Assignment - 2

Question: Describe the method of frequency and impedance measurement at microwave frequency.

Answer:

Frequency measurement :-

- Mechanical systems : Wave-meter
- Electronic systems : Frequency counters, high frequency heterodyne systems which compare known lower frequency with unknown higher frequency. These systems are complex and expensive but accurate.
- Use of slotted line : Microwave frequency is evaluated in slotted line or waveguide by generating standing waves and measuring the positions of minima and with dimensions of waveguide frequency is calculated.
- Use of Resonant Cavities :- This constitutes frequency meters - key element is a cylindrical or coaxial resonant cavity.
- Electronic techniques for frequency measurement: These techniques are based on the comparison of the unknown frequency with a harmonic of unknown standard frequency. Instruments use null-beating technique.

- Impedance measurement:
- Simplest method:- unknown impedance is placed at one end of waveguide

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

- Slotted line is a fundamental tool for microwave measurements.
- Probe is also a tool for microwave measurement.
- Impedance measurement by network analyzer:

→ Most convenient when rapid measurements are required over broad frequency range, or variation with some circuit parameter is to be monitored.

→ Method is based on direct measurement of complex reflection coefficient.

→ In scalar network analyzer amplitude is measured but with vector analyzer phase is also measured.

Ques(2) Draw the schematic diagram of PIN diode and explain its characteristics.

Answer

Diode Circuit Symbol

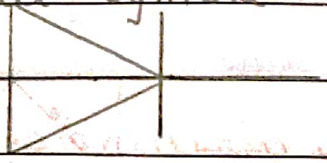

Fig: PIN Diode

A PIN diode can be defined as:
A diode with a wide and undoped intrinsic semiconductor region b/w a p-type and n-type semiconductor region.

- Characteristics of Pin diode:

(i) The capacitance of PIN diode is independent of bias level as the net charge is said to be very less in the intrinsic layer.

(ii) PIN diode possesses very low reverse recovery time.

(iii) The diode obeys standard diode equation for all low frequency signals.

(iv) This diode appears like a resistor than any other non-linear devices and is said to produce no distortion or rectification

Ques(3) Explain the velocity modulation and bunching process in two cavity Klystron. Also derive expression for bunching parameters.

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dummy

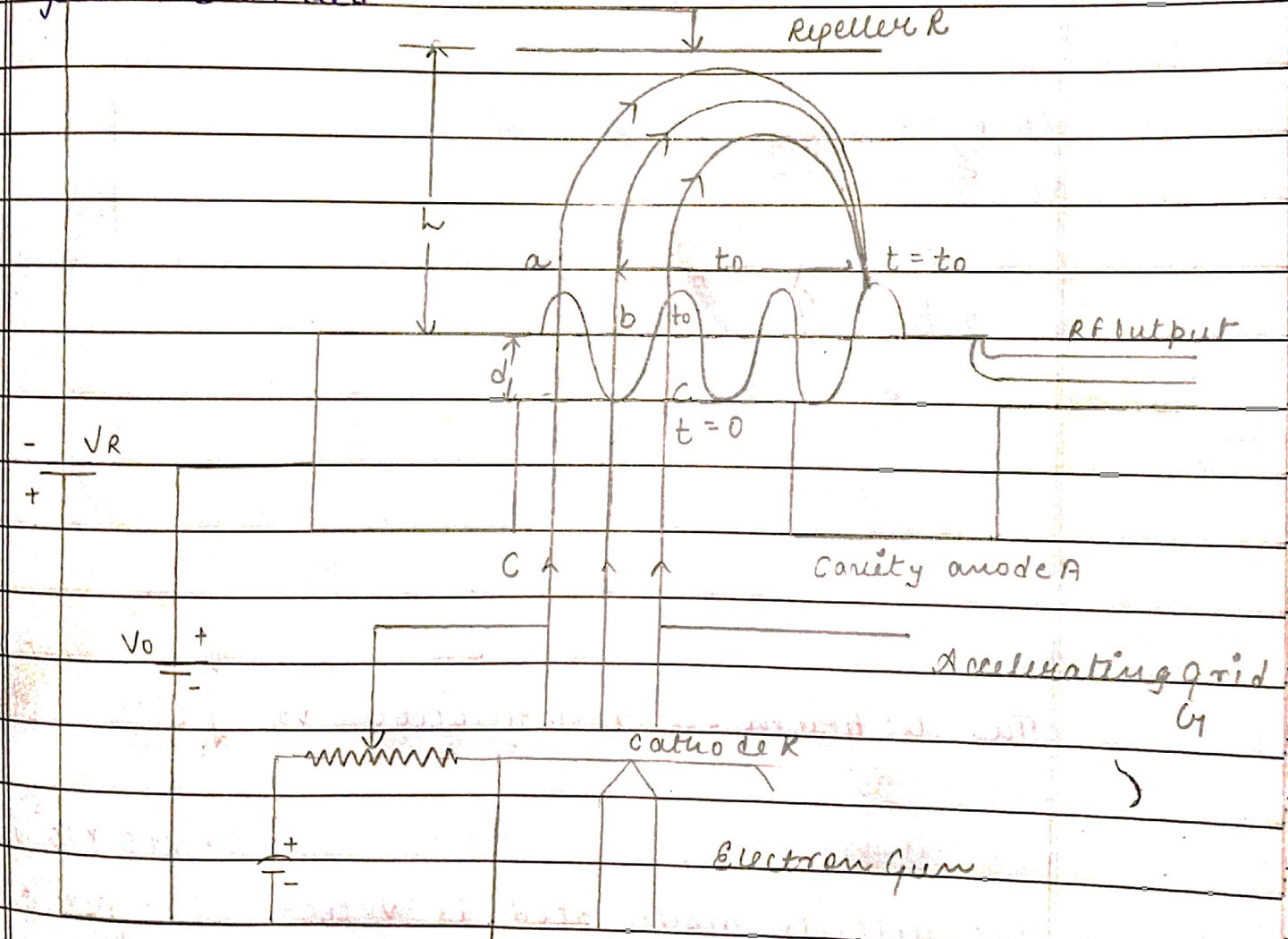
Velocity Modulation :-

→ Electron a encounters +ve half cycles of RF field in the cavity gaps → gets accelerated.

→ Electron b encounters zero RF field passes without acceleration.

→ Electron c encounter negative RF field.

→ gets retarded



Bunching of Electron :-

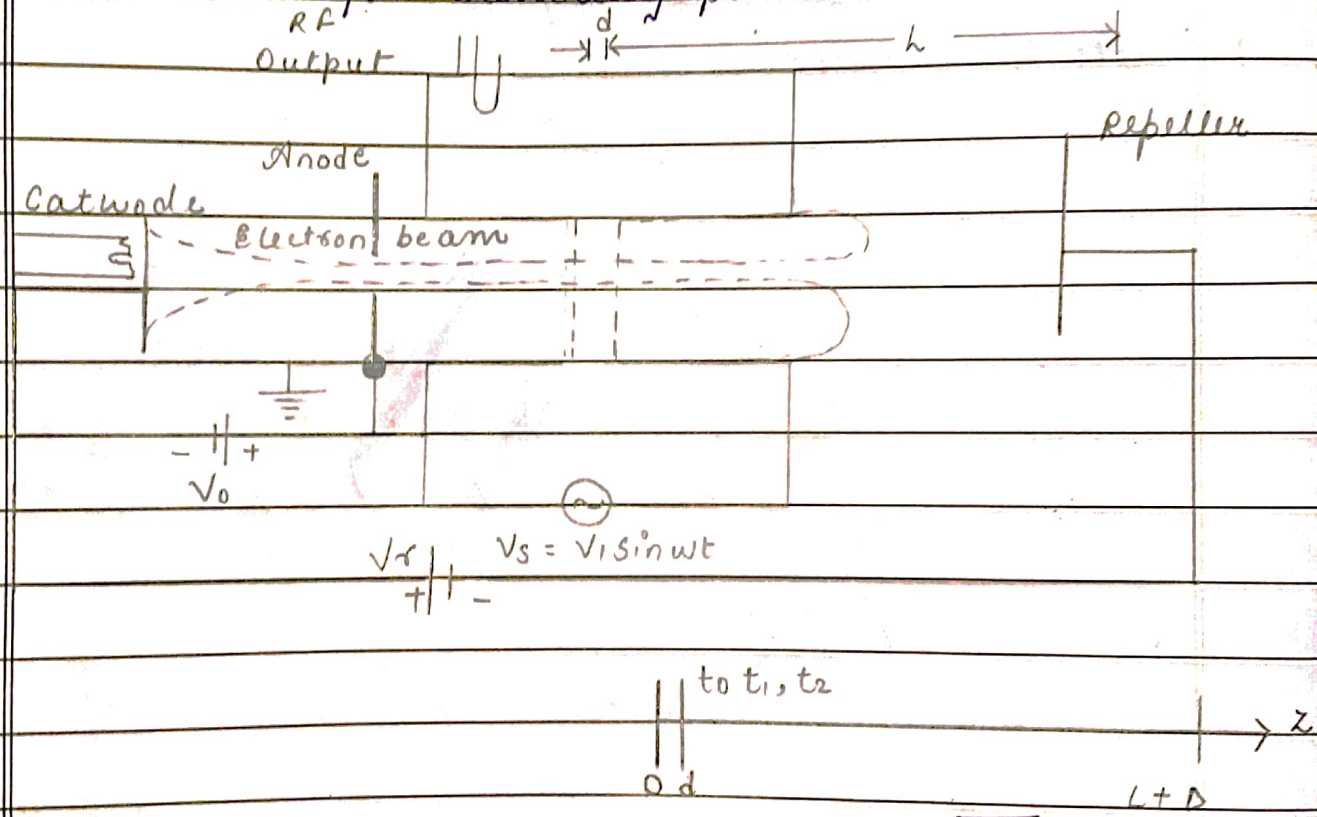
→ All these electrons are repelled back by repeller.

→ Repeller distance l and repeller voltages can be

adjusted to recieve all electrons simultaneously at the cavity during +ve RF peak.

→ Electron transfer their Kinetic energy to the RF field in cavity.

• Derivation for bunching parameters:



The DC beam electron velocity $v_0 = \sqrt{\frac{2eV_0}{m}}$

$= 0.593 \times 10^6 \sqrt{V_0}$

The velocity modulated is $v(t_1) = v_0 \left[1 + \frac{\beta_i V_1}{2V_0} \sin(\omega t_1 - \theta_g/2)\right]$

The Retarding electric field $= E = \frac{V_0 + V_r + V_1 \sin \omega t}{L}$

$\because V_0 + V_r >> V_i$ resistor ; $E = \frac{V_0 + V_r}{mL}$

The force experience by electron due to 'E'.

$$f = -eE$$

$$ma = -e\left(\frac{V_0 + V_r}{L}\right)$$

$$m\frac{d^2z}{dt^2} = -e\left(\frac{V_0 + V_r}{L}\right)$$

$$\frac{d^2z}{dt^2} = \frac{-e}{m}\left(\frac{V_0 + V_r}{L}\right)$$

$$\frac{dz}{dt} = \frac{-e(V_0 + V_r)}{mL}\int_{t_1}^{t} dt = \frac{-e(V_0 + V_r)}{mL}(t - t_1) + K_1$$

$$\frac{dz}{dt} = \frac{-e(V_0 + V_r)}{mL}(t - t_1) + K_1$$

at $t = t_1$: $\frac{dz}{dt} = v(t_1)$; $v(t_1) = K_1$

$$\frac{dz}{dt} = \frac{-e(V_0 + V_r)}{mL}(t - t_1) + v(t_1)$$

Integrating on both side w.r.t 't'

$$z = \frac{-e(V_0 + V_r)}{mL}\int_{t_1}^{t}(t - t_1)\,dt + v(t_1)\int_{t_1}^{t} dt$$

$$z = \frac{-e(V_0 + V_r)}{2mL}(t - t_1)^2 + v(t_1)(t - t_1) + K_2$$

at $t = t_1$; $d = K_2$

$$\tau = -\frac{e(V_0+V_r)}{\alpha m L}(t-t_1)^2 + v(t_1)(t-t_1) + d$$

at $t = t_2$:

$$d = -\frac{e(V_0+V_r)}{\alpha m L}(t_2-t_1)^2 + v(t_1)(t_2-t_1) + A$$

$$\frac{e(V_0+V_r)}{\alpha m L}(t_2-t_1)^2 = v(t_1)(t_2-t_1)$$

$$t_2 - t_1 = \frac{\alpha m L}{e(V_0+V_r)} v(t_1)$$

- Round Trip transit time:

$$T = t_2 - t_1 = \frac{\alpha m L}{e(V_0+V_r)} V_0 \left[1 + \frac{B i V_i}{\alpha V_0} \sin(\omega t_1 - \theta_g/2)\right]$$

$T_0' = \frac{\alpha m L V_0}{e(V_0+V_r)}$ – DC round trip transit time

$$T = T_0'\left[1 + B i V_i \sin(\omega t - \theta_g/2)\right]$$

Let $\theta_0' = \omega T_0'$ = DC round trip transit angle

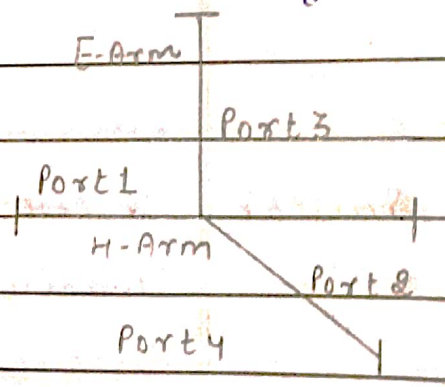
$$\omega T = \theta_0' + \frac{\beta_i V_1}{2V_0}\theta_0' \sin(\omega t_1 - \theta_g/2)$$

Bunching parameter $X' = \frac{\beta_i V_1}{2V_0}\theta_0'$

$$\omega T = \omega(t_2 - t_1)$$
$$= \theta_0' + X' \sin(\omega t_1 - \theta_g/2).$$

Ques(4) Write a short note on:

(a) Magic tee :- A magic tee is a combination of E-plane tee and H-plane tee. It is also known as hybrid or 3 dB coupler used in microwave systems. A magic tee can be used to measure by connecting a null detector to the E-plane port. The term magic tee is derived from the unusual manner in which the power gets divided / combined among various ports. A magic tee has four ports. S matrix of a magic tee can be expressed as:



$$S = \begin{bmatrix} 0 & 0 & S_{13} & S_{14} \\ 0 & 0 & S_{23} & S_{24} \\ S_{31} & S_{32} & 0 & 0 \\ S_{41} & S_{42} & 0 & 0 \end{bmatrix}$$

(b) Directional Couplers :- A directional coupler is a device that samples a small amount of microwave power

for measurement purposes. The power measurements include incident power, reflected power, VSWR value etc. Directional Coupler is a 4-port waveguide junction consisting of a primary main waveguide and a secondary auxiliary waveguide. Directional Coupler is used to couple the microwave power which may be unidirectional or bi-directional.

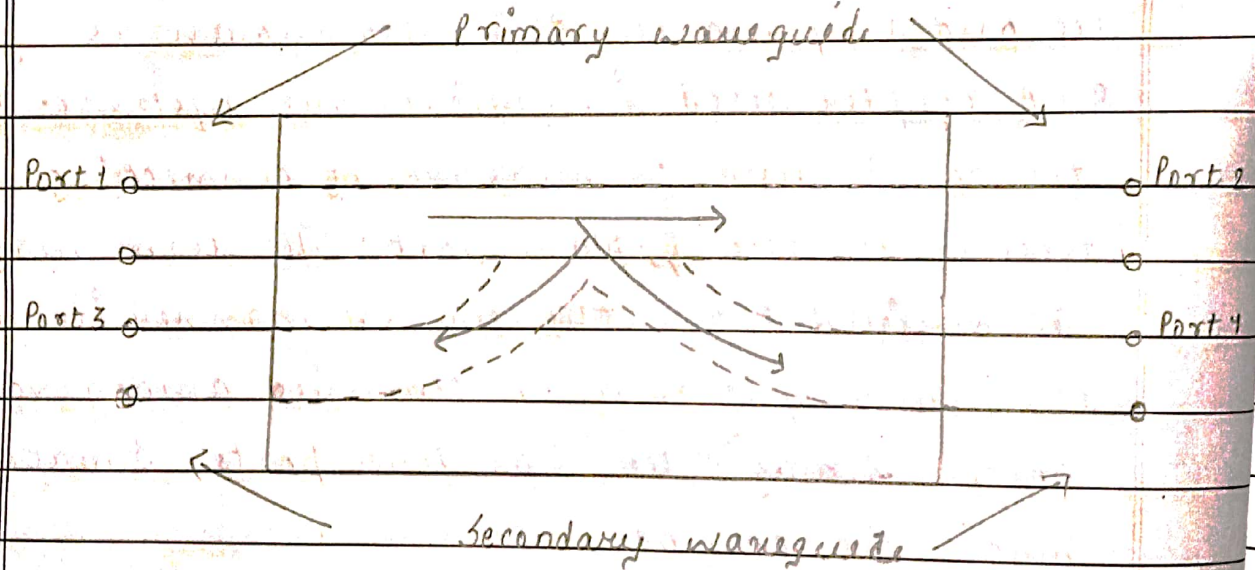


Fig: Directional Coupler

Ques(5) A certain GaAs MESFET has the following
Channel height a = 0.1 μm
Electron concentration = $N_d = 8 \times 10^{17}\ cm^3$
Relative dielectric constant = 13.10
Calculate the pinch-off voltage.

Experiment No.

Date

Answer: $V_p = \frac{qNd a^2}{2\epsilon_s} = \frac{1.6 \times 10^{-19} \times 8 \times 10^{23} \times (0.1 \times 10^{-6})^2}{2 \times 8.854 \times 10^{-12} \times 13.10}$

$= 6.00$ volts