Experiment 6 : TE_{10} mode in Rectangular Waveguide

Aim

To determine the frequency & wavelength in a rectangular waveguide working on TE_{10} mode.

Instruments/Equipments

1. Klystron Power Supply
2. Klystron tube with Klystron mounts
3. Isolator
4. Variable attenuator
5. Frequency meter
6. Slotted section
7. Tunable probe
8. oscilloscope
9. BNC cable

Theory

Mode represents in wave guides as either TE_{mn}/ TM_{mn}, Where TE-Transverse electric, TM-Transverse magnetic. m - Number of half wavelength variation in broader direction. n - Number of half wavelength variation in shorter direction.

$$\frac{\lambda_g}{2} = d_1 - d_2$$

Where d_1 and d_2 are the distance between two successive minima/maxima. It is having highest cut off frequency hence dominant mode. For dominant TE_{10} mode in rectangular wave guide $\lambda_0, \lambda_g, \lambda_c$ are related as below.

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

Where λ_0 is free space wavelength, λ_g is guide wavelength, λ_c is cutoff wavelength. For TE_{10} mode

$$\lambda_c = \frac{2a}{m}$$

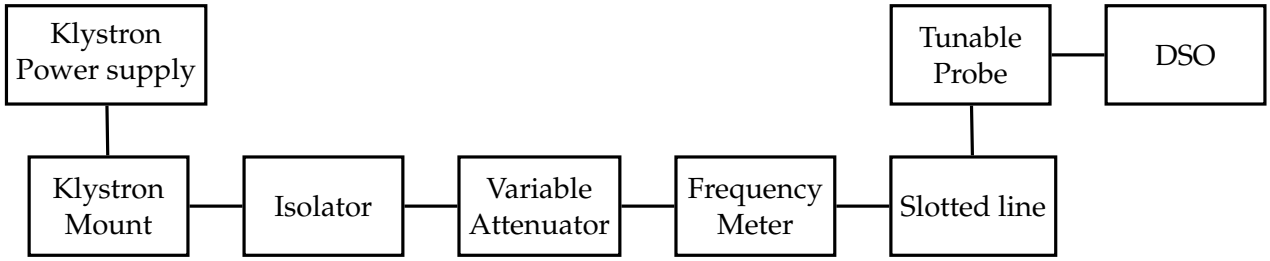
Where m = 1 in TE_{10} mode and a is inner broad dimension of waveguide. The wavelength of the signal in an unbounded medium (air or vacuum), calculated as

$$\lambda_0 = c/f$$

Where $c = 3 \times 10^8$ m/s is velocity of light and f is frequency. For propagation to occur, the operating free space wavelength must be less than the cutoff wavelength ($\lambda_0 < \lambda_c$)

Procedure

1. Set up the components and equipments as shown in figure.



2. Set Mode selector switch to FM-Mode position with FM amplitude and FM frequency knob at mid position. Keep beam voltage control knob minimum and reflector voltage knob to Maximum.
3. Fan should be kept infront of klystron
4. Switch on Fan and the klystron power supply and oscilloscope. Adjust the repeller voltage until a square wave on a DSO is obtained .Record the parameters beam voltage,beam current,repeller voltage correctly using the Mode Select switch on the Klystron Power Supply

Frequency Measurement

Direct Method (Frequency Meter)

1. Slowly rotate the knob of the Direct Reading Frequency Meter.
2. Observe the DSO square waveform for a sharp dip in the reading, which occurs at resonance.
3. The frequency indicated on the meter dial at this dip is the operating frequency (f_0)

Guide Wavelength (λ_g) Measurement

This method uses a slotted line terminated with a open, Short Circuit and loaded to produce standing waves.

1. Move the control knob of the slotted line slowly from a minimum position. Observe the output on the Oscilloscope and note the distance at the point where a peak is achieved.
2. Record this position as d_1
3. Move to the next adjacent minimum position and record it as d_2. Repeat this procedure
4. Calculate λ_g: The distance between two successive minima is half the guide wavelength:
$$\lambda_g = 2|d_1 - d_2|$$

Indirect Method (Calculation)

1. Measure Waveguide Dimension (a): Use the broader inner dimension of the waveguide (typically 2.286cm for X-band).
2. Calculate Cutoff Wavelength (λ_c): For the dominant TE_{10} mode, $m = 1, \lambda_c = 2a/m$
3. Find Free Space Wavelength (λ_0): Use the relation: $1/\lambda_0^2 = 1/\lambda_g^2 + 1/\lambda_c^2$
4. Determine Frequency (f): Use $f = c/\lambda_0$, where $c \approx 3 \times 10^8$m/s.
5. Finally, compare the calculated frequency from the slotted line method with the direct reading from the frequency meter to verify accuracy
$$\frac{\text{Obtained value}(f) - \text{Observed value}(f_0)}{\text{Obtained value}(f)} \times 100$$

Result Analysis

1. Measure the frequency obtained by frequency meter.
2. Calculate the guide wavelength as twice the distance between two successive minimum positions obtained as above: $\lambda_g = 2(d_1 - d_2)$
3. Measure the wave-guide inner broad dimension a which will be around 22.86 mm for X band: $\lambda_c = 2a$
4. Calculate the frequency by following equation:
$$f = \frac{c}{\lambda_0} = c\sqrt{\frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}}$$
5. Calculate % error in frequency in open, shorted and loaded condition