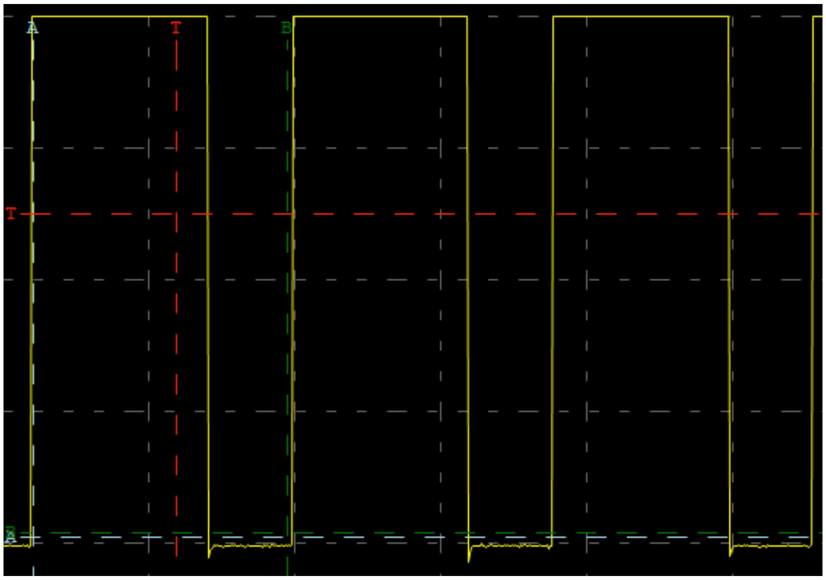
Assuming that the transistor is off, we ignore the 50-k resistor. For the minimum value of resistance (corresponding to the pot turned to the minimum position) we choose R1 = 0. Therefore, the frequency is calculated as

$$= 1.44 / (0 + 2 * 47{,}000) * 1 * 10^{-8}) = 1532 \text{ Hz}$$

For the maximum value of resistance corresponding to the pot turned to the maximum position we choose R1 = 50K

$$= 1.44 / (50{,}000 + 2 * 47{,}000) * 1 * 10^{-8}) = 1000 \text{ Hz}$$

3. Answers will vary between 1 and 1.2 kHz with duty cycle between 60 – 67%. Smaller frequencies will have smaller duty cycles.



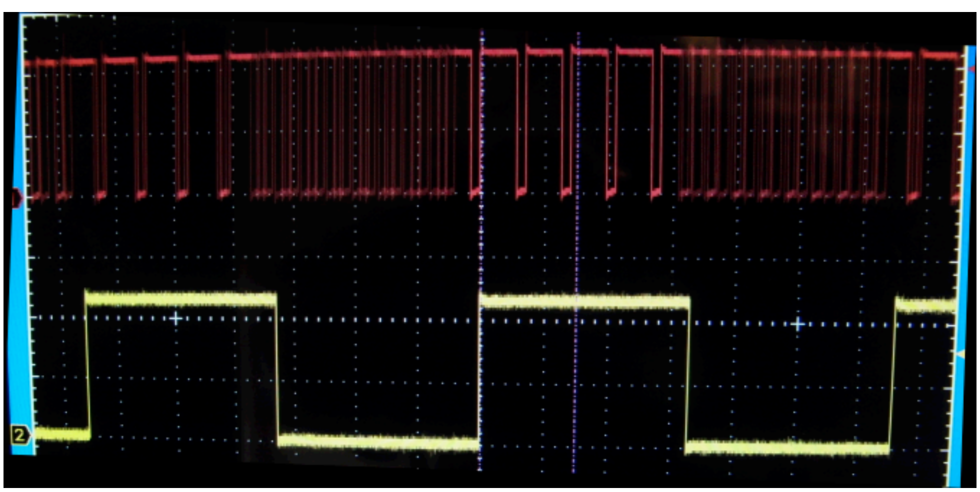
Mark Frequency _____1200_____ Hz Duty cycle ________67____________ %

4. The amount will vary based on the Mark Frequency selected above. Note we have selected a low input resistance to the BJT, which means that the transistor is pulling the 555 lower. To obtain more traditional performance use a 10-k input resistor to the BJT. With this addition, the space frequency would then be calculated from the 39-k resistor in parallel with the pot.

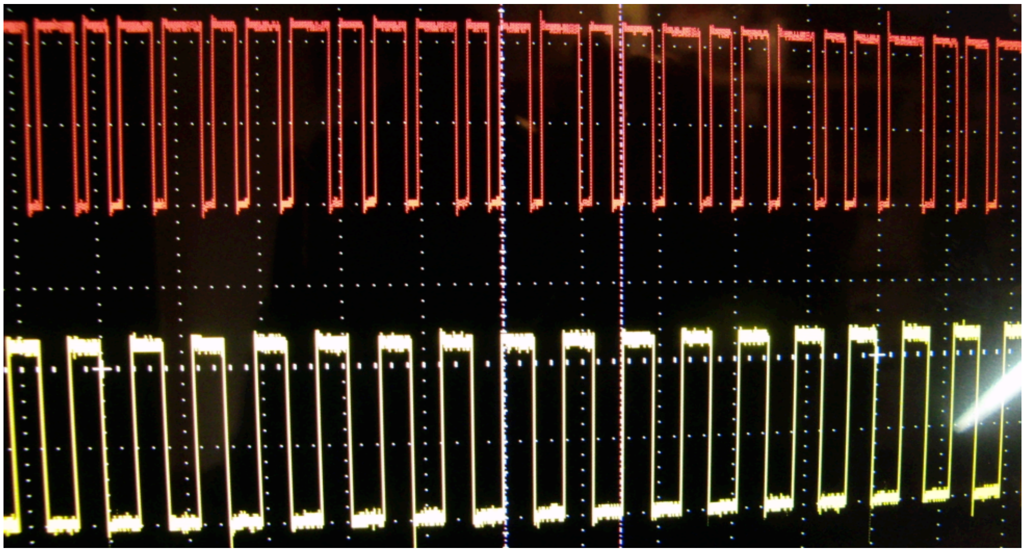
Space frequency ______680_____Hz Duty cycle _________56____________ %

5. Center Frequency ________940_________ Hz

6.



7.



Once the frequency of the input wave is greater then the frequency of the carrier frequency the signal will be completely unrecognizable. However things will get much worse prior to that. At half the mark frequency the observed carrier frequency will be the average of the mark and space frequency. This is an opportunity to talk about the Nyquist theorem or the Shannon-Hartley theorem as approprirate.

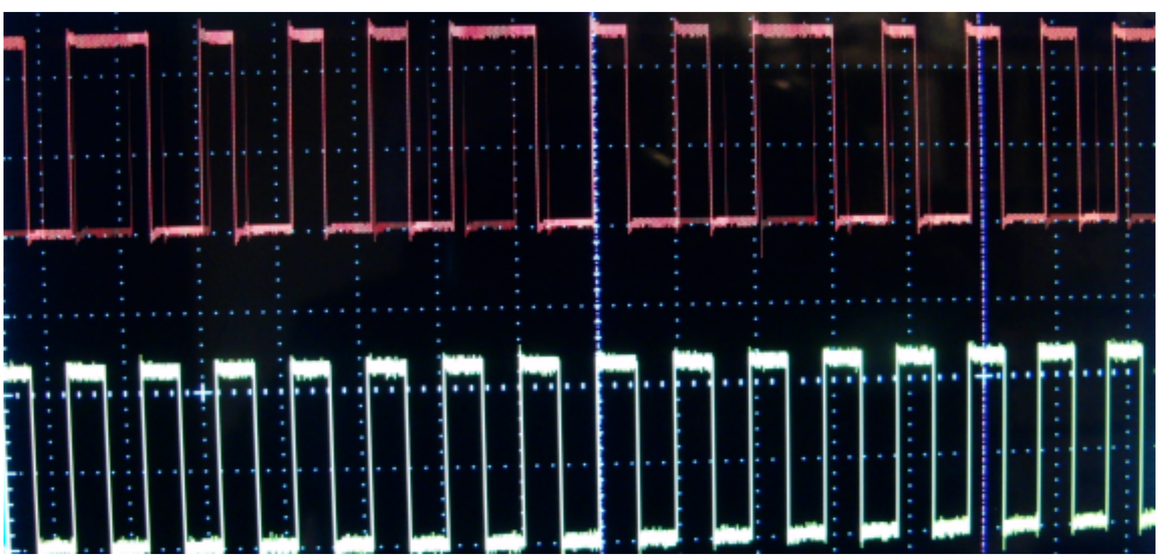
Cutoff Frequency ___340____Hz Observed Frequency _____940______ Hz

Part II: FSK Demodulation

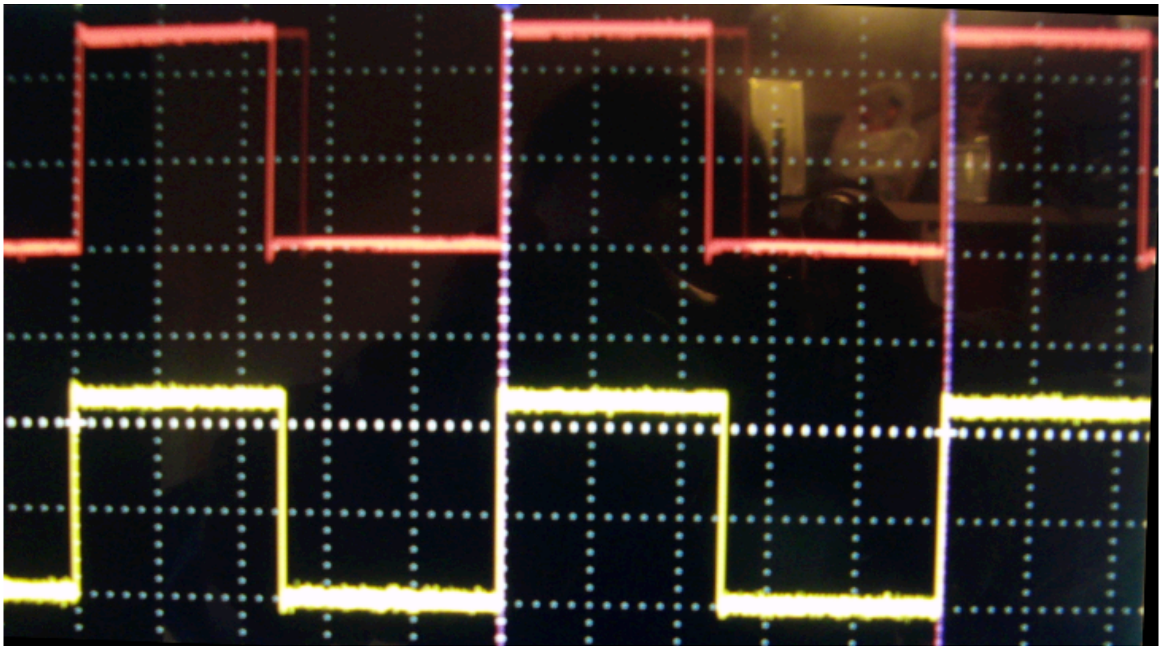
10. Space Frequency __680___Hz Mark Frequency __1200__ Hz

Center Frequency __940_ Hz

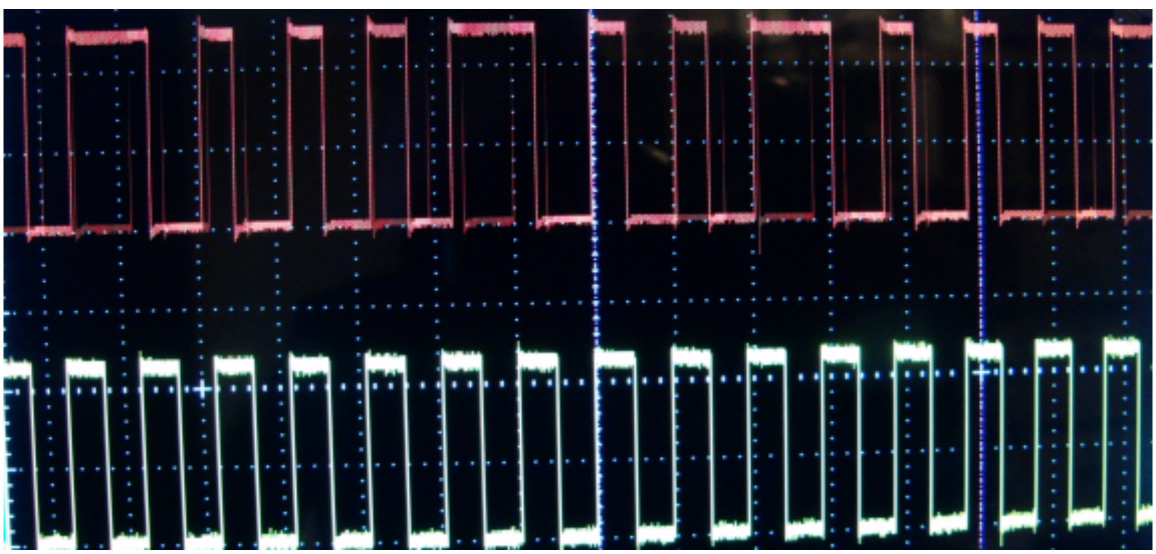
11.



12.

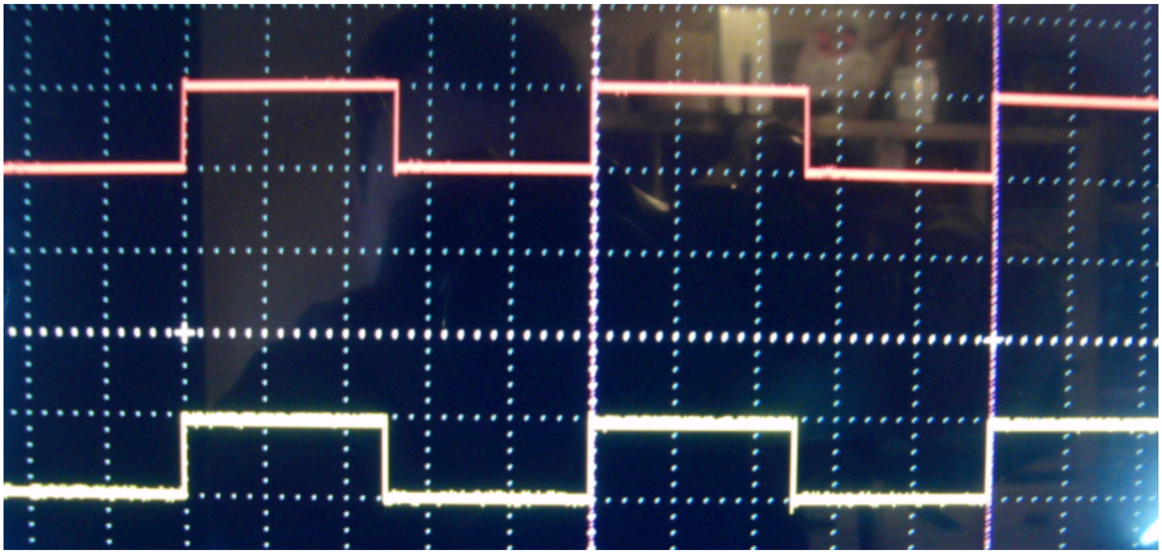


13/14.



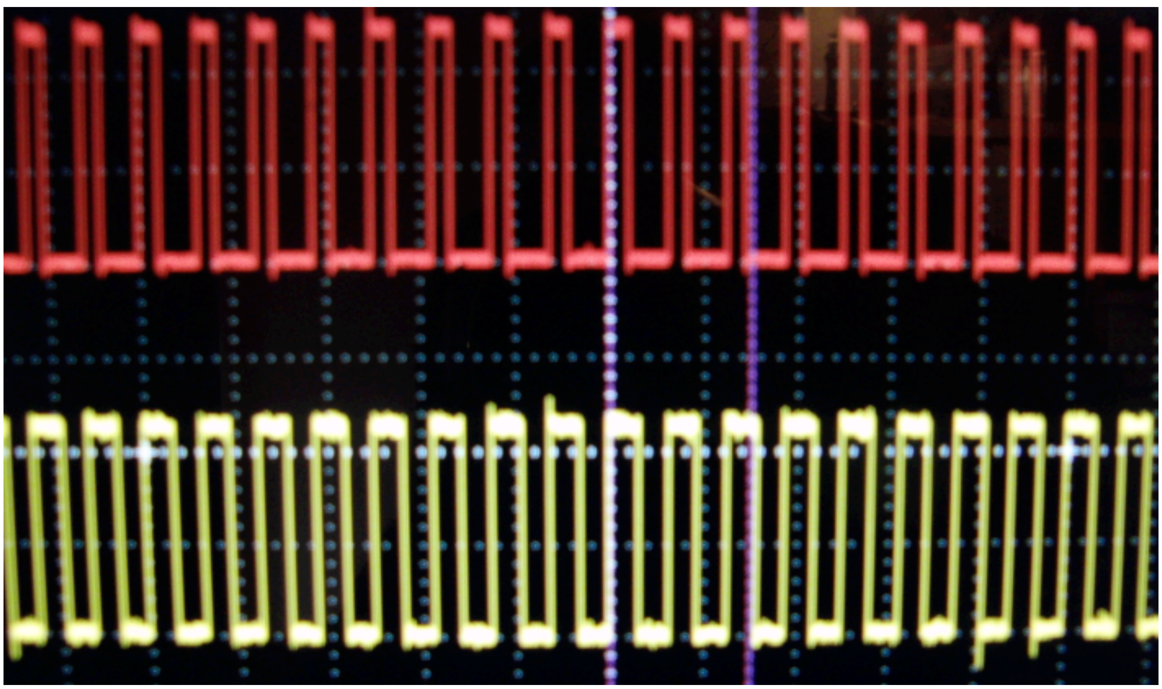
Space Frequency __842_Hz   Mark Frequency __1270_ Hz Center Frequency _1056_ Hz

15.



Cutoff Frequency ____440_______Hz Observed Frequency _____1056____ Hz

16.



Questions

Part I:

1. Calculate the maximum baud rate that the digital communication link can handle without any errors resulting.

   Answer: Baud rate is the number of signals per second, so the maximum baud rate would be equivalent to the measured cutoff frequency. This should be on the order of 410 bps.

2. In your own words, write a brief theory of operation section for the digital communications link analyzed in this experiment. Assume that this system is being sold as a product to the technical public and that this theory section is to be incorporated as part of a manual for the product.

   Answer: FSK stands for Frequency Shift Key, which is a form of digital frequency modulation. FSK is a communications method that employs discrete frequencies for specific tasks, such as sending particular signals. The transmitter is changed from one frequency to another, keyed to represent a different information character with each frequency. There are two components to the system, the modulator which takes digital signals and encodes them as either of two distinct, pre-determined frequencies, a mark frequency and a space frequency. The demodulation component takes the frequencies and returns the original digital signals.

3. How is the cutoff frequency you measured related to the mark and space frequency?

   Answer: The cutoff frequency is one-half the lower of the mark and space frequency.

4. What does the demodulator circuit do when the input frequency exceeds the cutoff (or bit clock). Explain in detail. Is this behavior always the same?

   Answer: Initially there will be aliasing, where a zero will be encoded as a one or vice versa due to sampling alignment. For input frequencies near the bit clock, the error rate will be low (related to the difference in frequency and the bit clock). As the frequency increases errors will increase.

5. In the MSK operating mode, how did the cutoff frequency compare to the mark and space frequencies? How did this cutoff frequency compare to the cutoff frequency in the non-MSK implementation in Part I?

   Answer: The cutoff in MSK was exactly ½ the mark frequency. However in the non-MSK implementation, the cutoff frequency for perfect encoding is much lower (~1/2 Mark Frequency – ¼ space frequency) as there are effects due to the lack of alignment.

6. Write a technical test procedure for the calibration of the FSK encoder for the generation of MSK FSK.

   a. Test Procedure:
      i. Set the potentiometer in the center of its range.
      ii. Pull the transistor high and measure the frequency.
      iii. Pull the transistor low and measure the frequency.
      iv. Calculate the difference in frequency determined in steps ii and iii.
      v. If the difference is greater than half that determined in step iii, then you will need to increase the frequency of step ii, else if the difference is less than half iii, you will need to decrease ii.
      vi. Adjust the difference in mark and space frequencies (step iv) until it is one-half of the value measured in step iii.
      vii. In the final state the difference between the measured frequency with the transistor pulled high and the measured frequency with the transistor pulled low should be half the frequency measured when the transistor is pulled low.

Experiment 19: Modem Communications

Procedure

13. Answers may vary based on the modem and quality of the line generator circuit.

17. Answers may vary based on the modem and quality of the line generator circuit.

18. The default location for Tera Term file transfers is c:\program files (x86)\teraterm but can be changed by clicking File, Change Directory.

19. Answers may vary as the student may select any of the following protocols: Kermit, XMODEM, YMODEM, ZMODEM, B-Plus, Quick-VAN

Questions

1. a) Computer 1 – DTE
   b) Modem 1 – DCE
   c) Modem 2 – DCE
   d) Computer 2 – DTE

2. This command can be broken into parts for a clearer understanding. AT – attention, ATX3 – disable dial tone detection, &C0 – force DCD signal active

3. This command is necessary because the line simulator circuit does not actually have a dial tone.

4. The fastest modem speed supported is 56k, though most phone lines can only support 52 kbps.

5. The protocols are Kermit, XMODEM, YMODEM, ZMODEM, B-Plus, and Quick-VAN

Experiment 20: Router Configuration

Procedure

35. Yes, PC1 should be able to ping R1's Fast Ethernet interface.

36. Yes, PC1 should be able to ping R1's Serial interface.

37. Yes, R1 should be able to ping PC1's Fast Ethernet interface.

38. Yes, PC2 should be able to ping R2's Fast Ethernet interface.

39. No, because no routing is setup yet R1 and R2 do not know how to reach each other.

58. Now that routing is setup using RIP V2 the routers can communicate and send information between the two networks.

Questions

1. The clock rate allows the routers to communicate and synchronize their communications. The DCE provides the clock rate.

2. Encapsulation defines how different layers that are logically separate can send or encapsulate information inside a higher layer. In networking terms, as the data traverses the OSI model, the previous layer encapsulates the data in the next layer. For example, the Network layer encapsulates packets in the Data Link layer's frames.

3. A protocol allows different nodes to communicate. A protocol defines the rules and conventions. A protocol is similar to the rules of a particular written or spoken language; both sides need to understand the language to communicate.

4. Routers and networks depend on the TCP/IP suite which consists of many protocols. TCP is the transmission control protocol, IP is the internet protocol, the ping utility utilizes ICMP which is the internet control message protocol, and RIP V2 uses the routing information protocol.

5. Typically the CSU/DSU will reside on the Telco's side of the demarc, meaning it is the property of the Telco.

Experiment 21: Wireless Computer Networks

Procedure

7. a), b) – IPv4 addresses will vary

10. a), b) – IPv4 addresses will vary

16. IPv4 address of POE WAP will vary

22. Connectivity should be obtainable to each profile created

23. Information in table will vary

28. IPv4 addresses will vary

29. Results may vary

37. The occupied bandwidth appears as 20 MHz, close to the theoretical 22-MHz bandwidth for 802.11b channels. In Figure 21-1, each major division horizontally represents a frequency span of 4 MHz; therefore, about 10 MHz appears occupied on either side of the center frequency. The transmission is a form of direct-sequence spread spectrum (DSSS). At 1 Mbps, the modulation format is differential bi-phase shift keying (DBPSK).

Questions

1. WEP, WAP, and WAP2 are the most common security protocols.

2. A 64-bit wide WEP key would require a 10 digit key.

3. The signal strength should experience a 6 dB loss when the distance from the source is doubled.

4. Interference from ceilings, people, or anything else in the room could account for discrepancies. A true test would require a wave guide like testing environment.

5. ERP-OFDM for 802.11G, and BPSK/HRDSSS for 802.11B

6. Channels 1, 6, and 11 are non-overlapping which means there is no signal interference between the frequency bandwidth.

7. Same channeled WAPs located near each other would cause major interference and would degrade the performance of each WAP.

Experiment 22: Planning and Designing Local-Area Networks (LANs).

Procedure

Answers will vary

Questions

1. CSMA/CD follows the following basic process: when a device wants to gain access to the network, it checks to see if the network is free. If the network is not free, it waits a random amount of time before retrying. If the network is free and two devices access at the same time there is a collision. When the collision is detected, both nodes back off and wait a random time and try again.

2. A wireless network can use either a star (WAP) topology or a point to point (ad-hoc) topology.

3. A terminator is necessary to prevent the bounce back or reflection of the transmitted signal. The terminator terminates the signal to ground.

4. Single mode (yellow jacket): longer distances, laser light source, smaller diametrical core, and only one mode of light is propagated. Multimode (orange jacket): shorter distances, LED light source, larger diametrical core, and multiple modes of light are propagated.

Experiment 23: Local-Area Network (LAN) Troubleshooting

Procedure

Each group should be able to correctly identify the various faults the other group has introduced to their computers.

Questions

1. The Top Down approach is best suited for an Application layer problem.

2. The Bottom Up approach is best suited for networking problems since networking occurs in the bottom three layers.

3. The best approach here is the Divide and Conquer as it will start in the middle and quickly identify the problem. The Spot-The-Difference approach could also apply.

4. Answers should be similar to the descriptions found on pages 402 and 403 of the text.

Experiment 24: Binary and IP Addressing

Questions

1. a) 10110011 binary is 179 decimal
   b) A95 hexadecimal is 101010010101 binary
   c) 7564 octal is F74 hexadecimal
   d) 240.187.35.17 decimal is 11110000.10111011.00100011.00010001 binary
   e) 01111010 binary is 7A hexadecimal
   f) 65254 decimal is 177346 octal

2. An IP of 140.133.28.72 and a subnet mask of 255.248.0.0 would have a network ID of 140.128.0.0

3. A /26 subnet mask has 26 bits for the networks and 6 bits for the hosts.

4. 45 computers + 10 servers + 4 printers + 3 WAPs = 62 hosts. 10% growth would add an additional 7 hosts after 5 years for a total of 69 hosts. Therefore, the best network mask is 255.255.255.128, which allows for 126 hosts.

Experiment 26: Using Capacitors for Impedance Matching

Procedure

Part I: Circuit Description

1. Compute wavelength in centimeters. C = 3×10^{10} cm/sec. 30 cm (a)

Part II: Measuring Z_{in} along the Transmission Line

4. What is the VSWR for all points on this circle? 2:1 (b)

5. Compute the number of wavelengths for a distance of 3 cm. 0.1 (c)

6. From the point identified in step 2, move along the circle (towards the generator) by 3 cm. Using a ruler measure Z_i/Z_o 0.67 + j 0.48 (d)

7. Calculate Z_i = 33.5 + j 24.0 (e)

Part III: Impedance Matching with a Series Capacitor

8. Find the number of wavelengths from the point in step 2 required to make Re (Zi) = 50 ohms. 0.15 (f)

9. Compute the corresponding physical distance. 4.5 cm (g)

10. What is the magnitude and phase of the reflection coefficient at this point? 0.34, 70 degrees (h)

11. What is Im (Zi)? $0.7 \times 50 = 35$ ohms (i)

12. Compute the amount of series capacitive reactance required to make the reflection coefficient equal to zero. 35 ohms (j)

13. Compute the corresponding capacitance for step 12. 4.5 pF (k)

Part IV: Impedance Matching with a Shunt Capacitor

14. Start at a point defined in Z_L = 15 + j 15 ohms. (0.3 + j 0.3)

17. Note the value located along the scale "wavelength towards generator" and record. 0.30 (l)

19. Note the wavelength towards the generator and record. 0.326 (m)

20. What is the physical distance between the locations recorded in steps 17 and 19. $\underline{0.026 \times 30 = 0.78 \text{ cm}}$ (n)

21. What is Im (Y_i/Y_o)? 1.4 (o)

22. Compute Y_i: 0.02 - j 0.028 (p)

23. Compute the value of shunt capacitance that is required to make the reflection coefficient equal to zero. 4.456 pF (q)

24. Compute the value of inductance, for a reactance of 15 ohms at 1 GHz. 2.4 nH (r)

Part V: Change Frequency and Dielectric Constant

25. For the series matching capacitor.

    a. Calculate the capacitance if the frequency is changed from 1 GHz to 100 MHz: 45 pF (s)
    b. Calculate the length for the matching element if the dielectric constant is 2.1 (Teflon): $45 \text{ cm} / \sqrt{2.1} = 31 \text{ cm}$ (t)

    HINT: See page 428, Equation 12-21. The velocity equals "c" divided by the square root of the dielectric constant.

26. For the parallel matching circuit start with a 25-ohm load. Change the frequency to 100 MHz and the dielectric constant to 2.1.

    a. Calculate the capacitive reactance and capacitance.
        (i) $X_c = 1/0.014 = 71.42$ ohms (u)
        (ii) C = 22 pF (v)

    b. Calculate the # wavelengths and length for the matching element.
        (i) Wavelengths 0.10 (w)
        (ii) Length 20.7 cm (x)

Questions

1. The VSWR can be read directly from the point where the circle intersects the horizontal resistance line in the center of the Smith chart on the right side. Alternatively, the radius of the circle is an indication of VSWR, and this radius can be read from the "radially scaled parameters" rule appearing below the chart.

2. The impedance (both resistance and reactance) at any point within a half-wavelength section of the transmission line.

3. One full revolution around the Smith chart represents one-half wavelength.

4. The magnitude of reflection coefficient is determined from the radius of the VSWR circle. Use the “radially scaled parameters” rule appearing below the chart to determine either the voltage reflection coefficient (use the scale “rfl. coeff, E or I”) or the power reflection coefficient (“rfl. coeff, P”); these quantities are found by placing the compass at the center of the scale and extending it to the left by an amount equal to the radius of the VSWR circle. The phase angle of the reflection coefficient is determined by extending a straight line from the origin through the normalized impedance and out to the outer edge, through the scale labeled “angle of reflection coefficient in degrees.”

5. Reactances opposite in type to those present, when added in series, will cancel out the reactive components of the impedance, thus making it appear purely resistive. A reflection coefficient of zero means that the load impedance is well matched to that of the source and transmission line, and this condition is often most easily achieved with a purely resistive load.

6. Shunt means parallel. The reciprocal of impedance is admittance, and the reciprocal of reactance is susceptance. These quantities are used because adding reactances in series may be impractical (particularly in microwave contexts) because of the need to “break in” to the installation to add elements. Rather, it is often more practical to add reactive elements in parallel because parallel elements can often be added without modifying the underlying installation.

7. A shunt reactive element would be useful whenever it would not be possible to add reactive components in series. In many cases, such as with the stub filter shown in Example 12-10, lengths of transmission line are used rather than physical inductors or capacitors. However, finding the appropriate values for shunt-connected elements requires that all impedances be converted to admittances (reciprocal quantities), including the impedance of the short-circuited stub itself, which is zero ohms. A short-circuited stub is most often used to minimize radiation off the end of the stub. The reciprocal admittance of a short-circuited impedance is, therefore, infinity, which is located at the right-hand side of the chart.

Experiment 27: Smith Chart Measurements Using the Multisim Network Analyzer

Procedure

Part I: Using the Network Analyzer

3. Table 27-1:

R1 (ohms)	Network Impedance, Z_{11}	Resistance (ohms)
75	1 + j 0.0	75
50	0.667 + j 0.0	50
100	1.3333 + j 0.0	100
600	8.000 + j 0.0	600
300	4.00 + j0.0	300

Part II: Measuring Complex Impedances with the Network Analyzer

4. Xc = 24.87 ohms

5. Table 27-2:

R1 (ohms)	C1	Frequency	Network Impedance, Z_{11}
25	6.4 nF	100 kHz	0.5 – j 4.9736
25	6.4 nF	100 MHz	0.5 – j 0.005
10	10 pF	1 MHz	0.2 – j 318.31
10	10 pF	100 MHz	0.2 – j 3.1831
50	50 nF	100 kHz	1.0 – j 0.6366

6. X_L = 25.133 ohms

7. Table 27-3:

R1 (ohms)	L1	Frequency	Network Impedance, Z_{11}
25	4 µH	10 kHz	0.5 + j 0.0050
25	4 µH	100 kHz	0.5 + j 0.0503
25	4 µH	10 MHz	0.5 + j 5.0265
25	4 µH	100 MHz	0.5 + j 50.265
25	4 µH	1 GHz	0.5 + j 502.65

8. See the following answer to question 6.

Questions

1. The Smith chart is a modified Cartesian coordinate representation of resistive and reactive components of impedance. Resistances are represented by circles that are tangent to each other at the right-hand end through the center of the chart. Reactances are represented by arcs, also tangent to one another at the right-hand side of the chart. Inductive reactances occupy the arcs above the center resistance line, and capacitive reactances are represented by those below.

2. Normalization allows a general form of the Smith chart to be used for all characteristic impedances. The characteristic impedance is represented by the center of the chart. In the general form, this point is labeled 1.0. To normalize, divide both the resistive and reactive values of the impedance (rectangular form) by the characteristic impedance, as shown in Equation 12-33. To denormalize, reverse the process by multiplying the normalized values of resistance and reactance by the characteristic impedance.

3. Yes. A pure resistance equal to the system characteristic impedance is represented by a point at the center of the Smith chart.

4. Probably not. Lead inductance and the physical dimensions of the device are among the factors that would cause a resistor to have reactive properties at microwave frequencies.

5. Points above the center line represent impedances with inductive reactance; those below the center line indicate impedances with capacitive reactance. In either case, a resistive match can be achieved by placing an opposite-type reactance in series to cancel out the reactance already present.

6. At the low frequency of 10 kHz, the inductive reactance is only 0.25 ohm, so the inductor essentially appears as a short circuit. Therefore, the normalized impedance of 0.5 + j0.0050 ohms (shown in Table 27-3) is almost purely resistive. Conversely, at the highest frequencies, such as 3 GHz, the reactance is over 75 kilohms, thus representing essentially an open condition.

Experiment 28: Multisim—Impedance Matching

Procedure

Part II: Measurements for the Series Capacitor

5. (a) Record the minimum value of S11: 0.007
   (b) Record the frequency when S11 is minimum: 1016 MHz

10. Table 34-1:

#	S_{11}	Frequency (MHz)	VSWR	Bandwidth (MHz)
1	Min: (0.007)	1016.0	1.01	-------
2	0.05L	966.0	1.11	-------
3	0.10L	918.3	1.22	-------
4	0.15L	868.9	1.35	-------
5	0.05R	1079.0	1.11	113
6	0.10R	1140.0	1.22	221.7
7	0.15R	1211.0	1.35	342.1

Part III: Measurements for a Shunt Capacitor

13. Minimum S11: 0.013
    Frequency at minimum S11: 1045.0 MHz

    Table 28-2:

#	S_{11}	Frequency (MHz)	VSWR	Bandwidth (MHz)
1	Min: 0.013	1045.0	1.025	------
2	0.15L	909.8	1.35	------
3	0.15R	1161.0	1.35	251.2

Part V: Optimizing the Shunt Capacitor Design

17. Table 28-3

#	C1	S_{11}	Phase (Degrees)	Frequency (MHz)
1	22.0 pF	0.012	42.3	99.76
2	22.5 pF	0.007	41.9	98.90
3	23.0 pF	0.002	42.8	98.05
4	23.5 pF	0.003	-140.2	97.21
5	24.0 pF	0.008	-140.2	96.38
6	23.1 pF	0.0009	98.8	97.77
7	23.2 pF	0.0006	-104.4	97.77
8	23.3 pF	0.002	-94.1	97.77

Part VI: Optimizing the Series Capacitor Design

22. Table 28-4.

#	C1	S_{11}	Phase (Degrees)	Frequency (MHz)
1	43.7 pF	0.003	-83.2	101.2
2	43.8 pF	0.002	-84.9	101.2
3	43.9 pF	0.001	-79.5	101.2
4	44.0 pF	0.0006	-66.5	101.5
5	44.1 pF	0.0003	39.4	101.5
6	44.2 pF	0.001	75.5	101.5
7	44.3 pF	0.002	176	101.5
8	44.4 pF	0.002	152	101.5

Questions

1. For S parameter test sets, all unused ports must be terminated in characteristic impedance.

2. An abrupt change from a positive to a negative phase angle (or vise versa) indicates that the optimum value resides between those where the change occurred. For example, in Table 28-3, the phase angle changes from a positive value at 23.0 pF to a negative value at 23.5 pF; the optimum capacitance is, therefore, between these values.

3. A spectrum analyzer is a frequency-domain instrument that displays signal amplitude as a function of frequency. A scalar network analyzer displays the magnitude of impedance of a device under test. A vector network analyzer displays both the magnitude and phase angles of devices under test.

4. Probably not. Lead inductance and the physical dimensions of the device are among the factors that would cause a resistor to have reactive properties at microwave frequencies.

5. In S Parameter notation, the first subscript number indicates the port from which the signal emerges, and the second number represents the port to which the signal is applied. The designation S_{11} indicates that the signal has emerged from the same port to which it was applied, or, in other words, is a reflected signal. Therefore, the S_{11} notation designates reflection coefficient.

6. S Parameter measurements are made with all ports terminated in their characteristic impedances, rather than with open or short circuits. Open circuits are difficult to achieve, particularly at microwave frequencies. At UHF and above, an open circuit can appear capacitive and, as such, can spring into oscillation, possibly causing the device under test to self-destruct. High-power devices (such as amplifiers) cannot have short-circuited outputs without causing them to be destroyed. Also S Parameters can be determined on devices being tested some distance from the measurement transducers provided that residual transmission-line effects can be eliminated from subsequent calculations. For this reason, network analyzers are used in conjunction with calibration kits consisting of known and accurately characterized opens, shorts, and loads.

Experiment 29: Scalar Network Analysis and Voltage Standing-Wave Ratio (VSWR) Measurements

Procedure

Part I: Two-Port Measurements

1 (e) What is the minimum insertion loss of this filter in the passband? approx. 0.9 dB typical.

What is the minimum insertion loss of the filter in the stopband? 35 dB typical. (Note: stopband attenuations are manufacturer-specific. Mini-Circuits provides specifications for both 20-dB and 35-dB attenuations in the stopband for many of their filters.

f_1 = 58 MHz; f_2 = 82 MHz; bandwidth: 24 MHz (typical for Mini-Circuits NBP-70+ filter)

Part II: One-Port Measurements

2 (d) Answers will vary depending on whether a low-pass or high-pass filter is used.

Questions.

1. Answers will vary depending on manufacturer. Students should be made aware that some manufacturers represent return losses in terms of positive decibel values, whereas the Rigol spectrum analyzer, like most others, displays the losses as negative numbers. Therefore, a graph of return loss versus frequency may appear inverted on the analyzer when compared with the manufacturer's published data.

2. All are terms that express the relative degree of match or mismatch between source, transmission line, and load, and any of them can be derived from the others. A matched source and load is evidenced by a low VSWR (approaching or equaling 1:1), a low reflection coefficient (approaching or equaling zero), and/or a high return loss (approaching infinity). Conversely, an open- or short-circuited condition is represented by a VSWR of infinity, a reflection coefficient of 1, or a return loss of zero.

3. This is an example of frequency-domain reflectometry. Knowledge of the velocity factor, coupled with the ability to view the first amplitude reduction created at one-quarter wavelength, allows one to estimate the length of transmission line. This would be useful in determining the distance to a fault (open- or short-circuited condition) in a length of cable that is buried or otherwise hidden from view. Another technique for determining distance to fault is time-domain reflectometry, in which a short-duration pulse is transmitted down a line. The time-domain reflectometer measures the time a pulse takes to travel down a cable and return to the source. The instrument uses this duration, coupled with propagation velocity, to calculate the distance to fault.

4. For a cable of known length, the equation in step 5(f) can be rearranged to solve for the velocity factor.

5. Yes, additional dips would occur at odd quarter-wavelengths, so the associated frequencies would be associated with lengths of $3\lambda/4$, $5\lambda/4$, and so forth.

6. Yes, the antenna can function effectively at other than its resonant frequency. As long as current is flowing within a conductor or system of conductors, electromagnetic energy will radiate. An antenna appears to a source as a series RLC circuit, possibly consisting of both resistance and reactance, depending on frequency. The antenna will appear purely resistive at its resonant frequency, but at frequencies above or below resonance, reactive components will be present as well, presenting an impedance mismatch. This mismatch manifests itself as VSWR on the transmission line and results in some power being reflected back to the source, thus representing less-than total power transfer of power from source to load. The bandwidth of an antenna is generally expressed in terms of the range of frequencies over which it has a VSWR less than some predetermined value, usually 1.5:1 or 2:1, depending on application.

7. Yes, a dipole antenna will be resonant at frequencies at which it is (electrically) a multiple of a half-wavelength. So, the dipole will be resonant at a full wavelength, 1-1/2 wavelengths, and so forth.

8. The student should recognize that VSWR measurements (either with a VSWR meter or with a "thruline" wattmeter capable of measuring both forward and reflected power) are often the most practical indications of antenna and feedline health. Often in new installations, a "frequency sweep" over the intended frequency range is made, either with a spectrum analyzer and tracking generator combination similar to the one used in this experiment or with a purpose-built (and portable) scalar network analyzer that provides a visual display of return loss over a user-defined frequency range.

Experiment 30: Antenna Polar Plots and Gain Calculations

Notes to instructor: This experiment makes use of the tracking generator installed in many spectrum analyzers (available as the "-TG" option in the Rigol DSA-815 instrument) as a signal source. Set frequency span to "zero span" and enter the desired frequency as the center frequency to produce a constant-output signal level. The output level is adjustable but was set to 0 dBm for this experiment. For best results in determining antenna gain, take into account all possible signal losses within the cables used to connect the antennas to the analyzer. (These losses can be significant—often 3 dB or so—at frequencies close to 1 GHz, particularly with inexpensive coaxial cables.) A convenient way to remove cable loss effects is to make use of the "normalize" routine built into the analyzer's self-calibration capability.

The antenna used in the prototype is the LPY 915 PC board antenna (6-dBi gain) available from Ramsey Electronics (www.ramseykits.com). This antenna was chosen because it is inexpensive, is designed to operate within the frequency range of the DSA-815-TG, and because it is supplied with pre-attached BNC connectors. Other types of directional antennas would also be suitable with appropriate procedure modifications. Figures 30-1 through 30-3 show the prototype configuration. We recommend that the setup be provided to students in either pre-assembled or easy-to-assemble form. Each mount consists of a circular base (obtained from a local hardware store), a 4-ft-long by ½-in.-diam length of dowel rod, and a 4-in. long section of Schedule 80 PVC pipe. A narrow slit cut into the end of the pipe provides a convenient mount for the antenna board (Fig. 30-3), and a hole drilled into the opposite end of the PVC pipe allows the assembly to be fitted through the dowel rod. A circular protractor on the receive-antenna stand allows for its orientation to be determined easily with respect to the transmit antenna and can be used to record the data in tables 30-2 and 30-4.

This experiment is critically dependent on its surroundings. Ideally, measurements should be performed outdoors in an open space (parking lot, athletic field, etc.) free from large objects and reflective surfaces. However, the results obtained below were obtained indoors with all large objects removed from the immediate surroundings. Results closer to the ideal were obtained by

Figure 30-1 View of overall experimental setup

Figure 30-2 View of the circular protractor at the base of the receive antenna

placing the stands on a workbench (approx. 30 in. above ground level) rather than by placing them on the floor; be aware that the ceiling and floor, as well as walls, will have a waveguide effect and will substantially impact the radiation characteristics of the antenna.

Figure 30-4 shows a reflector formed from aluminum sheet on a substantially longer dowel than that used to make the measurements in this exercise. The longer stand minimizes reflective effects from the ground or ceiling. Reflectors should be, at a minimum, one wavelength or more on all sides of the radiating element. For classroom purposes, a temporary reflector can be made with aluminum foil over a suitably sized cardboard form.

Procedure

1. a. $\lambda = \frac{c}{f} = \frac{3\times10^8\,\text{m/s}}{915\times10^6\,\text{Hz}} = 32.8\text{ cm}$

   b. D = 12 cm (for Ramsey Electronics LPY 915 PC board antenna).

   c. R_{ff} = 40 cm (use Equation 14-1b from text because the long dimension of the antenna, D, identified in step 1b, divided by the wavelength calculated in step 1a, is 0.366, which falls between the range 0.32 and 2.5).

Figure 30-3 Close-up view of PVC antenna mount

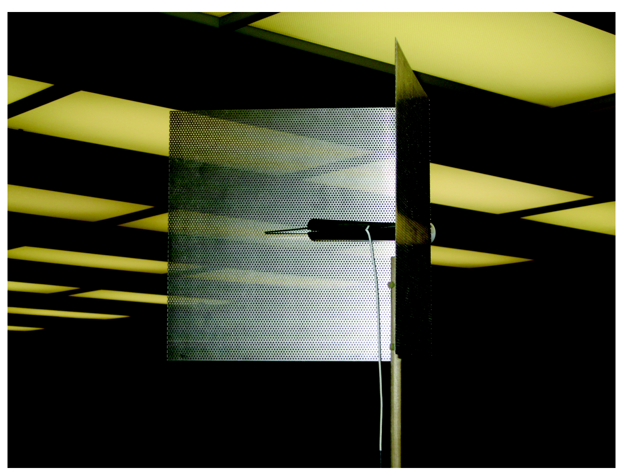


Figure 30-4 View of reflector formed from aluminum sheet

5. Table 30-1.

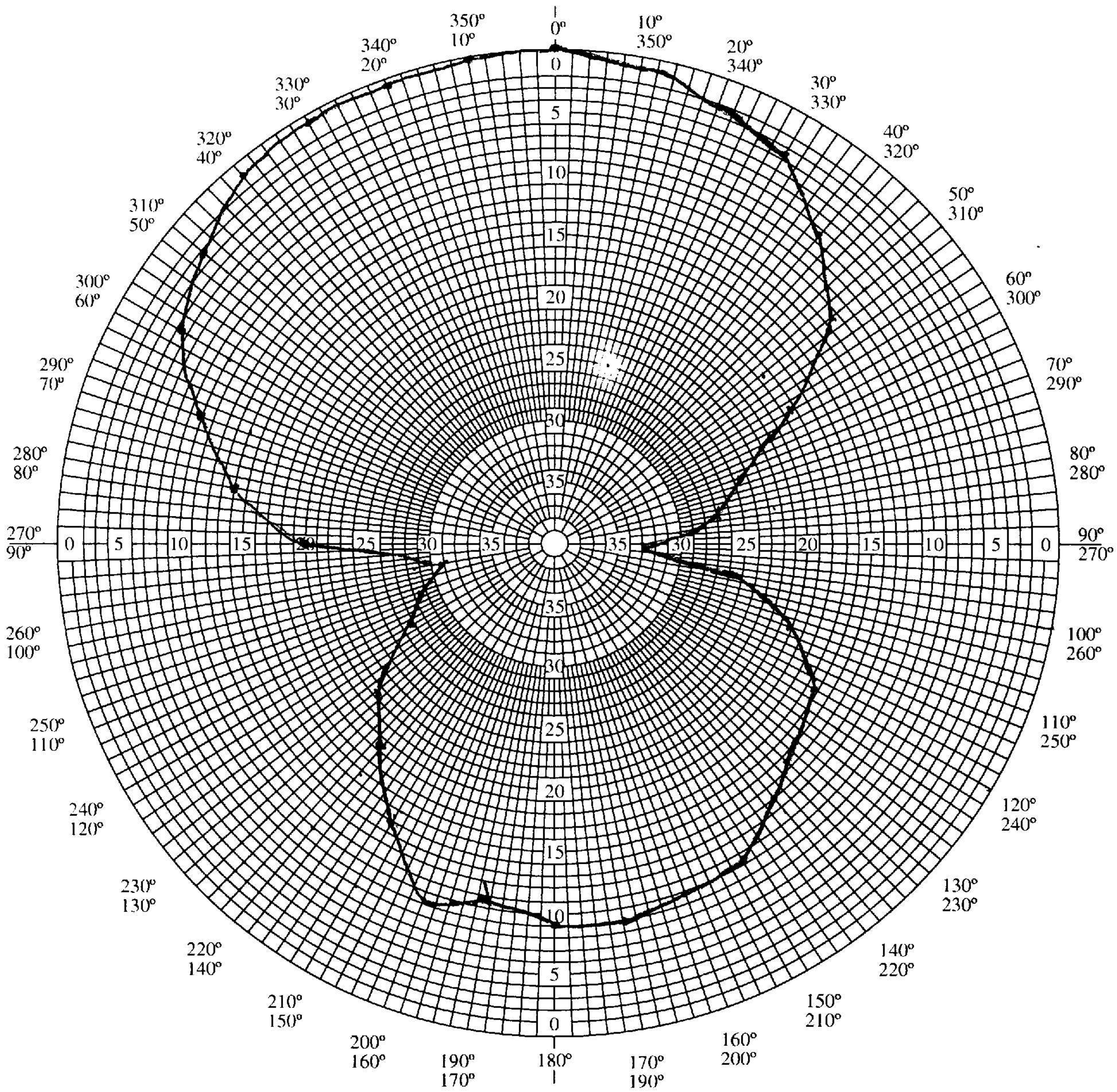
Distance (meters)	Received Signal Level (dBm)
0.5	-17
1	-21.0
1.5	-25.3
2	-26.9
3	-32.7
4	-38.0

Compare the levels at 1 m and 2 m. By how many decibels is the signal at 2 m reduced from the level at 1 m? 5.9 dB. At 3 m from 2 m? 5.8 dB.

6. Table 30-2.

Antenna Azimuth (Degrees)	Received Signal Level (dBm)	Power Ratio (dB)	Antenna Azimuth (Degrees)	Received Signal Level (dBm)	Power Ratio (dB)
0	-22.0	0	180	-31.3	9.3
10	-22.7	0.7	190	-32.3	10.3
20	-24.1	2.1	200	-31.1	9.1
30	-26.2	4.2	210	-35.7	13.7
40	-29.2	7.2	220	-40.5	18.5
50	-33.5	11.5	230	-43.2	21.2
60	-40.5	18.5	240	-49.0	27.0
70	-46.7	24.7	250	-50.4	28.4
80	-49.2	27.2	260	-52.8	30.8
90	-55.0	33.0	270	-42.0	20.0
100	-47.5	25.5	280	-36.0	14.0
110	-42.0	20.0	290	-31.5	9.5
120	-38.2	16.2	300	-27.5	5.5
130	-37.0	15.0	310	-25.2	3.2
140	-35.0	13.0	320	-23.4	1.4
150	-32.5	10.5	330	-22.4	0.4
160	-32.0	10.0	340	-22.4	0.4
170	-31.0	9.0	350	-22.1	0.1

7. Polar plot diagram from data recorded in Table 30-2



10/11. Answers will vary based on size and type of reflector but, in general, will show a narrower beam width and no energy 180 degrees from the direction of maximum radiation.

12. From the above data, the antenna beamwidth without reflector appears as 75 degrees between half-power points (seen at 310 degrees and 25 degrees). Results will vary, but the experimentally determined beamwidth is typical at UHF frequencies for antennas without reflectors. With reflector, beamwidth is expected to be narrower (producing higher gain in the direction of maximum radiation). The effect on radiation is determined primarily by the size of the reflector in wavelengths.

13. Answers will vary, but subsequent calculations were based on a transmit power of 0 dBm.

14. -21 dB.

15. At 1 meter: $\frac{P_R}{P_T} = 10^{(-21/10)} = 10^{-2.1} = 0.007943$.

16. At 1 meter (100 cm): $G = \frac{4\pi 100}{32.8}\sqrt{0.007943} = 3.415$

17. G(dB) = 10 log 3.415 = 5.33 dBi (Note: the Ramsey Electronics LPY-915 is designed to be a 6-dBi gain antenna at 915 MHz.)

18. At 2 meters: $\frac{P_R}{P_T} = 10^{(-26.9/10)} = 10^{-2.69} = 0.002042$

At 2 meters (200 cm): $G = \frac{4\pi 200}{32.8}\sqrt{0.002042} = 3.463$

19. G(dB) = 10 log 3.463 = 5.4 dBi at two meters. Note the very close agreement in gain calculations at both 1 m and 2 m, indicating that the gain calculations were made within the antenna's far field (radiation) region.

Questions

1. Power falls off as the inverse square of distance. Thus, a doubling of distance causes power to decrease by 2^2, or four times, which is a 6-dB power reduction.

2. Amplitude falls off linearly with distance. Therefore, a doubling of distance will cause the amplitude to be reduced by half, which is a 6-dB voltage reduction.

3. Most likely, any variations from theory would be caused by the presence of nearby objects or people causing reflections. These could also be reflections from the ground, walls, or ceiling. Also, the identical antennas method used in this experiment is best suited to short wavelengths, where antennas more closely approximate a point source radiator. Some deviation can be expected at lower frequencies because of the longer wavelengths involved.

4. Most likely, there would not be a constant reduction in signal strength from 25 cm to 50 cm with the antennas specified for this experiment. Antennas spaced 25 cm apart would place them within the induction field (near field), as predicted by Equation (14-1b). In the induction field, some of the field energy collapses back into the antenna rather than being

radiated into the surrounding environment. This collapse of energy causes changes in the current flowing in the antenna conductors, affecting the radiation resistance of the antenna and manifesting itself as a change in impedance. From 50 cm to 1 m, as well as from 1 to 2 m, the antennas are within the far field (radiation field), and the falloff in power identified in Question 1 should be more readily apparent.

5. The reflectors should focus the energy over a narrower beamwidth. This effect causes an increase in gain in a preferred direction by redirecting energy from other directions. Increased gain is achieved by narrowing the antenna beamwidth.

6. The calculated gain should be approximately the same at both 1 and 2 m. Referring back to the antenna gain formula given in the introduction, one sees that a doubling of distance causes the radius, r, to increase at the same time the ratio of received to transmitted power decreases. These terms balance out, resulting in similar values for gain. This consistency lends confidence to the validity of the gain calculations.

7. If the transmit antenna is not supplied with its resonant frequency, then some power is reflected back to the source. This will affect the value for transmitted power in the antenna gain calculation, causing the calculated gain value to be less than the theoretical maximum.

Experiment 31: Fiber Optics

Procedure

9. a), b), and c) answers will vary

11. a), b), and c) answers will vary

Questions

1. 3.5 dB/1000 m × 100 m + 0.5 dB + 0.5 dB + 0.5 dB = 1.85 dB

2. Cable length = 5.25 dB × 1000 m / 4 dB = 1320 m

3. Single mode (yellow jacket): longer distances, laser light source, smaller diametrical core, and only one mode of light is propagated. Multimode (orange jacket): shorter distances, LED light source, larger diametrical core, and multiple modes of light are propagated.

4. I would choose fiber optic cabling because it is immune to electromagnetic interference EMI and fiber optic cabling cannot be easily tapped.