

DESIGNING A SIMULATED METHOD FOR TESTING A TRANSMISSION LINE. STUDY CASE- MISMATCHED SYSTEM

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Abstract: The paper is showing the methodology and the research results dedicated to test and simulate the transmission line behavior in mismatching conditions. The testing method is proposing a fast and reliable evaluation of the line by measuring the voltage standing wave ratio (VSWR) It has been tested on a simulated line (100 m composed by three segments) as a measure of matching level, with the main result: the cut-off frequency on a specific geometry of the cable, with the evaluation of dominant mode of wave propagation- the transverse electromagnetic mode (TEM).

Keywords: Simulated transmission line, coaxial cable, Fast Fourier analysis, matched lines, testing transmission lines.

1. TRANSMISSION LINES FUNDAMENTALS

This experiment studies the attenuation of the simulated transmission line, which is defined as the decrease in power level at the load [4]. Every transmission has some losses, since the resistance of the conductors and power is consumed in the dielectric which used for insulating the conductors. Power lost in a transmission line is not directly proportional to the line length, but varies logarithmically with the length. And line losses are usually presented in terms of decibels per unit length. Losses in transmission line arise from sources: radiation, dielectric loss, skin effect loss.

As shown in figure 1, the attenuation to any reduction in the strength of a signal (loss). It is usually measured in decibels (dB) which is a logarithmic term that ratios the output voltage (V_{out}) or power, as a function of input voltage (V_{in}) or power.

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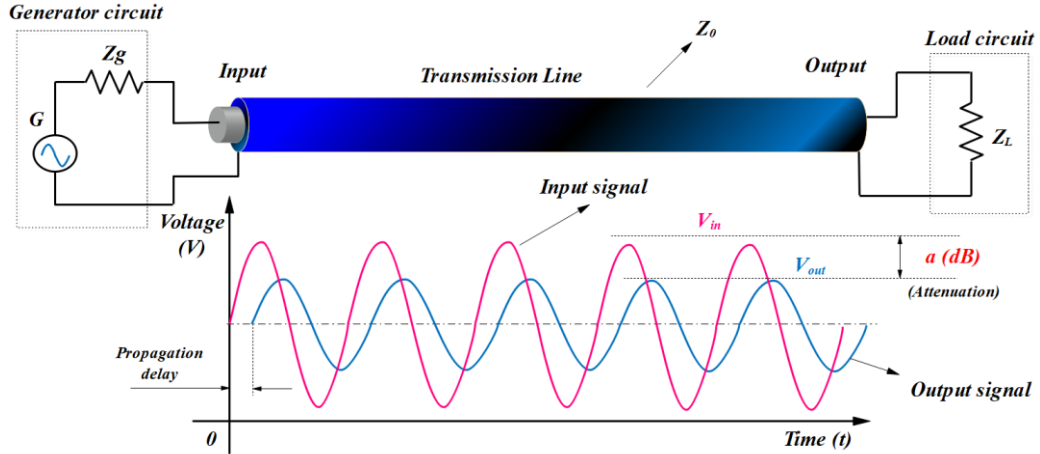


Fig. 1. Schematic diagram of attenuation in transmission lines (Z_g – generator impedance, Z_L – load impedance, Z_o – Characteristic impedance of the line, V_{in} – Input voltage current, V_{out} – Output voltage)

The ohmic resistance R' and the conductance G' are responsible within the line of the energy dissipation in the form of heat. This occurs within both the conductor and the dielectric material. These losses, which determine the attenuation characteristics of the line, are expressed in terms of "attenuation constant".

Attenuation occurs in all length of transmission lines. It is small enough in shorter lines that, for practical purposes, it can be ignored. For long transmission lines it is significant enough that it must be accounted for to have an accurate enough model of the system. It is important to remember that no transmission line model is perfect. The question is if it is accurate enough for the purposes you are using it.

The attenuation is represented with the symbol a , and can be calculated through the following formula:

$$a_p = 10 \cdot \log \frac{P_{out}}{P_{in}} \quad (a_p - \text{power attenuation}) \quad (1)$$

$$a_v = 20 \cdot \log \frac{V_{out}}{V_{in}} \quad (a_v - \text{voltage attenuation}) \quad (2)$$

where:

V_{in} = amplitude of the signal at the input of the line

V_{out} = amplitude of the signal at the output of the line

As a voltage attenuation example: 3dB loss is equivalent to 30% loss of voltage and 6dB loss is equivalent to 50% loss of voltage.

As a power attenuation example: 1.5dB loss is equivalent to 30% loss of power and 3dB loss is equivalent to 50% loss of power.

Voltage standing wave ratio (VSWR): it applies specifically to the voltage standing waves that are set up on a transmission line. Because it is easier to detect the voltage standing

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waves, the term VSWR is more often used than SWR, especially within radiofrequency (RF) systems.

VSWR is defined as the ratio of the maximum voltage to the minimum voltage in standing wave pattern along the length of a transmission line structure. It varies from 1 to (plus) infinity and is always positive. Unless you have a piece of slotted line-test equipment this is a hard definition to use, especially since the concept of voltage in a microwave structure has many interpretations.

In radio frequency systems, the power is transferred from the source to the load using a transmission line of feeder (simulated coaxial cable in our case). This transmission line has a characteristic impedance Z_0 .

The maximum power transfer occurs when the load has the same impedance with the simulated transmission line. Similarly, the maximum power transferred into the waveguide occurs when the source has the same impedance with the waveguide.

Figure 1 shows a system that has the simulated transmission line matched with the load. The characteristic impedance of the simulated transmission line ($Z_0 = 68\Omega$) is the same as the characteristic impedance of the load ($Z_L = 68\Omega$). In this example, all the power is transferred from the simulated transmission line to the load (when matched approximately no power will be reflected to the source). Figure 2 shows a mismatched system where the waveguide impedance ($Z_0 = 50\Omega$) and the load impedance ($Z_L \neq 50\Omega$) have different values.

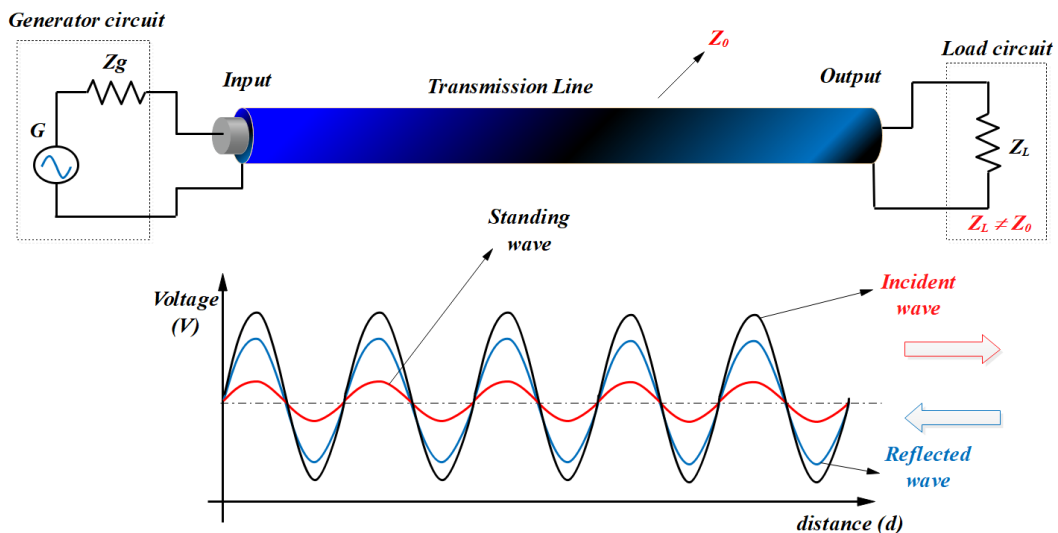


Fig. 2. Schematic diagram of frequency characteristic in transmission lines (Z_g – generator impedance, Z_L – load impedance, Z_0 – Characteristic impedance of the line, V_{in} – Input voltage current, V_{out} – Output voltage, f – variable frequency of the input signal).

In the upper example, not all the power is transferred from the waveguide to the load. The remaining power travels back to the source, as a reflected wave. In this case, we have a superposition of two waves: the incident wave travelling to the load direction and a reflected wave travelling to the generator direction.

2. SIMULATED TRANSMISSION LINES

In figures 3 and 4 shows the schematic diagram related to the experiment, where the simulated transmission lines will be supplied with a sinusoidal voltage with variable frequency, from the signal generator (G). One end of the line is closed on the impedance load (Z_L), while on the other end the sine-wave signal generator is connected. At the input stage of the signal generator, the value of input impedance is equal to the characteristic impedance of the line, i.e. 68 ohms.

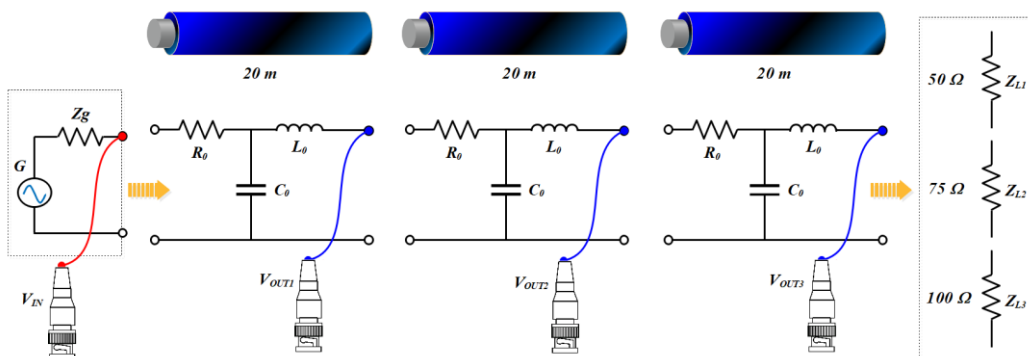


Fig. 3. Schematic diagram for measuring the attenuation.

This is true when the signal generator used has a neglectable internal impedance when compared to this ohmic value.

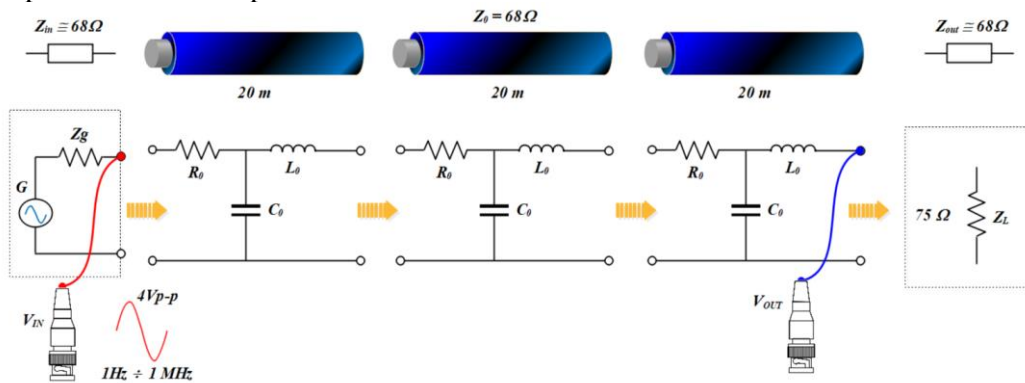


Fig. 4. Schematic diagram for measuring the frequency characteristic.

By perform the circuit configuration shown in the wiring diagram we will measure the amplitude of the signal at the input and output of the line for each different section of the simulated transmission line (i.e. 20 m, 40 m, 60 m and 80 m).

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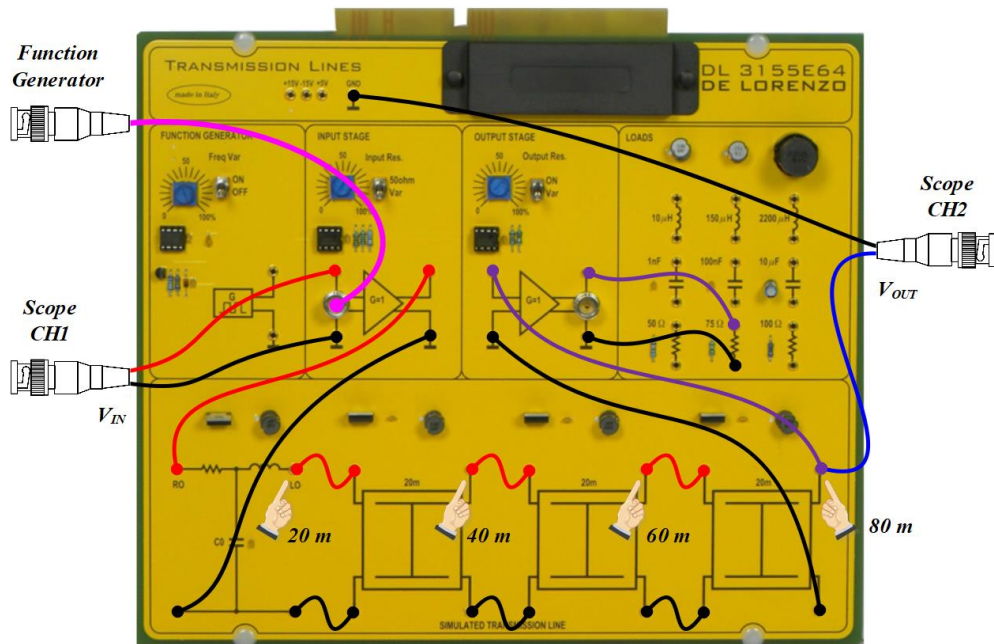


Fig. 5. Wiring diagram for measuring the attenuation (matched load).

The propagation delay between input and output can be measured using a dual channel oscilloscope. Select the “Cursor” menu and then select “Time” (1) so the cursors will be moved on horizontal axis. Select channel 1 as source and cursor E (2). Using the front panel knob position the cursor (in some oscilloscopes this knob is labeled V0) where the signal 1 is crossing zero. Select the cursor S (3) and using the front panel knob position the cursor where the signal 2 is crossing zero. The difference between the two cursors is the propagation delay (i.e. 750ns in this case)

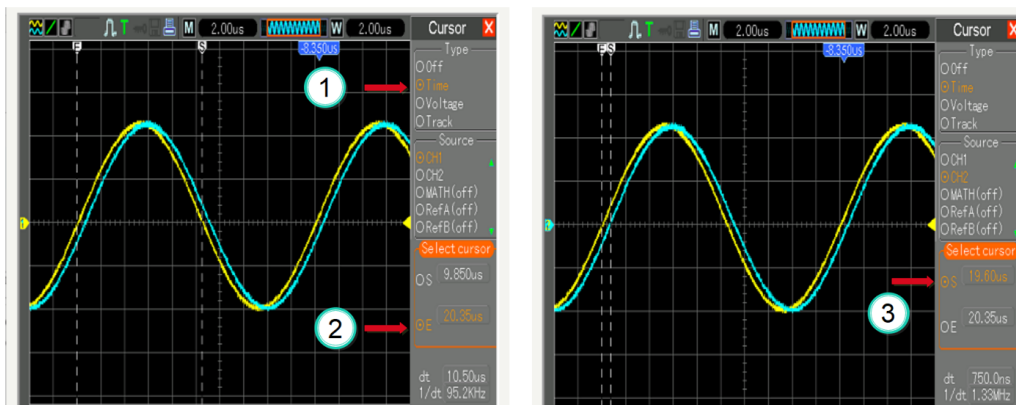


Fig. 6. Transmission line propagation delay

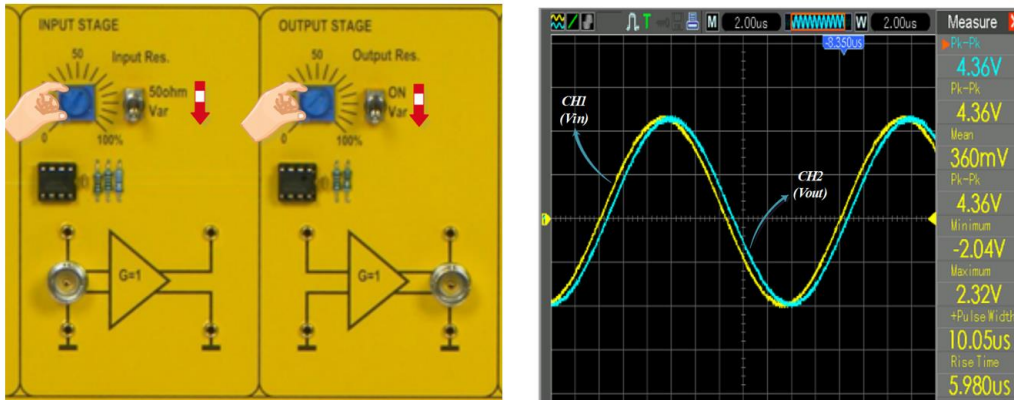


Fig. 7. Electronic input/output matching circuit

In this configuration the signals will be equal if the input stage potentiometer is at approx. minimum position and the output stage potentiometer is at approx. maximum position. Remember from the previous experiment that the characteristic impedance of the line is $Z_0 = 68 \Omega$.

3. SIMULATED TRANSMISSION LINES TESTING RESULTS

The attenuation characteristic for the simulated line attenuation as a function of the line length when the impedance load is not matched with the line, is shown in figure below.

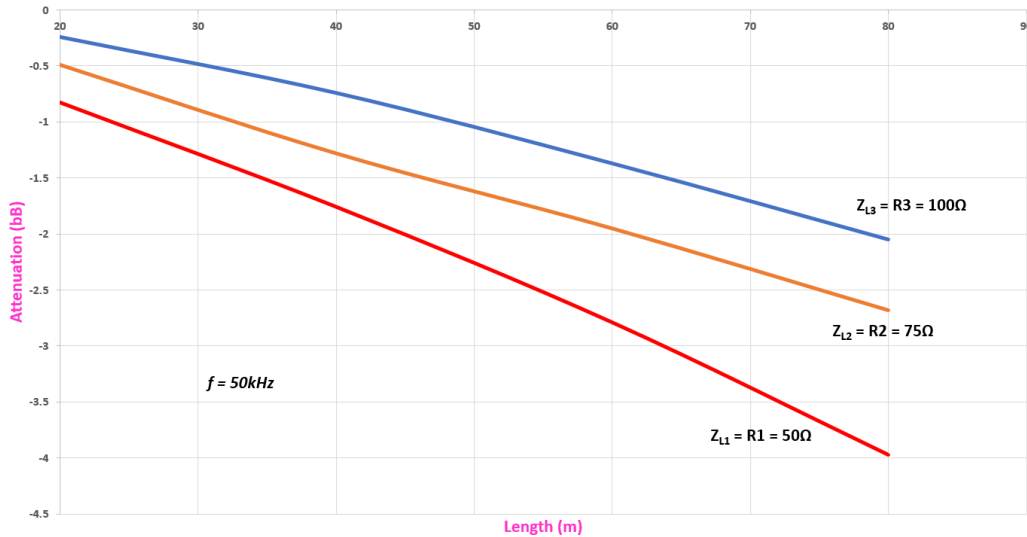


Fig. 8. Attenuation of the signal measured at different distances and different loads

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As shown in the attenuation chart above, when the impedance load (Z_L) is not matched with the line impedance (Z_0) the output voltage is attenuated compared to the input voltage. The attenuation of the output signal is higher as the output impedance decreases compared with the characteristic load of the line [1].

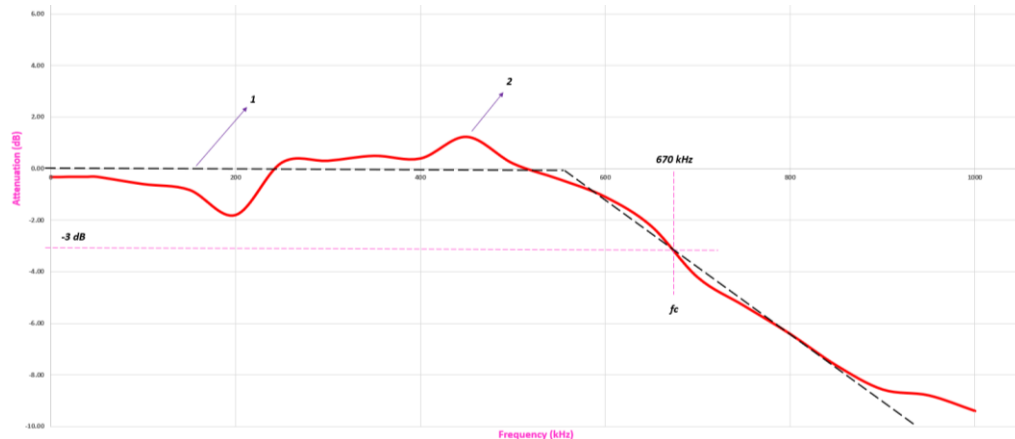


Fig. 9. Attenuation characteristic of the simulated transmission line

As shown in the frequency chart, the ideal characteristic is plotted with black dotted line (1) and the red dotted line (2) is the measured characteristic curve.

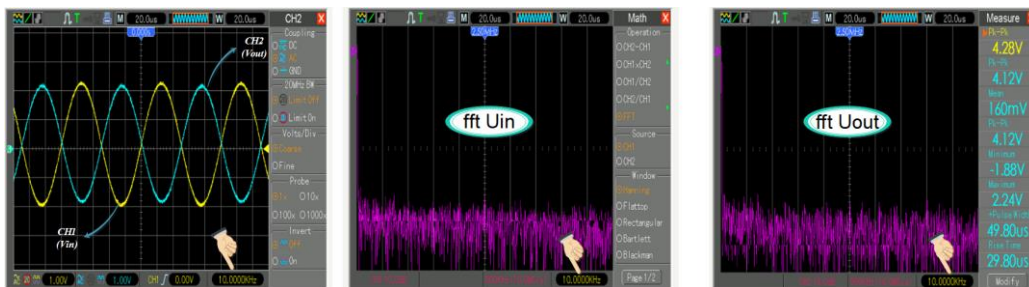


Fig. 10. Fourier analysis of the simulated transmission line (10kHz)

By increasing the frequency of the input signal will have an effect on an attenuated output signal. Also, the Fourier transform shows that the signals have many harmonics [2]. This is one main reason why the frequency characteristic is not linear as the theoretical characteristic (line 1 from the plotted frequency characteristic). Poor power quality can impact reception, so it's important to choose the best cable for the designing the transmission lines [3].

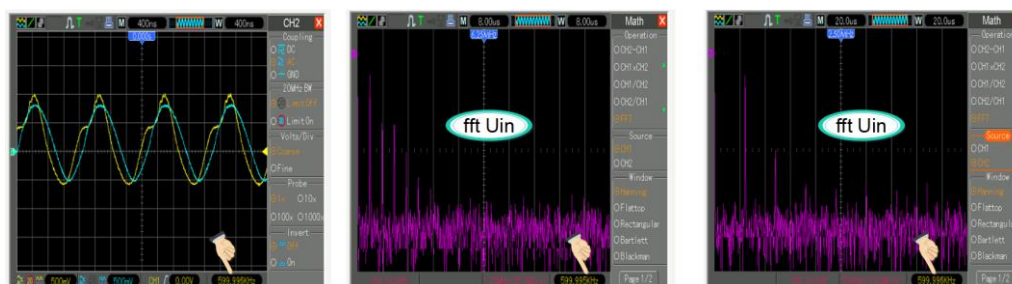


Fig. 11. Fourier analysis of the simulated transmission line (500 kHz)

4. CONCLUSIONS

A coaxial cable analysis determines the distributed capacitance and inductance of a coaxial cable, its impedance and cut-off frequency for a given cable geometry, and relative permittivity or velocity factor. The dominant mode of wave propagation in a coaxial cable is the transverse electromagnetic (TEM) mode. In this mode, both the electric and the magnetic field are transverse (normal or perpendicular) to the direction of wave travel and perpendicular to one another. The electric field lines in this mode run radially and the magnetic field lines run in circles around the center conductor. Coaxial cables support also transverse electric (TE) with only the magnetic field along the direction of propagation and transverse magnetic (TM) modes with only electric field along the direction of propagation. For the coaxial cable the non-TEM mode with the lowest frequency f_c is the TE₁₁ mode. This frequency is the upper usable or cutoff frequency for a coaxial cable. The signal can propagate in the TE₁₁ mode if the wavelength in the cable dielectric is shorter than the average circumference of the dielectric. In this paper a frequency analysis was made on the simulated transmission line that has a characteristic impedance of 68 ohms.

REFERENCES

- [1]. Niculescu T., Pasculescu D., *Use of numerical simulation to study capacitive loads which is connecting to an AC power source*, 15th International Multidisciplinary Scientific GeoConference SGEM 2015, Conference Proceedings, June 18-24, 2015, Book2 Vol. 1, pp. 391-398, 2015.
- [2]. Shin, Y-J., et al. *Application of time-frequency domain reflectometry for detection and localization of a fault on a coaxial cable*, IEEE Transactions on Instrumentation and Measurement 54.6 (2005): 2493-2500.
- [3]. Utu I., Pasculescu D., *Power quality study in order to comply with European Norms*, Supplement of Quality-Access to Success, Vol. 18, S1, January 2017, pp. 366-371, 2017.
- [4]. xxx, *Virtual reality workstation*, www.deloreonzoglobal.com, last visited in October 2019.