Angel Vilaseca, HB 9 SLV

Measuring Wavelengths at Microwave Frequencies – Simply and Cheaply

A difficulty which was always cropping up when using microwave equipment was the problem of knowing the frequency of operation. Of course, the solution to the problem is the use of a microwave frequency counter but for most amateurs this lies well outside the bounds of possibility. A further method is the use of an absorption wavemeter but the construction of such an item of test equipment requires care, precision and experience. Also a microwave frequency meter must be used for calibration when it has been constructed!

I then chose another solution which is simple, gives a three-place resolution and costs practically nothing – the Michelson Interferometer.

1.
THE MICHELSON INTERFEROMETER

When two waves from different sources superimpose on each other at the same place, an interference occurs, that is, their amplitudes add. The resultant amplitude depends upon the relative phase difference between the two waves. A constant amplitude is apparent where there is a constant phase difference between the two waves: in other words, they must be **coherent**.

The best way of obtaining two coherent waves is to split a single beam into two divergent beams. The two beams are, from the laws of physics, inherently coherent. The phase difference, as observed from a distant point depends only upon the path length that each beam has to the point where they are made to converge and impinge on each other.

The sketch of **fig. 1** shows Michelson's Interferometer. The beam splitting is carried out by means of a grid which divides the beam into two equal power paths, one directed to reflector A and the other to reflector B. The practical aspects of both grid and reflectors are quite simple and will be dealt with later.

The beam deflected from reflector A is directed back through the grid where it undergoes a further splitting, one part going to a receiver and the other part away to a place of no importance for the moment.

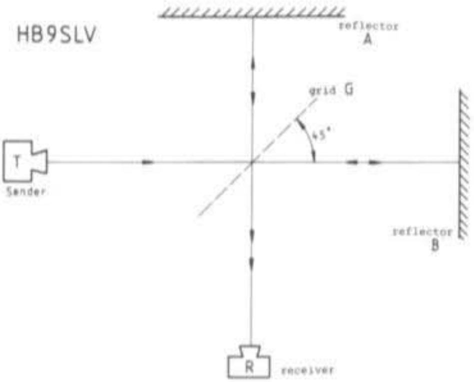

Fig. 1: Principle arrangement of a Michelson Interferometer

Fig. 2: Measurement of the distance between 20 maxima

The beam deflected from reflector B is also divided in the same manner and one of the component beams again directed to the receiver.

Recapping then: a portion of the beam produced by the microwave sender follows the path T-G-A-G-R and another portion follows the path T-G-B-G-R. The receiver will receive a maximum amplitude when both waves are in phase and that occurs when the path length between the two waves differs by a multiple of the wavelength.

If, for example, the reflector B of path T-G-B was moved, but always ensuring that it remained perpendicular to this path-axis, the amplitude at the receiver would go through a series of maxima and minima. The distance the reflector moves between two observed maxima (or minima) amounts to a half wavelength. This may be proved quantitively, see the appendix.

An interferometer was built by the author which worked at a frequency of 10 GHz. At this wavelength – about 3 cm – it is very difficult to measure such a small fraction of a wavelength. This is alleviated by measuring over a distance of 20 maxima – the first one being counted as zero – and dividing by 10, thus effectively increasing the resolution of the measurement of the wavelength (**fig. 2**).

In order to obtain the frequency in GHz, the number 30 is merely divided by the result (in centimetre) found for the wavelength.

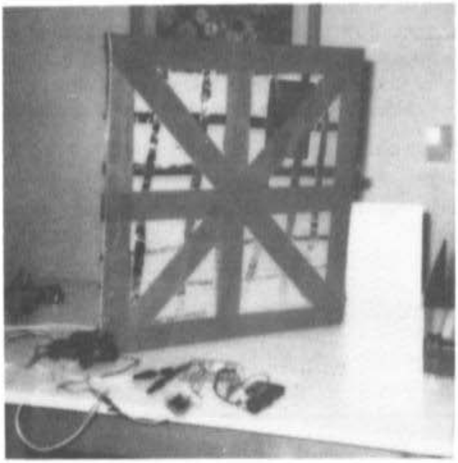

Fig. 3: The grid construction can be clearly seen in this photograph

2.
A PRACTICAL INTERFEROMETER

The main problem when measuring with an interferometer is the unwanted reflections from surrounding objects which affect the reading on the receiver S-meter. For this reason it is better to construct the interferometer away, as far as possible, from vertical reflecting surfaces. This could be on a table in the middle of the room or even in the open air.

The grid is the most critical part of an interferometer. After much searching and experimentation the best results were obtained with a 50 cm x 50 cm square of cardboard which, on one side, was criss-crossed with 2.5 cm strips of aluminium foil about 4 cm apart. These strips may be affixed with adhesive tape (**fig. 3**).

The reflectors were made from ready-to-hand materials. One consisted of a large piece of unetched printed-circuit-board, the copper side towards the microwave source. The other was a 50 cm x 50 cm piece of aluminium sheet. Although it is not absolutely necessary, it would be good practice to use reflectors which are of the same material and size.

Small horn radiators were employed for the sender and receiver directional antennas. The sender produced about 10 mW from a Gunn element. The receiver consisted of a mixer with an MA 41453 crystal. The local oscillator signal was derived, also from a similar Gunn oscillator, and fed to the mixer via a 30 dB directional coupler. The IF amplifier was provided by the use of an FM car radio receiver.

The above mentioned microwave parts originated from a few dis-assembled car RADAR warning detectors. The aluminium die-castings were of remarkably good quality. Each had a horn, a 30 dB cross-coupler, a mixer-diode holder, a resonator with a Gunn element, a microwave choke with tuning screw as well as a special absorber for the excess power from the Gunn element. The mixer diode receives only a thousandth of the 10 mW of produced power owing to the 30 dB coupling loss of the directional coupler.

The only disadvantage of the equipment is that nothing can be soldered to the aluminium die-castings.

3.
MEASUREMENTS

Both the sender and the receiver are switched on and allow some time to thermally stabilize. Also in the interest of a stable frequency, stabilized supplies should be used for all equipment.

The sender and receiver are then both tuned to the test frequency and the system checked for any frequency drift. It is imperative that both receiver and sender remain tuned to each other during the minute or two duration of the test. The selectivity is rather high and therefore any frequency drift can quickly upset the test. High sensitivity is not, however, required owing to the proximity of the test components to each other. It should be therefore possible to use the mixer diode as a detector and thereby eliminate the selectivity. For this the receiver oscillator supply should be disconnected and the current measured between diode and ground. When doing this the usual precautions must be taken to prevent the diode from being destroyed by static charges. These are the same precautions that have to be taken with MOS devices.

The placement of sender, grid, reflectors and receiver is carried out according to the arrangements shown in **figs. 1 and 4**. The distance between the sender and the grid is about 65 cm, and also that between grid and reflector A and reflector B. These distances are not particularly critical.

The reflector B is then moved along axis E-G-B always keeping it perpendicular to the plane of movement. A maximum in the receiver is noted. If the maximum causes an S-meter deflection of more than 60 % FSD, the sender beam should be weakened by some power absorbent material – a stack of telephone books can be placed in front of the sender horn.

The reflector B's position for a maximum is noted for a zero reference and marked on a paper strip

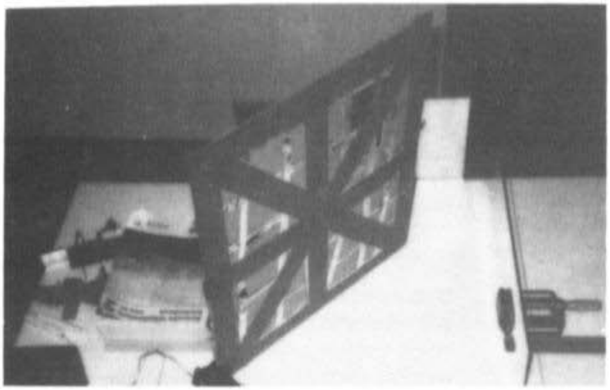

Fig. 4: The author's 10 GHz-range Michelson Interferometer arrangement

which has been previously affixed along the T-G-B axis.

Now the reflector B is again moved along the path T-G-B to the right, keeping the plane of the reflector always perpendicular to the path direction. As previously explained, the S-meter will exhibit a series of maxima and minima as the reflector B is moved. These maxima (the first being counted as zero) are counted and the twentieth marked. The distance to the reference point is now measured and divided by 10 in order to obtain the wavelength in centimetres. The figure 30 is then divided by the test result in cm and the frequency in GHz obtained.

4. APPENDIX

A portion of the beam takes the path T-G-A-G-R and the other portion takes the path T-G-B-G-R. The path-length difference between the two is:

$$\triangle = 2\,GA - 2\,GB = 2\,(GA - GB) \qquad (1)$$

The voltage at the receiver is a maximum when the path difference $\triangle$ is a multiple of a wavelength:

$$\triangle = n\lambda \qquad (2)$$

When reflector B is moved from point B_1 to B_2 – both maxima positions – then:

$$\triangle_1 = 2(GA - GB_1) = n_1\lambda \text{ and}$$
$$\triangle_2 = 2(GA - GB_2) = n_2\lambda \qquad (3)$$

The path-length difference between the two positions is:

$$\triangle_1 - \triangle_2 = 2(GB_2 - GB_1) = (n_1 - n_2)\lambda \qquad (4)$$

That is also a whole multiple of the wavelength λ.

$$\lambda = \frac{2\,(GB_2 - GB_1)}{n_1 - n_2} \qquad (5)$$

λ is included in the wavelength $GB_2 = GB_1$, i.e. the measured distance between the reference and end position of the reflector B.

$n_1 = 0$ and $n_2 = 20$:

In this case equation (5) can be simplified

$$\lambda = \frac{2 \times \text{measured distance}}{20} = \frac{\text{measured distance}}{10} \qquad (6)$$

Example: measured distance = 28.8 cm
wavelength = 2.88 cm
or frequency = 10.4 GHz