EE 442 Homework #1
(Spring 2018 – Due January 29, 2018)
Print out homework and do work on the printed pages.


Problem 1 Wavelengths in Radio Applications (15 points)

Radio waves propagate in free space (and in our atmosphere) at the speed of electromagnetic waves (e.g., light waves) – an EM wave velocity of \( v = 2.99792 \times 10^8 \) meters per second. **For this problem use** \( v = 3.00 \times 10^8 \) meters per second (m/sec). An important wave parameter for electromagnetic waves is the wavelength \( \lambda \) which is inversely related to the wave frequency \( f \) (cycles per second in units of Hertz). The relationship is as you know velocity equals wavelength times frequency \( (v = \lambda \cdot f) \).

The reason wavelength \( \lambda \) is important is because the wavelength is approximately the spatial resolving dimension of radar and antenna sizes scale with wavelength (e.g., long wavelengths requires large antennas where the antenna will be of the order of the wavelength in size for best transmission and reception).

To get a feel for the size of the free space wavelength \( \lambda \) for various radio communication systems fill out the table below: [Express all wavelengths in meters.]

<table>
<thead>
<tr>
<th>Radio Application</th>
<th>Frequency Band</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM broadcast radio</td>
<td>535 kHz to 1605 kHz</td>
<td></td>
</tr>
<tr>
<td>FM broadcast radio</td>
<td>88 MHz to 108 MHz</td>
<td></td>
</tr>
<tr>
<td>VHF Civil Aviation Band</td>
<td>108 MHz to 136 MHz</td>
<td>2.778 meters to 2.206 meters</td>
</tr>
<tr>
<td><strong>(example)</strong></td>
<td></td>
<td><strong>(example)</strong></td>
</tr>
<tr>
<td>GSM Cellular (Uplink)</td>
<td>890 MHz to 915 MHz</td>
<td></td>
</tr>
<tr>
<td>Wi-Fi 802.11b/g/n</td>
<td>2.400 GHz to 2.497 GHz</td>
<td></td>
</tr>
<tr>
<td>K-band Radar Sensor</td>
<td>24.125 GHz</td>
<td>(narrowband)</td>
</tr>
</tbody>
</table>
Problem 2 Frequency Requirement for a Cellular Phone (15 points)

In problem 1 you found that radio wavelengths cover a very broad span of values. For example, in broadcast AM radio (which has been around since the 1920s), the wavelengths over it band are very large. The photo of the AM broadcast antenna is designed to be one-quarter of a wavelength (λ/4). For a radio station broadcasting at \( f = 1240 \text{ kHz} \) the wavelength \( \lambda = 241.9 \text{ meters} = 793.7 \text{ feet} \) (because 1 meter = 3.2808 feet). Therefore, a quarter wavelength \( \lambda/4 = 198.4 \text{ feet} \) high.

For this problem we want to estimate how high a frequency must be to have a handheld cellular telephone without a separate antenna extruding from the case of the cell phone. Again, let us assume that we can use a quarter wavelength antenna in the direction of the height of the cell phone case (such as using the side of the case itself). Using the dimension of the height of your cell phone and setting that dimension equal to one-quarter wavelength, what frequency \( f \) meets this requirement? [Note: This would be the lowest frequency you would allow for operation.]

Problem 3 Voltage Gain & Power Gain (16 points)

Electrical engineers often specify, or characterize, circuit blocks and/or networks in terms of voltage gain and power gain. Voltage and power gains can be expressed either numerically or in decibels (see Handout #1 for a discussion of decibels). In this problem you are presented with the amplifier circuit shown diagrammatically shown below with input and output resistances and voltages levels as labeled.
Assume the amplifier is impedance matched at output and input. Calculate:

(a) The voltage gain ratio.

(b) The voltage gain expressed in decibels (dB).

(c) The power gain ratio.

(d) The power gain ratio expressed in decibels (dB).

Added note to the curious student: Cable line amplifiers (CATV) in cable television distribution systems typically use 75 ohm coaxial cable (rather than 50 ohm coaxial cables) because a 77 ohm coaxial cable provides the lowest loss per length of line and 75 ohm cable is therefore lower loss than a 50 ohm cable. The highest peak power carrying capability in a coaxial cable is a cable with a 30 ohm characteristic impedance. Thus, a 50 ohm coaxial cable is a compromise between 30 ohm and 77 ohm characteristic impedances. That is why 50 ohm coaxial cables are so widely used.
Problem 4 Voltage Gain & Power Gain continued (18 points)

Another amplifier but it has an output resistance of $R_{\text{out}} = 150$ ohms (no longer 75 ohms). This is illustrated in the diagram below. Again, assume input and output impedance matching.

\[ V_{\text{in}} = 0.4 \text{ volt} \quad \text{AMP} \quad V_{\text{out}} = 10 \text{ volts} \]

Calculate:

(a) The voltage gain ratio.

(b) The power gain ratio.

(c) The power gain expressed in decibels.

(d) Write an expression for the power gain in decibels in terms of $V_{\text{in}}, V_{\text{out}}$ and the ratio of $R_{\text{in}}$ to $R_{\text{out}}$. 
Problem 5 Voltage Gain & Power Gain continued (16 points)

We have four circuit components cascaded together as shown on the block diagram below.

(a) Express the gains and losses in decibels (use the second column in the table below):

<table>
<thead>
<tr>
<th>Numerical power ratio</th>
<th>Power ratio in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1/P_{in}=1/3$</td>
<td></td>
</tr>
<tr>
<td>$P_2/P_1=25$</td>
<td></td>
</tr>
<tr>
<td>$P_3/P_2=1/5$</td>
<td></td>
</tr>
<tr>
<td>$P_{out}/P_3=9$</td>
<td></td>
</tr>
</tbody>
</table>

(b) What is ratio of $(P_{out}/P_{in})$ (both numerical and in decibels)?

(c) If $P_{in}=30$ mW, what is $P_{out}$ in watts (W)?
Problem 6 Communication Link: Gain & Loss (20 points)

We have three circuit components cascaded together as shown on the block diagram below. The links (Link 1-2 and Link 2-3) are long stretches of transmission lines between the networks. Link 1-2 has a loss of 30 dB and Link 2-3 has a loss of 20 dB. We don’t know the power gain $G_1$ of Network 1, but we are told that with an input power of $P_{in1} = 500$ mW fed into Network 1, the power flowing into the input of Network 2 is $P_{in2} = 100$ mW.

![Block Diagram](block_diagram.png)

Calculate the following quantities:

(a) The output power (in milliWatts) from Network 1.

(b) The power gain (in decibels) of Network 1 (power gain denoted by $G_1$).

(c) The overall power gain, or power loss, of the entire chain (i.e., calculate $P_{out}/P_{in1}$). Express power gain (or loss) in decibels.

(d) The delivered output power $P_{out}$ in watts.

$P$