Pràctica 6. Ultrasound Communication

An Application of the Maximum Power Transfer Theorem.

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In this lab session we will set up an ultrasound communication channel. We will see the effect of proper impedance matching on the achievable communication range.

> ATTENTION: Please remember to work out individually those paragraphs looking as this one. This previous work has to be uploaded to the Atenea platform before 0:00 of the lab session day.
> Remember also to bring all the required tools for a hardware laboratory session (protoboard, cables, etc).

1 Introduction

Ultrasound communication relies on sound waves with a frequency higher than the upper limit of human hearing. This limit is often considered to be approximately 20 kHz, although this varies from person to person and gets lower with increasing age.

In such a communication system, the transmitter (Tx) is a transducer that converts electrical signals into mechanical vibration (a loudspeaker performs the same operation albeit relying on different physics) and the receiver (Rx) is a transducer that converts mechanical vibration into electrical signals. Figure 1 shows a pair of transducers, also called capsules. Some transducers may be used either as a transmitter or as a receiver but there are also designs where transmitter and receiver are different even if they are externally indistinguishable except by proper labeling (such as those that will be used in this session).

The communication channel is based on the ability of air to propagate pressure waves. It is a well-known fact that sound propagates in air (and other materials, such as water, iron, ...) but does not propagate in free space.

Figure 1: A pair of ultrasound capsules.

A simple communication channel consists in a function generator directly connected to the transmitting capsule and an oscilloscope connected to the receiving capsule with both capsules separated by a distance of ∼1 meter. An amplitude change in the transmitter translates in an amplitude change at the oscilloscope, hence we have a (wireless) communications system!

2 Matching

The ultrasound transmitter capsule admits the model in Figure 2 with $R = 838\ \Omega$ and $C = 900$ pF. The capsule is designed to operate at frequencies near 40 kHz.

> *Previous Work* 1. Considering that the generator has an equivalent impedance of 50 Ω, compute the fraction of the available power that is actually delivered to the capsule.

To improve the transmitted power, we may insert a matching network such as that depicted in Figure 3.

> *Previous Work* 2. Compute the element values of the required matching network. Quantify the increase in radiated power (in dB) obtained from the matching network.

> *Previous Work* 3. Consider that the inductor has an equivalent series resistance R_s such that $R_s = \omega L/50$. This makes the matching network lossy and, as a consequence, the power delivered to the load will be less. Compute the power loss (in dB) due to R_s.

3 Experimental work

Task 1. Build a communication channel without matching. Measure V_T and V_R at a distance of 50 cm. Explain the phase difference between both signals. What is the maximum distance that allows detecting the signal (explain your criterion)?

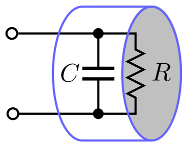

Figure 2: Equivalent circuit of the transmitting capsule.

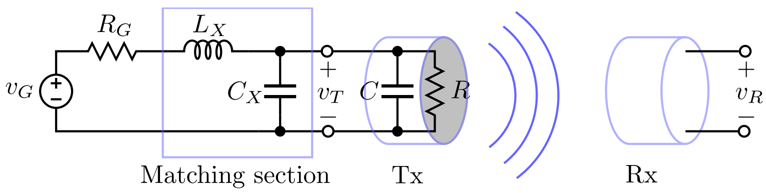

Figure 3: Equivalent circuit of the transmitting capsule.

Task 2. Measure the -3 dB channel bandwidth, i.e. change the input signal frequency until the received signal is 3 dB lower.

Task 3. Measure the -3 dB transmitter beamwidth, i.e. rotate the transmitter until the received signal is 3 dB lower.

Task 4. Insert the matching network into the system and measure again V_T and V_R. Do these signals increase as expected from your computations? What is the maximum distance that allows detecting the signal (with the same criterion as in task 1)? Does the matching network have an influence on the channel's bandwidth?

Task 5. Find out the wavelength of the sound waves in air adjusting the distance between transmitter and receiver until V_T and V_R are in phase (some thinking is required).

Task 6. Use an analog switch (of the 4066 kind) to generate bursts of a 40 kHz signal every 10 ms (for this you will need two signal generators). From the delay between the transmitted and the received burst, find out the distance between the transmitter and the receiver.

Task 7. Use as a pulsed radar: Place the transmitter and receiver nearby pointing to a target and investigate the received signal for different types of target.