Lab-Report
Analogue Communications

Waveguides

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2. Introduction

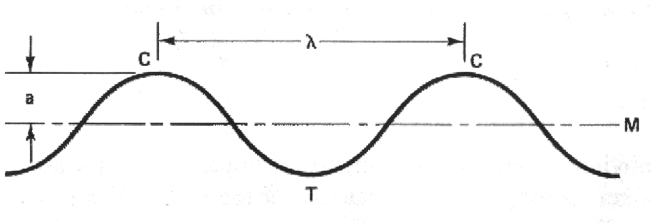
At very high frequencies the transmission of electrical energy from one point to another can be accomplished using hollow conduction pipe structures, called waveguides, which can have regular shaped cross sections. There is no “go and return” path for the current as in the normal two wire system, but instead the energy is carried by the electromagnetic field pattern set up within the pipe like structure. Regular cross section shapes are used in practice because they give mathematically predictable results.

a) Waves

A wave is a disturbance moving through a medium. Only the wave is transported, not the medium. A cork on the surface of water bops up and down with water, but it does not move across the surface with the wave.
A wave is a change of state propagation through a medium.

b) Wave length

The wavelength is the horizontal distance between two corresponding points. The wavelength is called λ.



a: amplitude
λ: wavelength
c: corresponding points

c) Velocity

The formula for velocity is given by: $v = \frac{s}{t}$

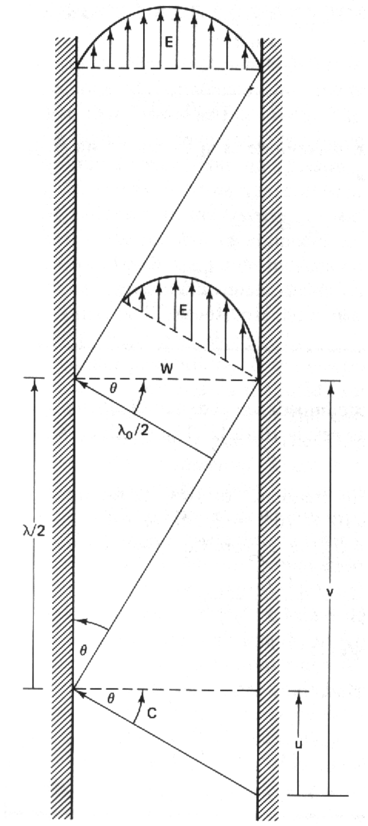
The velocity can be measured by counting the numbers of waves that pass a given point in an interval of time: $v = \frac{n\lambda}{t}$

The numbers of waves in an interval of time is called the frequency: $v = f\lambda$

Electromagnetic waves travel with the speed of light (c): $c = 300000\frac{km}{s}$

Hence: $c = \lambda f \quad \Rightarrow \quad f = \frac{c}{\lambda}$

d) Waveguides



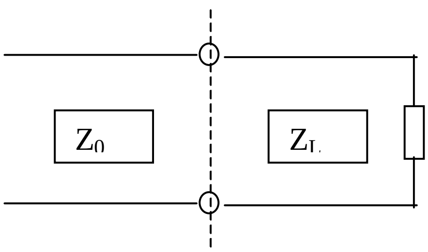
Any type of transmiision line or medium, even free space, can be considered to be a wave guide, but generally „waveguide“ is used to refer to a hollow, cylindrical, or rectangular pipe.

Since the voltage along the surface of an conductor is zero, electric waves form nulls at the coinducting walls of a guide. For this reason the oblique lines in the figure represent nulls, not crests, and are spaced half wavelength apart.

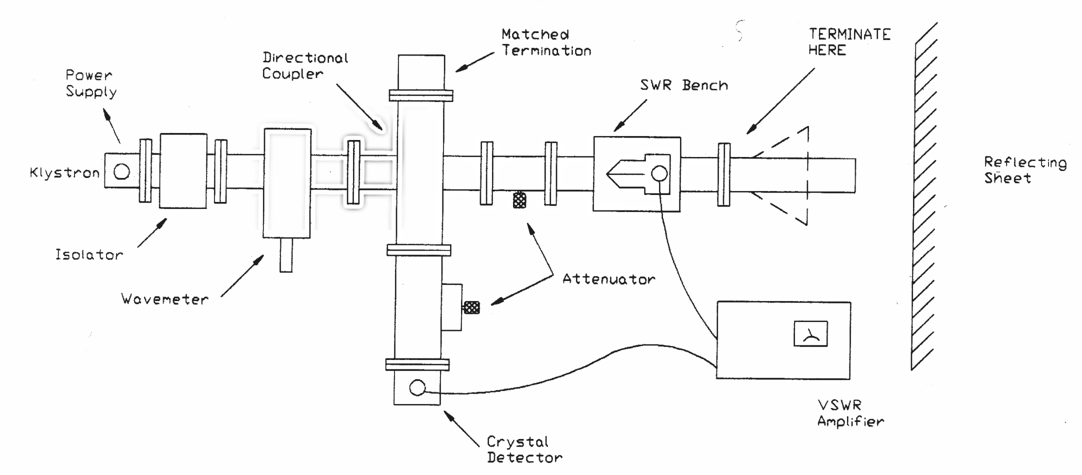
e) reflections

The reflection coefficient is defined as $r = \frac{Z_L - Z_O}{Z_L + Z_O}$

Transmission lines are constructed to deliver the maximum possible source power to the sink (load). If a circuit is not correct terminated reflections occur from the load back to the source: The waves cancel out each other.



3. The Lab



The lab equipment consists of a Klystron, as a microwave source, a directional coupler, an SWR Bench, a VSWR meter. Different terminations can be applied to the equipment, which were a matched termination, a short circuit and an open circuit and a matched horn aerial with reflector to measure the wavelength.

a) Klystron frequency

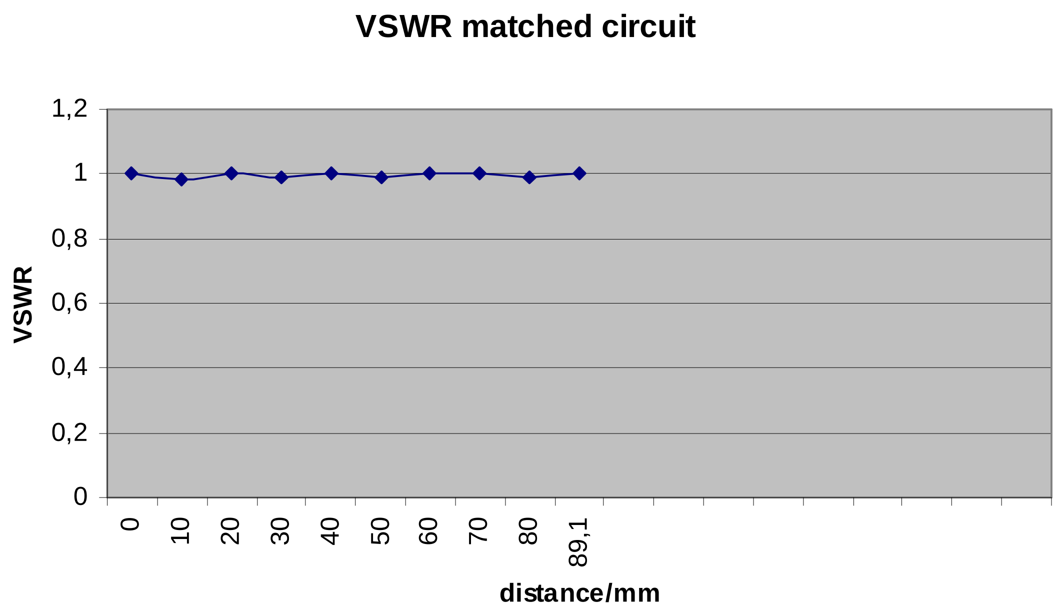
The frequency of the klystron was determined by the wavemeter to 9.33GHz.

b) Matched termination

First part of the lab was to obtain a standing wave pattern, when the test equipment was matched terminated.
Matched termination means, that any parts of the transmission line have the same impedance. With correct termination no energy reflects from the load back to the input.

With $Z_L = Z_O = Z$: $r = \frac{Z - Z}{Z + Z} = 0 \rightarrow$ no reflections occur

distance/mm	VSWR	
0	1	
10	0.985	
20	1	
30	0.99	
40	1	
50	0.99	
60	1	
70	1	
80	0.99	
89.1	1	



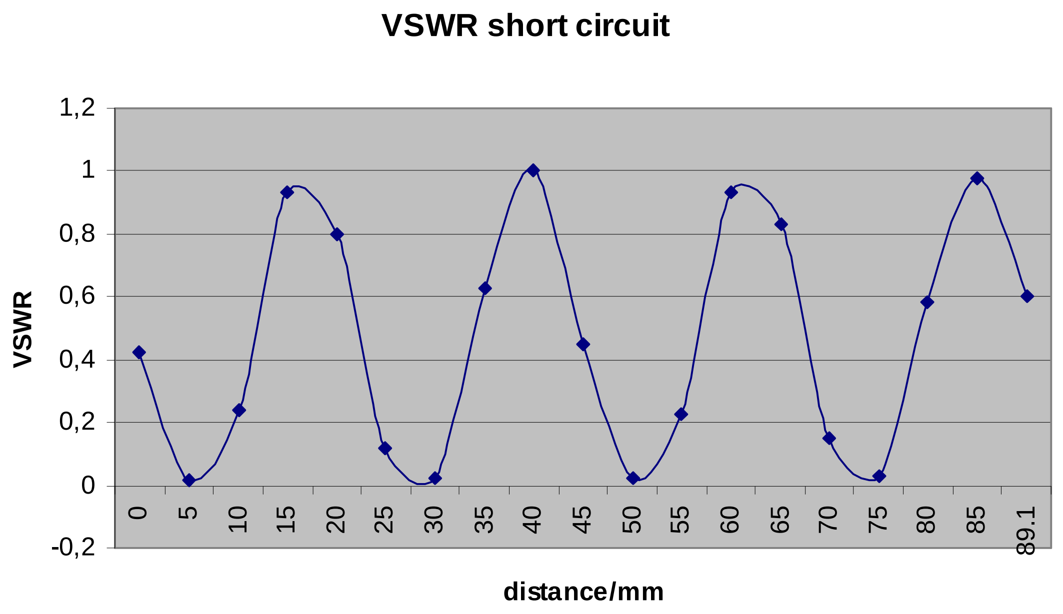
From the above graph can be seen, that no reflections have occurred.

c) Short circuit

On a line with a short circuit all the energy is reflected back, because the charge on the line is reverted at the short circuit and a reflected wave is set up.

$$\lim_{Z_L \to 0} r = \lim_{Z_L \to 0} \frac{Z_L - Z_O}{Z_L + Z_O} = \frac{-Z_O}{Z_O} = -1 \quad \rightarrow \text{all energy reflected back}$$

distance/mm	VSWR	
0	**0.425**	
5	**0.015**	**1st min**
10	**0.24**	
15	**0.93**	**1st max**
20	**0.8**	
25	**0.12**	
30	**0.025**	**2nd min**
35	**0.63**	
40	**1**	**2nd max**
45	**0.45**	
50	**0.02**	**3rd min**
55	**0.225**	
60	**0.93**	**3rd max**
65	**0.83**	
70	**0.15**	
75	**0.033**	**4th min**
80	**0.58**	
85	**0.98**	**4th max**
89.1	**0.60**	



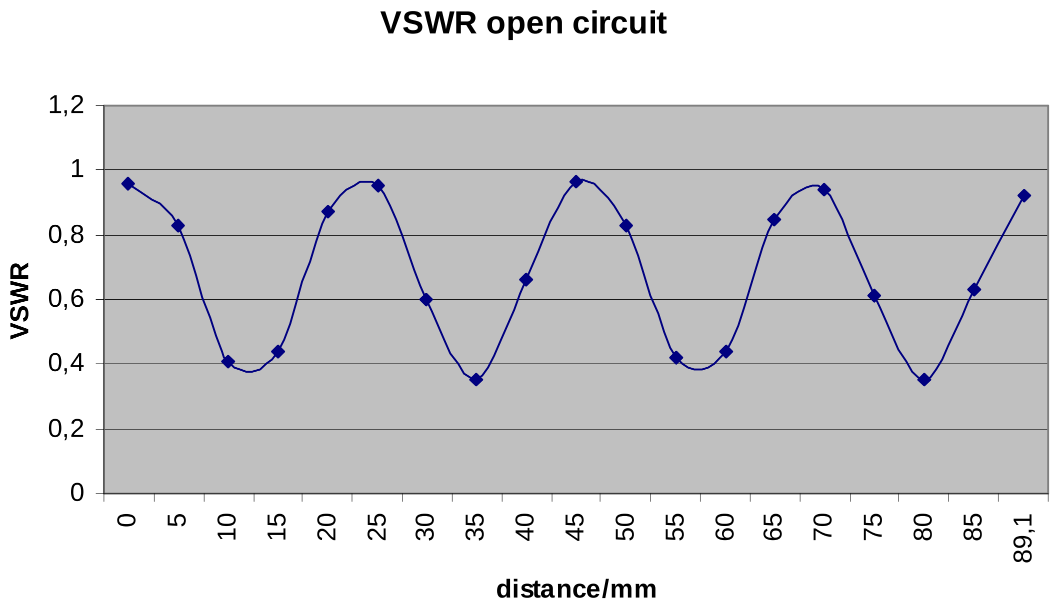
d) Open circuit

With an open end of the line the magnetic field collapses, because the current becoms zero. The collapse of the magnetic field produces an electrical field, which is added to the existing field and the voltage at the open end increases and a reflecting wave is set up.

$$\lim_{Z_L \to \infty} r = \lim_{Z_L \to \infty} \frac{Z_L - Z_O}{Z_L + Z_O} = \frac{\infty}{\infty}$$

l'Hospital: $$\lim_{Z_L \to 0} r = \lim_{Z_L \to 0} \frac{d\left(\frac{Z_L - Z_O}{dZ_L}\right)}{d\left(\frac{Z_L + Z_O}{dZ_L}\right)} = \frac{1}{1} = 1$$

distance/mm	VSWR	
0	0.96	1st max
5	0.83	
10	0.41	1st min
15	0.44	
20	0.87	
25	0.95	2nd max
30	0.6	
35	0.35	2nd min
40	0.66	
45	0.965	3rd max
50	0.83	
55	0.42	3rd min
60	0.44	
65	0.85	
70	0.94	4th max
75	0.61	
80	0.35	4th min
85	0.63	
89.1	0.92	



In the Lab not all of the energy was reflected (minimum VSWR=0.41), because some energy was absorbed on the open end.

e) Matched horn aerial

Last part of the Lab was to use a matched horn aerial with moving reflector to measure the wavelength. Therefore the distance between different minima on the VSWR meter when moving the reflector were measured.

Minima	Distance
1st	**19.95**
2nd	**18.4**
3rd	**16.7**
4th	**15.1**
5th	**13.5**

⇒1.55cm

⇒1.7cm

⇒1.6cm

⇒1.6cm

average=1.61cm
⇒ λ=3.22cm

$$f = \frac{c}{\lambda} = \frac{3*10^{10}\,\frac{cm}{s}}{3.22cm} = 9.32GHz$$