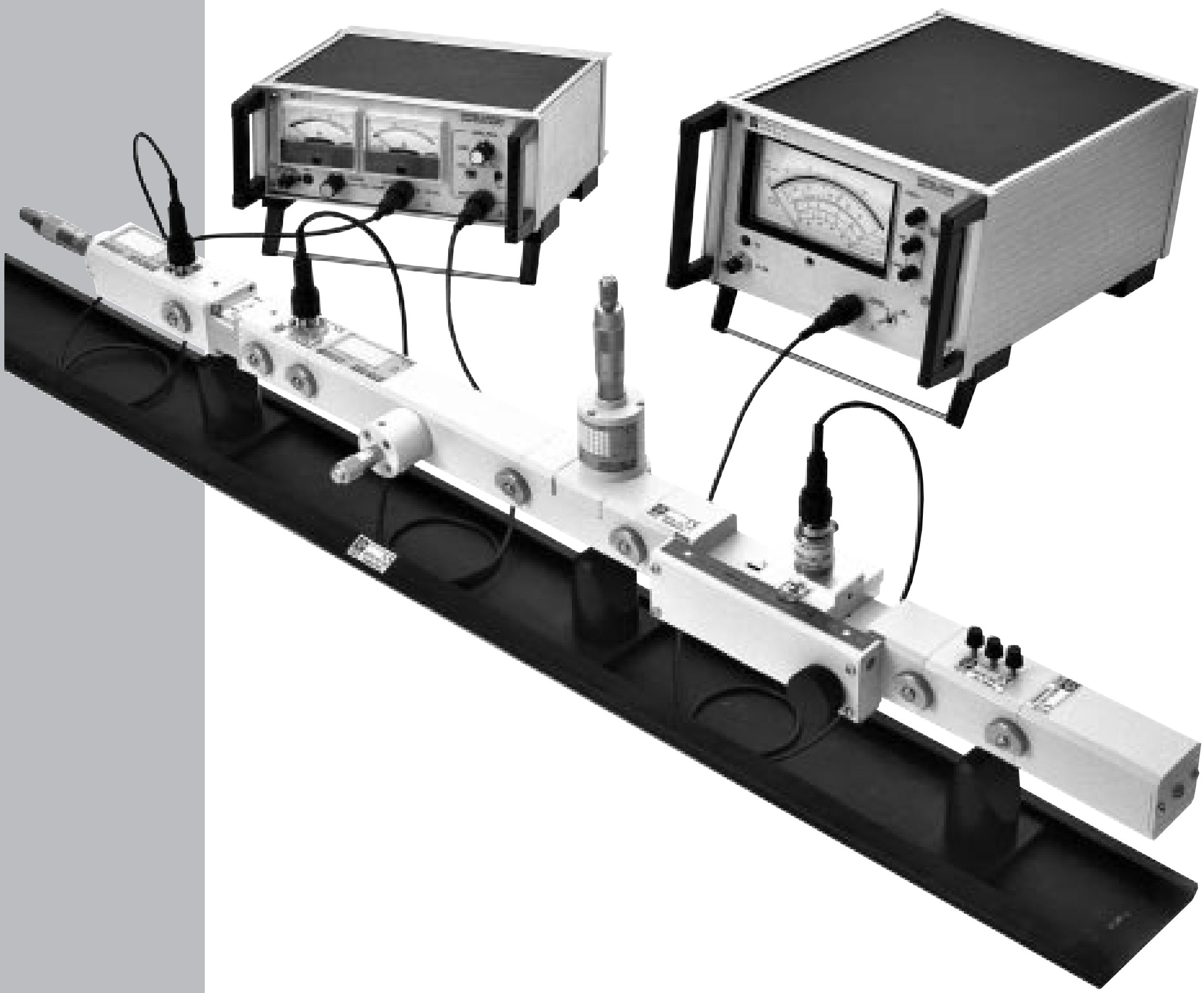
■ MICROWAVE EDUCATIONAL BENCH

ORITEL
BDH R100



ENGLISH

Experimentation manual

CHAUVIN ARNOUX

Meaning of the symbol ⚠:
CAUTION! Consult the experimentation manual before using the bench.
In this experimentation manual, the instructions preceded by this symbol may cause personal injury or damage the instrument and installations if they are not scrupulously abided by and carried out.

You have just bought an **ORITEL BDH-R100 microwave educational bench** and we thank you for the interest you show for our products.
In order to get the best use out of your bench assembly:
- carefully **read** this experimentation manual,
- **follow** the precautions for use.

⚠ PRECAUTIONS FOR USE ⚠

- The ferrite insulator shall be correctly oriented, with the arrow pointing towards the load.
- When the Gunn oscillator and PIN diode modulator are connected to the power supply, any crossed connection between the output connectors and the power supply may lead to the Gunn and PIN diodes being damaged (see § 3.2).
- The connecting leads and accessories shall comply with the applicable standards and shall be designed for an overvoltage category rated voltage which is at least equal to that of the circuits on which the measurements are carried out.
- Leave a free space of approximately 1 cm around the ORITEL CF 204A power supply unit (optional extra) and the ORITEL IR 205 SWR indicator (optional extra) for ventilation purposes.
- All instruments hooked up to the bench and connected to the AC network shall be earthed.
- No voltage of more than 30 V in relation to the earth shall be present on the bench.
- For more information regarding the precautions to be taken when using the subassemblies, refer to the individual manuals relative to each subassembly.

WARRANTY

Our guarantee is applicable for **twelve months** after the date on which the equipment is made available (extract from our General Conditions of Sale, available on request).

CONTENTS

1. INTRODUCTION

An increasing demand for training in microwave technology has led the ORITEL department of CHAUVIN ARNOUX to develop measuring equipment which is specially designed to be used in teaching.

Specialising for several years in microwave components and systems, the ORITEL department was concerned with simplifying the various elements making up these measuring benches. This set of techniques is thus brought within the reach of a large number of people interested in microwave technology.

The **ORITEL BDH R100 educational bench**, manufactured using a rectangular waveguide in accordance with the R100/WR90 standard (covering the frequency range between 8.5 and 9.6 GHz), makes the most frequent and ordinary measurements possible. Other components and accessories, available as optional extras, can be added to it in order to implement a large number of complementary experiments, among which we can mention the following studies:
- the circulator,
- the directional coupler,
- propagation,
- the gain and radiation pattern of an antenna.

The 8.5 GHz to 9.6 GHz (λ = 3 cm) frequency band was chosen, on the one hand, on the grounds of the considerable developments in this frequency range and, on the other hand, because of the dimensions of the components.

Other components featuring in the CHAUVIN ARNOUX catalogue can be supplied on request.

Far from being a lesson in microwave measurement, the sole aim of this manual is to illustrate the possibilities of the ORITEL BDH-R100 equipment with a few examples.

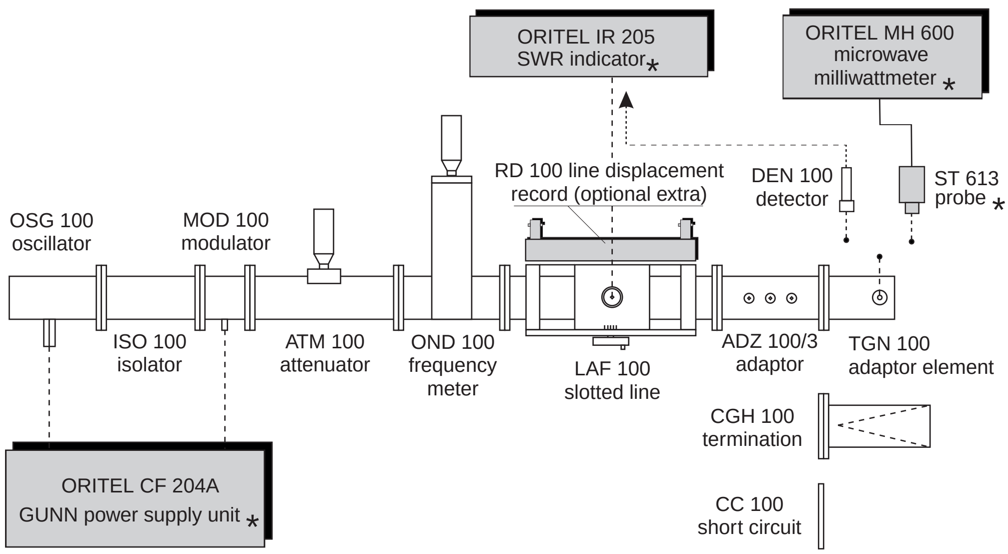
It should be noted that this educational bench has an innovative distinctive feature which makes it much easier to assemble its various components: the **EASYFIX** quick fastening system which, by a single operation, enables any waveguide component whatsoever (and manufactured to the R100/WR90 standard) to be connected.

EASYFIX™
fastening adaptor

2. PRESENTATION

The educational bench is made up of rectangular waveguide components manufactured to the R100/WR90 standard (covering the frequency range between 8.5 and 9.6 GHz) and presented in the flow chart below.
This assembly allows the following experiments to be carried out:
- Gunn oscillator study
- Standing wave ratio measurement
- Waveguide study
- Impedance measurement
- Frequency measurement
- Experimental determination of a detector’s quadratic law
- Power measurement

2.1 Composition of the ORITEL BDH R100 educational bench



***N.B.** The subassemblies represented in grey are supplied as optional extras.*

3. CHARACTERISTICS

3.1 ORITEL BDH R100 educational bench

- Frequency: 8.5 to 9.6 GHz
- Waveguide: R100
- Flange: UBR 100
- Connection by means of EASYFIX quick fastening lugs (see § 4.1)
- All the components making up the bench can be put away in a case
  Dimension / Weight: 540 x 130 x 430 mm / 7 kg
- Electromagnetic compatibility: NF EN 61326-1 standard, class B, 1998 edition

N.B. *The characteristics of the components making up the educational bench are mentioned in the following paragraphs.*

3.2 ORITEL CF 204A power supply unit (optional extra)

The power supply unit is specially designed to energize the Gunn-effect diode (ORITEL OSG 100) and the MOD 100 PIN diode modulator.
It supplies:
- a 0 to 10 V adjustable DC voltage,
- square signals at an adjustable frequency of approximately 1 kHz, modulating the microwave signal supplied by the Gunn diode.

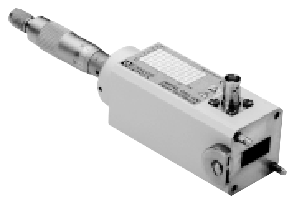
Gunn oscillator power supply
- Voltage adjustable between 0 V_{DC} and 10 V_{DC}
- Regulation ratio: better than $\pm 1.10^{-3}$
- Current: limited inside the unit to 1.2 A max.
- female BNC output connector

Pin diode modulator-cum-attenuator power supply
- Direct current: adjustable between 0 mA and + 10 mA
- Amplitude modulation: square signals from 0 mA to + 10 mA
  frequency 1 kHz ± 1.5% (adjustable on the front panel)
- female BNC output connector

General characteristics
- Mains power supply: 115 or 230 V ± 10%, 40 to 60 Hz
- Consumption: approximately 35 VA
- Dimensions (length x height x depth): 240 x 100 x 215 mm
- Weight: approximately 2.4 kg

3.3 ORITEL OSG 100 Gunn diode oscillator

The Gunn diode oscillator is the microwave energy source from which the ORITEL BDH-R100 educational bench is powered. This oscillator comprising a waveguide section, one of the ends of which is closed by a short-circuit, is tunable between 8.5 and 9.6 GHz by means of a micrometer screw.



- Frequency: 8.5 to 9.6 GHz
- Output power: > 17 dBm
- Supply voltage: 10 V_{DC}
- Waveguide: R100
- Flange: UBR 100
- Power supply connector: female BNC
- Weight: 535 g
- Dimensions: 53 x 59 x 225 mm

3.4 ORITEL ISO 100 ferrite isolator

The ferrite isolator protects the Gunn diode oscillator against load impedance variations as well as the mismatch caused by the PIN diode modulator.
The ferrite isolator lets microwave energy pass through with no attenuation in the oscillator-to-load direction, and produces a strong attenuation in the opposite direction.

- Frequency: 8.5 to 9.6 GHz
- Insertion loss: < 1 dB
- Isolation: > 20 dB
- SWR: ≤ 1.25
- Waveguide: R 100
- Flange: UBR 100
- Weight: 650 g (with 2 *EASYFIX* quick fastening lug adaptors)
- Dimensions: 99 x 46 x 87 mm

3.5 ORITEL MOD 100 PIN diode modulator

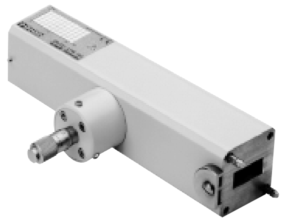
The PIN diode modulator enables the microwave wave produced by the Gunn oscillator to be modulated by square signals at 1 kHz.

- Frequency: 8.5 to 9.6 GHz
- Insertion loss: < 1 dB
- Depth of modulation: > 20 dB between 8.5 and 9.6 GHz
- Waveguide: R 100
- Flange: UBR 100
- Weight: 200 g
- Dimensions: 51 x 57.5 x 68 mm

3.6 ORITEL ATM 100 micrometer-adjustable variable attenuator

The variable attenuator mounted on the rectangular waveguide structure enables the energy transmitted on the line to be dosed and a comparison measurement of the dB levels to be carried out. The variable level control adjusted by means of a micrometer guarantees a high degree of accuracy and a good adjustment repeatability.

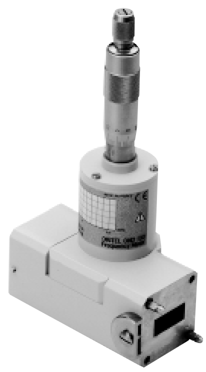
- Frequency: 8.5 to 9.6 GHz
- Max. attenuation: 20 dB
- SWR: 1.2 of 8.5 to 9.6 GHz
- Acceptable max. power: 1 average watt
- Waveguide: R100
- Flange: UBR 100
- Weight: 800 g
- Dimensions: 191 x 100 x 41.5 mm



3.7 ORITEL OND 100 curve frequency meter

The absorption frequency meter, formed by a cavity coupled onto a waveguide by means of an iris, measures the frequency of the energy coming from the oscillator mounting.
The volume of the cavity is adjusted by a micrometer graduated in millimeters, and a calibration curve specifies the cavity's tuning frequency according to the graduation.

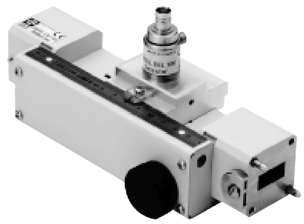
- Frequency: 8.5 to 9.6 GHz
- Readout accuracy: 5 MHz
- Absolute accuracy: 10^{-3}
- Waveguide: R100
- Flange: UBR 100
- Weight: 585 g
- Dimensions: 101 x 166 x 57.5 mm



3.8 ORITEL LAF 100 slotted line

The slotted line enables the amplitude and phase of the standing waves to be measured and, consequently, impedance measurements to be carried out.
A detector load, mounted on a sliding carriage, plunges into the waveguide through a longitudinal slot, draws a part of the energy and detects it. The sliding carriage makes movement along the whole length of the slot possible.

- Frequency: 8.5 to 9.6 GHz
- Residual SWR: < 1.05 between 8.5 and 9.6 GHz
- Waveguide: R100
- Flange: UBR 100
- Weight: 1,080 g
- Dimensions: 57 x 87 x 218 mm



3.9 ORITEL IR 205 SWR indicator (option)

The SWR indicator is a selective amplifier voltmeter whose frequency can be adjusted around 1,000 Hz.

This indicator can be used to carry out four main functions:

- ■ Measuring the standing wave ratio (SWR) using a slotted line
- ■ Measuring insertion loss or attenuation
- ■ Zero indicator for a metre bridge
- ■ Indicating the field received by an antenna

The instrument is designed to be combined with a square-law demodulator, and the microwave signal present at the input of the demodulator shall be amplitude modulated to 1 kHz.

- Nominal operating frequency: 1,000 Hz (tunable over ± 2.5%)
- Amplifier overvoltage coefficient: adjustable between 15 and 60
- Max. sensitivity at full scale: approximately1 µVrms on the «expanded dB» position
  2 µV on the (normal) «dB» position

- Background noise: ≤ 10% of the total value on the «60 dB» position, maximum gain adjustment
- Calibration in dB: in accordance with a quadratic law
- Measurement ranges: 0 to 60 dB on the «dB» scale, 10 dB on the «expanded dB» scale
- Gain adjustment *(1)*: approximately 15 dB with «Coarse» and «Fine» adjustments
- Reading scales:
  Normal: «SWR» from 1 to 4 and from 3.2 to 10, and «dB» from 0 to +10 dB
  Expanded: «SWR» from 1 to 1.3 and «dB» from 0 to + 2.5 dB
  Linear: 0 to 100
  Expanded dB: 2.5 dB over the whole scale
- Accuracy (on the incorporated attenuator): Better than ± 0.2 dB for each 10-dB jump
- Overall accuracy: ≤ 2 dB for the whole 10- to 60-dB range
- Accuracy of the linear calibration *(2)*: better than ± 5% of the total deflection
- Input impedance: approximately 100 kΩ
- Input connector: female BNC
- Mains power supply: 115 / 230 V ± 10%, 40 to 60 Hz
- Operating temperature: + 10 to +45°C
- Dimensions / Weight: 215 x 145 x 320 mm / 4.2 kg

(1) Adjustment of the reference level or calibration
(2) At the tuned frequency

3.10 ORITEL ADZ 100/3 three-screw impedance adaptor

This element made up of a waveguide section is equipped with 3 screws which enable impedance mismatching to be produced in the 8.5 to 9.6 GHz frequency band.

- Frequency: 8.5 to 9.6 GHz
- Wave: R100
- Flange: UBR 100
- Weight: 254 g
- Dimensions: 53 x 57 x 60 mm

3.11 ORITEL TGN 100 waveguide-to-coax R100/N adaptor

The waveguide-to-coax adaptor enables the waveguide to be terminated by a female N-type coax.

- Frequency: 8.5 to 9.6 GHz
- SWR: < 1.25 from 8.5 to 9.6 GHz
- Waveguide: R100
- Flange: UBR 100
- Connector : female «N» type
- Weight: 180 g
- Dimensions: 56.5 x 53 x 41.5 mm

3.12 ORITEL DEN 100 coaxial detector

This component makes it possible to convert the modulated microwave energy into low- or zero-frequency signals. A Schottky barrier diode provides detection, and the BNC coaxial plug provides connection to the instrument measuring the detected current. Fitted to the ORITEL TGN 100 waveguide-to-coax adaptor, it enables a detector to be set up on a R100/WR90 standard waveguide.

- Frequency: 8.5 to 9.6 GHz
- SWR: < 1.25 from 8.5 to 9.6 GHz
- Max. power: 19 dBm
- Input connector: male «N» type
- Output connector: female «BNC» type
- Weight: 65 g
- Dimensions: Ø 21 x 62 mm

3.13 ORITEL CHG 100 termination

This termination, built into a closed straight waveguide in which a dissipative element is set, allows the line to be terminated on its characteristic impedance.

- Frequency band: 8.5 to 9.6 GHz
- SWR: < 1.05
- Max. power: 4 W
- Waveguide: R100
- Flange: UBR 100
- Weight: 349 g
- Dimensions: 101 x 166 x 57.5 mm

3.14 ORITEL CC 100 short-circuit plate

This plate enables a perfect short circuit to be achieved in the reference plane of the transmission line achieved in the R100 waveguide.

- Frequency band: 8.5 to 9.6 GHz
- Wave guide: R100
- Bride : UBR 100
- Masse : 349 g
- Dimensions : 101 x 166 x 57,5 mm

3.15 ORITEL AFR 100 EASYFIX quick fastening lug

This piece allows 2 elements built into the waveguide to be joined in next to no time.
- Weight: 95 g
- Dimensions: 41.5 x 41.5 x 23 mm

3.16 ORITEL MH 600 microwave milliwattmeter (optional extra)

This microwave digital miliwattmeter:
- measures the power on a dynamic range of 50 dB, in dBm or mW, and the power variations in dB or %, in the LF, HF, UHF and SHF bands,
- uses the ORITEL ST 600 series thermocouple probes, the ORITEL SD 600 series Schottky barrier diode probes,
- is compatible with the probes in the HP 8480 family.

Measurement range (depending on the probe used): 100 kHz to 50 GHz,
-70 dBm to +44 dBm, 100 pW to 25 W

Units of measurement
Watt, dBm or dB and % in relation to a power taken as a reference

Measurement dynamic range
50 dB in 5 ranges of 10 dB

Accuracy *(1)*
Of the measurement: ± 0.5% of the full-scale value in mW, or ± 0.02 dB in logarithmic mode

Reference power *(1)*
1 mW / 50 Ω / 50 MHz
Accuracy: ± 1% (after preheating for half an hour)
Stability: ± 1.2% per year

Recorder output
0 to 1 V/1 kΩ for a full-scale deviation
BNC connector

Programming: In accordance with the IEC 625 standard (compatible with IEEE 488)
Mains power supply: 115 / 230 V, 48 Hz to 420 Hz, 15 VA
Power supply by external direct voltage: 24 V (20 to 30 V)
Dimensions / Weight: 210 x 88 x 300 mm / 3.5 kg

(1) In stable conditions of use at 25°C ± 2°C
(2) In % of the full scale of the most sensitive range over a period of 1 hour at a constant temperature 24 hours after energization.

3.17 ORITEL ST 613 coaxial probe with thermocouple (optional extra to be used with Oritel MH 600)

The ORITEL ST 613 measuring probe constitutes one of the microwave measuring components of the ORITEL MH 600 digital milliwattmeter (optional extra). This probe uses a thin film microwave thermocouple. It is supplied with its correction factor table.
- Frequency band: 10 MHz to 18 GHz
- Measurement dynamic range: 1µW to 100 mW
- SWR: 1.25 from 10 MHz to 12 GHz
- Connector: male N type

3.18 ORITEL RD 100 line line displacement record (optional extra for ORITEL LAF 100)

This optional extra makes it possible to record the level detected according to the displacement of the carriage along the ORITEL LAF 100 slotted line.

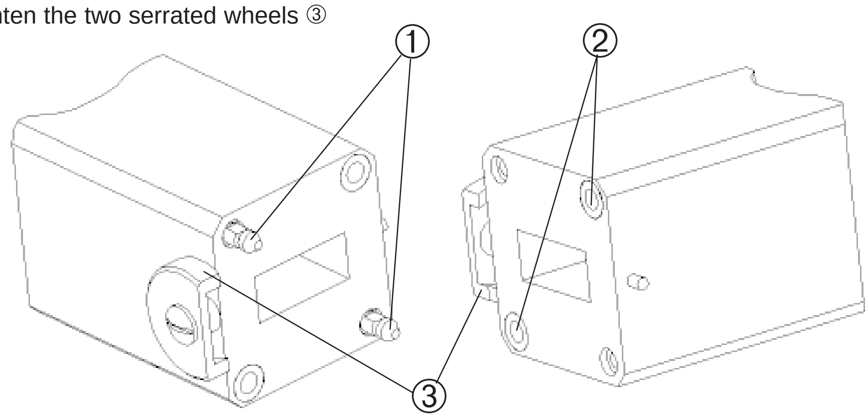
4. COMMISSIONING

4.1 Assembling the bench

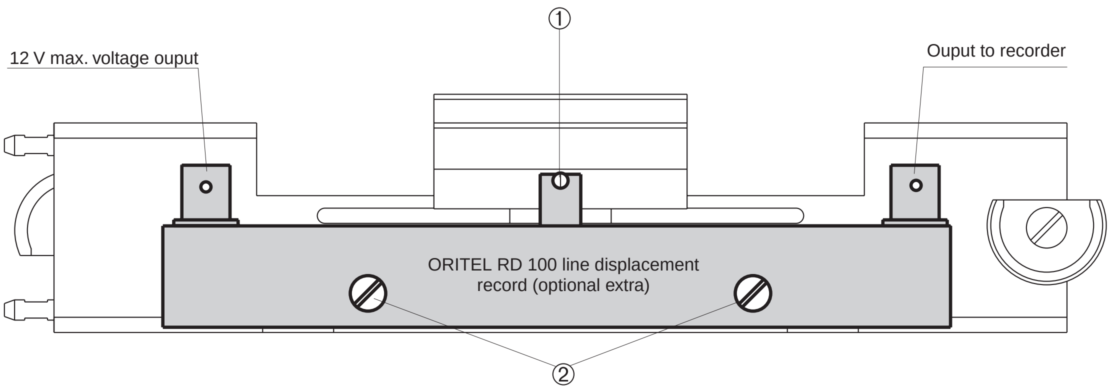
Since the assembling of the different components varies depending on the measurements you are considering carrying out, the subject will be dealt with as regards each of the manipulations described in this manual.
Generally speaking, and whatever the measurement, the insulator must be placed immediately after the Gunn oscillator since, in that way, the stability of the oscillator as regards frequency and power will not be (or, if so, only very slightly) affected by an impedance whatsoever placed after the insulator.

Using the EASYFIX quick fastening lug

- Arrange the two elements to be assembled in such a way as to correctly place the centring pins ① opposite the holes ②
- Simultaneously tighten the two serrated wheels ③



4.2 Mounting the ORITEL RD 100 line displacement record (optional extra)



- On the slotted line, remove the screws ①
- Place the line displacement record opposite the 2 holes where the screws go ②
- Position and tighten the screws ① and ②

4.3 Commissioning and using the ORITEL CF 204A power supply unit (optional extra)

Refer to the corresponding operating manual.

4.4 Commissioning and using the ORITEL IR 205 SWR indicator (optional extra)

Refer to the corresponding operating manual.

4.5 Commissioning the ORITEL MH 600 milliwattmeter (optional extra)

Refer to the corresponding operating manual.

5. MANIPULATIONS

5.1 Study of the Gunn-effect oscillator

5.1.1 Introduction

The aim of all these manipulations is to plot the characteristic curves which link the main operating parameters of the diode itself and the Gunn-effect oscillator:

- Reading the current-voltage characteristic of the Gunn-effect diode
- Reading the displacement-frequency characteristic of the Gunn-effect oscillator
- Reading the power-frequency characteristic of the Gunn-effect oscillator (optional extra)

5.1.2 A summary of the theory on which the experiment is based

Gunn-effect devices behave like an electron transfer oscillator within a gallium arsenide (GaAs) block, represented in diagram form below:.

It can be considered as a diode, but it does not comprise a p-n junction and, for this reason, does not have a rectifier characteristic.

Its operation is based on the presence of a space charge (so-called electrical field), which passes through the semi-conductor from the cathode to the anode during each cycle of the oscillation current. The effect is therefore associated with a transit time.

Mounted in a resonant cavity, the Gunn-effect diode is used as an active component for producing microwaves. It can therefore be considered as a device converting a weak direct current into microwave energy.

In that case, it is the volume of the cavity which determines the oscillation frequency.

5.1.3 Reading the current-voltage characteristic

The «current-voltage» response curve of the Gunn diode has a part with a negative dynamic range (see Fig. 3-1)

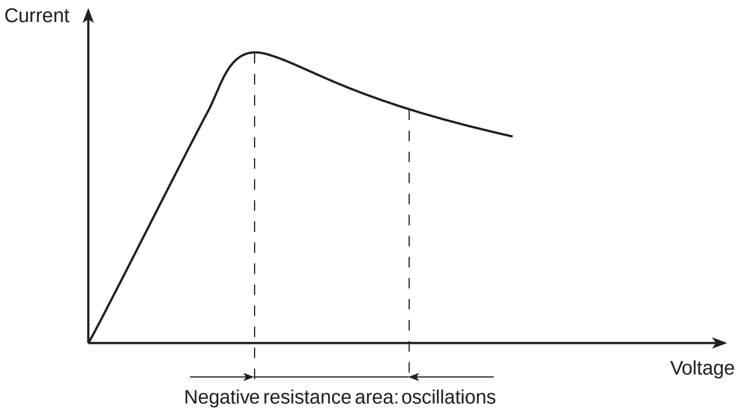


Figure 3-1

The assembly represented in figure 3-2 is such that it can be plotted and its characteristic appearance can be brought to the fore.

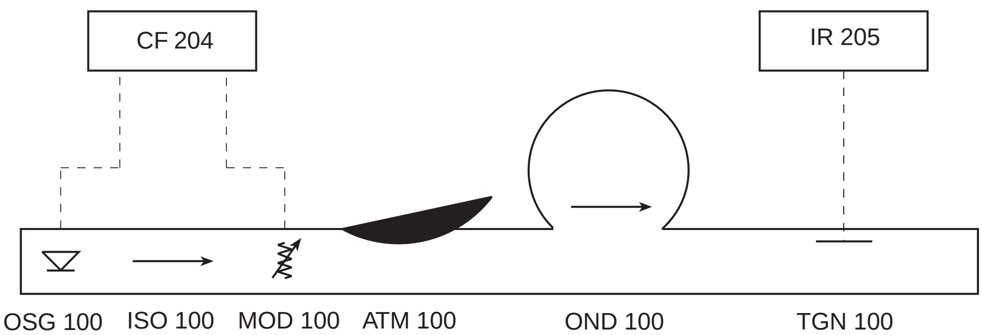


FIGURE 3-2

Once assembling is finished, proceed as follows:

- Turn the «OSC GUNN» CF 204 power supply unit voltage control knob anticlockwise as far as its limit stop (supply voltage ≥ 0 V).
- Progressively increase the voltage by increments of 0.5 V, then read and note down the corresponding current (direct reading on the galvanometers of the CF 204A power supply unit).
- Plot the «current-voltage» characteristic of the Gunn-effect diode and compare it to the one in figure 3-1.

5.1.4 Reading the power-frequency characteristic of the Gunn-effect oscillator

The frequency of the wave generated by the Gunn oscillator is measured so that its «displacement-frequency» characteristic can be read; indeed, the resonance frequency depends on the volume of the cavity determined by the position of the mobile short circuit.

The frequency is adjusted as follows:

- Consult the calibration curve of the OND 100 frequency meter and position its micrometer on the value corresponding to the desired frequency.
- Turn the control micrometer on the Gunn oscillator until the frequency is tuned and, consequently, the «displacement-frequency» reading is obtained.
- Carry the «displacement-frequency» correspondance points onto a graph and plot the curve.

N.B.

- The micrometer shall rotate clockwise if the oscillation frequency is too weak, and in the other direction if it is too high.
- In the vicinity of the resonance, it is recommended that the micrometer be turned slowly.

5.1.5 Reading the power-frequency characteristic of the Gunn-effect oscillator (optional extra)

In the same way, the power is read with respect to the oscillation frequency in order for its graph to be plotted.
The assembly shown in figure 3.3 is set up.

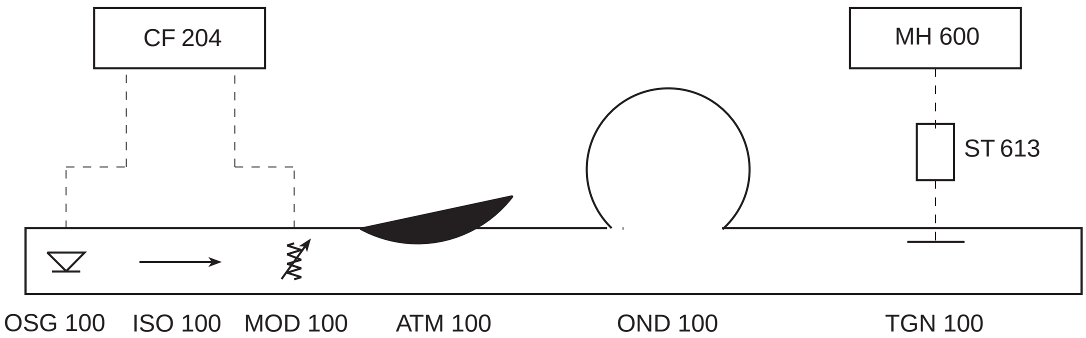


Figure 3.3

- Position the ORITEL ATM 100 attenuator on 10 dB.
- Remove the square signal modulation on the ORITEL CF 204 and suppress the attenuation by means of the level control knob.
- Energize the ORITEL CF 204 power supply unit.
- Read the power indicated by the ORITEL MH 600 milliwattmeter.
- Multiply this value by 10 in order to obtain the power actually supplied by the Gunn oscillator, so as to take into account the attenuation of 10 dB introduced by the ORITEL ATM 100 attenuator.
- Measure the frequency provided by the Gunn oscillator using the ORITEL OND 100 wavemeter.
- Carry the power measured with respect to the frequency over onto a graph.
- Read several points in the frequency band: 8.5 GHz - 9.6 GHz.

5.2 Measuring the standing wave ratio

5.2.1 Introduction

The standing wave ratio (SWR) is a parameter which is commonly used to characterise a load impedance on a line, in the same way as the voltage reflection coefficient to which it is linked.

The SWR is easy to obtain by means of the slotted line.

5.2.2 A summary of the theory on which the experiment is based

■ Definition

The voltage E at any point whatever of the transmission line can be considered as the sum

$$Ei + Er$$

of the voltages of the incident waves (Ei) and reflected waves (Er) at this point. It leads to a distribution of voltage along the line, which is called «standing wave».

Indeed, at certain points on the line, the voltages of both Ei and Er waves are in phase and they add to each other, thereby producing voltage maxima, whereas at other points they are in antiphase and they subtract from each other, thereby producing voltage minima.

The difference between the maxima and minima is all the greater as the load impedance Z moves away from the value of the wave impedance characteristic of the line Z_0.

In the particular case in which $Z = Z_0$, there is no standing wave and the voltage amplitude is constant along the whole line.

The distance between two consecutive minima or maxima is equal to half the wavelength λg in the line, i.e. $\lambda g/2$.

During the journey $\lambda g/2$, only one wave undergoes a phase shift equal to π radians.

The ratio between a voltage maximum and minimum is called the «standing wave ratio» (SWR).

Let S be this parameter.

$$S = \frac{E\ max.}{E\ min.} = \frac{|Ei| + |Er|}{|Ei| - |Er|} = \frac{1 + |Er/Ei|}{1 - |Er/Ei|}$$

The complex reflected wave to incident wave ratio is called the voltage reflection coefficient and is represented by the symbol "Γ".

$$\Gamma = \frac{Er}{Ei}$$

The relationship between the voltage reflection coefficient value and the standing wave ratio S is:

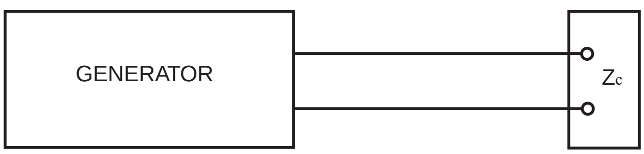
$$\Gamma = \frac{S - 1}{S + 1}$$

$$S = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

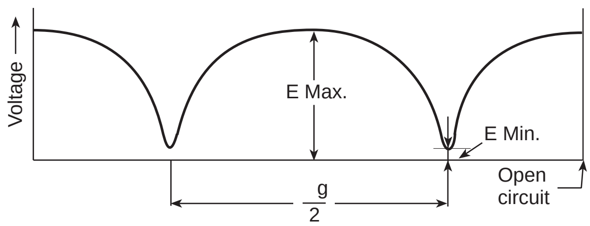
If the line has no attenuation, the standing wave ratio is the same everywhere and its value is determined by the load impedance reflection coefficient.

However, if the line has losses, the standing wave ratio diminishes progressively along the waveguide line from the source towards the load.

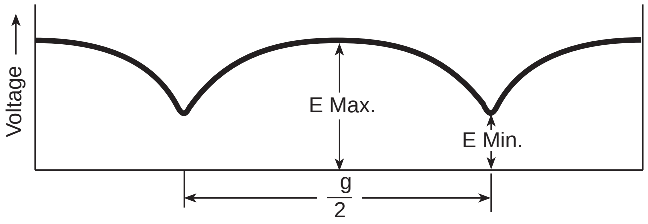
■ Distribution of standing waves with respect to the loads



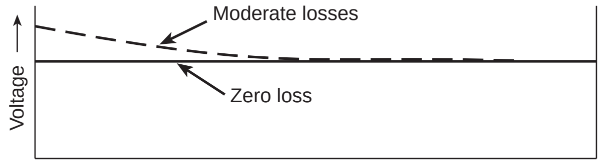
a) Line with generator and load



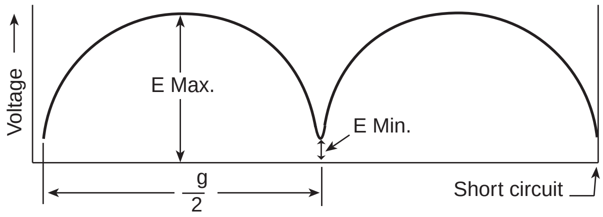
b) Load in open circuit: $Z_c = \infty$



c) Moderately high load impedance: $\infty < Z_c < Z_0$



d) Load impedance equal to the characteristic impedance: $Z_c = Z_0$



e) Short circuit load impedance: $Z_c = 0$

■ Percentage of reflected power with respect to the SWR

The standing wave is created by the fact that an incident wave is reflected by the load impedance.

This reflected power, which is not absorbed by the load, can be considered as lost for transmission.

It is therefore interesting to put a figure to this lost power with respect to the standing wave ratio.

This loss can be represented by the power reflection coefficient «ρ», which corresponds to a percentage of reflected power compared with the incident power:

$$|\rho| = 100 \left| \frac{Er}{Ei} \right|^2$$

since the power associated with the incident and reflected waves varies as does the field strength square.

$$|\rho| = 100 \left| \frac{S - 1}{S + 1} \right|^2$$

■ Using a slotted line to measure the SWR

It is known that the standing wave of a transmission line depends on the load seen by the line and its characteristic impedance. The resulting standing wave is detected by means of a waveguide section having a longitudinal slot on the large side.

The measuring probe is made to move by a carriage.

The role of the probe is to draw voltage along the line. It is made up of a coaxial line element, one end of which acts as an antenna. The latter penetrates the guide through the slot, parallel to the electric field; the microwave energy thus collected is transmitted to the coaxial part of the probe, inside which is located the detector diode.

The penetration depth of the antenna into the waveguide shall be set to the minimum in order not to interfere with the standing wave to be measured.

The loss of sensitivity shall in that case be compensated by changing the ORITEL IR 205 SWR indicator's measuring range.

Standing wave distribution is obtained by moving the carriage along the slot and observing the resulting variation in the detected current. The penetration depth of the probe in the waveguide remains constant when the carriage moves along the line. A graduated scale makes it possible to determine very accurately the position of the probe in relation to the end of the line where the unknown impedance is connected.

⚠ **CAUTION: When the penetration depth of the antenna is adjusted**, the detector and antenna assembly may inadvertently be removed. With the antenna being very fragile and the diode sensitive to electrostatic discharges, take great care when fitting the assembly back in. In the event of damage to the detector and antenna assembly, it is possible to replace it.

5.2.3 Measuring the SWR by means of the slotted line: Direct method

Set up the assembly in figure 2.3

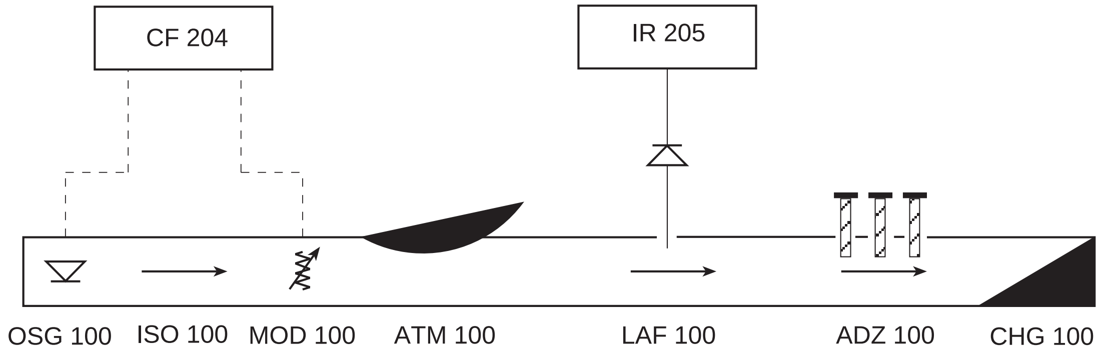


Figure 2.3

An SWR adaptor, of the ORITEL ADZ 100/3 type, is inserted between the termination and the slotted line; through «mismatching», it enables various SWRs to be obtained.

- Adjust the penetration depth of the SWR adaptor's screws.
- Adjust the ORITEL ATM 100 variable attenuator, in order to obtain a correct deviation on the galvanometer of the ORITEL IR 205 SWR indicator.
- Move the probe belonging to the LAF 100 line, and note down the max. I_d and min. I_d indications (see § 3.3.5).

The detection can be considered to be quadratic when the level detected is very low.

We can then write: $$SWR = S = \frac{I_d \text{ max.}}{I_d \text{ min.}} = \frac{V \text{ max.}}{V \text{ min.}}$$

Several manipulations can be carried out for different penetration depths of the SWR adaptor's reflector.

5.2.4 Measuring high standing wave ratios

- **Calibrated attenuator method**

When the standing wave ratio to be measured is higher than 3, the traditional slotted line way of measuring, which consists in measuring the V max./V min. ratio, is marred by mistakes. The detector law cannot be considered as uniform over a wide dynamic range.

The method described below consists in measuring this ratio by means of a calibrated attenuator.

- Set up the assembly in the following figure:

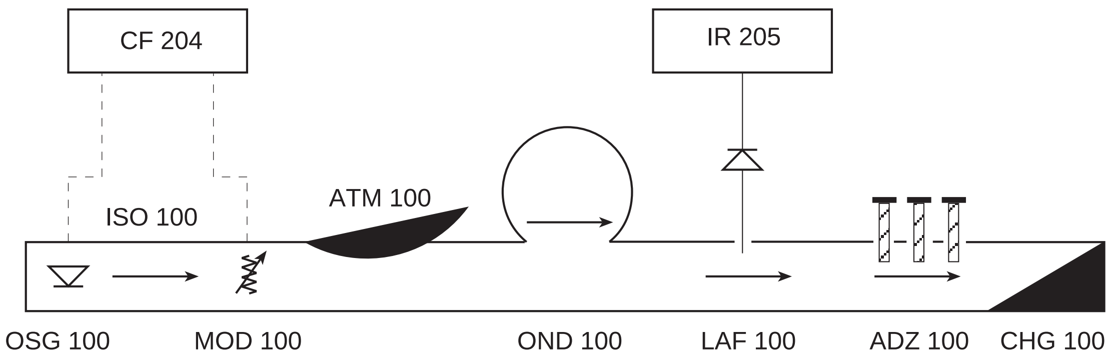


Figure 2.4

- Screw the SWR adaptor screws well down.
- Place the probe on a minimum and adjust the microwave level by means of the ORITEL ATM 100 attenuator in order to obtain a clearly readable D_1 deviation. Note down the A_1 value of the attenuator.
- Place the probe on a maximum. Adjust the attenuation so as to bring the indicator to the same D_1 value as previously. Note down the new A_2 value of the attenuator.

The difference in attenuation between these two minimum and maximum positions gives the standing wave ratio expressed in dB. The corresponding voltage ratio gives the value of the standing wave ratio.

$$A_2 - A_1 = 20 \log_{10} (\text{V Max./V min.}) = 20 \log_{10} S \quad \text{ou} \quad \frac{A_2 - A_1}{20}$$

■ **Measuring line method**

Another method can be used for measuring high standing wave ratio values.

In order to carry out this measurement correctly, the error caused by the probe coupling - compounded by an error due to variations in the reading law of the Schottky barrier diode used - must be eliminated. Generally speaking, the detector used is a crystal. The method boils down to measuring the distance between two points which have an amplitude twice that of the minimum.

Set up the following assembly:

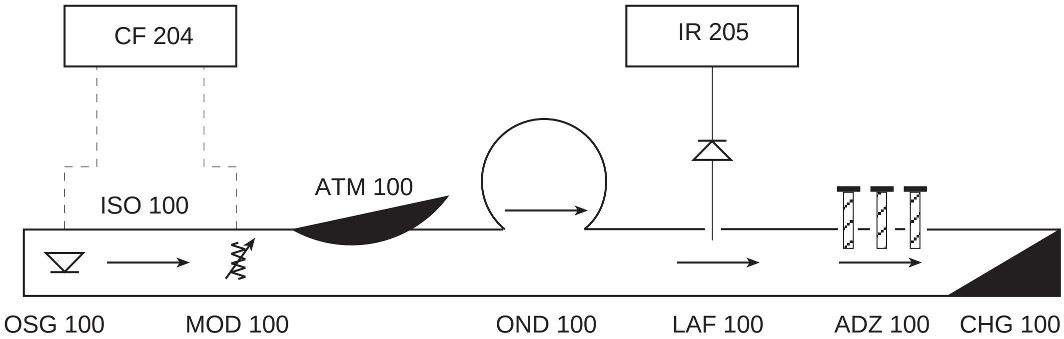


Figure 2.5

- Screw the SWR adaptor screws well down.
- Place the probe on a minimum and adjust the microwave level by means of the ORITEL ATM 100 attenuator in order to obtain a readable deviation.
- Attenuate the power transmitted in the line by 3 dB by adjusting the ORITEL ATM 100 attenuator.
- Move the probe on either side of the minimum and note down the distances d_1 and d_2 (see § 3.3.5) corresponding to the points A and B, which have the same amplitude as that of the previous minimum (fig 3.4).

  In order to obtain the standing wave ratio value, you just have to introduce the following distance: $d = d_1 - d_2$

  into the following equation:

$$S = \sqrt{1 + \frac{1}{\sin^2 \frac{(\pi d)}{\lambda g}}}$$

with λg being the wavelength in the waveguide, measured by means of the line.

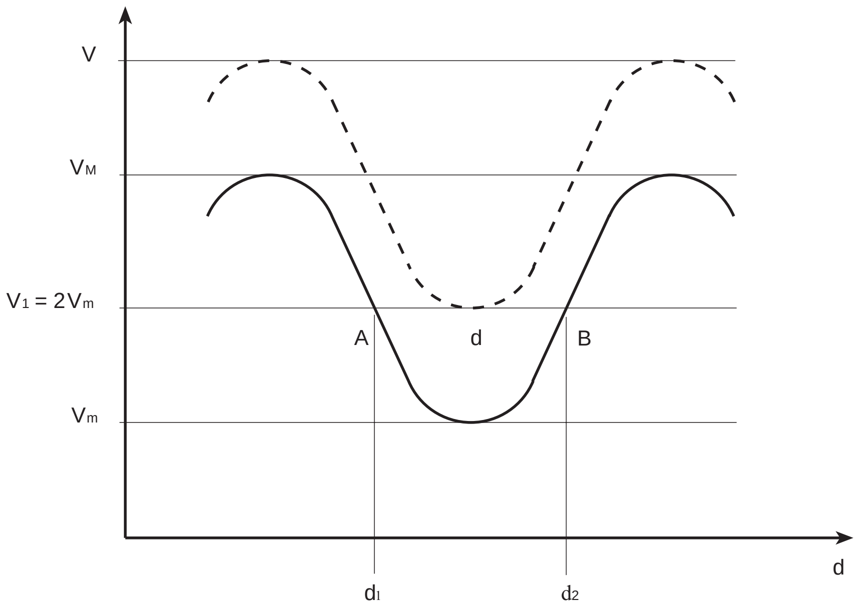


Figure 2.6

5.3 Studying the wavelength

5.3.1 Introduction

Because of the fact that frequency measuring methods call on complex instrumentation, it is often useful to be able to measure the wavelength in a simple fashion.

5.3.2 A summary of the theory on which the experiment is based

The frequency and wavelength of an electromagnetic wave are linked to the speed at which this wave propagates in the environment, as expressed by the following equation:

$$f \lambda = v \qquad (1)$$

with:
- f : frequency
- λ : wavelength
- v : electromagnetic wave propagation speed

The propagation speed depends on the characteristics of the environment: its permittivity (ε) and its permeability (μ).

In the open air, the propagation speed is given by:

$$v_0 = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \qquad (2)$$

with μ_0 and ε_0 being respectively the permeability and permittivity of the open air.

$\mu_0 = 4 \pi 10^{-7}$ H/m (Henry per metre)

$\varepsilon_0 = (1/36 \pi) 10^{-9}$ F/m (Farad per metre)

It should be remembered that μ_0 is in the region of one microhenry per metre and ε_0 in the region of 10 picofarads per metre.
For any environment whatsoever:

$$v = \frac{V_0}{\sqrt{\mu_r \varepsilon_r}} \qquad (2)$$

with :

$$\mu_r = \frac{\mu}{\mu_0}$$ relative permeability of the environment

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$ relative dielectric constant (permittivity) of the environment

For most cases:

$$\frac{\mu}{\mu_0} = 1$$

and :

$$v = \frac{v_0}{\sqrt{\varepsilon_r}} \qquad (4)$$

consequently:

$$\lambda = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \qquad (5)$$

with :

λ_0: wavelength in the open air

λ : wavelength in an ε_r dielectric constant environment

In the air, the propagation speed is very close to that in a vacuum, i.e. 3.10^8 m per second.

It should not be forgotten that in guided propagation conditions, the wavelengths λ_0 (in free space), λ_g (in the waveguide) and λ_c (at the cut-off point) are linked by:

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

with $\lambda_c = 2a$ for the TE_{10} fundamental mode, a = 22.86 mm.

For a predetermined frequency, the apparent wavelength in the waveguide (λ_c) is therefore greater than the wavelength either in the open air (λ_0) or in a coaxial transmission line.

There is also:

$$\lambda_g = \frac{\lambda_0}{\sqrt{1 - \left[\frac{\lambda_0}{2a}\right]^2}}$$

et :

$$V_p = \frac{v_0}{\sqrt{1 - \left[\frac{v_0}{2\,af}\right]^2}}$$

This is the TE_{10} mode phase speed in the waveguide filled with air.

Furthermore, since:

$$\lambda_0 = \frac{v_0}{f}$$

$$\lambda_g = \frac{v_p}{f}$$

The frequency can be determined from the wavelength by:

$$f = \frac{v_0 \sqrt{\lambda_g^2 + 4\,a^2}}{2\,a\,\lambda_g} \qquad (8)$$

It therefore suffices to measure the wavelength in the waveguide (λ_g) to obtain f, or vice versa.

5.3.3 Measurements

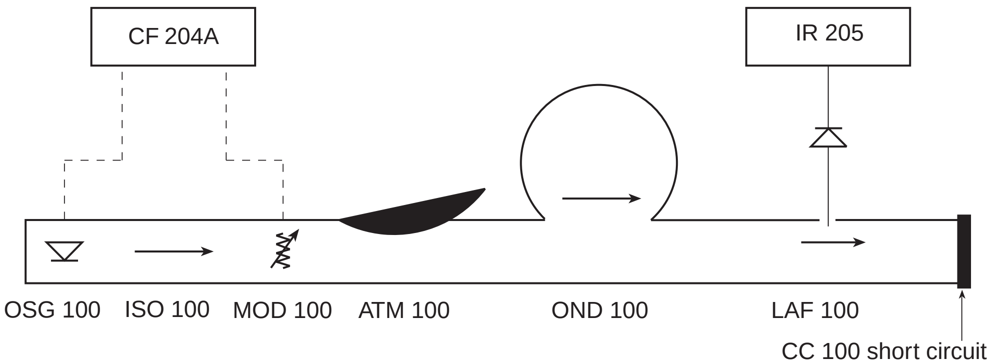
The method used is that whereby a direct measurement is performed on a standing wave. The accuracy obtained is approximately 0.05%.

To this effect, a slotted line is used to determine the divergence between two maxima (or two minima) on a transmission line in which a partition of the standing wave has been induced.

Indeed, it is known that - in the standing wave process - the wavelength in the line (λ_g) corresponds to twice the physical length between two «antinode points» or two «node points» of voltage.

The wavelength in the air as well as the frequency can be deducted from the λ_g measured value by using the expressions given in paragraph 4.3.2.

Set up the assembly in the figure below.



- Set the Gunn oscillator to a frequency f.
- Place the ORITEL ATM 100 attenuator to its maximum attenuation capability, set tuning to the maximum of the detected current, actuate the attenuator in order to bring up a clearly visible read-out on the scale on the galvanometer belonging to the IR 205.
- Move the probe carriage along the ORITEL LAF 100 line and observe the partition of the standing wave.
- Note down the number of maxima visible, e.g. 3.
- Make an accurate note of the position of the first and third maximum.
- The divergence between the first and third maximum is equal to λ_0.
  In order to note down accurately the position of a maximum, take a mean value between two points of equivalent amplitude on either side of the maximum.
- Calculate λ and f.
- Compare f found to f measured using the OND 100 wavemeter.

5.4 Measuring impedance

5.4.1 Introduction

The aim of this set of experiments is not limited to determining the impedance of the terminal load of a transmission line; it also enables us to become acquainted with the Smith chart.

This chart makes it possible to know the value of an impedance at a given point. The L/λ_g shifts, reactances and resistances are defined by families of curves.

All these parameters are calculated or determined in a transmission line by the use of a slotted line.

5.4.2 A summary of the theory on which the experiment is based

■ Reflection cœfficient - Standing wave ratio

Let us consider a transmission line, with a characteristic impedance Z_0, terminated by a load impedance Z_c. The reflection cœfficient, meaning the reflected wave-incident wave ratio at the Z_c level, is expressed as:

$$\rho = \frac{Z_c - Z_0}{Z_c + Z_0}$$

Broadly speaking, Z_c is complex and has the form:

$$Z_c = R + jX$$

with the result that ρ is a complex number having the form:

$$\rho = |\rho| e^{j\theta}$$

The amplitude $|\rho|$ gives the reflected and incident wave amplitude ratio, and the phase θ gives the phase angle rotation during reflection.

The voltage E, at any point whatever in the line, can be considered as the sum ($E_i + E_r$) of the voltages of the incident and reflected waves at this point. This leads to voltage distribution over the line which is called standing wave partition.

Indeed, at certain points along the line, the voltages of the two waves are in phase and they add to each other, producing voltage maxima; at other points they are in antiphase and they subtract from each other, thereby producing voltage minima.

The ratio between the value of a voltage maximum and that of a voltage (or current) minimum is called the «***standing wave ratio***». Let S be the SWR.

By definition :

$$S = \frac{E_{Max.}}{E_{min.}}$$

with $$E_{Max.} = |E_i| + |E_r|$$

and $$E_{min.} = |E_i| - |E_r|$$

hence :

$$\frac{E_{Max.}}{E_{min.}} = \frac{1 + \frac{|E_r|}{|E_i|}}{1 - \frac{|E_r|}{|E_i|}}$$

Now, the vectorial ratio:

$$\frac{|E_r|}{|E_i|}$$

is the reflection cœfficient module « ρ»; the « ρ « to « S « ratio is given by:

$$|\rho| = \frac{S - 1}{S + 1}$$

or

$$S = \frac{1 + |\rho|}{1 - |\rho|}$$

Thus, S varies between 1 (perfect adaptation) and + ∞ (short or open circuit).

The phase angle rotation θ results in a shift of the whole standing wave assembly, and, if the distance between the impedance Z and the first voltage minimum is «d», we can write:

$$\theta - 2 \frac{2 \pi d}{\lambda g} = - \pi$$

The problem comes down to obtaining Z, in module and in phase, from elements which can be measured on the waveguide. The R and X values are obtained on a chart known as the Smith chart.

Using the Smith chart

Definition

We can express the impedance of a load reduced to the characteristic impedance of the line in the form of its standardised (or reduced) value.

$$z = \frac{Z}{Z_0}$$

It is linked to the reflection cœfficient on the load plane by the equation:

$$\rho = \frac{z - 1}{z + 1}$$

The reciprocal equation enables Z to be expressed in relation to ρ.

$$Z = \frac{1 + \rho}{1 - \rho}$$

The Smith chart is a diagram which makes this direct crossover, one with no calculus, possible. It gives both the polar representation (ρ, θ) of the reflection coefficient, with the outer circle being the unit, and, directly, the standardised value of z via its real r (standardised resistance) and imaginary x (standardised reactance) components.

Four types of loci can be singled out:
- constant and positive resistance circles (circle r)
- constant reactance circles (circle x)
- constant attenuation circles or constant standing wave ratio circles (circle u)
- constant phase radius lines.

Standardised impedance and admittance

Every uniform transmission line is characterised by four parameters reduced to the unit of length:

The resistance	: R	Distributed parameters
The self-induction coil	: L	
The capacitance	: C	
The conductance	: G	

The characteristic impedance Z_0, practically independent from the frequency, is a pure resistance value:

$$Z_0 = \sqrt{\frac{L}{C}}$$

The attenuation by unit of length is defined using the coefficient α, generally expressed in dB per unit length.

The wavelength in the waveguide line (λ_g), which can be different from the wavelength in the air (λ_0), shall be used for measurements on the line.

It should not be forgotten that impedance is a complex quantity:

$$Z = R + j X$$

with :

R : Resistance
X : Reactance (reactive component)

If X > 0 The reactance is inductive (self-induction coil)

If X < 0 The reactance is capacitive (capacitance).

Using the Smith chart requires that the values of the resistances, reactances and shifts be standardised beforehand.

The shifts are reduced to the wavelength. The L/λ parameter, which corresponds to the phase expressed in degrees, is therefore used:

$$\theta = \frac{L}{\lambda_g/2} \times 360$$

The same diagram can be used to calculate the admittances by replacing the resistance with the conductance and the reactance with the susceptance:

$$Y = \frac{1}{Z} = G + jB$$

B and G are, respectively, the susceptance and the conductance expressed in terms of standardised admittance:

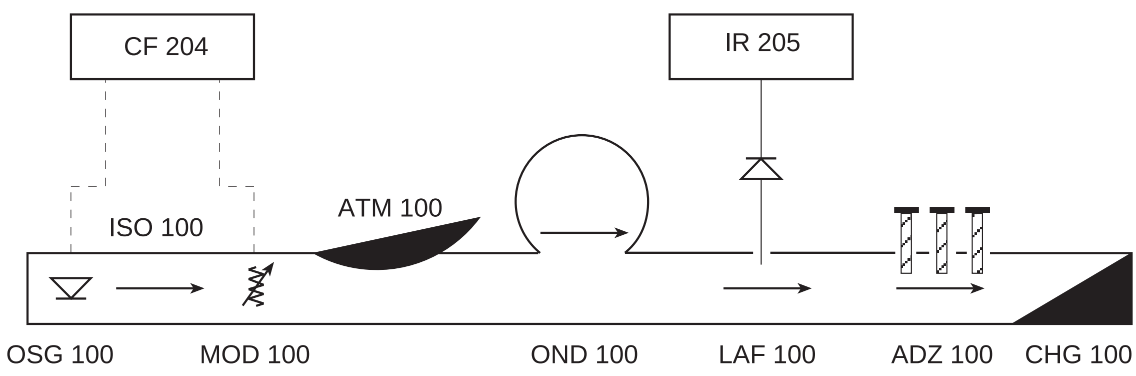
$$Y_0 = \frac{1}{Z_0}$$

$$Y = \frac{G}{Y_0} \pm j \frac{B}{Y_0}$$

$$= G \pm jB$$

5.4.3 Measuring an impedance placed at the end of a line with no loss, with a characteristic impedance Z_0.

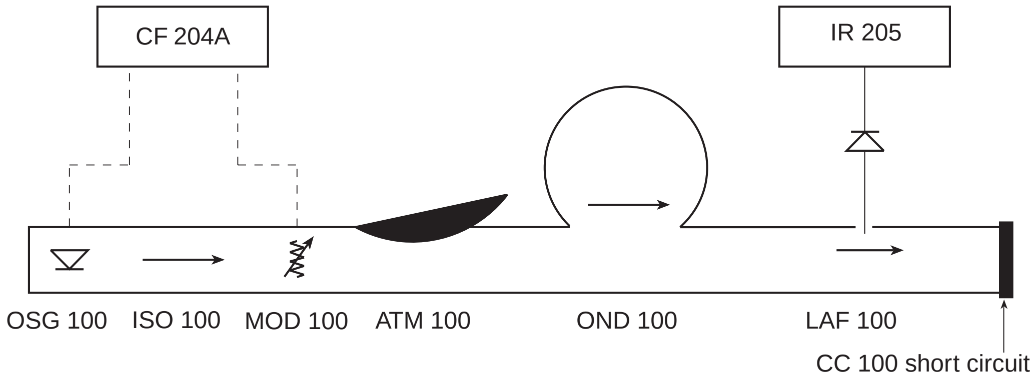
Set up the assembly in the figure below.



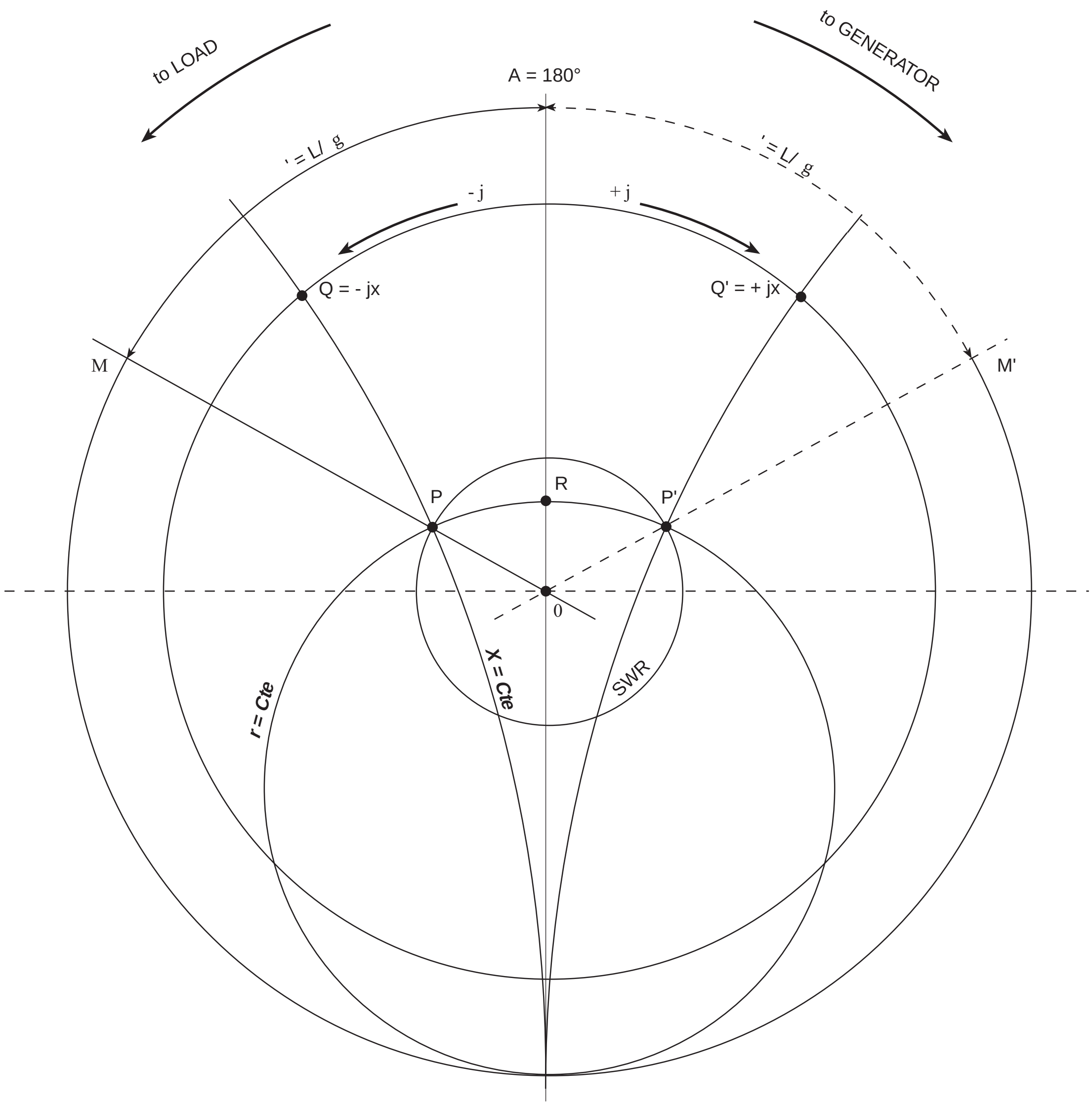
- Place the component whose impedance is to be measured (in this case a load preceded by a SWR adaptor) right at the end of the line.
- Measure the standing wave ratio.

- Plot the corresponding circle on the diagram (value of the standing wave ratio on the real axis starting out from the centre of the diagram).
- Look for the voltage minimum which is closest to the load, i.e. identified by the letter A.
- Replace the component to be measured by a short circuit (the plane of the short circuit corresponds to the point A = 180° on the diagram); see the figure below.

  By moving the carriage, look for the minimum which is closest to the identification letter A, i.e. B.



- Determine L = A - B
- Determine λ_g, the wavelength in the waveguide
- Deduce L/λ_g



- If the minimum L shifted towards the generator, turn backwards on the diagram from point A = 180° (in the direction of the generator) following the quantity α' (or L/λ_g). The corresponding point is the point M' (see the figure on the previous page).
  If, on the contrary, the shift happened towards the load, turn forwards on the diagram (in the direction of the load) following the quantity α' (or L/λ_g). The corresponding point is the point M.
- Draw a straight line joining the centre of the diagram to M (or M'):
  This straight line cuts the standing wave ratio circle at a point P (or P');
  The following pass through this point P (or P'):
  a) a constant reactance circle giving the value jx of the impedance; the corresponding point is the point Q
  b) a constant resistance circle giving the real value r of the impedance; the corresponding point is the point R.
  What we have is the reduced impedance:

  $$z = r - j\,x$$

  By following the same line of reasoning as above, in the case whereby $\alpha' = L/\lambda_g$ shifted backwards (in the direction of the generator), the points R and Q' are determined.
  In which case, the reduced impedance is expressed as:

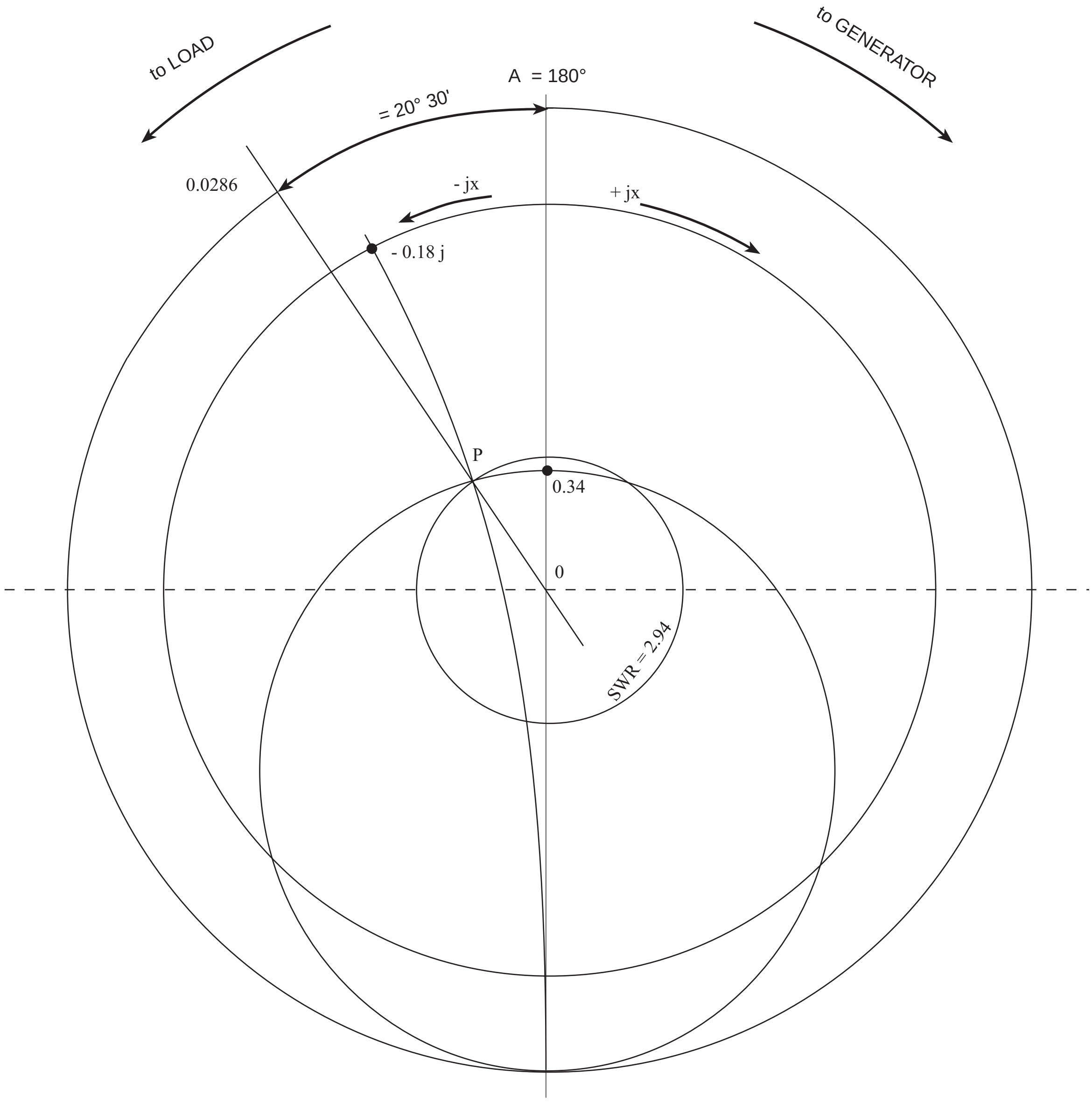
  $$z = r + j\,x$$

  hence :

  $$Z = Z_0\,(r + jx)$$

■ Example of application

Let us take a transmission line on a waveguide with a characteristic impedance Z_0, and, at the end, an unknown impedance Z (see figure below).
- λ_g measured on a line: 45.45mm (9,300 MHz)
- L: 1.3 mm
- SWR: 2.94



$L/\lambda_g = 1{,}3 / 45{,}45 = 0{,}0286$

- From the point A = 180° on the diagram, carry forward in the direction of the load, on the (L/λ_g) circle, the quantity: $L/\lambda_g = 0.0286$. The corresponding point is point M

$$L/\lambda g = \frac{720 \times 1{,}3}{45{,}45} = 20° \, 30'$$

- Plot the 2.94 standing wave ratio circle
- Draw a straight line joining 0 to the point M.
  This straight line cuts the standing wave ratio circle at a point P.
  The constant X circle going through P gives:
  $jx = j\,0.18 = X/Z_0$
  $r = 0.34 = R/Z_0$
  The impedance will be expressed as:
  $Z_u = Z_0\,(0{,}34 - 0{,}18\,j)$

5.5 Measuring frequency

5.5.1 Introduction

The aim of this manipulation is to directly obtain the frequency emitted by the microwave source.
To achieve that, a freqency meter or a wavemeter is used.

5.5.2 A summary of the theory on which the experiment is based

A method for directly measuring microwave frequency requires using a wavemeter.

An absorption wavemeter comprises a rectangular waveguide section having, in parallel, a coupled cylindrical resonant cavity.

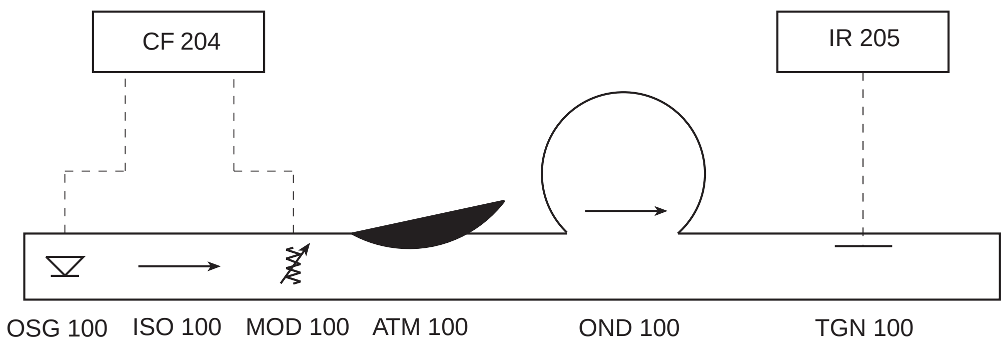
The volume of the resonant cavity is changed by the shifting of a short circuit, thereby bringing about a change in the resonance frequency.

When the frequency generated by the oscillator corresponds to the tuning frequency of the wavemeter (resonance), the microwave energy transmitted via the straight waveguide section is absorbed by the resonant cavity. the tuning is then highlighted by a drop in the power level. The frequency is measured by means of a micrometer graduated in hundreds of millimeters.

A calibration curve makes it possible to determine a frequency depending on the shift indicated by the micrometer.

5.5.3 Measuring frequency

Set up the assembly in the figure below.



Turn the micrometer screw on the ORITEL OND 100 wavemeter until you obtain an absorption of the microwave energy characterised by a sudden deviation to zero of the galvanometer reading. Read the position indicated by the micrometer screw, with the galvanometer reading being as close as possible to zero.

- Once the position is identified, refer to the calibration curve provided with the wavemeter in order to determine the frequency.

N.B.

Once the measurement has been carried out, do not leave the ORITEL OND 100 wavemeter on its resonance frequency so as not to needlessly attenuate the microwave energy.

5.6 Experimental determination of a detector's quadratic law

5.6.1 Introduction

The crystal diode enables microwave energy to be detected. It is a non-linear element (governed by quadratic law), whose characteristic we are going to determine experimentally.

The minimum detectable signal level of a crystal diode, which is estimated by measuring its sensitivity, is also an important parameter.

5.6.2 A summary of the theory on which the experiment is based

The crystal enables the microwave electric field to be detected and consequently its power to be measured.

The principle of this detection is based on the non-linearity of the crystal's junction resistance.

Let v_0 be the polarisation voltage and v the signal to be detected. We can consider that the variations in current are small around the polarisation point and link them to the corresponding variations in voltage through a second-degree equation:

$$i_{(v_0 + v)} = i_{(v_0)} + \frac{di}{dv}\bigg|_{(v_0)} v + \frac{1}{2}\frac{d^2i}{dv^2}\bigg|_{(v_0)} v^2$$

If the element were linear, we would simply have:

$$i_{(v_0 + v)} = i_{(v_0)} + \frac{v}{R}$$

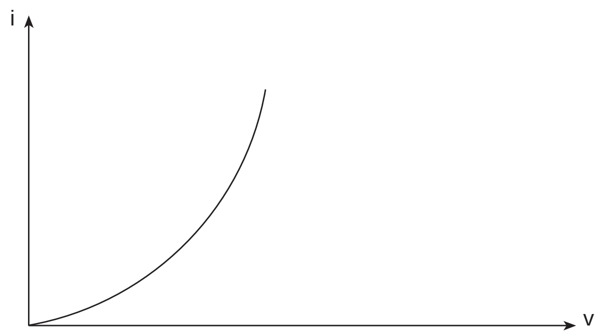
Let v = V cos ωt

$$i_{(V_0 + V\cos\omega t)} = i_{(v_0)} + v\frac{di}{dv}\bigg|_{(v_0)} \cos\omega t + \frac{V^2}{2}\frac{d^2i}{dt^2}\bigg|_{(v_0)} \cos^2\omega t$$

or :

$$\cos^2\omega t = \frac{\cos 2\omega t + 1}{2}$$

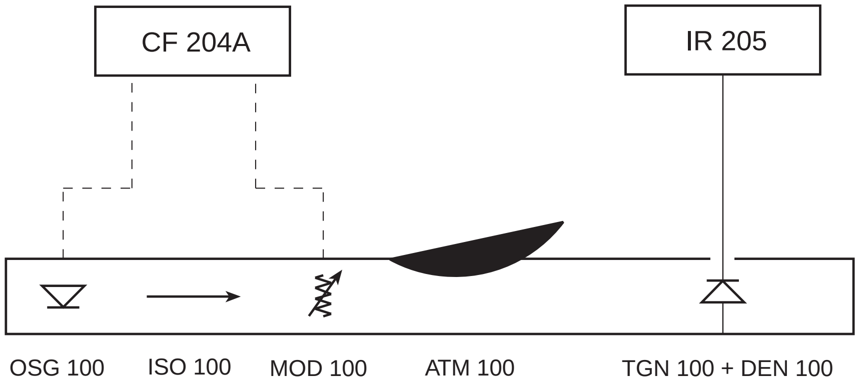
The current-voltage law therefore includes a V^2 term, DC component of the current, proportional to the square of the microwave electric field. The detection is quadratic (figure below).



5.6.3 Observing and recording the characteristic

The method consists in observing and recording the crystal current detected depending on the microwave level applied.

Set up the assembly in the figure below.



- Place the ORITEL ATM 100 attenuator on position A_1 = 0 dB; note down the I_1 reading given by the ORITEL IR 205 SWR indicator.
- Increase attenuation by increments of 3 dB and note down the value I_i indicated by the IR 205 for each position A_i.
- Continue in this way in order to obtain the greatest number of points, and plot the voltage curve detected in relation to dB attenuation.

  Using the detector thus calibrated, we can determine a level or an attenuation depending on the level recorded on the galvanometer.

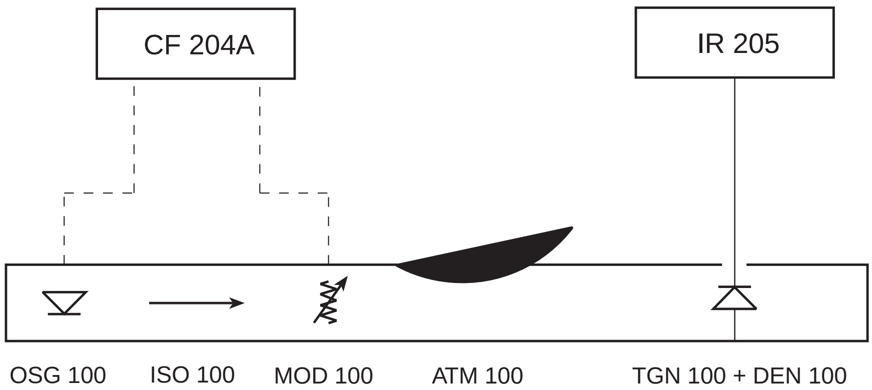
5.6.4 Measuring the tangential sensitivity of the detecting crystal

The tangential sensitivity of a detector is the level of power injected (in dBm) necessary to distinguish the signal detected from the noise.

We determine it by bringing it to the level of the lower part of the noise superimposed on the detected signal (S+N) with the top part of the noise on its own (N).

Another definition consists in considering that S_T is the power corresponding to a Signal/Noise ratio of 2, i.e. 6 dB in voltage or 3 dB in power.

Set up the assembly in the figure below.



- Go into maximum attenuation with the ORITEL ATM 100 attenuator.
- Set the ORITEL IR 205 SWR indicator to maximum sensitivity; adjust the deviation due to the noise to 4 dB using the gain adjusting buttons («Course» and «Fine»).
- Actuate the attenuator in order to bring the pointer of the IR 205's galvanometer back to 10 dB (full scale), i.e. 6 dB in voltage or 3 dB in power above the noise level; determine the level S_T.

  Here the tangential sensitivity is measured for the bandwidth of the IR 205's amplifier. Indeed, the noise level depends on the bandwidth of the measuring chain.

5.7 Measuring power

5.7.1 General aspects

Power measurement is a very important measurement in microwave technology because it enables the values of the energies involved to be determined.

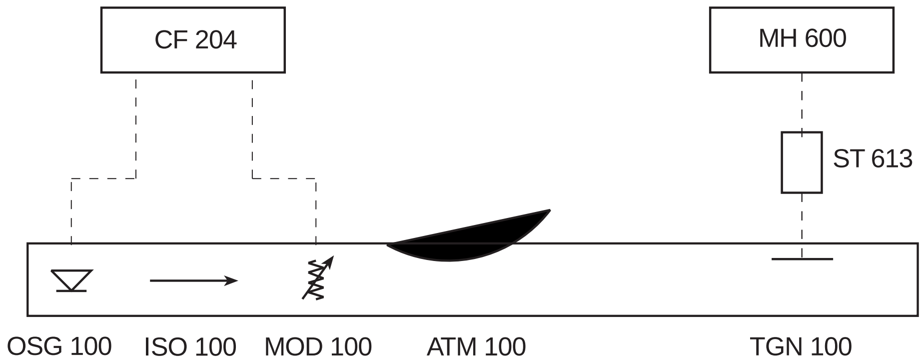
These accurate measurements are easily achieved with the ORITEL MH 600 microwave milliwattmeter fitted with its ST 613 probe.

The principle of this measurement is based on the use of microwave thermistors fitted into a Wheatstone bridge, the imbalance of which is measured. The microwave energy to be measured causes the thermistor to heat, thereby unbalancing the bridge. The imbalance voltage is proportional to the power measured.

For instructions on activation, calibrating the MH 600 as well as the precautions for use, consult the operating manual pertaining to the instrument.

5.7.2 Measuring a power

Set up the assembly in the figure below:



When we do not know the order of magnitude of the power to be measured, it is essential to take certain precautions, in particular so as not to apply a power greater than 200 mW to the measuring probe.

Once the zero point adjustments have been made, we proceed in the following way to measure a power:

- Position the ORITEL ATM 100 attenuator at maximum attenuation.
- Activate the ORITEL CF 204A power supply unit.
- Progressively reduce the ATM 100’s attenuation until the ORITEL MH 600 milliwattmeter gives a reading between 1 and 10 mW.
- Read the power measured in mW or in dBm depending on the unit programmed directly on the screen of the milliwattmeter.

For further information concerning how to use the instrument, the different measurements possible and the possibilities of the ORITEL MH 600 microwave milliwattmeter, refer to the operating manual.

5.8 Measuring attenuation

5.8.1 General aspects

Generally speaking, attenuation expresses a reduction in amplitude, voltage or current, therefore power, caused by an attenuating element being introduced into the circuit.

a) Insertion loss L

In the case of a transmission line whose input and output impedances are different, insertion loss is defined as the ratio, in terms of dB, of the powers dissipated in the load in the absence and presence of the attenuator.
It depends on:
- the characteristics of the attenuator,
- the impedance of the generator,
- the load impedance.

b) Attenuation A

If the attenuator is placed in a known real impedance transmission line, terminated at both ends by a generator and a load adapted to its characteristic impedance, the insertion loss becomes attenuation.

It is defined as follows:

$$A_{(dB)} = 10 \log_{10} P1/P2$$

A = Attenuation in dB
P1 = Power dissipated in the load without the attenuator
P2 = Power dissipated in the load with the attenuator

c) The attenuation constant of a line
Transmission lines with distributed constants, such as waveguides, are characterised by their propagation constant, which is defined by:

$$Y = \alpha + j\beta$$

β : expresses the phase variation along the line in radians; this is the phase constant.
α : expresses attenuation in nepers per unit of length; this is the waveguide attenuation constant.

In all the measurements which will now be described, the attenuation constant α - specific to the waveguide - will be considered to be zero (line without loss).

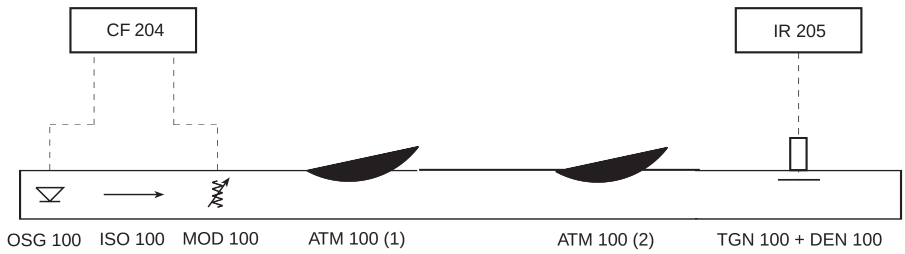
We can mention various measuring methods:
1) Direct measurement:
It consists in determining, experimentally, the powers P1 and P2 and in calculating the ratio

$$A_{(dB)} = 10 \log_{10} P1/P2$$

2) Measurement by substitution or comparison with a calibrated attenuator.

5.8.2 Measurement by comparison

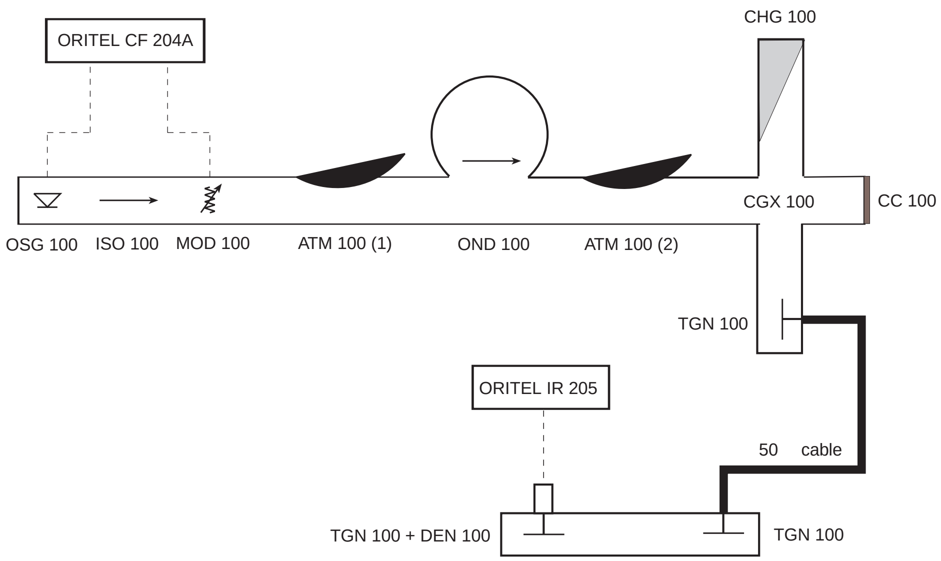
- Set up the assembly shown in the figure below:



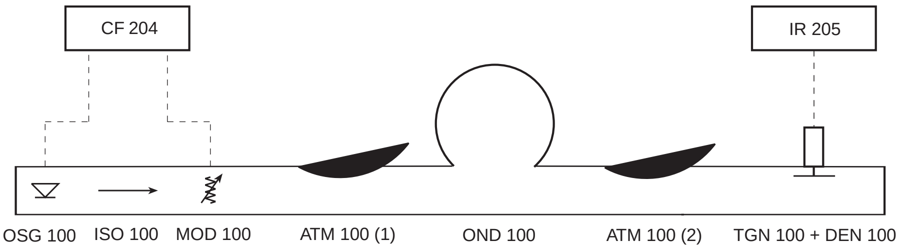
- Place the ATM 100 calibrated antenna (2) at 0 dB.
- Place the ATM 100 attenuator to be calibrated (1) at a certain attenuation and identify the reading on the IR 205's galvanometer, i.e. I_1. Then place this attenuator at 0 dB.
- Actuate the ATM 100 reference attenuator (2) until you obtain the same deviation as previously (I_1) on the IR 205's galvanometer. Read the attenuation in dB directly on this attenuator.
- Begin these measurements again for different attenuation values of the ATM 100 (1), and in that way this attenuator will be calibrated.

5.8.3 Measuring attenuation by substitution

This method enables the insertion loss due to an assembly made up of a coupler and two waveguide-coaxial adaptors connected by a cable to be measured.
- Set up the following assembly:



- Place the ORITEL ATM 100 calibrated attenuator (2) at 0 dB.
- Set the ORITEL ATM 100 calibration attenuator (1) to an attenuation enabling a correct reading to be made on the galvanometer of the ORITEL IR 205's SWR indicator, then identify this indication (I_1 for example).
- Set up the following assembly, keeping the attenuator settings.



- Adjust the ORITEL ATM 100 calibrated attenuator (2) until you obtain the previous indication (I_1).
- Read the attenuation in dB introduced by the ORITEL ATM 100 attenuator (2) in order to know the insertion loss introduced by the coupler, the waveguide-to-coax adaptors and the cable.

This same manipulation can be carried out:
- either with the coupler on its own,
- or with the adaptors and the cable.

Carry out these measurements at several frequency points.

6. MAINTENANCE

For maintenance, use only specified spare parts. The manufacturer will not be held responsible for any accident occuring following a repair done other than by its After Sales Service or approved repairers.

6.1 Cleaning

Before assembling the educational bench's microwave components, make sure no dust is present inside the waveguide.

Caution: do not use a pressurised air jet for fear of damaging certain components.

Do not use solvent, and take precautions when dusting.

6.2 Metrological inspection

It is essential that all measuring instruments are regularly calibrated.
For checking and calibration of your instrument, please contact our accredited laboratories (list on request) or the Chauvin Arnoux subsidiary or Agent in your country.

■ **Repairs under or out of guarantee**
Please return the product to your distributor.

7. TO ORDER

ORITEL BDH R100 microwave educational bench P01.**2751.01**
Delivered with a case to put it away in and this experimentation manual

Options
ORITEL CF 204A power supply unit .... please consult us
ORITEL IR 205 SWR indicator P01.**2705.01**
ORITEL MH 600 microwave milliwattmeter P01.**2501.01**
ORITEL ST 613 coaxial probe with thermocouple P01.**2851.01**
ORITEL ANC 100/15 (15 dB) horn antenna P01.**2753.04**
CGX 100/20 (20 dB) waveguide cross coupler P01.**2753.05**
ORITEL IRIS 100 (20 and 30 dB) coupling irises P01.**2753.06**

Accessories
ORITEL RD 100 line displacement record P01.**2753.02**
ORITEL RS 100 support rail, length: 1 metre P01.**2753.03**
male BNC / male BNC lead, length:1 metre P01.**2951.85**

Replacement parts
ORITEL OSG 100 Gunn diode oscillator P01.**2753.07**
ORITEL ISO 100 ferrite isolator P01.**2753.08**
ORITEL MOD 100 PIN diode modulator P01.**2753.09**
ORITEL ATM 100 micrometer-adjustable variable attenuator P01.**2753.10**
ORITEL OND 100 curve frequency meter P01.**2753.11**
ORITEL LAF 100 slotted line P01.**2753.12**
ORITEL ADZ 100/3 three-screw impedance adaptor P01.**2753.13**
ORITEL TGN 100 waveguide-to-coax adaptor P01.**2753.14**
ORITEL DEN 100 coaxial detector P01.**2753.15**
ORITEL CHG 100 termination P01.**2753.16**
ORITEL CC 100 short circuit platelet P01.**2753.17**
ORITEL SUP 100 waveguide support P01.**2753.18**
ORITEL DEL 100 detector for slotted line (LAF 100) P01.**2753.19**
Empty case in which to put the instrument away P01.**2980.54**
Gunn diode for ORITEL OSG 100 oscillator P01.**2753.20**
Pin diode for ORITEL MOD 100 modulator P01.**2753.21**
Schottky barrier diode for ORITEL LAF 100 slotted line P01.**2753.22**
ORITEL AFR 100 *EASYFIX* quick fastening adaptor P01.**2753.01**

04 - 2001

Code 688 972 A01 - Ed. 2

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