Majors

-ve resistance devices => $V = -I$

$P = -I^2 R$

(active device / power generated)

Date 19/11/1

Transferred Electrons Devices

Transferred Electron device (TED) (usually diode) is a semiconductor device that depends on internal -ve resistance caused by transfered e⁻ in gallium arsenide or indium phosphide at high electric field; transit time (time to travel from one electrode to another by e⁻ of charge carriers) is minimized, permitting oscillation at frequencies upto several hundred megahertz.

* The difference b/w microwave transistors and TEDs:

1) Transistors operate ~~at~~ with junctions or gates but TEDs are bulk devices having no junctions or gates.

2) Majority of transistors are fabricated from elemental semiconductors, such as Silicon or germanium; whereas TEDs are fabricated from compound semiconductors such gallium arsenide (GaAs) or indium phosphide (InP).

3) Transistors operate with "warm" e⁻ whose energy is not much greater than thermal energy of e⁻ in semiconductor, whereas TEDs operate with "hot" e⁻ whose energy is very much greater than

*my*companion

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+ve devices ⇒ I=V (not in mag)
$P = I^2 R$
(consumer / passive device).

the thermal energy.

Gun-Effect Diodes - GaAs diodes

* J.B Gunn discovered a periodic fluctuations of current passing through n-type GaAs specimen when applied voltage exceeded a certain critical value.

* IMPATT, LSA, InP diodes are bulk devices in the sense that they use bulk -ve resistance property of uniform semiconductors

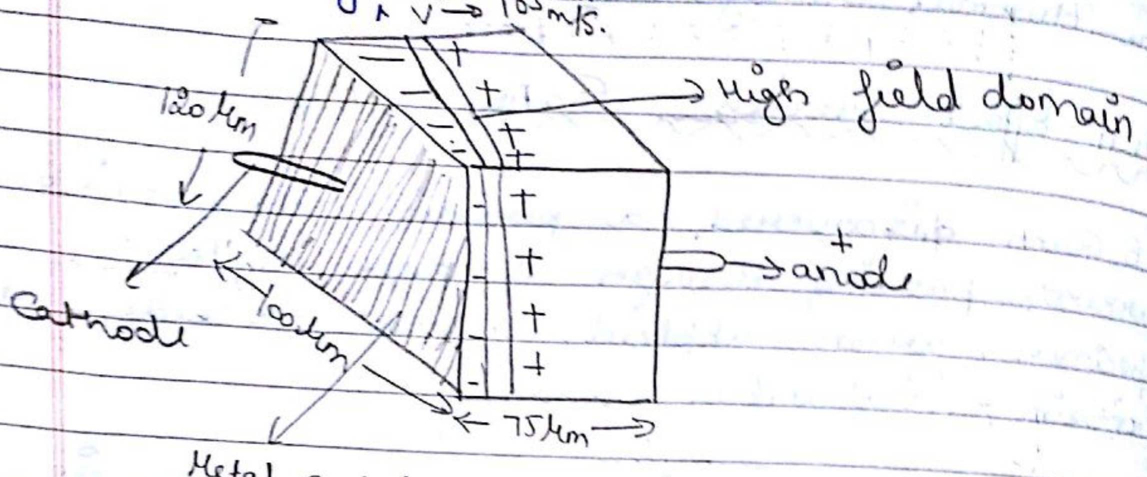
Gunn Effect

Above some critical voltage, corresponding to an electric field of 2000-4000 V/cm, the current in every specimen became a fluctuating function of time.

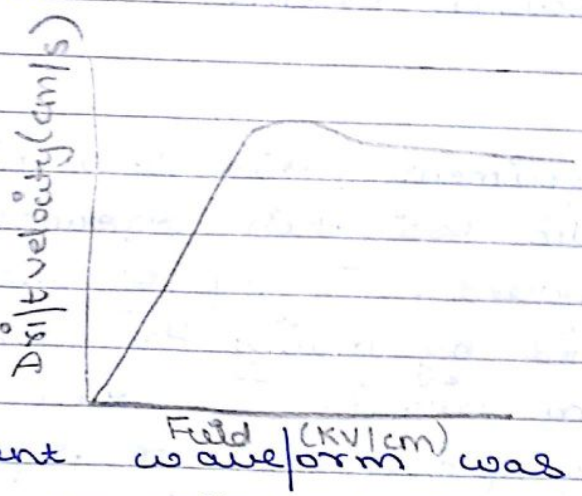
In GaAs specimens, this fluctuation took the form of periodic oscillation superimposed upon the pulse current. The freq of oscillation was determined by mainly the specimen, & not by external circuit. The period of oscillation was inversely proportional to specimen length and closely equal to transit time of e- b/w electrodes, calculated from their estimated velocity of slightly over 10^7 cm/s.

The peak pulse microwave power delivered by GaAs specimen to matched load was.

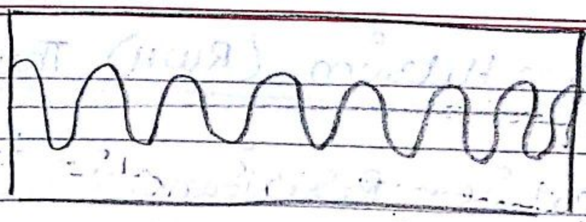
1-2%. pulse of i/p power.

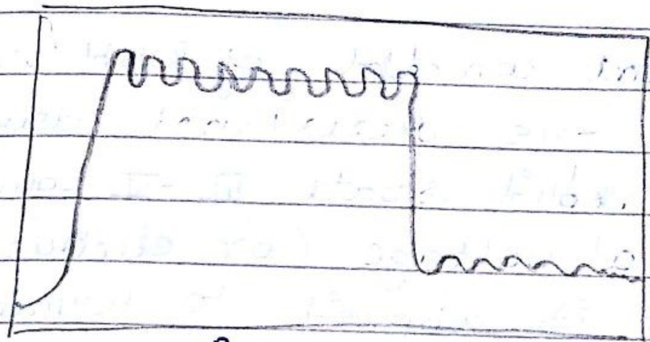


Gunn observed that carrier drift velocity is linearly increased from zero to max when electric field is varied from 0 to threshold value. When electric field is beyond 3000 V/cm for n-type GaAs, the drift velocity is decreased & diode exhibits -ve resistance



The current waveform was produced by applying a voltage pulse of 16-V amplitude and 10-ns duration to a specimen of n-type GaAS 2.5×10^{-3} cm in length. The osc freq. was 4.5GHZ.





Current waveform of n-type GaAs

Gunn also discovered that the threshold electric field E_{th} varied with length and type of material (GaAs specimen)

$$E_{th} = \frac{V}{L}$$

$L \rightarrow$ (should be in cm)

He used $V = 59$ $\quad L = 210 \times 10^{-6}$ m

$$E_{th} = \frac{59}{210 \times 10^{-4}} = 2810 \text{ V/cm}.$$

Ridley - Watkins - Hilsum (RWH) Theory:

* Differential Negative Resistance:

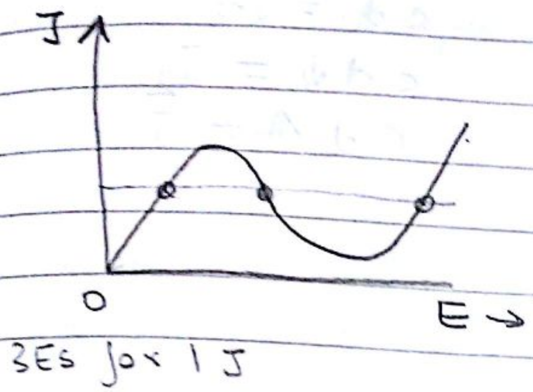
The fundamental concept of RWH theory is differential -ve resistance developed in a bulk solid state III-V compound when either a voltage (or electric field) or a current is applied to terminals of the sample.

There are two modes of -ve resistance devices: voltage controlled & current controlled modes.

The major effect of appearance of differential -ve resistance region in current density - field curve is to render the sample electrically unstable. As a result, the initially homogenius sample becomes electrically heterogeneous in an attempt to reach stability.

(I) Voltage controlled mode:

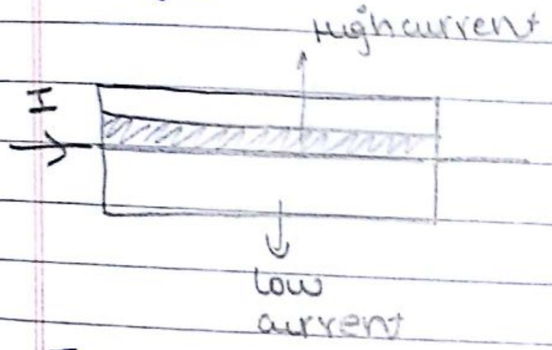
- In this mode the current density can be multivalued.
- In voltage controlled -ve resistance mode high field domains are formed seperating two low field regions.
- The interfaces seperating low & high field domains lie along equipotentials; thus they are in plane ⊥ to direction of current.

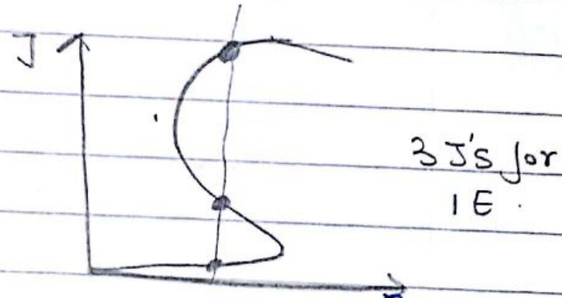


(II) Current controlled mode :

↳ In this mode ~~current~~ voltage is multivalued.

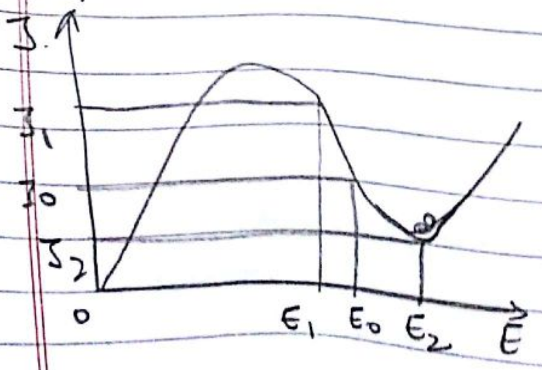
↳ In current controlled -ve resistance mode splits sample in high current filaments running along field direction.

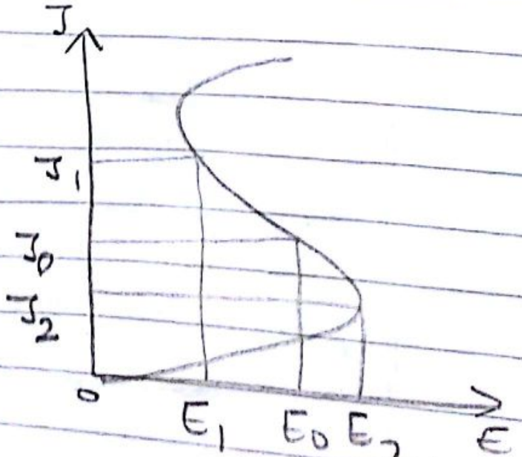




Expressed mathematically, the -ve resistance of sample at particular region is :-

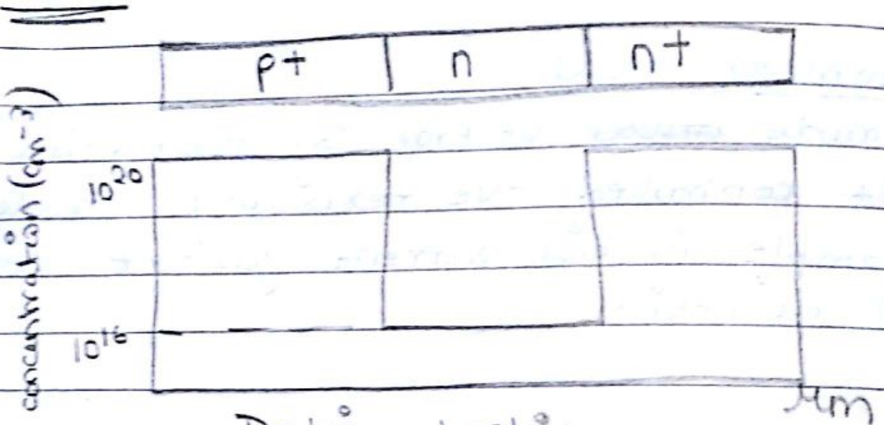
$$\frac{dI}{dV} = \frac{dJ}{dE} = \text{-ve resistance}$$



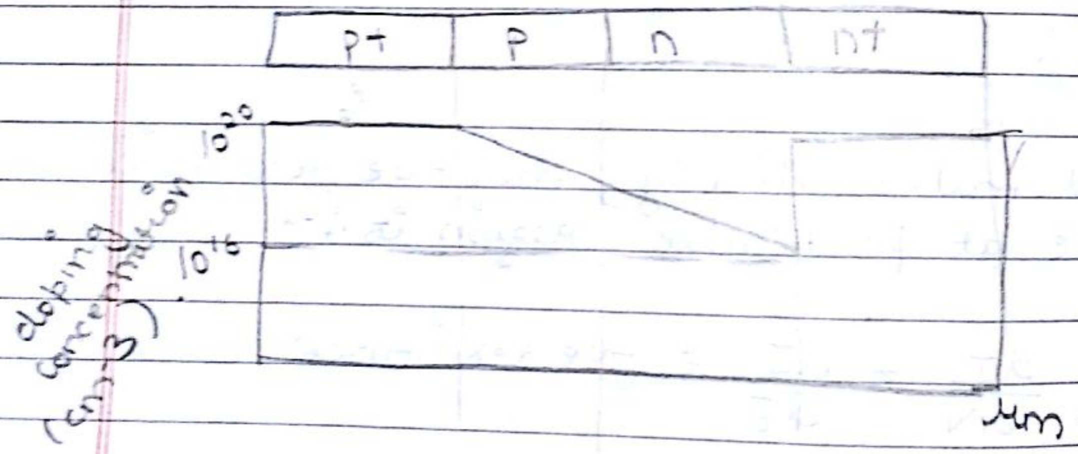


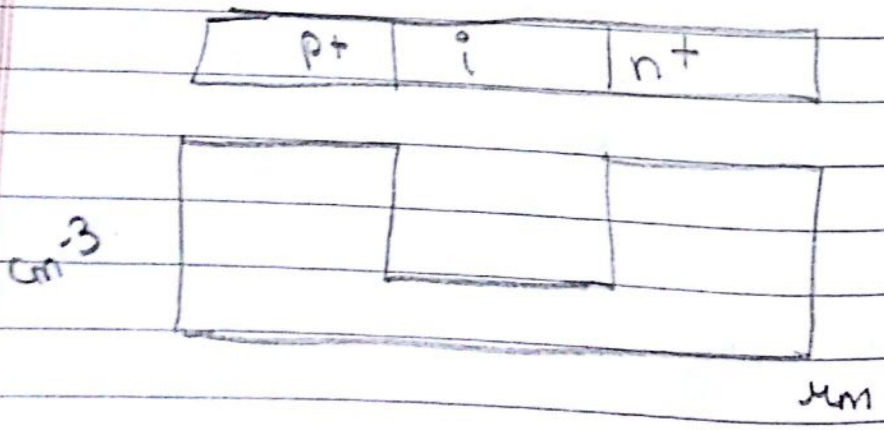
If electric field $= E_0$ c.d $= J_0$
" " " $\uparrow = E_2$ c.d $\downarrow = J_2$
" " " $\downarrow = E_1$ c.d $\uparrow = J_1$.

IMPATT



Doping profile





Avalanche Transit Time Devices

Avalanche transit time diodes oscillators rely on effect of voltage breakdown across a reverse - biased p-n junction to produce a supply of holes and e⁻.

The avalanche diode oscillator uses carrier impact ionization and drift in the high field region of semiconductor to produce a -ve resistance at µwave freq.

There are two modes of avalanche oscillator have been observed :

1) IMPATT ~~Diode~~ mode : (dc to RF conversion efficiency is 5 to 10%)
2) TRAPTT mode : (" " " 20 - 60 %).

(I) IMPATT Diodes : [Impact ionization avalanche transit time Diode]

The IMPATT diode is made of $p^+ - p - n - n^+$, $p^+ - i - n^+$ structure. Its basic physical mechanism is interaction of impact ionisation, avalanche and transit time of charge carrier. Hence IMPATT diode are called read time diode.

These diodes exhibit a differential -ve resistance by two effects :

Impact Ionization: It is the process in a material by which one energetic charge carrier can lose energy by creation of other carriers.
ex: e⁻ with K.E can knock a bonded e⁻ out of covalent bond

1) The impact ionisation avalanche effect which causes current $I_o(t)$ and AC voltage to be out of phase by 90°.

2) The transit time effect which further delays external current $I_e(t)$ relative to AC voltage by 90°.

The freq range for operation of IMPATT diode is given as carrier drift velocity

$$f = \frac{V_d}{2L}$$

V_d → carrier drift velocity.

L → specimen length.

V_d → constant (& if not given the take $V_d = 2 \times 10^7$ cm/s).

(II) TRAPATT Diode

(TRapped Plasma Avalanche triggered Transit mode).

It is a high eficiency microwave generator capable of operating from several KHz to GHz.

The basic operation of oscillator is a semiconductor p-n junction diode reverse when rev bias is ↑ then depletion region widens & field is strong when these the field excites e⁻ these e⁻ further ionizes e⁻ in bonds

Avalanche breakdown

biased to current densities well in excess of those encountered in normal avalanche operation

High peak power diode are typically silicon n^+-p-p^+ (or p^+-n-n^+) structures with n-type depletion region width varying from 2.5 to 12.5 μm. The doping of depletion region is generally such that diodes are well "punched through" at breakdown; that is, the dc electric field in depletion region just prior to break down is well above saturated drift velocity level. The p^+ reg is kept as thin as possible.

p^+	n	n^+

Microwave

Frequency measurement in waveguide:

VSWR Measurement:

~ Double minimum method:

↳ Can be used only if VSWR over the line is more than 3dB and it requires to be used only when SWR > 10.

↳ Bench is to be terminated with the DUT (Device Under Test) which can be established a high VSWR which is more than 10 over slotted section.

↳ Move the tunable probe to ~~either side until the pointed moves to zero in dB scale~~ over to a minimum position and by varying the gain place the pointer on 3 in dB scale of VSWR meter.

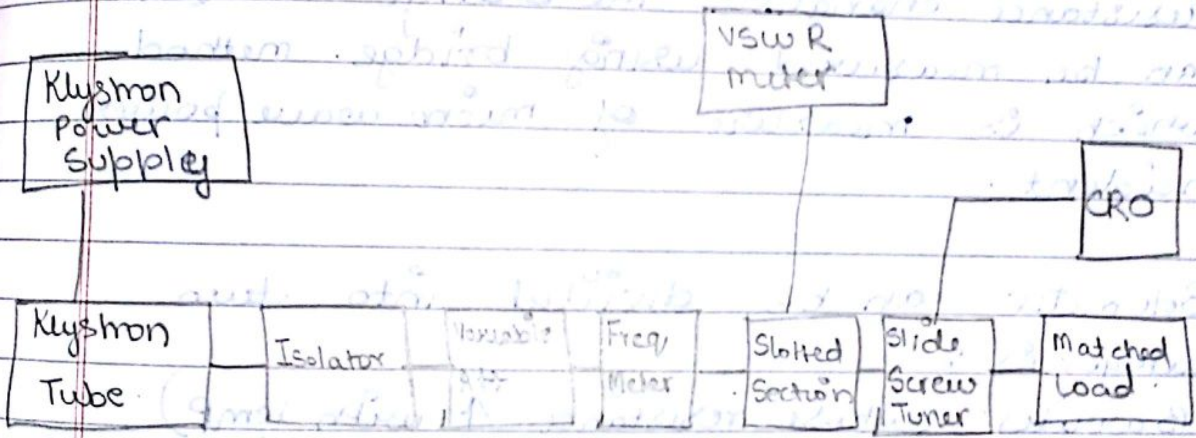
↳ Move the tunable probe to either side until the pointer moves to zero in dB scale

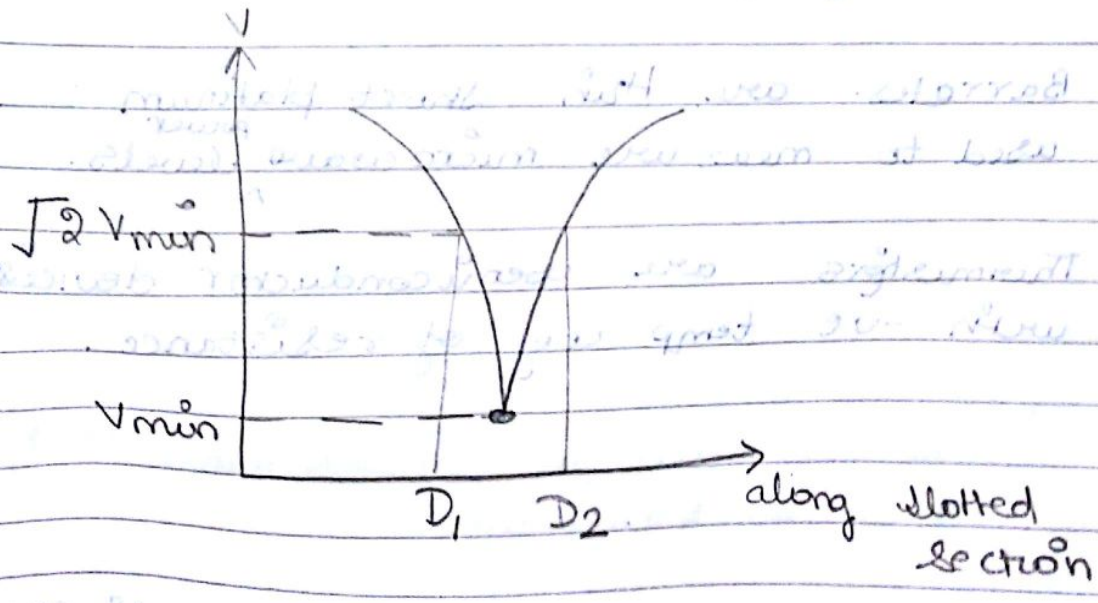
↳ Note down the position of tunable probe on vernier scale. (Let the position be D_1).

↳ Now move the probe in opposite direction until the pointer again stands over the zero after passing over the '3' on dB's scale. Note the position as D_2.

↳ Now measure distance b/w the two consecutive minima D_1 & D_2 and twice the distance gives the guided wavelength λg.

$$VSWR = \frac{\lambda g}{\pi}\left[D_1 - D_2\right].$$





Measurement of Power

The μwave power is measured using a device known as bolometer.

Bolometer are devices whose resistance varies with temp.

When μwave power falls over the surface it gets converted into heat raising the temp. With ↑ in temp resistance changes. The change in resistance can be measured using bridge method. which is measure of micro wave power incident.

Bolometer can be divided into two categories:

↳ Barretes (whose resistance ↑ with temp)

↳ Thermistors. (" " ↓ " ").

Barretes are thin short platinum used to measure microwave power levels.

Thermistors are semiconductor devices with -ve temp coef of resistance.

Q Difference in low freq measurements & microwave measurements:

1) No voltage or current measurements can be made at μwave freq unlike low freq.

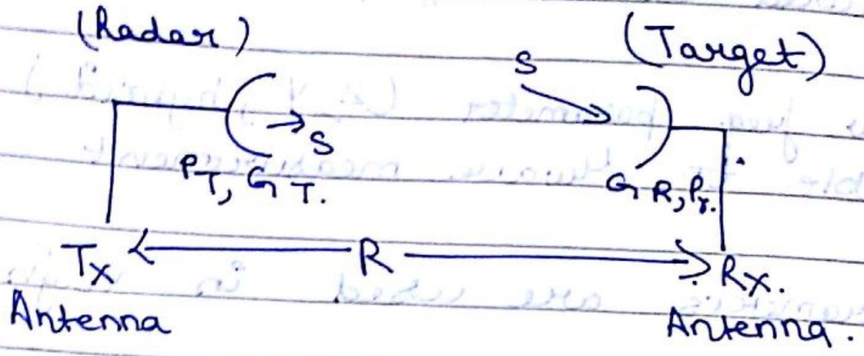
2) Only power i/p & o/p can be measured at μwave freq unlike current & voltage been measured at low freq.

3) No low freq parameter (Z, Y, hybrid) are applicable to μwave measurement

4) S-parameters are used in high freq.

5) No low freq components & ckt can be used at high freq & μwave freq due to effects such as transmit time effect.

Radar
(Radio Detection & Ranging).



$S \rightarrow$ density $\rightarrow \dfrac{P_T G_T}{4\pi R^2}$ (Power) (Surface of sphere)

Isotropic antenna $\rightarrow$ Radar ✗

∴ has gain.

$A_e \rightarrow$ effective aperture area.

$\rightarrow$ Radar cross section area.

$P_r = S \times A_e$

(W) $\quad$ $S \downarrow$ (W/m²) $\quad$ $A_e \rightarrow$ (m²).

$\cong$ Friis Tx eq^n

$$G_r = \frac{4\pi A_e}{\lambda^2}$$

$$A_e = \frac{G_r \lambda^2}{4\pi}$$

$$P_r = S \times \frac{G_r \lambda^2}{4\pi}$$

$$P_r = \frac{P_t . G_t}{4\pi R^2} \times \frac{G_r \lambda^2}{4\pi}.$$

$$\boxed{P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2}$$

Power recieved.

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