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COMPUTATIONAL METHOD AND EXPERIMENTAL MEASUREMENT FOR DETERMINING VOLTAGE STANDING WAVE RATIO

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Abstract: The measuring results and computational methodology is showing that when a transmission line and a waveguide is terminated by an impedance that does not match the characteristic impedance of the transmission line, not all of the power is absorbed by the load impedance. Some of the power is reflected back down the transmission line. The incident signal mixes with the reflected signal to cause a voltage standing wave pattern on the transmission line. The ratio of the maximum to minimum voltage is known as VSWR, or Voltage Standing Wave Ratio. In this paper shows research results dedicated to methods of measuring and calculating the VSWR.

Keywords: Voltage standing wave ratio, transmission line model, impedance, reflect, matched lines, testing transmission lines, waveguide.

1. STANDING WAVE RATIO FUNDAMENTALS

This experiment studies the standing wave basics, voltage standing wave ratio (VSWR) and reflection coefficient (Γ). Standing wave ratio (SWR): it describes the voltage and current standing waves that appear on the transmission line (waveguide). SWR is a measure of impedance matching of loads to the characteristic impedance of a waveguide [6].

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

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voltage standing waves, the term VSWR is more often used then SWR, especially within radiofrequency (RF) systems [2].

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 [4].

In figure 1 is described two general cases where the waveguide is terminated with any given complex impedance Z_L (a) and with a shorting plate (b).

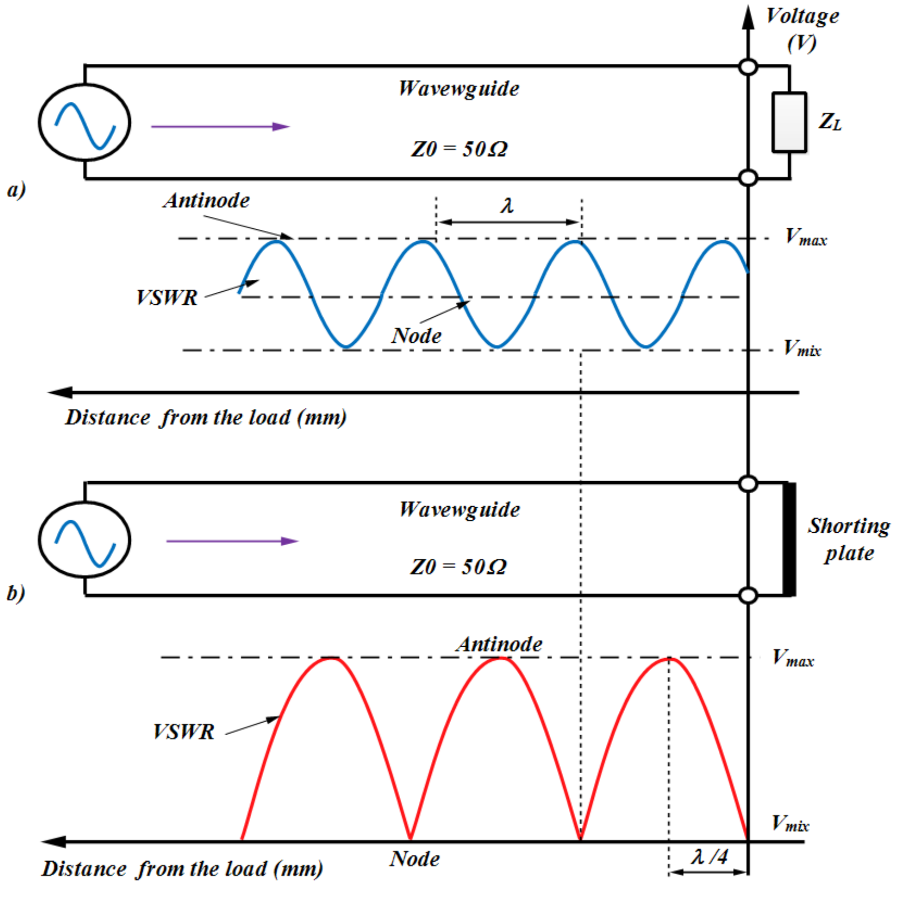


Fig.1. Schematic diagram of matched simulated waveguide at 50 Ω

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 $\mathbf{Z_0}$.

Figure 2 shows a system that has the simulated transmission line matched with the load. The characteristic impedance of the simulated transmission line **(Z_0 = 68Ω)** is the same as the characteristic impedance of the load **(Z_L = 68Ω).** In this example, *all the* *power is transferred from the simulated transmission line to the load* (when matched approximatively no power will be reflected to the source).

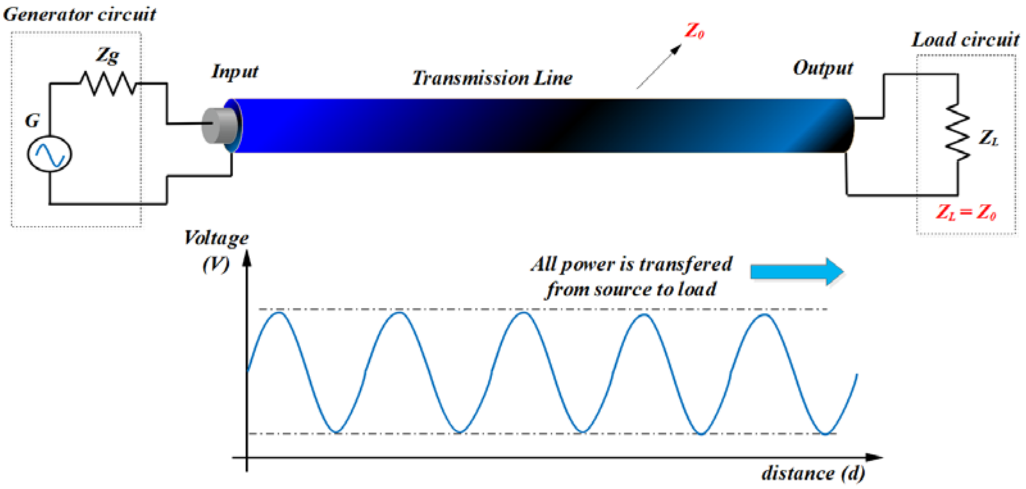


Fig.2. Schematic diagram of matched simulated transmission line and load at 68 Ω (no signal is reflected to the source)

Figure 3 shows a mismatched system where the simulated transmission line impedance (**Z_0 = 68Ω)** and the load impedance (**$Z_L \neq$ 68Ω**) have different values.

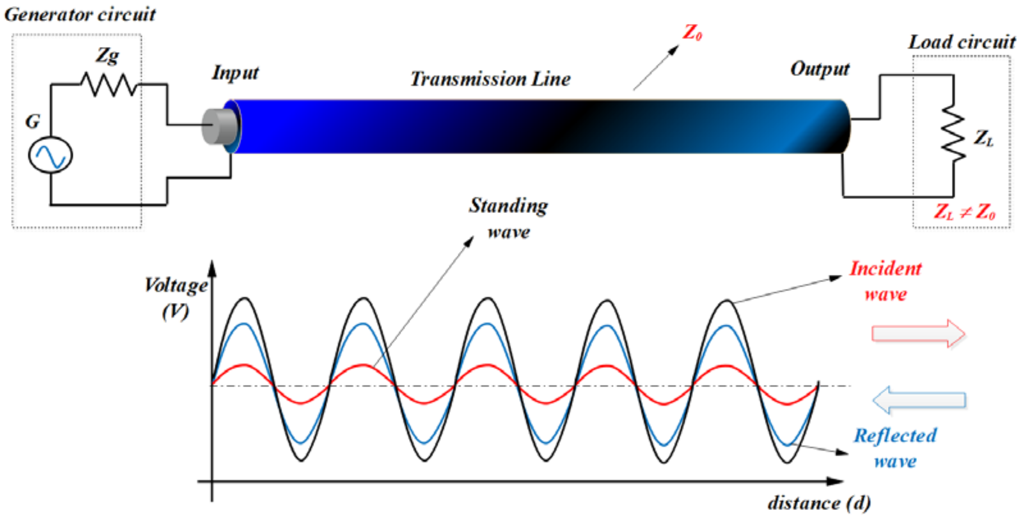


Fig.3. Schematic diagram of mismatched simulated transmission line and load (signal is reflected to the source).

In figures 2 and 3 the notations are: Zg – generator impedance, ZL – load impedance, Z0 – Characteristic impedance of the line, Vin – Input voltage current, Vout – Output voltage, f – variable frequency of the input signal. The maximum power transfer occurs when the load has the same impedance with the simulated transmission line. Technical literature [1], [3], [5] presents that the maximum power transferred into the waveguide occurs when the source has the same impedance with the waveguide.

2. TRANSMISSION LINE MODEL FOR VSWR MEASUREMENT

In figure 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.

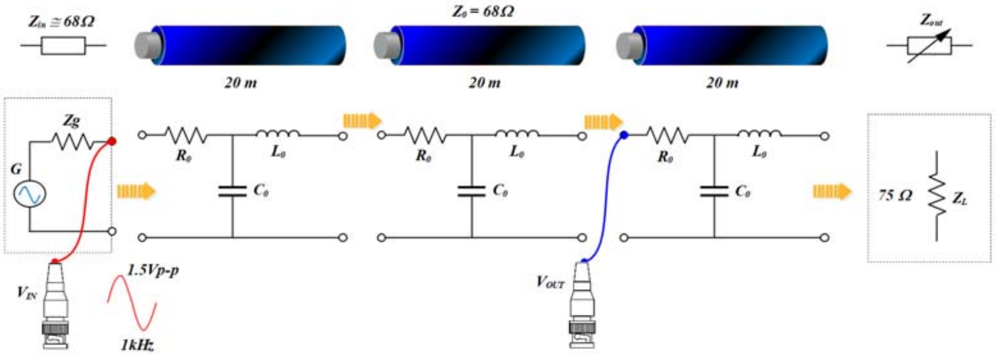


Fig.4. Schematic diagram for measuring the voltage standing wave ratio (VSWR).

VSWR is defined as the ratio of the maximum voltage to the minimum voltage in a standing wave pattern along the length of a simulated transmission line. Theoretically, it varies from 1 to (plus) infinity and it is always positive.

$$\boldsymbol{VSWR} = \left|\frac{V_{max}}{V_{min}}\right| \quad \mathbf{1} \leq \boldsymbol{VSWR} \leq \infty \tag{1}$$

VSWR describes the voltage standing wave pattern that is present in the transmission line due to phase addition and subtraction of the incident and reflected waves.

In a simulated transmission line, with the characteristic impedance of Z_0, the reflection coefficient (absolute magnitude $|\Gamma|$) between the incident and the reflected signal is defined as:

$$|\boldsymbol{\Gamma}| = \frac{\boldsymbol{VSWR-1}}{\boldsymbol{VSWR+1}} \tag{2}$$

When the load is perfectly matched to the transmission line:

$$\mathbf{VSWR} = \mathbf{1} \qquad \Rightarrow \qquad |\boldsymbol{\Gamma}| = \mathbf{0} \tag{3}$$

When the load is a short circuit, an open circuit or a pure reactance:

$$\mathbf{VSWR} = \infty \qquad \Rightarrow \qquad |\boldsymbol{\Gamma}| = \mathbf{1} \tag{4}$$

In this experiment you will use the frequency selective amplifier and slotted line to measure a matched load a shorting plate load and a variable load.

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).

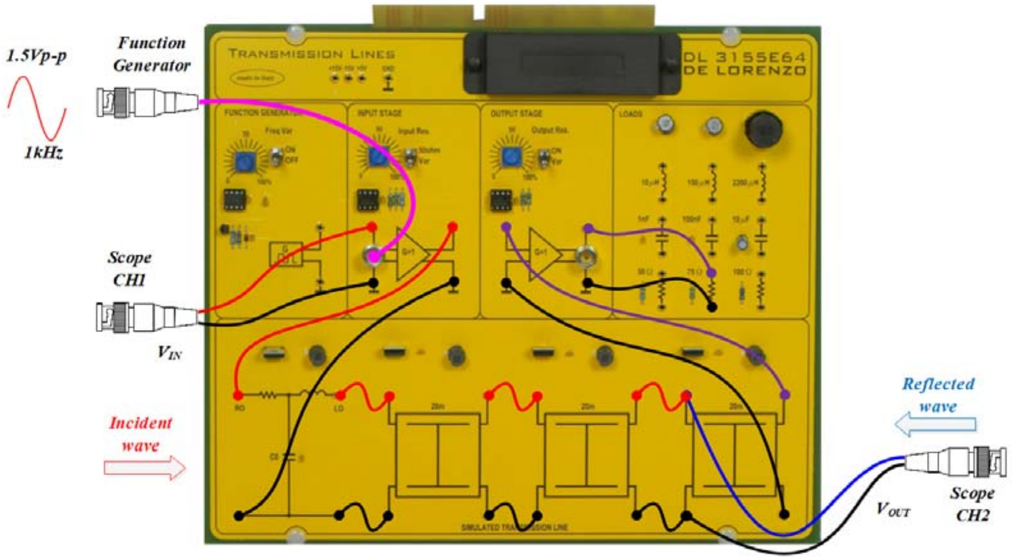


Fig.5. Wiring diagram for measuring the voltage standing wave ratio (VSWR).

For measuring function generator was set up for an amplitude output signal of 750mV and a frequency of 1 kHz. 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. The characteristic impedance of the line is $Z_0 = 68\ \Omega$

The SWR is usually thought of in terms of the maximum and minimum AC voltages along the transmission line, thus called the voltage standing wave ratio or VSWR. The MATH menu of the oscilloscope was used to display the standing wave. Selecting the CH1+CH2 to add the incident wave to the reflected wave and to obtain the standing wave ratio.

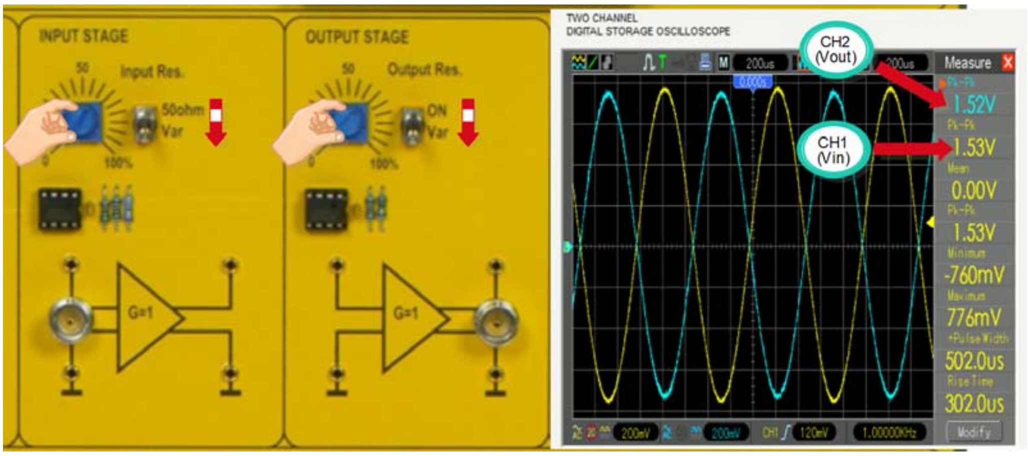


Fig.6. Input/output transmission line voltage measurements

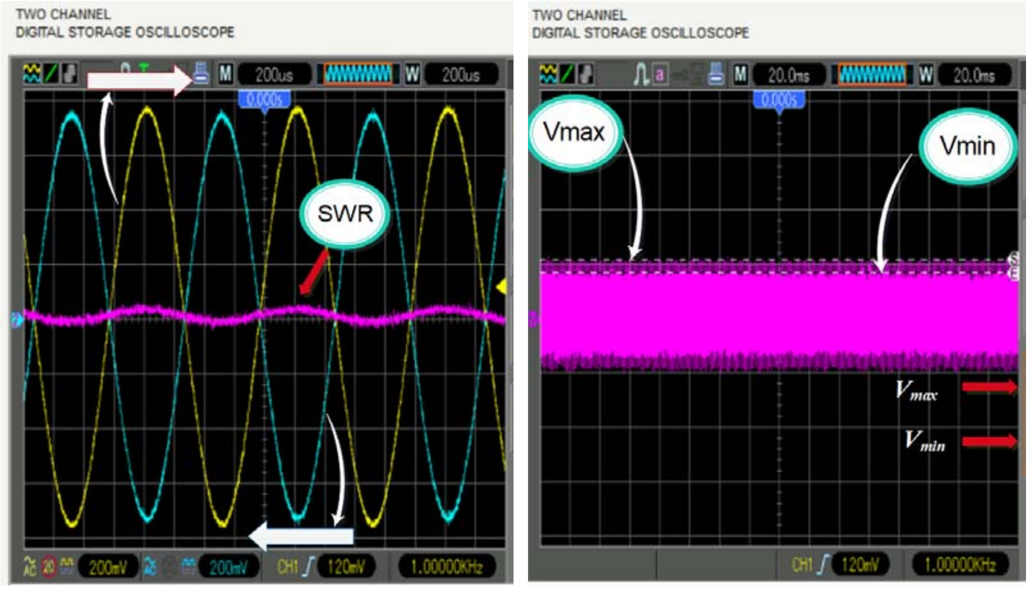
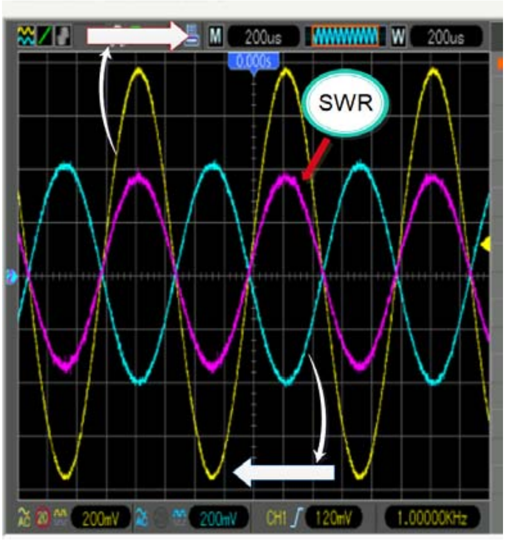
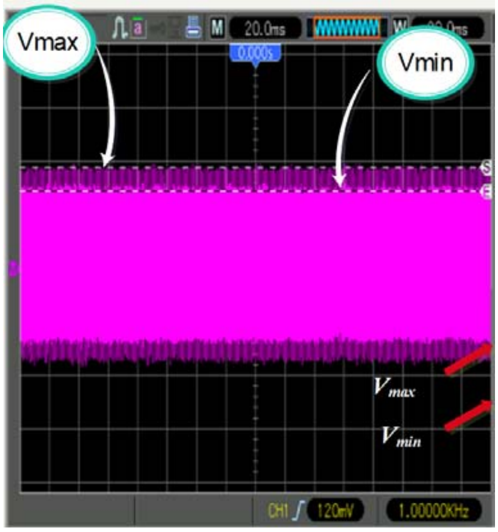


Fig.7. Voltage standing wave ratio (VSWR) determination

The relevant metric is the standing wave ratio (SWR). SWR is defined as the ratio between the amplitude of a partial standing wave at antinodes [max] to the amplitude of the adjacent mode [min]. Thus, a ratio of 1.5:1 means the maximum standing wave amplitude is 1.5 times greater than the minimum standing wave value.

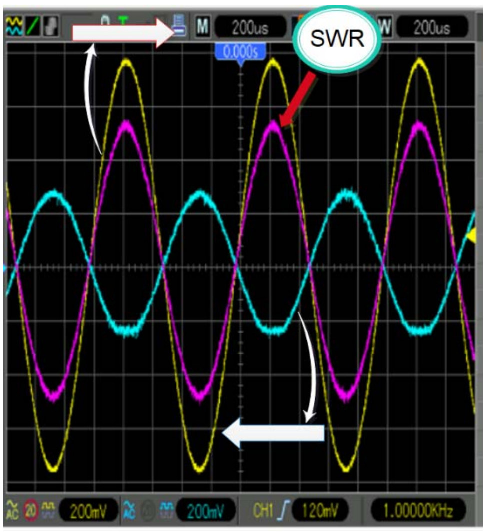
Calculating the Voltage Standing Wave Ratio (VSWR) with mismatched load and the the reflection coefficient (absolute magnitude $|\Gamma|$):

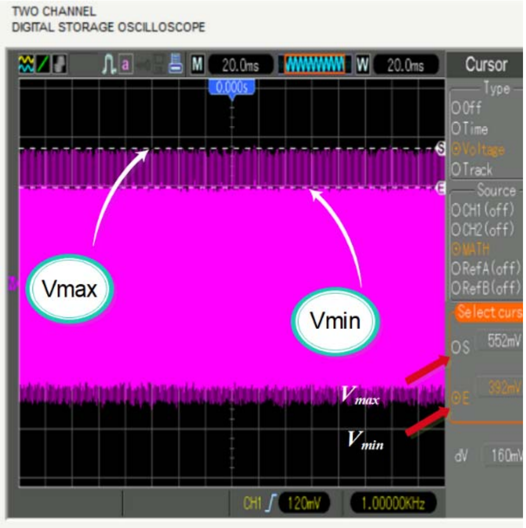




$$VSWR = \frac{V_{max}}{V_{min}} = \frac{376mV}{288mV} = 1.3 \tag{5}$$

$$|\Gamma| = \frac{VSWR-1}{VSWR+1} = \frac{1.3-1}{1.3+1} = 0.13 \tag{6}$$





Calculate the Voltage Standing Wave Ratio (VSWR) with mismatched load:

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{552mV}{392mV} = 1.4 \tag{7}$$

Calculate the reflection coefficient (absolute magnitude |Γ |):

$$|\Gamma| = \frac{VSWR-1}{VSWR+1} = \frac{1.4-1}{1.4+1} = 0.16 \tag{8}$$

3. WAVEGUIDE MODEL FOR VSWR MEASUREMENT

The maximum power transfer occurs when the waveguide transfer power to a load that has the same impedance with the waveguide. Similarly, the maximum power transferred into the waveguide occurs when the source has the same impedance with the waveguide.

The waveguide acts as a high pass filter, where most of the energy above a certain frequency (the cutoff frequency) will pass through the waveguide, whereas most of the energy that is below the cutoff frequency will be attenuated by the waveguide. Waveguides are a special form of transmission line used for microwave applications. Dimensions of the waveguide which determines the operating frequency range. For our testing method, as shown in fig.8, is used a rectangular waveguide and microwave signal source (10GHz), frequency selective amplifier, coaxial adapter, variable attenuator, slotted line, slide screw tuner, shorting plate and a matched termination plate

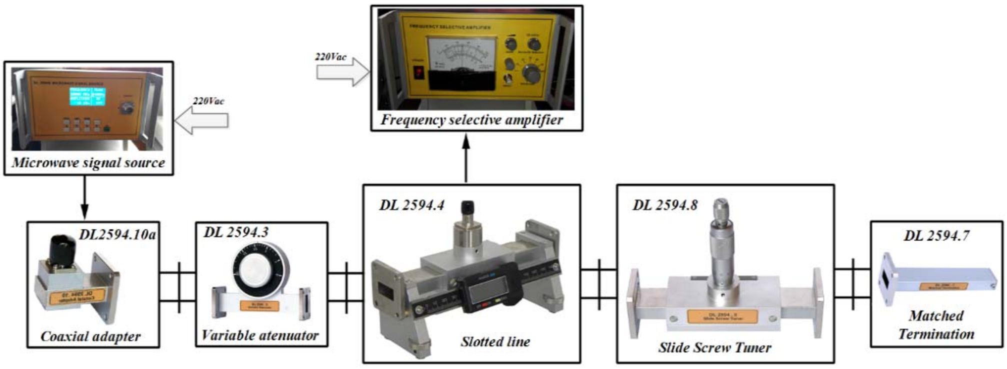


Fig.8. Laboratory setup for measuring VSWR

By moving the slotted line - mobile part to the left until the minimum position Vmin is measured. Continuing to move the slotted line - mobile part to the left until the minimum position Vmax is measured.

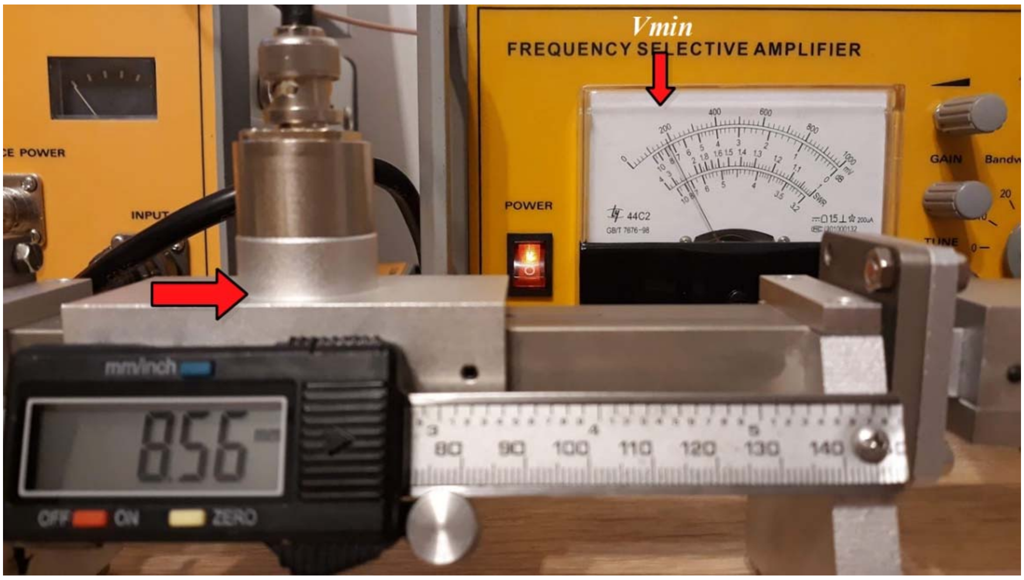


Fig. 9. Measuring the minimum voltage Vmin

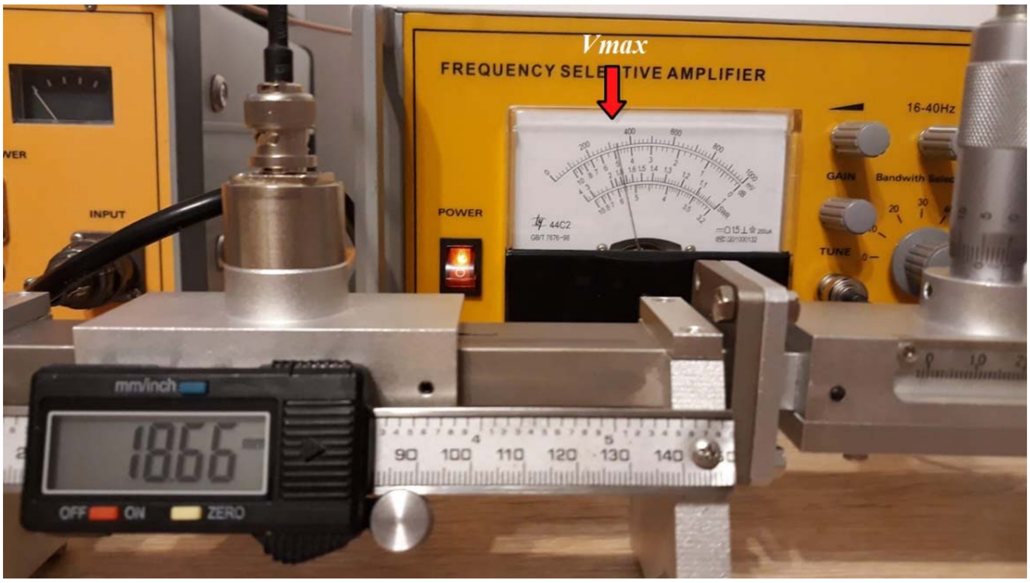


Fig.10. Measuring the maximum voltage Vmax

Calculate the Voltage Standing Wave Ratio (VSWR)

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{420mV}{180mV} = 2.33 \tag{9}$$

Calculate reflection coefficient (absolute magnitude |Γ |)

$$|\Gamma| = \frac{VSWR-1}{VSWR+1} = \frac{3.77-1}{3.77+1} = 0.39 \qquad (10)$$

4. CONCLUSIONS

With slotted line module we have studied the standing wave in three cases:

- using a shorting plate (zero impedance of the load)
- matched termination (50Ω)
- by using a waveguide with unknown impedance.

By using the relationships between standing waves and frequencies, using slotted line module we measure minimum and maximum voltages, used to calculate VSWR. Also, VSWR was measured directly using slotted line module and the frequency selective amplifier.

In terms of efficiency, for three situations of mismatched load we have calculated the reflection coefficient. The reflection coefficient as increased as the load impedance increased compared with the characteristic impedance of the transmission line. VSWR is a very important parameter in RF transmission systems where a high VSWR can reduce the power delivered to an antenna or system significantly. This can lead to reduced range, heating of cables, damaged amplifiers, etc.

REFERENCES

[1]. **Anson W. J.** *Technique of VSWR Measurement*. Journal of Research of the National Bureau of Standards: Engineering and instrumentation. C, 65: 217.

[2]. **Dobra R., Buica G., Pasculescu D., Leba M.,** *Safety management diagnostic method regarding work cost accidents from electrical power installations*, Proceedings of the 1st International Conference on Industrial and Manufacturing Technologies, ISSN: 2227-4596, ISBN: 978-1-61804-186-9, 2013.

[3]. **Elrashidi A., Khaled M. E., Hassan B.**, *Input impedance, VSWR and return loss of a conformal microstrip printed antenna for TM01 mode using two different substrates*, International Journal of Networks and Communications, pag.13-19, DOI: 10.5923/j.ijnc.20120202.03, 2012.

[4]. **Marcu M., Niculescu T., Popescu F.G., Slusariuc R.I.,** *Comparative Analysis of Methods for Reducing Distorting Regime by Simulating Active Power Filters*, 2018 International Conference on Applied Mathematics & Computer Science (ICAMCS), 13-15 April 2018, Paris, France, pp.87-96 DOI 10.1109/ICAMCS46079.2018.00023, ISBN:978-1-7281-3258-7.

[5]. **Umayah E., Srivastava V.,** *Comparative view of return loss, VSWR, gain, and efficiency of cylindrical surrounding patch antenna with frequency shift*. Int J Electr Electron Eng Telecommun, pag. 352-357, 2019.

[6]. *** www.deloreonzoglobal.com, last visited in November 2021.