ECE 498YVS **Homework 1** **Due: Thursday, September 5, 2022, 11:59PM Central Time**

- Homeworks are due Thursday at 11:59 p.m (Champaign local time). Late homework will not be accepted.
- Put name and NetID on the top of every sheet. Scan and submit your homework through Gradescope.
- Each student must submit individual solutions for each homework. You may discuss homework problems with other students registered in the course, but you may not copy their solutions.
- One problem is bonus problem for undergraduate student, but it is required if you are a graduate student.
- Penalties for cheating on homework: 0 points on that homework for first offense and an F on the course for any subsequent offense.

Recommended Reading: Paul: Chapter 1-2

1. Determine the wavelength at the following frequencies in metric and in English units:
   a) LORAN C long-range navigation 90Hz in km and mile.
   b) Submarine communication (in air) 1kHz in km and mile.
   c) GPS Satellite L1 (1575.42 MHz) in cm and inch.
   d) 5G cell phone 28 GHz in mm and mil (1 mil = 0.001 inch).

   Solution: Use equation $\lambda = c/f$

   a) $\lambda = \frac{3\times10^8 m/s}{90\,Hz} = 3.3333\times10^6\,m = 3333.3\,km = 2071.2\,mile$
   b) $\lambda = \frac{3\times10^8 m/s}{1000\,Hz} = 300\,km = 186.41\,mile$
   c) $\lambda = \frac{3\times10^8 m/s}{1575.42\times10^6\,Hz} = 19.04\,cm = 7.50\,in$
   d) $\lambda = \frac{3\times10^8 m/s}{28\times10^9\,Hz} = 10.71\,mm = 421.65\,mil$

2. Determine the following voltages in $dB\mu V$ and dBm (assume $50\,\Omega$ system).
   a) 0.3 μV.
   b) 300 mV.
   c) 1 V.

   Solution:
   a) $U_{dB\mu V} = 20log_{10}(\frac{U_v}{1\mu V}) = 20log_{10}(\frac{0.3\mu V}{1\mu V}) = -10.46\,dB\mu V$
   $P_{dBm} = U_{dB\mu V} - 107dB = -117.46\ dBm$

   b) $U_{dB\mu V} = 20log_{10}(\frac{U_v}{1\mu V}) = 20log_{10}(\frac{0.3V}{1\times10^{-6}V}) = 109.54\,dB\mu V$
   $P_{dBm} = 109.54 - 107 = 2.54\ dBm$

   d) $U_{dB\mu V} = 20log_{10}(\frac{U_v}{1\mu V}) = 20log_{10}(\frac{1V}{1\times10^{-6}V}) = 120\,dB\mu V$
   $P_{dBm} = 120 - 107 = 13\ dBm$

3. Determine a simple expression to convert (RMS) voltage V_{RMS} to dBm with 50 Ω of system impedance.

Solution:
We know the equation for power is $P_W = \frac{V_{RMS}^2}{R}$
Using decibels, we have

$$P_{dBW} = 20log_{10}V_{RMS} - 10logR$$

where

$$P_{dBW} = 10log_{10}(P_W)$$

Then we can express the power in dBm unit,

$$P_{dBm} = 10log_{10}\left(\frac{P_W}{1mW}\right) = 10log_{10}(P_W) + 30dB$$

So convert to P_{dBm},

$$P_{dBm} = P_{dBW} + 30dB = 20log_{10}V_{RMS} - 10logR + 30dB = 20log_{10}V_{RMS} + 13dB$$

The final expression is $P_{dBm} = 20log_{10}V_{RMS} + 13dB$

4. The radiated emmisions from a product are measured at 50 MHz at 15 m away and are found to be 21 $\mu V/m$.

   a) Does the product comply with the FCC Class B limit?

   b) By how much does the product pass or fail at 15 m away?

   Solution:
   a) FCC class B limit is measured at 3m. Use inverse distance rule

$$E_{3m} = E_{15m} \times \frac{15}{3} = 105\ \mu V/m = 20log_{10}\left(\frac{105\mu V}{1\mu V}\right) = 40.424\ dB\mu V/m$$

   Figure 2.2(a) in the textbook is FCC class B limit at 50 MHz.
   So the product fails the requirement

   b) FCC class B limit at 3m of 50MHz is 40 $dB\mu V/m$.
   The limit transfers to 15m away is

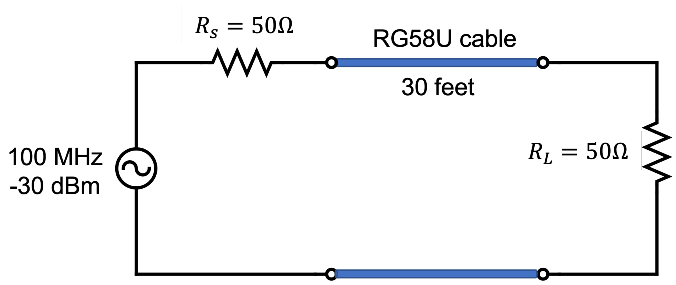
$$40\ dB\mu V/m - 20log_{10}\left(\frac{15}{3}\right) = 26.02\ dB\mu V/m$$

   The product measured at 15m is

$$20log_{10}\left(\frac{21\mu V/m}{1 \times 10^{-6}\mu V}\right) = 26.444\ dB\mu V/m$$

   So it fails by 0.424 dB at 15m away.
   (Note that it also fails by 0.424 dB at 3m away since we are using decibels.)

5. A 50 Ω source is connected to a 50 Ω receiver using 30 ft of RG58U coaxial cable. Cable loss is $4.5dB/100feet$. If the source output is 100 MHz and −30 dBm, determine the voltage at the receiver in mV and $dB\mu V$.



Solution:
The power at receiver (50 Ω resister) is

$$P_{rec,dBm} = P_{src,dBm} + Gain_{dB} = -30dBm - \frac{4.5dB}{100ft} \times 30ft = -31.35\ dBm$$

when we have $R_L = 50\Omega$ matched with $R_s = 50\Omega$.
The voltage at receiver is

$$U_{rec,dB\mu V} = 107 + P_{rec,dBm} = 107 - 31.35 = 75.65dB\mu V$$
$$U_{rec} = 10^{75.65/20} \times 10^{6}V = 6.06mV$$

6. **Required for graduate students and is optional for undergraduate student:**
Are the FCC's or the European Union's CISPR Class B radiated emission limits more restrictive
   a) In the frequency range of 30 to 88 MHz?
   b) In the frequency range of 88 to 230 MHz?
   c) In the frequency range of 230 to 960 MHz?
   d) In the frequency range of 960 to 1000 MHz?
   e) Draw a table for worse case combination of the FCC and CISPR radiated emission limits when measured from 30MHz to 1GHz. (Rows: frequency ranges, columns: Class A and Class B both measured at 3m.)

Solution: Compare the FCC and CISPR Class B radiated emission limits over different frequency band. A lower number means more restrictive.

Table 2.4 FCC Emission Limits for Class B Digital Devices

Frequency (MHz)	Limit at 3m ($dB\mu V/m$)
30-88	40
88-216	43.5
216-960	46
>960	54

Table 2.6 CISPR 22 Emission Limits for Class B LTE Equipment (Using inverse distance rule, convert 10m to 3m by add $20log_{10}(10/3)$ =10.5dB)

Frequency (MHz)	Limit at 3m ($dB\mu V/m$)
30-230	40.5
230-1000	47.5

a) From 30 - 88 MHz, FCC is more restrictive.

b) From 88 - 230 MHz, CISPR is more restrictive.

c) From 230 - 960 MHz, FCC is more restrictive.

d) From 960 - 1000 MHz, CISPR is more restrictive.

f) Here is a table for worse case combination, all measured at 3m.

Frequency (MHz)	Class A $dB\mu V/m$			Class B $dB\mu V/m$		
	FCC	CISPR	Worst Case	FCC	CISPR	Worst Case
30 - 88	49.5	50.5	49.5	40	40.5	40
88 - 216	54	50.5	50.5	43.5	40.5	40.5
216 - 230	56.9	50.5	50.5	46	40.5	40.5
230 - 960	56.9	57.5	56.9	46	47.5	46
960 - 1000	60	57.5	57.5	54	47.5	47.5