Aalto University
School of Electrical
Engineering

# ELEC-E7250 - Laboratory Course in Communications Engineering

## Preliminary exercises: Reflection Coefficient measurement

Group members: Xingji Chen and Zheyuan Liu

(1) State the difference between lumped element circuits and distributed element circuits.

In lumped element circuits, components such as resistors, capacitors, inductors, and transistors are treated as "lumped" elements with their properties concentrated at a single point. Each element is represented by a discrete symbol in circuit diagrams. These circuits are typically applicable in the low to mid-frequency range, where the signal's wavelength is much greater than the physical dimensions of the circuit. The analysis of lumped element circuits relies on traditional circuit theory, utilizing laws such as Ohm's Law, Kirchhoff's Voltage and Current Laws, and network theorems. In these circuits, the propagation time of a signal through a component is negligible, and phase differences across components due to signal propagation are not considered.

Distributed element circuits take into account the physical dimensions and layout of circuit components, as these are related to the operating frequency's wavelength. The analysis considers the distributed properties over length of components like transmission lines, waveguides, and microstrips. These are typically used at high frequencies (such as RF and microwave frequencies), where the wavelength is comparable to or smaller than the physical dimensions of the components. The analysis of distributed element circuits involves electromagnetic theory and concepts like wave propagation, impedance matching, and standing wave patterns. In these circuits, the time delay and phase shift of signals traveling through components are significant and must be accounted for.

Aalto University
School of Electrical
Engineering

(2) Consider a two-port device. Is the $S_{11}$ always equal to the reflection coefficient? If not, why? Provide proof.

Hint: write up two port S parameters equation. Set the ports to be in matched or non-matched condition.

$S_{11}$ is not always equal to the reflection coefficient. It is only under specific conditions, namely when the other port (Port 2) is perfectly matched (i.e., terminated in its characteristic impedance), that $S_{11}$ equals the reflection coefficient.

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

When Port 2 is terminated in a load that matches its characteristic impedance, such as $Z_0$, there is no reflection at Port 2. This means $S_{22} = S_{12} = 0$. Under these conditions, $S_{11}$ represents the input reflection coefficient accurately, as reflections from Port 2 do not affect the measurements at Port 1. However, if Port 2 is not perfectly matched, some of the signal reaching Port 2 will be reflected back. These reflections can interact with the reflections at Port 1. In this situation, S11 does not solely represent the reflection at Port 1, as it may include effects from reflections originating from Port 2. Therefore, under non-matched conditions, $S_{11}$ is not equal to the reflection coefficient at Port 1. The reflection seen at Port 1 is a combination of $S_{11}$, $S_{21}$, $S_{12}$ and $S_{22}$ due to the interactions of the forward and reverse waves in the network.

Aalto University
School of Electrical
Engineering

(3) For certain frequency $f$ & characteristic impedance $Z_0$, S parameters of the two port system is defined as

$$S = \begin{bmatrix} 0.1 & 0.8\angle 90 \\ 0.8\angle 90 & 0.2 \end{bmatrix}$$

Calculate the reflection coefficient $\tau$, when port 2 is short circuited.

When port 2 is short-circuited, the reflection coefficient $\tau$ at port 1 is simply the $S_{11}$ parameter of the two-port system. Therefore, $\tau = S_{11} = 0.1$.

(4) In a class of size 35, the mean score was 8 points for the assignment. The standard deviation (of one student) was found to be 1.5. Calculate the confidence interval for the mean over the class

(a) 95 % confidence level

(b) 99 % confidence level

(c) Which interval is bigger and Why?

The Standard Error of the Mean (SEM) is

$$SEM = \frac{s}{\sqrt{n}} = \frac{1.5}{\sqrt{35}} \approx 0.254$$

For 95 % confidence level

$$CI_{95\%} = \bar{x} \pm 1.96 \times SEM \approx 8 \pm 0.497 = (7.503, 8.497)$$

For 99 % confidence level

$$CI_{99\%} = \bar{x} \pm 2.576 \times SEM \approx 8 \pm 0.653 = (7.347, 8.653)$$

The 99% confidence interval is wider than the 95% confidence interval because the z-score is higher, reflecting the increased certainty required to contain the true mean 99% of the time. The wider interval compensates for potential sample variability, thus providing a higher level of confidence.