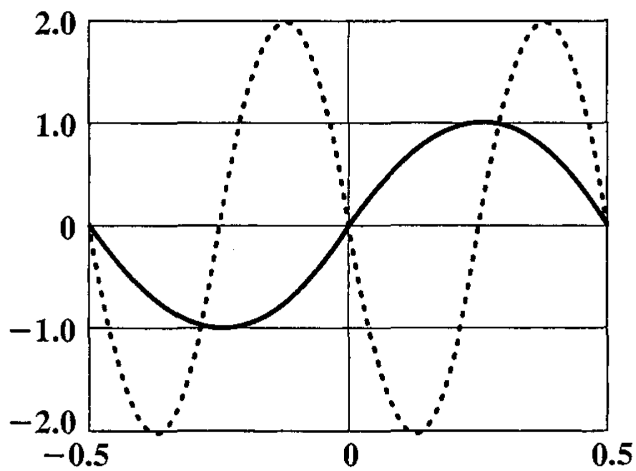
Mobile Communication Networks

Exercices 2

1. If the solid curve in figure represents *sin(2πt),* what does the dotted curve represent? That is, the dotted curve can be written in the form *A sin(2πft + Φ)*; what are *A, f,* and *Φ*?



2. Read:
   a. Appendix 2A from the textbook *Beard & Stallings - Wireless Communication Networks and Systems, Pearson Education Limited, 2015. ISBN: 978-1292108711*
   (see two last pages of this worksheet)

   b. http://www.ittc.ku.edu/~jstiles/622/handouts/dB.pdf

3. Convert the following values to dBs (try to avoid using a calculator):
   a. 1.
   b. 2.
   c. 0.5
   d. 4.
   e. 0.25
   f. 8.
   g. 0.125.
   h. 10.

i. 0.1
j. 20
k. 0.05
l. 100
m. 0.01
n. 200
o. 1000
p. 20000
q. 40000

4. Convert the following values in dBs to non-dBs (try to avoid using a calculator)::
   a. 20 dBs.
   b. 23 dBs.
   c. 40 dBs.
   d. 46 dBs.
   e. -46 dBs.
   f. 0 dBs.
   g. -10 dBs.
   h. -13 dBs.
   i. -23 dBs.

5. Sort the following values in **non-decreasing order**:
   10, 30dB, -10dB, 0.5, 100, 10dB, 0dB, 2.

6. An amplifier has an output of 20 W.
   a. What is its output in dBW?
   b. What is the output in dBm?
   c. If the amplifier output is changed to 40W, what will be the output in dBW and in dBm, respectively (try to answer with no calculations)?
   d. If the amplifier output suddenly drops 6dB, what will be the output power in Watts?

7. What is the channel capacity for a channel with a 300 Hz bandwidth and a signal-to-noise ratio of 3 dB?

8. Given the narrow (usable) audio bandwidth (3 kHz) of a telephone transmission facility, and a nominal SNR of 56dB.
    a. What is the theoretical maximum channel capacity of traditional telephone lines?
    b. How many bits per symbol should be used to transmit at a rate equal to this capacity?

9. Given a channel with an intended capacity of 20 Mbps, the bandwidth of the channel is 3 MHz. What signal-to-noise ratio is required to achieve this capacity?

10. A digital signaling system is required to operate at 9600 bps.
    a. If a signal element encodes a 4-bit word, what is the minimum required bandwidth of the channel?
    b. Repeat part (a) for the case of 8-bit words.

From: *Beard & Stallings - Wireless Communication Networks and Systems, Pearson Education Limited, 2015.* *ISBN: 978-1292108711*

APPENDIX 2A DECIBELS AND SIGNAL STRENGTH

An important parameter in any transmission system is the signal strength. As a signal propagates along a transmission medium, there will be a loss, or *attenuation*, of signal strength. To compensate, amplifiers may be inserted at various points to impart a gain in signal strength.

It is customary to express gains, losses, and relative levels in decibels because

- Signal strength often falls off exponentially, so loss is easily expressed in terms of the decibel, which is a logarithmic unit.
- The net gain or loss in a cascaded transmission path can be calculated with simple addition and subtraction.

The decibel is a measure of the ratio between two signal levels. The decibel gain is given by

$$G_{\mathrm{dB}} = 10 \log_{10} \frac{P_{\mathrm{out}}}{P_{\mathrm{in}}}$$

where

G_{dB} = gain, in decibels
P_{in} = input power level
P_{out} = output power level
$\log_{10}$ = logarithm to the base 10 (from now on, we will simply use log to mean $\log_{10}$)

Table 2.3 shows the relationship between decibel values and powers of 10.

There is some inconsistency in the literature over the use of the terms *gain* and *loss*. If the value of G_{dB} is positive, this represents an actual gain in power. For example, a gain of 3 dB means that the power has doubled. If the value of G_{dB} is negative, this represents an actual loss in power. For example a gain of -3 dB means that the power has halved, and this is a loss of power. Normally, this is expressed by saying there is a loss of 3 dB. However, some of the literature would say that this is a loss of -3 dB. It makes more sense to say that a negative gain corresponds to a positive loss. Therefore, we define a decibel loss as

$$L_{\mathrm{dB}} = -10 \log_{10} \frac{P_{\mathrm{out}}}{P_{\mathrm{in}}} = 10 \log_{10} \frac{P_{\mathrm{in}}}{P_{\mathrm{out}}} \tag{2.3}$$

Table 2.3 Decibel Values

Power Ratio	dB	Power Ratio	dB
10^1	10	10^{-1}	–10
10^2	20	10^{-2}	–20
10^3	30	10^{-3}	–30
10^4	40	10^{-4}	–40
10^5	50	10^{-5}	–50
10^6	60	10^{-6}	–60

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Example 2.2 If a signal with a power level of 10 mW is inserted onto a transmission line and the measured power some distance away is 5 mW, the loss can be expressed as $L_{dB} = 10 \log(10/5) = 10(0.3) = 3$ dB.

Note that the decibel is a measure of relative, not absolute, difference. A loss from 1000 mW to 500 mW is also a loss of 3 dB.

The decibel is also used to measure the difference in voltage, taking into account that power is proportional to the square of the voltage:

$$P = \frac{V^2}{R}$$

where

P = power dissipated across resistance R
V = voltage across resistance R

Thus

$$L_{dB} = 10 \log \frac{P_{in}}{P_{out}} = 10 \log \frac{V_{in}^2/R}{V_{out}^2/R} = 20 \log \frac{V_{in}}{V_{out}}$$

Example 2.3 Decibels are useful in determining the gain or loss over a series of transmission elements. Consider a series in which the input is at a power level of 4 mW, the first element is a transmission line with a 12-dB loss (-12 dB gain), the second element is an amplifier with a 35-dB gain, and the third element is a transmission line with a 10-dB loss. The net gain is $(-12 + 35 - 10) = 13$ dB. To calculate the output power P_{out},

$$G_{db} = 13 = 10 \log(P_{out}/4 \text{ mW})$$
$$P_{out} = 4 \times 10^{1.3} \text{ mW} = 79.8 \text{ mW}$$

Decibel values refer to relative magnitudes or changes in magnitude, not to an absolute level. It is convenient to be able to refer to an absolute level of power or voltage in decibels so that gains and losses with reference to an initial signal level may be calculated easily. The **dBW (decibel-Watt)** is used extensively in microwave applications. The value of 1 W is selected as a reference and defined to be 0 dBW. The absolute decibel level of power in dBW is defined as

$$\text{Power}_{dBW} = 10 \log \frac{\text{Power}_W}{1 \text{ W}}$$

Example 2.4 A power of 1000 W is 30 dBW, and a power of 1 mW is -30 dBW.

Another common unit is the **dBm (decibel-milliWatt)**, which uses 1 mW as the reference. Thus 0 dBm = 1 mW. The formula is

$$\text{Power}_{dBm} = 10 \log \frac{\text{Power}_{mW}}{1 \text{ mW}}$$

Note the following relationships:

$$+30 \text{ dBm} = 0 \text{ dBW}$$
$$0 \text{ dBm} = -30 \text{ dBW}$$