10 Waveguide

10.1 Summary

In this experiment we compare the properties of microwave transmission in a rectangular waveguide.

Objectives

- To set up and observe standing waves in a rectangular guide.
- To verify the waveguide equation for a range of wavelengths.
- To determine the cut-off frequency.

Equipment

Rectengular waveguide, RF generator and antenna, probe installed on a probe motor and connected to a Pico-logger (and a PC), metal bung and a stopwatch.

Principal Data Taken

1. Wavelength in the waveguide at different signal frequencies.
2. Speed of the probe.

Things to Watch Out For

- At the start of data collection for each frequency, adjust up the bung at the end of the guide to setup the optimal standing wave.
- The equipment in this experiment is already wired up. There is no need for you to connect or disconnect anything.

10.2 Introduction

Waveguides are generally used to carry high power microwave signals, to a radar antenna for example, for long range transmission purposes. For extreme high power purposes the cavity inside the waveguide may be a vacuum to avoid the intense electric field strength ionizing the air and creating a conducting plasma that would short the field, and stop propagation of the signal.

We have a signal generator connected to an antenna that projects into the waveguide. A probe that is able to move along the guide, is connected to an analogue to digital converter; which enables you to record the probe voltages on the computer running the PicoLog software.

- The dimensions of the waveguide limit the size of the electric wave that can propagate inside the guide. What happens to the electric field at the walls of the metallic guide? By measuring the of the guide, determine the cut-off wavelength.
- Set the signal generator to 3000 Mega cycles. What is the wavelength of this 3 GHz microwave in free space?

By blocking the open end of the waveguide with a metal bung, reflections are created that interfere with the transmitted wave. If the reflections interfere constructively with the transmitted wave, a standing wave is created.

Try different positions of the metal bung, and move the probe to voltage maxima by hand, and create the strongest standing wave you can. You should be able to achieve a standing wave with a maxima of up 150 - 200 mV.

- What is the condition of the electric field at the location of the movable bung, and the fixed plate at the other end of the guide, close to the antenna?
- What is significance of the distance of the fixed end-plate from the antenna with respect to the transmitted frequency?
- How does the total length of the cavity between the two endpoints relate to the transmitted wavelength?

Having achieved a good standing wave you can put the probe on the motorized transport and record the voltages on the probe as it traverses the length of the waveguide slot. You will need to determine the velocity of the motorized probe transport. You can then determine the wavelength of the standing wave.

10.3 Standing Wave Relation

We can now test the relation between the standing wave and the cut-off frequency, by measuring the standing wave produced by different transmitted waves. The relation is,

$$\frac{1}{\lambda_{wg}^2} = \frac{1}{\lambda_t^2} - \frac{1}{\lambda_{cut}^2}, \tag{10.1}$$

If you examine this equation, you can see what happens to the standing wave in the guide λ_{wg} as the transmitted wavelength λ_t approaches the cut-off frequency λ_{cut}.

Experiment with different transmitted frequencies to verify the above equation is true.

What happens to the standing wave as you try approach the cut-off frequency? How close to the cut-off frequency can you get?

You will need to consider the distance of the fixed end-plate from the antenna. You may need to reverse the waveguide stub length containing the antenna to change the distance of the end-plate from the antenna, in order to get the wave to propagate at a frequency much lower than 3 GHz.

When you have recorded data over a large range of wavelengths, plot a suitable graph to verify the waveguide equation 10.1 and determine the cut-off frequency from the graph.

10.4 Discussion

1. How do the waveguide dimensions define the cut-off frequency?
2. Which electromagnetic wave mode are we measuring in the waveguide, TE_{ab} or TM_{ab}, and in which a, b dimensions?
3. Discuss how standing waves are formed by the interaction of transmitted and reflected waves.

References

Pain, H.J. 1983, *The Physics of Vibrations and Waves, 3rd Edition*, John Wiley & Sons Ltd, p. 241