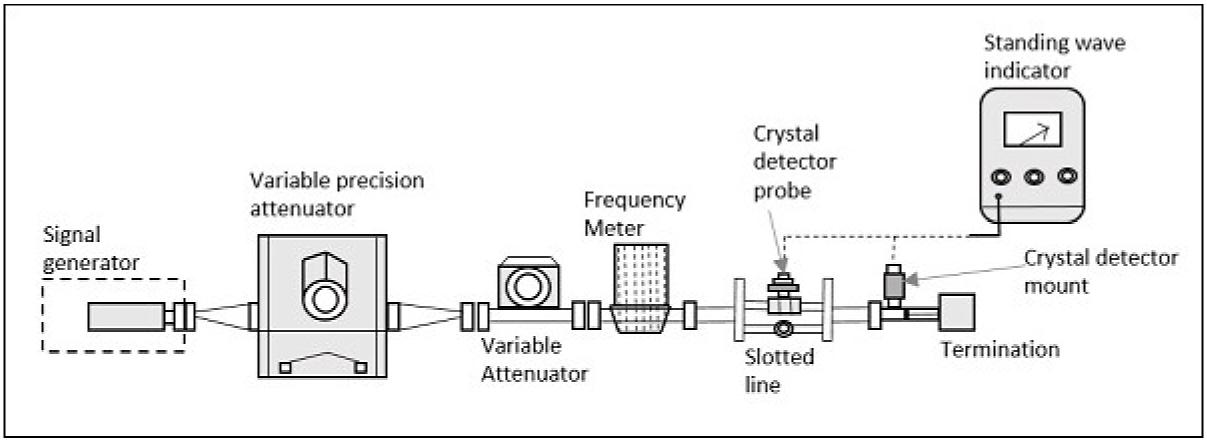
UNIT-V

MICROWAVE MEASUREMENTS

Microwave Bench General Measurement Setup

This setup is a combination of different parts which can be observed in detail. The following figure clearly explains the setup.



Signal Generator

As the name implies, it generates a microwave signal, in the order of a few milliwatts. This uses velocity modulation technique to transfer continuous wave beam into milliwatt power.

A Gunn diode oscillator or a Reflex Klystron tube could be an example for this microwave signal generator.

Precision Attenuator

This is the attenuator which selects the desired frequency and confines the output around 0 to 50db. This is variable and can be adjusted according to the requirement.

Variable Attenuator

This attenuator sets the amount of attenuation. It can be understood as a fine adjustment of values, where the readings are checked against the values of Precision Attenuator.

Isolator

This removes the signal that is not required to reach the detector mount. Isolator allows the signal to pass through the waveguide only in one direction.

Frequency Meter

This is the device which measures the frequency of the signal. With this frequency meter, the signal can be adjusted to its resonance frequency. It also gives provision to couple the signal to waveguide.

Crystal Detector

A crystal detector probe and crystal detector mount are indicated in the above figure, where the detector is connected through a probe to the mount. This is used to demodulate the signals.

Standing Wave Indicator

The standing wave voltmeter provides the reading of standing wave ratio in dB. The waveguide is slotted by some gap to adjust the clock cycles of the signal. Signals transmitted by waveguide are forwarded through BNC cable to VSWR or CRO to measure its characteristics.

A microwave bench set up in real-time application would look as follows −

Now, let us take a look at the important part of this microwave bench, the slotted line.

Slotted Line

In a microwave transmission line or waveguide, the electromagnetic field is considered as the sum of incident wave from the generator and the reflected wave to the generator. The reflections indicate a mismatch or a discontinuity. The magnitude and phase of the reflected wave depends upon the amplitude and phase of the reflecting impedance.

The standing waves obtained are measured to know the transmission line imperfections which is necessary to have a knowledge on impedance mismatch for effective transmission. This slotted line helps in measuring the standing wave ratio of a microwave device.

Construction

The slotted line consists of a slotted section of a transmission line, where the measurement has to be done. It has a travelling probe carriage, to let the probe get connected wherever necessary, and the facility for attaching and detecting the instrument.

In a waveguide, a slot is made at the center of the broad side, axially. A movable probe connected to a crystal detector is inserted into the slot of the waveguide.

Operation

The output of the crystal detector is proportional to the square of the input voltage applied. The movable probe permits convenient and accurate measurement at its position. But, as the probe is moved along, its output is proportional to the standing wave pattern, which is formed inside the waveguide. A variable attenuator is employed here to obtain accurate results.

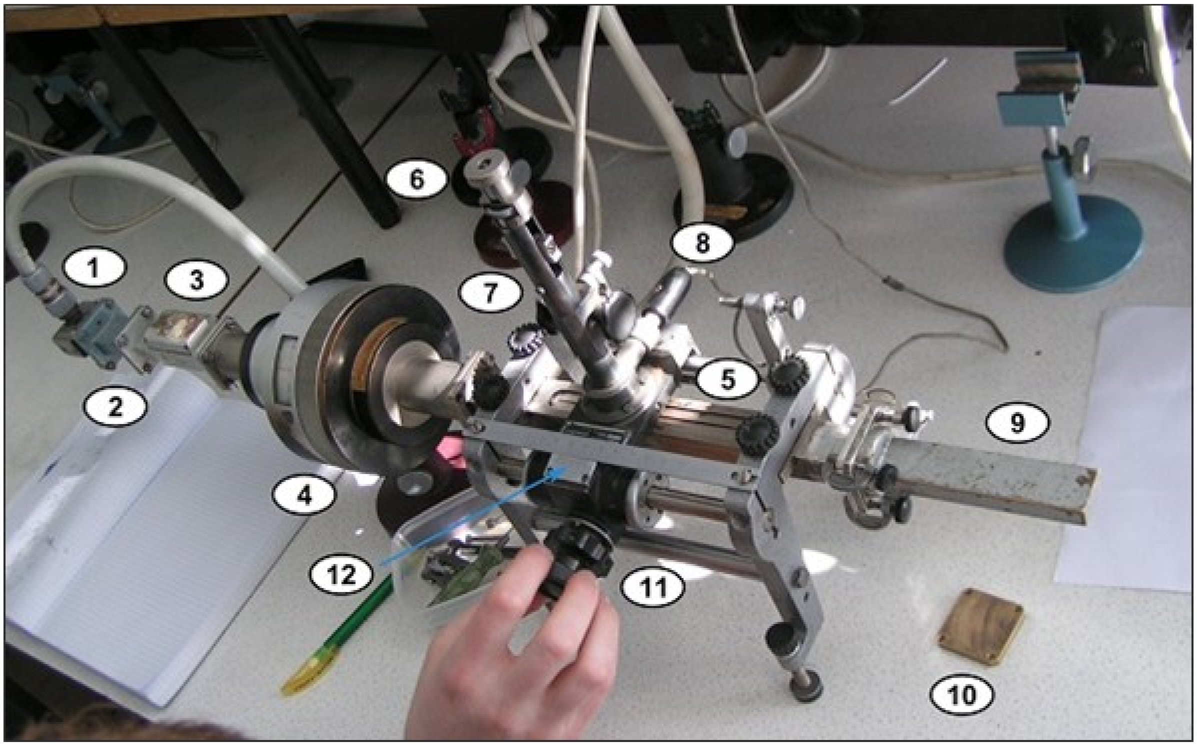
The output VSWR can be obtained by

$$VSWR = \sqrt{\frac{V_{max}}{V_{min}}}$$

Where, V

is the output voltage.

The following figure shows the different parts of a slotted line labelled.



The parts labelled in the above figure indicate the following.

- Launcher − Invites the signal.
- Smaller section of the waveguide.
- Isolator − Prevents reflections to the source.
- Rotary variable attenuator − For fine adjustments.
- Slotted section − To measure the signal.
- Probe depth adjustment.
- Tuning adjustments − To obtain accuracy.
- Crystal detector − Detects the signal.
- Matched load − Absorbs the power exited.
- Short circuit − Provision to get replaced by a load.
- Rotary knob − To adjust while measuring.

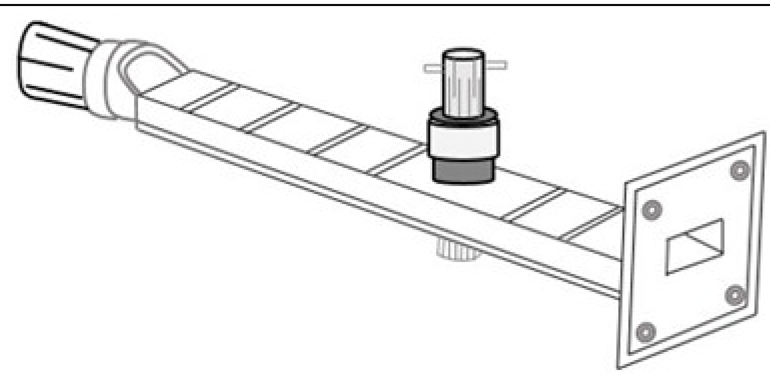
- Vernier gauge − For accurate results.

In order to obtain a low frequency modulated signal on an oscilloscope, a slotted line with a tunable detector is employed. A slotted line carriage with a tunable detector can be used to measure the following.

- VSWR (Voltage Standing Wave Ratio)
- Standing wave pattern
- Impedance
- Reflection coefficient
- Return loss
- Frequency of the generator used

Tunable Detector

The tunable detector is a detector mount which is used to detect the low frequency square wave modulated microwave signals. The following figure gives an idea of a tunable detector mount.



Tunable waveguide detector

The following image represents the practical application of this device. It is terminated at the end and has an opening at the other end just as the above one.

To provide a match between the Microwave transmission system and the detector mount, a tunable stub is often used. There are three different types of tunable stubs.

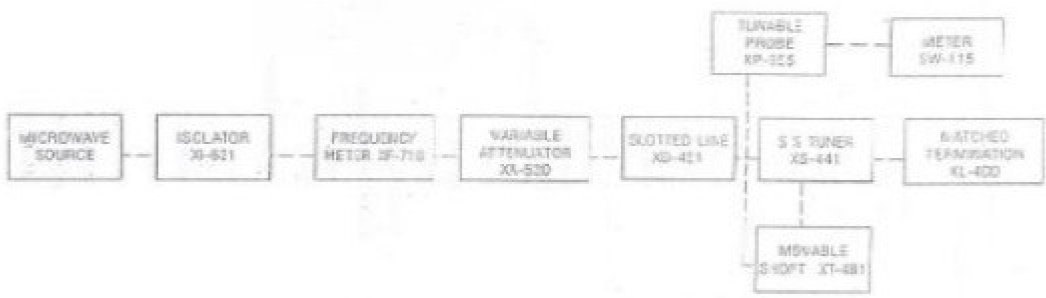
- Tunable waveguide detector
- Tunable co-axial detector
- Tunable probe detector

Also, there are fixed stubs like −

- Fixed broad band tuned probe
- Fixed waveguide matched detector mount

The detector mount is the final stage on a Microwave bench which is terminated at the end.

MEASUREMENT OF WAVELENGTH AND IMPEADENCE



SET UP FOR IMPEDANCE MEASUREMENT

The impedance at any point on a transmission line can be written in the form R+jX For comparison SWR can be calculated

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

Where

Reflection co-efficient

$$R = \frac{Z - Z}{Z + Z}$$

Z0= characteristics impedance of w/g at operating frequency

Z= load impedance. The measurement is performed in following way.

The unknown device is connected to the slotted line and the position of one minima is determined. The unknown device is replaced by movable short to the slotted line . Two successive minima positions are noted.The twice of the difference between minima position will be guidewave length. One of the minima is used as reference for impedance measurement .find the difference of reference minima and minima position obtained from unknown load. Let it be ‘d’. Take a smith chart , taking ‘1’ as centre, draw a circle of radius equal to S. mark a point on circumference of smith chart towards load side at a distance equal to d/g. join the centre with this point .

find the point where it cut the drawn circle.the co-ordinates of this point will show the normalized impedance of load.

PROCEDURE:

1.Setup the components and equipments as shown in figure.

2. Setup variable attenuator at minimum attenuation position.

3.Keep the control knobs of VSWR meter as below: Range - 50db position

Input switch - Crystal low impedance Meter switch - Normal position Gain(Coarse & Fine)- Mid position

4.Keep the control knobs of Klystron power supply as below Beam voltage - ‘OFF’

Mod-switch -AM

Beam Voltage knob-Fully anticlockwise Reflector Voltage- Fully clockwise

AM- Amplitude knob- Around fully clockwise AM- Frequency knob – Around Mid position

5.Switch ‘ON’ the Klystron power supply, VSWR Meter and cooling fan switch.

6. Switch ‘ON’ the beam voltage switch and set beam voltage around 250V-300V with help of beam voltage knob.

7.Adjust the reflector voltage to get some deflection in VSWR meter.

8.Maximize the deflection with AM amplitude and frequency control knob of power supply.

9.Tune the plunger of Klystron Mount for maximum deflection.

10. Tune the reflector voltage knob for maximum deflection .

11. Tune the probe for maximum deflection in VSWR Meter.

12.Tune the frequency meter knob to get a ‘dip’ on the VSWR scale and note down the frequency directly from frequency meter.

13. Keep the depth of pin S S. Tuner to around 3-4 mm and lock it.

14. Move the probe along the slotted line to get maximum deflection.

15. Adjust VSWR meter gain control knob and variable attenuator until the meter indicates

1.0 on the normal db SWR scale.

16. Move the probe to next minimum position and note down the SWR S0 on the scale .also note down the probe position. Let it be ‘d’.

17. Remove the SS tuner and matched termination and place movable short at slotted line. The plunger of short should be at zero.

18. Note the position of two successive minima position .let it be as d1 and d2 .Hence $\lambda g = 2(d1- d2)$.

19. Calculate

$$\frac{d}{\lambda_g}$$

20. Find out the normalized impedance as described in the theory section.

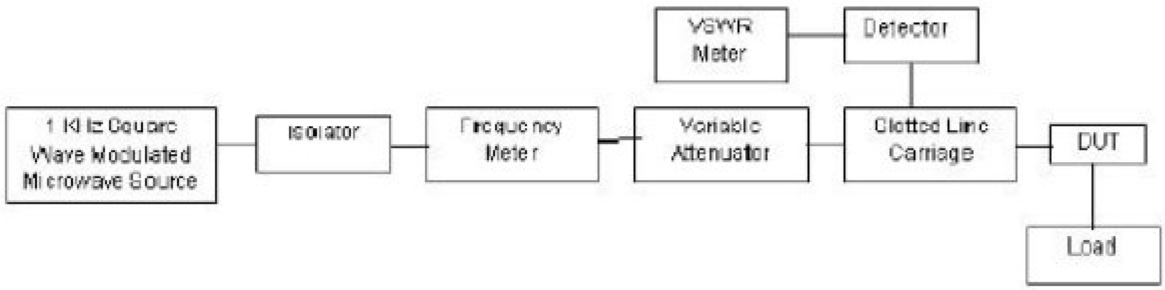
21. Repeat the same experiment for other frequency if required.

MEASUREMENT OF SWR AND ATTUNUATION

In a microwave network, if load impedance and line impedance are not matched, signal fed from the source is reflected again towards source causing standing wave pattern in the network. Voltage Standing Wave Ratio is a measure used for finding the magnitude of ration of reflected signals maximum and minimum amplitudes For analyzing standing wave pattern and to find S slotted line carriage is used in laboratory.

$$S = \frac{V_{max}}{V_{min}} \qquad \text{\_\_\_\_\_\_\_\_\_ (1)}$$

Low VSWR Measurements: (S<20)



Procedure:

1.Microwave Source is energized with 1 KHz square wave signal as carrier.

2.Tunable passive components are so adjusted to get reading across the VSWR meter in 30 dB scale.

3.Detector (Tunable probe detector) is adjusted to get maximum power across the VSWR meter.

4. Slotted line carriage is moved from the load towards source to find the standing wave minimum position.

5.By adjusting the gain control knob of VSWR meter and attenuator the reading across the VSWR meter is made as 1 or 0 dB known as normalization.

6. Again the slotted carriage is moved towards source to find the next minimum position. The reading shown at this point in the VSWR meter is the ratio of magnitude of reflected signals minimum and maximum voltages ( ). min max VV S

7. VSWR meter has three different scales with different ranges as specified below.

a) NORMAL SWR Scale 1 ---- 1 – 4

b) NORMAL SWR Scale 2 ---- 3.2 – 10

c) EXPANDED SWR Scale 3 ---- 1 – 1.33

8.If the device under test (DUT) is having the range of VSWR 1 – 4, reading is taken from the first scale from the top (NORMAL SWR Scale 1 – 1 – 4).

9.If the device under test (DUT) is having the range of VSWR 3.2 – 10, reading is taken from the second scale from the top (NORMAL SWR Scale 2 (3.2 – 10).

10. If the device under test (DUT) is having the range of VSWR 1 – 1.33, reading is taken from the third scale from the top (EXPANDED SWR Scale 3 (1 – 1.33).

11. If the device under test (DUT) is having the range of VSWR 10 – 40, a 20 dB range is selected in the VSWR meter and reading is taken from the first scale from the top (NORMAL SWR Scale 1 – 1 – 4) which is then multiplied by 10 for getting the actual reading.

Possible Errors in Measurements:

1.Detector may not work square law region for both Vmax. and Vmin.

2.Depth of the probe in the slotted line carriage is made as minimum. If not, it may cause reflections in addition to the load reflections.

3.For the device having low VSWR, connector used for measurement must have proper matching with line impedance.

4.If the geometrical shape of the slotted line is not proper, Vmax. (or) Vmin. Value will not constant across the slotted line.

5.If the microwave signal is not properly modulated by a 1 KHz square wave, then signal becomes frequency modulated thereby it causes error in the Vmin. value measured. The value becomes lower than the actual.

6.Residual VSWR of slotted line carriage may cause error in the measurements.

High VSWR Measurements - Double Minima Method - (S>20)

Measurement of high VSWR needs separate procedure because the detector may not be tuned to work in square law region. An alternate method known as double minimum method is used for finding high VSWR with the same experimental set up as shown above.

Procedure:

1.Microwave Source is energized with 1 KHz square wave signal as carrier.

2.Tunable passive components are so adjusted to get reading across the VSWR meter in 30 dB scale.

3.Detector (Tunable probe detector) is adjusted to get maximum power across the VSWR meter.

4.Slotted line carriage is moved from the load towards source to find the standing wave minimum position. Let it be d1.

5.Slotted line carriage is moved further to find the next immediate minimum position. Let it be d2. Now

$$g = 2 (d1 - d2)$$

6.By adjusting the gain control knob of VSWR meter and attenuator the reading across the VSWR meter is made as 3 dB at this minimum position.

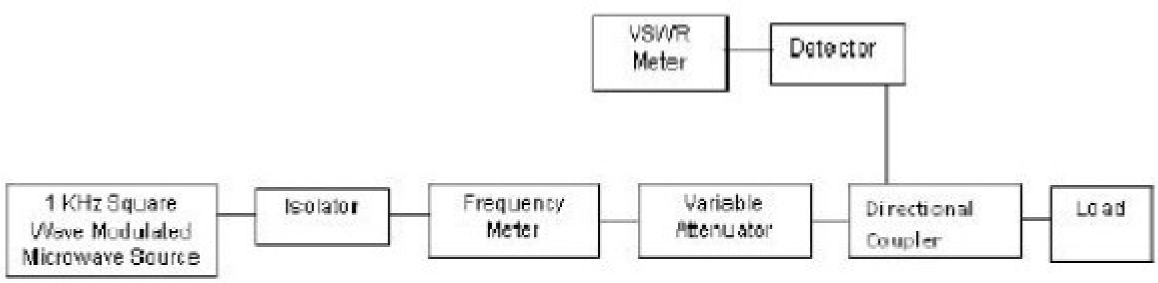
7.By taking this point as reference, slotted line carriage is moved on either side. The points at which the VSWR meter shows 0 dB reading on both sides are noted as x1 and x2.

8.High VSWR can be calculated by using the formula

$$S = \frac{\lambda_g}{\pi(x_1 - x_2)}$$

VSWR Measurements by Return Loss (Reflectometer) Method:

To overcome the difficulties faced in slotted line carriage for measuring VSWR, reflectometer can be used. Reflectometer is a device having two directional couplers combined together with ideal coupling factor and directivity. It is a four-port device.



Experimental Procedure:

1.Microwave Source is energized with 1 KHz square wave signal as carrier.
2.Tunable passive components are so adjusted to get reading across the VSWR meter in 30 dB scale.

3.Detector (Tunable probe detector) is adjusted to get maximum power across the VSWR meter.

4.Port 2 is with a movable short and is adjusted for getting the output across the detector to unity in VSWR meter. Port 3 is matched terminated.

5.VSWR meter and matched load at port4 and port 3 are interchanged. The output of the port3 is noted which should be ideally equal to the output from port 4.

6.Without disturbing the VSWR meter adjustment, the unknown load is connected at port 2 byreplacing the short and the output at port3 is noted to obtain

the short and the output at port3 is noted to obtain $\frac{1}{\Gamma_L}$

directly from the VSWR meter.

Return loss = $-20\log|\Gamma_L|$

$$VSWR = \frac{1+|\Gamma_L|}{1-|\Gamma_L|}$$

This method is well suited for loads having low VSWR. The major sources of errors are

1.Unstability of the signal source causes a change of signal power level during measurement of input and reflected signals.

2.Non-ideal directional couplers and detectors are also sources of error.

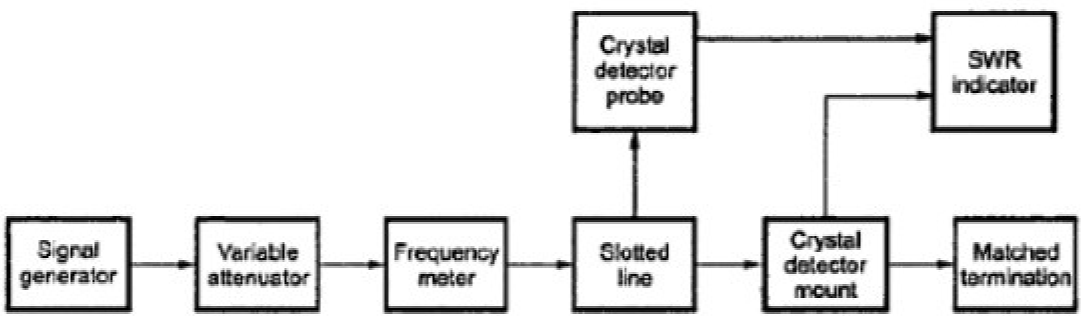
Q AND PHASE SHIFT

Microwave frequency can be measured by a number of different mechanical and electronic techniques.

- Mechanical techniques

- Slotted Line Method (Indirect Method)

The standing waves setup in a transmission line or a waveguide produce minima every half wavelength apart.



These minima are detected and the distance between them is measured. From which the wavelength and frequency can be calculated by

$$\lambda_g = 2d_{min}$$

$$f = \frac{C}{\lambda_0} \qquad \because \lambda_0 = \frac{\lambda_g \lambda_c}{\sqrt{\lambda_g^2 + \lambda_c^2}}$$

where λ_0 – free space wavelength

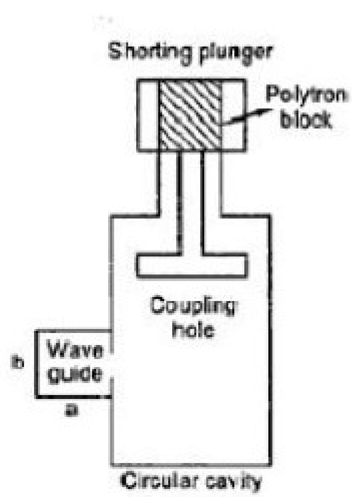
λ_c - cut off wavelength

λ_g – guide wavelength

d_{min} can be measured by the slotted line probe carriage.

Resonant Cavity Method (Direct Method)

The most commonly used type of microwave frequency meter is wave meters. It consists of a cylindrical or coaxial resonant cavity. The size of the cavity can be altered by adjustable plunger. The cavity is designed in such a way that for a given position of the plunger, the cavity is resonant only at one frequency in the specified range.



WAVEMETER

The cavity is coupled to the waveguide through an iris in the narrow wall of the waveguide. If the frequency of the wave passing through the waveguide is different from the resonance frequency of the cavity, the transmission is not affected. If these two frequencies coincide then the wave passing through the waveguide is attenuated due to power loss. It will be indicated as a dip in the meter.

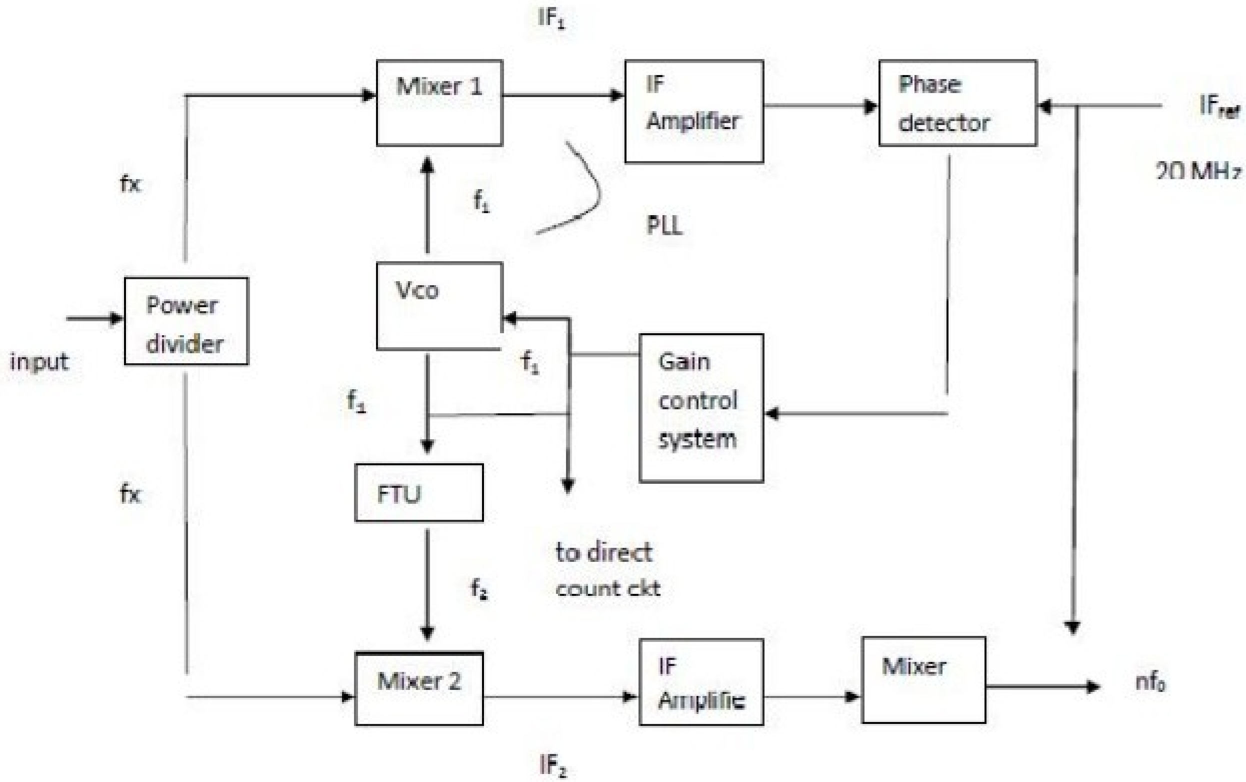
Electronic Technique

Counter Method

An accurate measurement of microwave frequency can be measured here. The input signal is divided into two equal signals by a resistive power divider. These two parts of the signal are fed to 2 mixers. The mixer 1 is used in the input PLL (Phase Locked Loop) and the mixer 2 is used to determine the harmonic number. The frequency f1 of the input PLL is also fed to the direct counter circuits. The input PLL consists of a voltage controlled oscillator (VCO), mixer, an IF amplifier, a phase detector and a gain control block. The VCO searches over its range until an IF signal equal to 20MHz is found. Phase lock occurs when the phase detector output sets the VCO frequency f1 such that

$$f_x = nf_1 - IF_1$$

where IF1 = 20 MHz at the phase lock and fx is the unknown frequency to be measured.



The f1 is translated to a frequency f2 so that

$$f_2 = f_1 \pm f_0$$

where f0 = 20 MHz offset frequency. This is done by a frequency translation unit (FTU). The frequency f2 drives the second sampler and produces a second output. IF2 is given as

$$\begin{aligned} IF_2 &= nf_2 - f_x \\ &= n(f_1 \pm f_0) - (nf_1 - 20MHz) \\ &= \pm nf_0 + 20 \end{aligned}$$

By mixing IF2 with IF1 and rejecting 20 MHz and higher frequencies, nf0 is obtained. Counting the number of zero crossing for the period of f0, determines the harmonic number n of the phase lock loop. The input frequency is then calculated by presetting into IFref counter, measuring f1 and extending gate time according to number n.