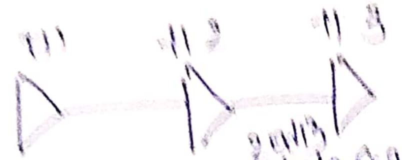
Example 2



$G_1 = 10\,dB \quad G_2 = 20\,dB \quad G_3 = 30\,dB$

$NF_1 = 3\,dB \quad NF_2 = 7\,dB \quad NF_3 = 6\,dB$

$G = 10 + 20 + 30 = 60\,dB$

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$$

$F_1 = 1.99 \approx 2 \qquad G_1 = 10$

$F_2 = 5 \qquad G_2 = 100$

$F_3 = 4 \qquad G_3 = 1000.$

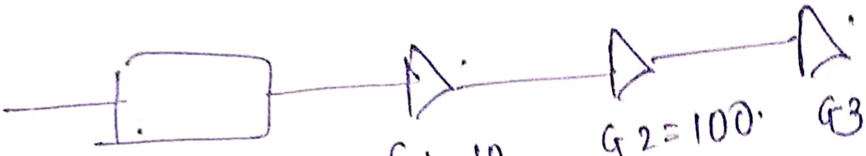
$$F = 2 + \frac{5-1}{10} + \frac{(4-1)}{(10)(100)}$$

$$= 2 + 0.4 + 0.003$$

$$\boxed{F = 2.403}$$

$NF = 10 \log F$

$$\boxed{NF = 3.81\,dB}$$




Cable loss

$L_1 = 6dB$

$G_1 = -6dB$

$\Downarrow$

$NF_1 = 6dB$

$= 4$

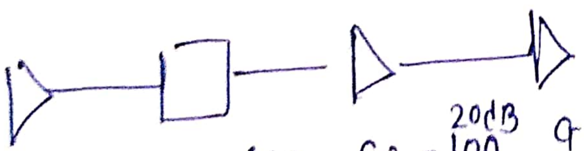
$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3}$$

$$= 4 + \frac{2-1}{1/4} + \frac{5-1}{\frac{1}{4} \times 10} + \frac{4-1}{\frac{1}{4} \times 10 \times 100}$$

$= 9.612.$

$NF = 10 \log (9.612)$

$= 9.83$ dB.



$G_1 = 10$    $G_2 = 6dB$    $G_3 = \overset{20dB}{\cancel{100}}$    $G_4 = 30$ dB.

$= 10$    $= 1/4$    $= 100$    $= 1000.$

$NF_1 = 4$    $F_2 = 4$    $F_3 = 5$    $F_4 = 5$

$F\ 2$

Scanned by CamScanner

$$F = 2 + \frac{4-1}{10} + \frac{5-1}{10 \times \frac{1}{4}} + \frac{4-1}{10 \times \frac{1}{4} + 100}$$

$$= 2 + 0.3 + 1.6 + 0.012$$

1 dB = 0.1 million dollar

$F = 3.912$

$NF = 10 \log (3.92) = 5.92\,dB$

$\Downarrow$

4 dB improve

$T_e = ?$

$T_e =$

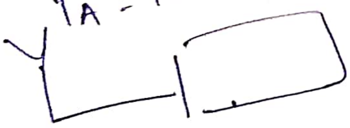
overall $T_e = (F-1) T_0$

$= (\cancel{3.8} - 1)\, \cancel{240}$

$= (2.403 - 1) 290$

$=$

$T_A = 15A$



$N_0 = K T_A B G + K T_e B G$ (unit of $N_0$ = Watt)

$\Downarrow$ convert in dBm

$\Downarrow \quad = (K (T_A + T_e) B G)$

Always ~~in~~ convert in terms dBm

$= -98.7\,dBm$

Scanned by CamScanner

Ex.

$S_i = ?$

$N_O = -98.7 dB = 1.35 \times 10^{-13}$ W.

$G = 3.95$ X.

$S_O/N_O = 20 dB = 100$

$S_i = \frac{S_O}{G} = \frac{S_O}{N_O} \cdot \frac{N_O}{G}$

$= 100 \times \frac{1.35 \times 10^{-13}}{3.95}$

$= 3.42 \times 10^{-12}$ W

$= 3.42 \times 10^{-9}$ mW

$= 10 \log (\quad)$ dBm

$=$

$v_o =$

$v_o = a_0 + a_1 v_i + a_2 v_i^2 + \dots$

Taylor's series

If $a_0$ is only non-zero value

if $a_0$ = nonzero $\Rightarrow v_o = a_0 \Rightarrow$ (analog to DC)

↓ analog

↳ Rectifier eqn.

if $a_1$ = nz $\Rightarrow v_o = a_1 v_i \Rightarrow$ ampl eqn.

$a_2$ = nz ..!

1) Gain compression

$v_i \longrightarrow$ Non linear N/O $\longrightarrow$ $V_o = a_0 + a_1 v_i + a_2 v_i^2 + \dots$ ; $V_i = V_0 \cos \omega_0 t$

$$V_o = a_0 + a_1 V_0 \cos \omega_0 t + a_2 V_0^2 \cos^2 \omega_0 t + a_3 V_0^3 \cos^3 \omega_0 t + \dots$$

$$\cos 2\theta = 2\cos^2\theta - 1$$

$$\Rightarrow \cos^2\theta = \frac{1}{2}(1 + \cos 2\theta)$$

$$\cos^3\theta = \frac{3}{4}\cos\theta + \frac{1}{4}\cos 3\theta$$

$$\theta = \omega_0 t$$

$$V_o = a_0 + a_1 V_0 \cos \omega_0 t + \frac{a_2 V_0^2}{2} + \frac{1}{2} a_2 V_0^2 \cos 2\omega_0 t$$

$$+ a_3 V_0^3 \left(\frac{3}{4}\cos \omega_0 t\right) + \frac{a_3 V_0^3}{4} \cos 3\omega_0 t$$

$= \cancel{a_0 + a_1 V_0}$

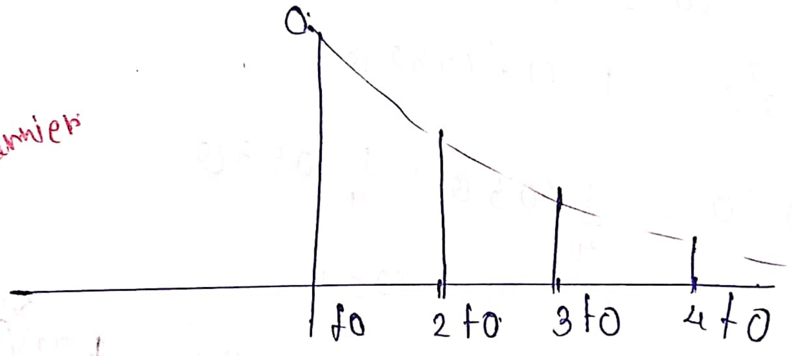
$$= \left(a_0 + \frac{a_2 V_0^2}{2}\right) + \left(a_1 V_0 \cos \omega_0 t + \frac{3}{4} a_3 V_0^3 \cos \omega_0 t\right)$$

$$+ \frac{a_2 \cancel{V_0}^2}{\ } + \left(\frac{V_0^2}{2} a_2 \cos 2\omega_0 t\right) + \left(\frac{a_3 V_0^3}{4} \cos 3\omega_0 t\right)$$

Scanned by CamScanner

* Harmonic distortion

→ due to linearity we are getting Harmonic distortion.

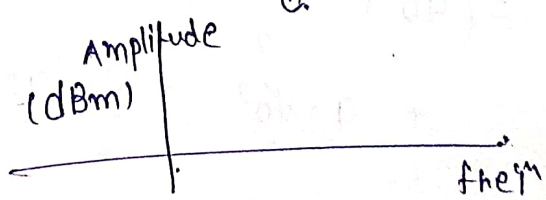



dBc
⇓
decible with respect to carrier
↓ ⇓
$\frac{S}{N}$, $\frac{C}{N}$, $\frac{E_b}{N_0}$

⇓
Undesired freq^n give less power to it.

time domain instrument → ossiloscope.

freq^n domain instrument → spectrum Analyzer
⇓




Gain at $G|_{\omega=\omega_0}$ $= \frac{V_o}{V_i} = \frac{(a_1 V_0 + \frac{3}{4} a_3 V_0^3)\cos\omega_0 t}{V_0 \cos\omega_0}$

⇓
desired freq^n.

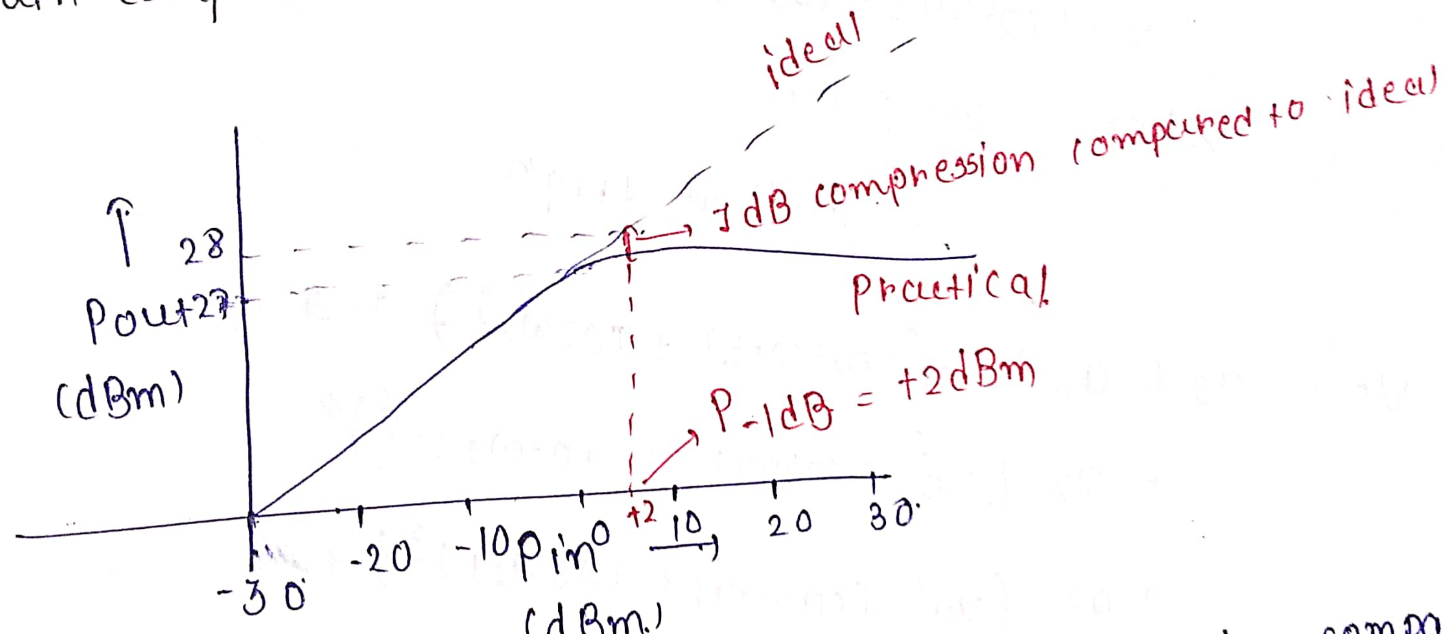
Typically $a_3$ is -ve ⇒ limitation of power supply to ampli·

Q5 → $a_3$ (-ve) ⇒ Gain ↓ (compression)

⇓

1 dB compression point

Gain compression graphical understanding



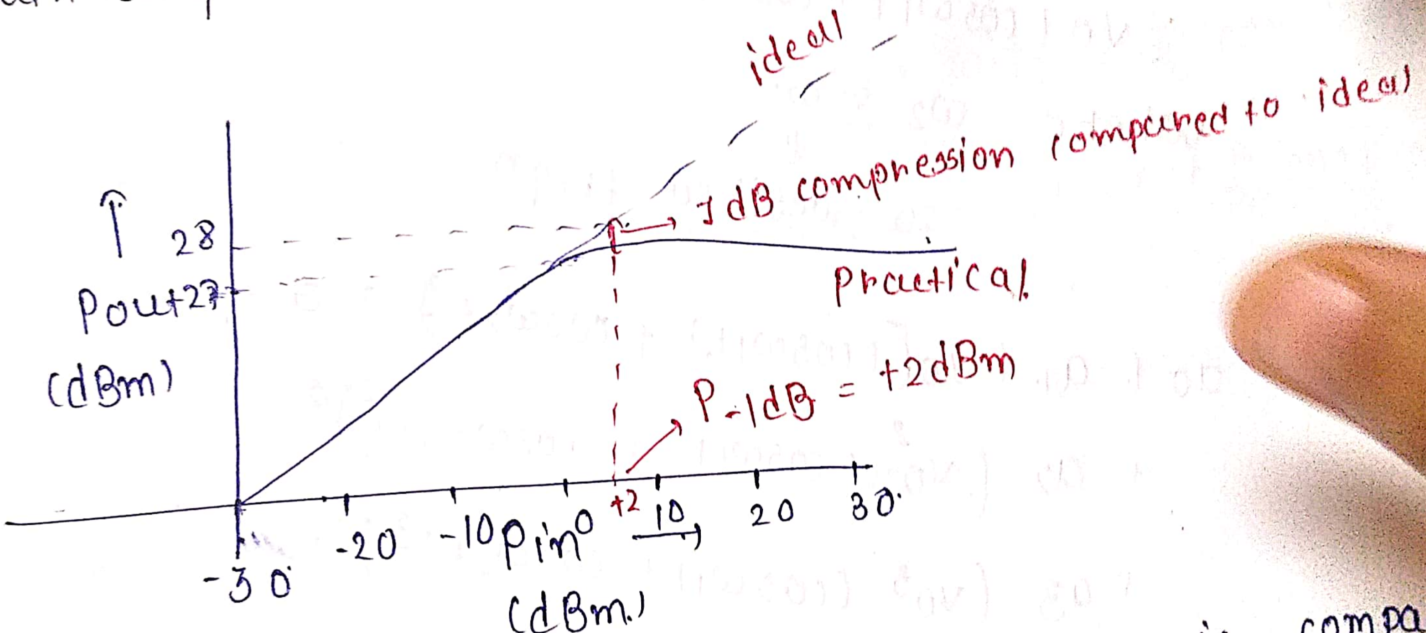

→ It is i/p point at which o/p power is compared as 1dB from its ideal characteristic.

→ up to 1-dB $P_{-1dB}$ it is linear after that no gain as it goes in saturation level. we can identify up to how much level we have to give input.

Typically $a_3$ is -ve ⇒ limitation of power supply to ampl.

Q5 → $a_3$ (-ve) ⇒ Gain ↓ (compression)
⇓
1 dB compression point

Gain compression graphical understanding

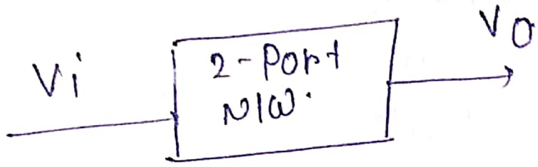



→ It is i/p point at which o/p Power is compared as 1dB from its ideal characteristic.

→ up to ~~1-dB~~ P-1dB it is linear after that no gain as it goes in saturation level. We can identify up to how much level we have to give input.

* IMD (3rd order ~~Intra~~ Inter Modulation Distort.)

$V_o = a_0 + a_1 v_i + a_2 v_i^2 + a_3 v_i^3 + \dots$




$V_i = V_o \cos\omega_1 t + V_o \cos\omega_2 t$

$= V_o(\cos\omega_1 t + \cos\omega_2 t)$

where $\omega_2 \simeq \omega_1$

$\Downarrow$

desired freq$^n$

$$V_o = a_0 + a_1 (V_o[(\cos\omega_1 t) + \cos\omega_2 t]) + a_2 (V_o^2 (\cos\omega_1 t + \cos\omega_2 t)^2) + a_3 (V_o^3 (\cos\omega_1 t + \cos\omega_2 t)^3) + \dots$$

$\cos^2\theta = \frac{1}{2}(1 + \cos 2\theta)$, $\theta = \omega t$

$\cos^3\theta = \frac{1}{4}(3\cos\theta + \cancel{4}\cos 3\theta)$

$\cos\theta_1 \cos\theta_2 = \frac{1}{2}[\cos(\theta_1 + \theta_2) + \cos(\theta_1 - \theta_2)]$

$$V_o = a_0 + a_1 V_o \cos\omega_1 t + a_1 V_o \cos\omega_2 t + a_2 V_o^2 (\cos^2\omega_1 t + 2\cos\omega_1 t \cos\omega_2 t + \cos^2\omega_2 t) + a_3 V_o^3 ($$

$a_1 v_0 \cos\omega_2 t + a_2$

$= a_0 + a_1 v_0 \cos\omega_1 t + \frac{a_2 v_0^2}{2}(1 + \cos 2\omega_2 t)$

$+ \frac{a_2 v_0^2}{2}(1 + \cos 2\omega_1 t) + \cancel{\cos(} \; a_2 v_0^2 \cos(\omega_1 - \omega_2)t$

$+ a_2 v_0^2 (\cos(\omega_1 + \omega_2)t$

$\cancel{+ a_3}$

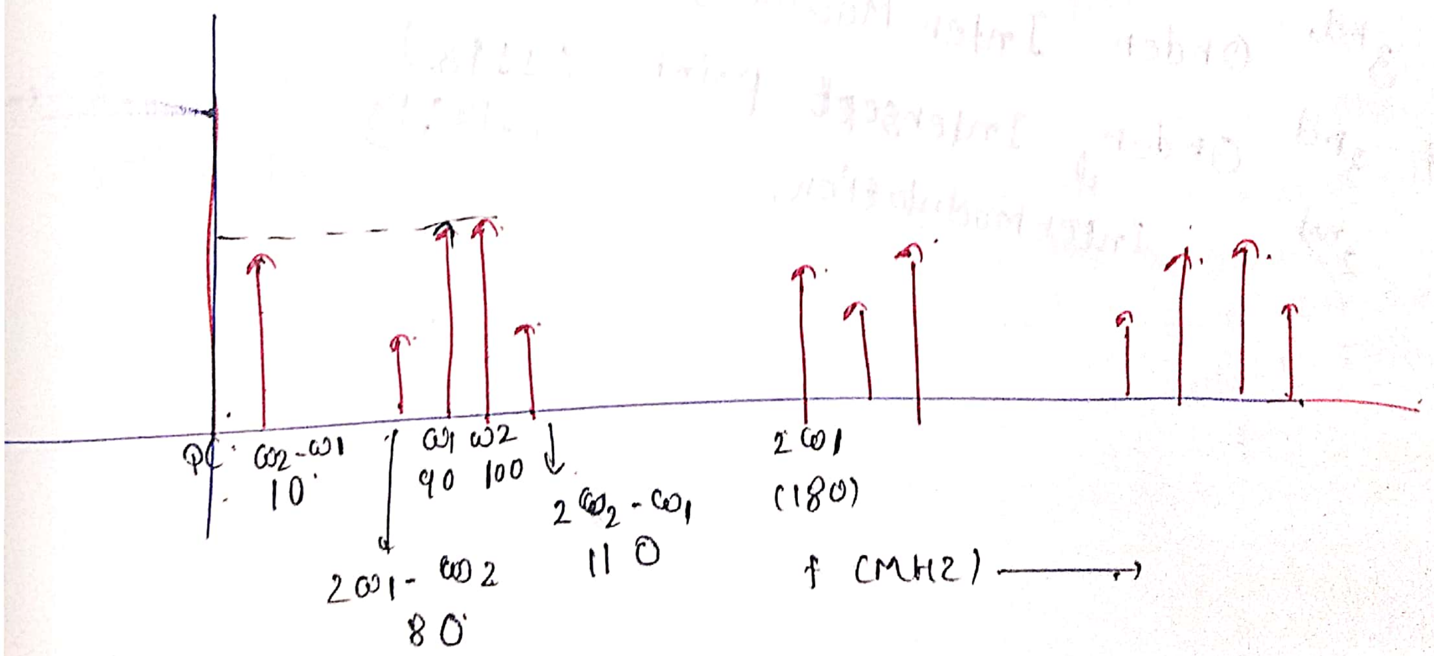
$+ a_3 v_0^3 \left(\frac{3}{4}\cos\omega_1 t + \frac{1}{4}(\cos 3\omega_1 t)\right) + a_3 v_0^3 \left(\frac{3}{4}\cos\omega_2 t + \frac{1}{4}\cos 3\omega_2 t\right)$

$+ \frac{3}{2} a_3 v_0^3 \left[\frac{3}{2}\cos\omega_2 t + \frac{3}{4}\cos(2\omega_1 - \omega_2)t + \frac{3}{4}\cos(2\omega_1 + \omega_2)t\right]$

$+ a_3 v_0^3 \left[\frac{3}{2}\cos\omega_1 t + \frac{3}{4}\cos(2\omega_2 - \omega_1)t + \frac{3}{4}\cos(2\omega_2 + \omega_1)t\right]$

bluetooth 18 M

$\omega_1 = f_1 = 90\,MHz, \quad \omega_2 = f_2 = 100\,MHz$



→ Order of IMD

$|m| + |n|$

where $m, n$, $0 \pm 1, \pm 2, \pm 3 \ldots$

2, 1
1, 2
3, 0
0, 3
-2, -1
-1, -2
-3, 0
0, -3

order

13 →

0 → 0 DC $|m| + |n| = 0$

1 → 2 $|m| + |n| = 1$
$\omega_1$. $m = 1, n = 0$
$\omega_2$ $m = 0, n = 1$

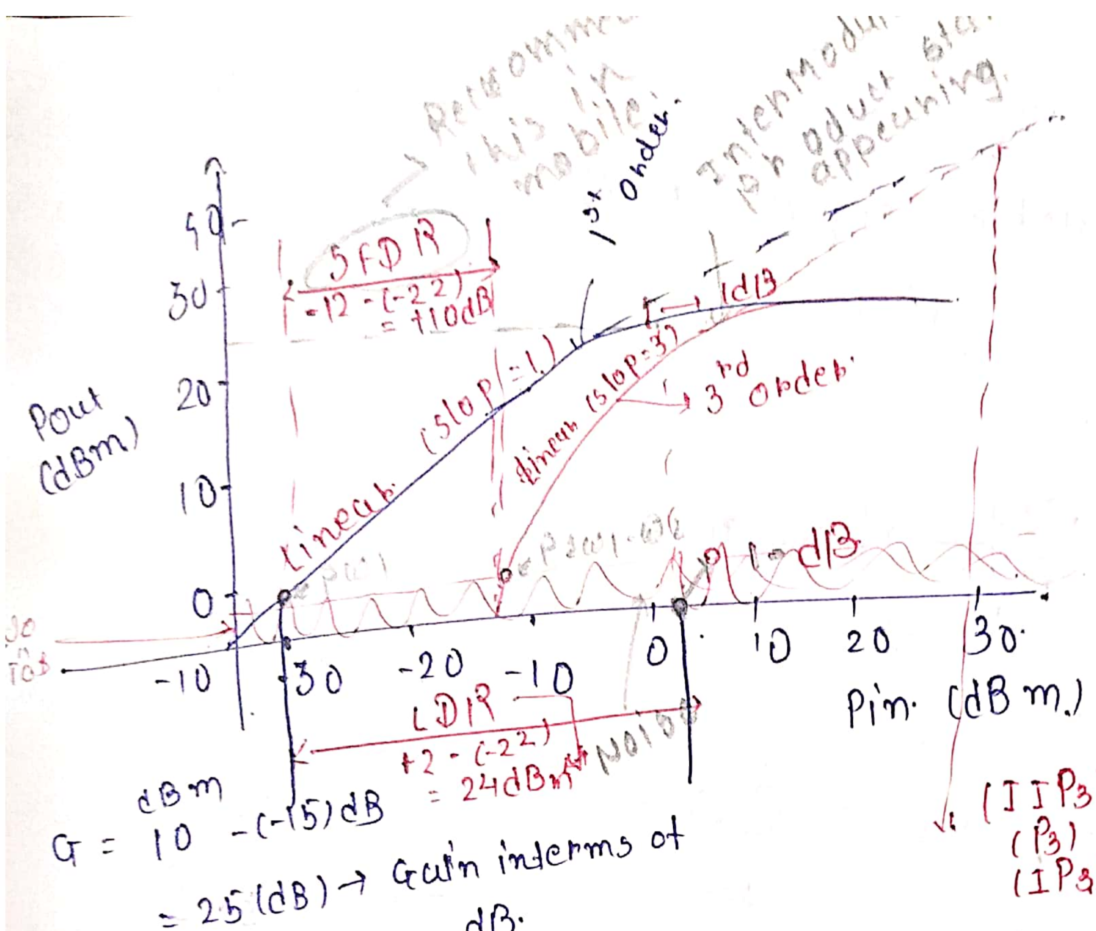
2 → 4. →
$\omega_1 + \omega_2$ $\cancel{m=1}$ $= m = 1, n = 1$
$\omega_1 - \omega_2$ $m = 1, n = 1$
$2\omega_1$ $m = 2, n = 0$
$2\omega_2$ $m = 0, n = 2$

3 → 6. →
$3\omega_1$ $m = 3, n = 0$
$3\omega_2$ $m = 0, n = 3$
$2\omega_2 - \omega_1$ $m = 2, n = 1$
$2\omega_2 + \omega_1$ $m = 1, n = 2$
$2\omega_1 - \omega_2$ $m = 2, n = 1$
$2\omega_1 + \omega_2$

Dt -

* 3rd Order Inter Modulation distortion
* 3rd Order Intersept point (IIP3.) (IP3), P3

2nd ~~Inter Modulation~~




freq^n gain relation not

small increase in i/p Amplitude big increase in i/p power, $P \propto V^2$

→ $IIP_3$ is the input power corresponds to the hypothetical intersection point of first order & 3rd order IMD product.

→ $IIP_3$ is +ve input power at which first order & 3rd order power equal.

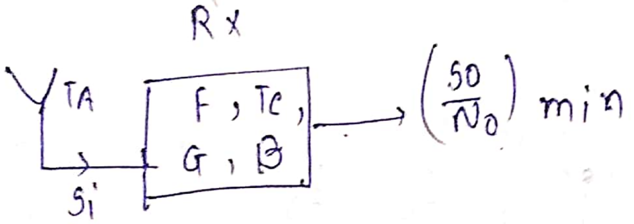
Interference (always prefer to have large IIP3) less cs. with our signal) (move curve right side further)

* Sensitivity

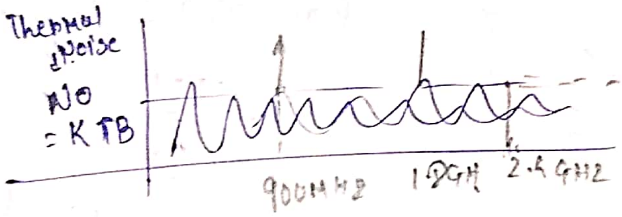
→ Specific Absorption Rate of a phone. Times of India today page 7

→ Minimum detectable signal (MDS)

(More as less as possible detected)




$-100 dBm$




$-10 = 20 \log \frac{P_c}{1mW}$

$-1 = \log \frac{P_c}{1mW}$

$10^{-1}$

SIM $S_{imin} = \frac{S_{omin}}{G}$

$$S_{imin} = \frac{N_o}{G} \left(\frac{S_o}{N_o}\right)_{min}$$

Interested to find this.

$$N_o = \frac{KB(T_A + T_e)G}{G} \times \left(\frac{S_o}{N_o}\right)_{min}$$

$$= KB(T_A + T_e)\left(\frac{S_o}{N_o}\right)_{min}$$

$$\boxed{S_{imin} = KB[T_A + (F-1)T_o]\left(\frac{S_o}{N_o}\right)_{min}}$$

Scanned by CamScanner

Suppose it is a stand alone system

$S_{imin}|_{dBm} = 10\log(KT_0) + 10\log B + NF(dB) \rightarrow 10\log F$

$+ \left(\frac{S_0}{N_0}\right)_{min}|_{dB}$

$-174\ dBm/Hz$

no antenna → stand alone system

IS-54 PCS telephone system

$\left(\frac{S_0}{N_0}\right)_{min} = 15.5 \rightarrow$ requirement, $T_A = 900K$

$B = 30KHz$

$NF = 8dB$

Analog voice → 5-10dB (SNR$_m$)

phone — 15-30dB

TV — 45-55dB

cellular — 18-50dB

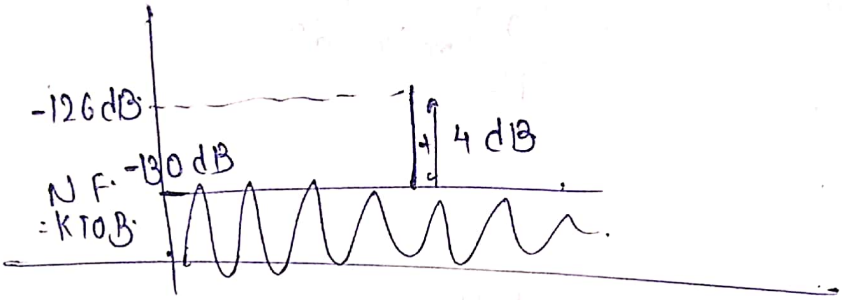
$S_{imin} = KB[T_A + (F-1)T_0]\left(\frac{S_0}{N_0}\right)_{min}$

$= 1.38 \times 10^{-23} \times 30 \times 10^3 [900 + (6.3-1) 290] \times 15.5$

$= 1.57 \times 10^{-14}$ Watts

$= 1.57 \times 10^{-11}$ m watts

$S_{imin}|_{dBm} = 10\log(1.57 \times 10^{-11}) = -110 + 2 \simeq -108\ dBm.$




1 dBm → no power
0 dBm → 1mW power

TSS = MDS + 4 dB
⇓
Tangetial signal sensitivity

+ 90 dB (-10dBm to +80dBm)

(more sensitive) + 90dB (-30dBm to +60dBm)
⇓
minimum detectable signal, more costly.

$a_3 V_0^3$ ↳ co-efficient of $(2\omega_1 - \omega_2)$

o/p power of 3rd order IMD produces is proportional i/p power

$P \propto V^2$

* dynamic range.

1) Linear (or blocking) dynamic range. (LDR)

2) Spuriouce free Dynamic Range (SFDR)
(unwanted signal)

→ i/p Power range from noise figure up to 1dB compression point.

→ i/p Power range from noise figur upto i/p power that creates IMD products (3rd order)

Noise floor $N_0 = KTB$

$= -174 \ \frac{dBm}{Hz} + 10\log B$

$TSS = MDS + 4dB$

$\underset{(dBm)}{LDR} = \underset{(dBm)}{P_{-1dB}} - \underset{(dBm)}{\text{Noise floor}}$

$\underset{(dBm)}{P_{-1dB}} \simeq IIP_3 - 9.64 \cong 10, 15 \ldots$

⇓

Amperical (not Mathematically derived)

$SFDR = \frac{2}{3}(IIP_3 - \text{Noise floor})$

Ex Rx has. $NF = 7\,dB$

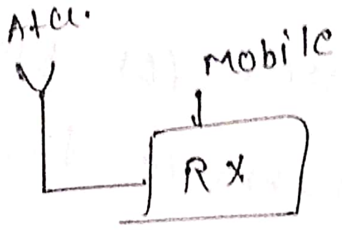
$P_{-1dB} = 25\,dBm$

$G = 40\,dB$

$IIP_3 = 35\,dBm$

$B = 100\,MHz$

$T_A = 150\,K$




stand alone → dBm
compare, range, ratio → dB

$LDR = ?$

$SFDR = ?$

$N_0 = \cancel{K T_A B} + K T_e B$

Ata temp given.

$0^\circ C \rightarrow 273\,K$

$LDR = \cancel{K T_0 B}\ P_{-1dB} - N_0$

$= -25 - 174$

$N_0 = K T_A B G + K T_e B G$

$= K B G (T_A + T_e)$

$= 1.38 \times 10^{-23} \times 100 \times 10^{6} \times \underbrace{10^{4}}_{40dB} (150 +$

$T_e = (F-1) T_0$

$= (\underbrace{5}_{10^{0.7}} - 1) \times 290$  ($NF = 7\,dB$, $F = 5$)

$=$

$N_0 = 1.38\times10^{-23} \times 100 \times 10^{6} \times 10^{4} / 150\ t.$

$= 1.8\times10^{-8}$ watt $= 1.8\times10^{-5}$ mw.

$=.$

$LDR = P_{-1dB} - N_0$

$= 25\,dBm - (-47.4)\ dBm$

$LDR \cong 72\ dB$ → comparing so find dB )

$SFDR = \frac{2}{3}(P_3 - N_0)$

$= \frac{2}{3}(135 + 47.4)$

$\cong 48\ dB.$

$\boxed{SFDR << LDR}$ → standard

$V_0$ = - - - -

$(\omega_1)$

$(2\omega_1 - \omega_2)$

$$P_{\omega_1} = \frac{1}{2} a_1^2 V_0^2$$

$$P_{2\omega_1 - \omega_2} = \frac{1}{2}\left(\frac{3}{4} a_3 V_0^3\right)^2$$

By designing o/p IIP3

at IIP3, $P_{\omega_1} = P_{2\omega_1 - \omega_2}$

$$\frac{1}{2} a_1^2 V_{IP}^2 = \frac{1}{2}\left(\frac{3}{4} a_3 V_{IP}^3\right)^2$$

$$\frac{1}{2} a_1^2 V_{IP}^2 = \frac{9}{32} a_3^2 V_{IP}^6$$

$$V_{IP}^4 = \frac{a_1^2}{a_3^2}\left(\frac{16}{9}\right)$$

$$V_{IP}^2 = \frac{4}{3} \frac{a_1}{a_3}$$

$$V_{IP} = \sqrt{\frac{4}{3} \frac{a_1}{a_3}}$$

$$V_{IP} = \sqrt{\frac{4}{3}\frac{a_1}{a_3}}$$

$$P_{\omega_1}\Big|_{V_0 = V_{IP}} = \frac{1}{2} a_1^2 V_{IP}^2$$

$$= \frac{1}{2} a_1^2 \times \frac{4}{3} \times \frac{a_1}{a_3}$$

$$\boxed{P_{\omega_1}\Big|_{V_0 = V_{IP}} = \frac{2}{3}\frac{a_1^3}{a_3}}$$ $\Rightarrow$ Independent of i/p power $V_0$.

$$V = V_0(\underset{\text{desired freq}^n}{\cos\omega_1 t} + \cos\omega_2 t)$$

$\omega_1 \simeq \omega_2$.

SFDR = (Dynamic Range) $\dfrac{P_{\omega_1}}{P_{2\omega_1 - \omega_2}}$ $\rightarrow$ $\dfrac{\text{required}}{3^{rd}\text{ order}}$

$$P_{2\omega_1 - \omega_2} = \frac{9}{32} a_3^2 V_0^6$$

$$P_{\omega_1} = \frac{2}{3}\frac{a_1^3}{a_3}$$

Scanned by CamScanner

$SFDR = \frac{9}{32} a_3$

$$SFDR = \frac{\frac{2}{3}\frac{a_1^3}{a_3}}{\frac{9}{32} a_3^2 V_0^6} = \frac{P_{\omega 1}}{P_{2\omega_1 - \omega_2}}$$

$$= \frac{2 \times 32 \times a_1^3}{9 \times 3 \times a_3^4 \times V_0^6}$$

$$= \frac{64}{27} \cdot \frac{a_1^3}{a_3^4 V_0^6}$$

$$P_{2\omega_1 - \omega_2} = \frac{9}{32} a_3^2 V_0^6$$

$$= \frac{\frac{1}{8} a_1^6 V_0^6}{\frac{4 a_1^6}{9 a_3^2}}$$

$$P_{2\omega_1 - \omega_2} = \frac{(P_{\omega_1})^3}{(P_{IIP3})^2} \rightarrow P_{\omega 1} = \frac{1}{2} a_1^2 V_0^2$$

$P_{\cancel{2}\omega_1}$

from that curve.

$$P_{2\omega_1 - \omega_2} = N_0 = \frac{(P_{\omega_1})^3}{(P_{\omega_3})^2} \rightarrow \text{IIP}_3 \text{ power.}$$

$$P_{\omega_1} = (N_0)^{1/3} (P_{\omega_2})^{2/3}$$

$$SFDR = \frac{P_{\omega_1}}{P_{2\omega_1 - \omega_2}}$$

$$= \cancel{N_0^{1/3}} = \frac{N_0^{1/3} \cdot P_3^{2/3}}{N_0}$$

$$SFDR = \left(\frac{P_3}{N_0}\right)^{2/3}$$

i/p power ↑ + it's not easy for A+4 (noise ↑, o/p power ↑)

IIP3 ↑

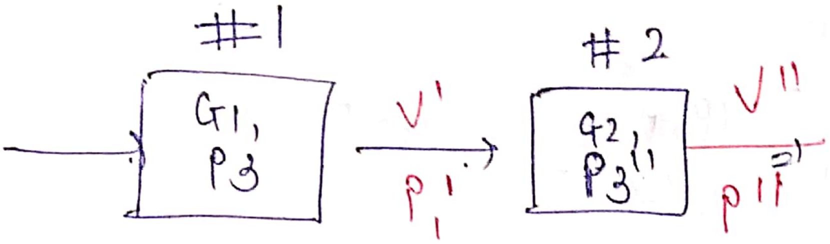
SFDR ↑

$$SFDR)_{dB} = \frac{2}{3}(P_3 - N_0)$$

$\Downarrow$

?

* Cascaded intercept point.
(3$^{rd}$ order)




$\boxed{G = G_1 G_2 \quad F = F_1 + \frac{F_2 - 1}{G_1}}$

$P_3'$ = $IIP_3$ point by 1$^{st}$ system

$P_3''$ = " " " 2$^{nd}$ system

$P_3$ = ?

$P'_{2\omega_1 - \omega_2}$ = Power at O/P 1$^{st}$ system (3$^{rd}$ order)

I (desh) first sub-system

$$P'_{2\omega_1 - \omega_2} = \frac{(P'_{\omega_1})^3}{(P_3')^2} \quad \begin{matrix} \Rightarrow 1^{st} \text{ system } 1^{st} \text{ order} \\ \Rightarrow 3^{rd} \text{ order } 1^{st} \text{ system} \end{matrix}$$

Voltage controlled over this Power.

$$V'_{2\omega_1 - \omega_2} = \sqrt{P'_{2\omega_1 - \omega_2} \cdot Z_0}$$

$$= \sqrt{\frac{(P'_{\omega_1})^3 \cdot Z_0}{(P_3')^2}}$$

3rd order disto

2.

$$V''_{2\omega_1-\omega_2} = \sqrt{\frac{G_2(P'_{\omega_1})^3 Z_0}{P_3'}} + \frac{\sqrt{(P_{\omega_1}'')^3 Z'_0}}{P_3''}$$

$P_\omega'' = G_2$.

$P_\omega'' = G_2 P_\omega'$

$$P_\omega' = \frac{P_\omega''}{G_2}$$

$$V''_{2\omega_1-\omega_2} = \sqrt{\frac{G_2\left(\frac{P_{\omega_1}''}{G_2}\right)^3}{P_3'}} + \frac{\sqrt{(P_{\omega_1}'')^3 Z_0}}{P_3''}$$

$$= \sqrt{\frac{(P_{\omega_1}'')^3 \cdot Z_0}{G_2 P_3'}} + \frac{\sqrt{(P_{\omega_1}'')^3 \cdot Z_0}}{P_3''}$$

$$V''_{2\omega_1-\omega_2} = \left(\frac{1}{G_2 P_3'} + \frac{1}{P_3''}\right) \sqrt{(P_{\omega_1}'')^3 Z_0}$$

O/P Power

$$P''_{2\omega_1-\omega_2} = \frac{(V''_{\omega_1-\omega_2})^2}{Z_0}$$

$$= \left(\frac{1}{G_2 P_3'} + \frac{1}{P_3''}\right)^2 \cdot (P''_{\omega_1})^3$$

$P_3$ of cascaded system.

Impedance Matching concept is used. (characteristic impedance)

$$= \frac{1}{\frac{1}{G_2 P_3'} + \frac{1}{P_3''}} =$$

$$= \left(\frac{1}{G_2 P_3'} + \frac{1}{P_3''}\right)^{-1}$$

$$P'' = (P_{\omega_1}'')^3 / (P_3^2)$$

for three system

$$= \frac{1}{G}\left(\frac{1}{G_3 G_2 P_3'} + \frac{1}{G_2 \cdot P_3''} + \frac{1}{P_3''}\right)^{-1}$$

→ for four subsystem.

$$= \left( \frac{1}{G_4 G_3 G_2 P_3'} + \frac{1}{G_3 G_2 P_3''} + \frac{1}{G_2 P_3'} + \frac{1}{P_3'''} \right)^{-1}$$

$$\Downarrow$$

$$\times G_1$$

Ex

$G_1 = 20\,dB$ $G_2 = -6\,dB$

$P_3' = 22\,dBm$ $P_3'' = 7\,dBm$

$$P_3 = \left( \frac{1}{G_2 P_3'} + \frac{1}{P_3''} \right)$$

$G_2 \to -6 \to \frac{1}{4} = 0.25$

$$= \left( \cancel{\frac{1}{G_{21}}} \frac{1}{0.25 \times 158} + \frac{1}{5} \right)^{-1}$$

$P_3 = 4.4\,mW$

$$\boxed{P_3 = 6.4\,dBm}$$

$\Rightarrow$ SFDR $\downarrow$

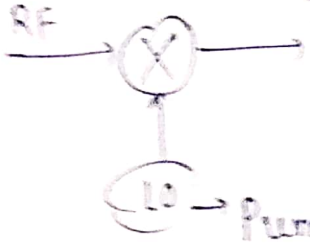
$\uparrow$

$\Downarrow$

overall $P_3 \Rightarrow$ at O/P

D1 - 09/09/2019

* Image frequency




IF (intermediate freqn)

Rf = 10

Rf = 10

LO → Pump oscillator/ injection freqn.

RF = 2 GHz

LO = 1.8 GHz

IF = 200 MHz

LO > RF

~~work to~~ Prefer
Prefer to work at low freqn

RF = 2

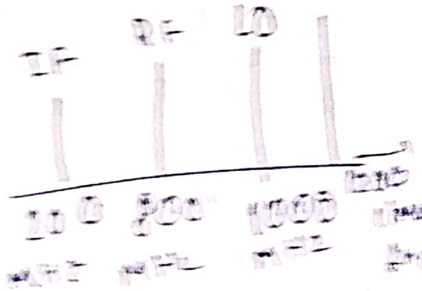
LO = 2.2

IF = 200 MHz

LO > IF
→ (High side injection)
⇓
$f_{LO} = f_{RF} + f_{IF}$

\+
$f_{RF}$
↓ LPF
$f_{IF}$

LO < IF
(Low side injection)




1000 - 800 = 200
200
↓ LPF
200

If a freq$^n$ $f = f_{LO} + f_{IF}$. → 1200 : 1000 + 200

i.e., $f = f_{RF} + f_{IF} + f_{IF}$.

Image freq$^n$ → $f = f_{RF} + 2f_{IF}$

manages to reach Rx / mixer

$f \times f_{LO}$

↓ LPF.

$f_{IF}$

$$\boxed{\text{Image freq}^n = f_{RF} + 2\,IF}$$

1200 × 1000 LO (2200, 200)

↓ LPF.

200

→ Equal to some other RF produced desired IF. when multiply by LO.

→ To reject image IF should be very high.

Disadvantage

→ Power selectivity lead to tracking problem.

2) Low side injection ($LO < RF$)

$f_{LO} = f_{RF} - f_{IF}$

$\cancel{f_{RF}}$

↓ LPF

Intermi → $f_{IF}$
freq^n

600 = 800 - 400

×

800

↓ LPF   1400, 200

200

If a freq^n

$f = f_{LO} - f_{IF}$.

ie; $f = (f_{RF} - f_{IF}) - f_{IF}$.

$$\boxed{f_i = f_{RF} - 2IF}$$

⇓

Image freq^n

If

400 = 600 - 200

= 800 - 200 - 200

= 800 - 2(200)

400 × 600

↓   1400, 200

200

* ~~AM~~ * AM broadcast

$f_{RF}$ = 600 KHZ

$f_{LO}$ = 1055 KHZ

$f_{IF}$ = 455 KHZ

VCO ( voltage controlled oscillator)

· varactor diode.

voltage → ch.
capacitor → chn.
freq^n → change

Image freq$^n$

$f_{LO} > f_{RF}$. (High side injection)

Image = $f_{RF} + 2IF$

$= 600 + 2(455)$

Image freq$^n$ $= 1510$ KHz.

Image $f_i$ $= f_{LO} + IF$ intermediate freq

$= 1055 + 455$

$f_i = 1510$

* IFRR (image freq$^n$ rejection ratio)

$$IFRR = \sqrt{1 + Q^2 \rho^2}$$

$$Q = \frac{f_0}{B.W} = \frac{f_0}{\Delta F}$$

where $\rho = \frac{f_{im}}{f_{RF}} - \frac{f_{RF}}{f_i}$

numerical measure of ability of filter to reject image freq$^n$.

$$IFRR\ dB = 10 \log (IFRR)$$

IFRR

$$\rho = \frac{1510}{600} - \frac{600}{1510}$$

Q. → given

Q ↑ → design to difficult

$$= 2.51 - 0.347$$

$$= 2.113$$

$$IFRR = \sqrt{1 + (100)^2 + (2.113)^2}$$

$$= 212.15$$

$$IFRR|_{dB} = 10\log(212.15)$$

$$\boxed{IFRR|_{dB} = 28.25\,dB}$$

$$f_{IF} > \frac{f_{RF}}{2}$$

$$> \frac{20}{2}$$

$$f_{IF} > 10$$

$$f_{IF} = 10.7\ MHz$$

FM

↓

88 - 108 MHz

B.W = 20 MHz

FM :-

~~fi~~ If = fRF + 2IF.

High than power

fRF = 88-108 MHz

fIF = 10.7 MHz.

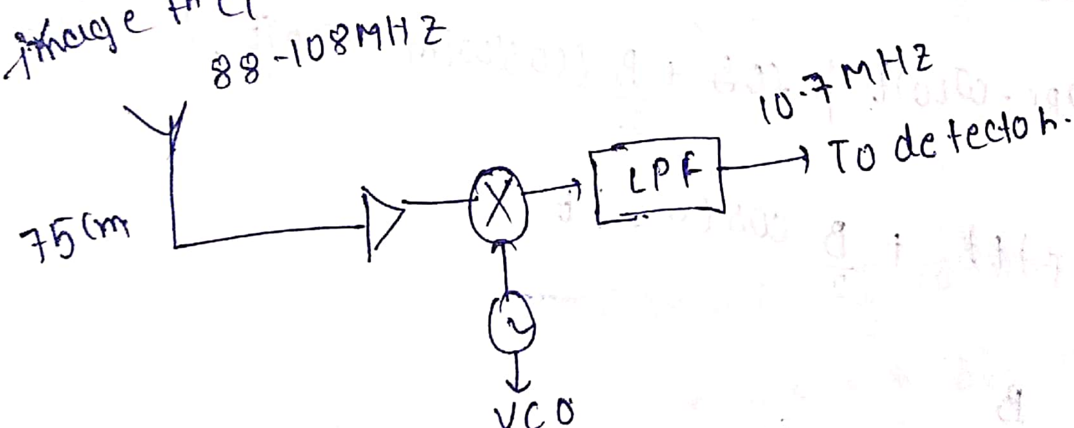
fLO = 98.7 to 118.7 (High ~~than~~ side injection

$f_i = f_{RF} + 2IF \;/\; f_{LO} + IF$

$= (88 \text{ to } 108) + 2(10.7)$

$\boxed{f_i = 109.4 \text{ to } 129.4}$

image freqn.




= ~~77.3 to 99.3 MHz~~

77.3 to 99.3 MHz

~~for~~ $f_i = f_{RF} - 2.f(I_f)$

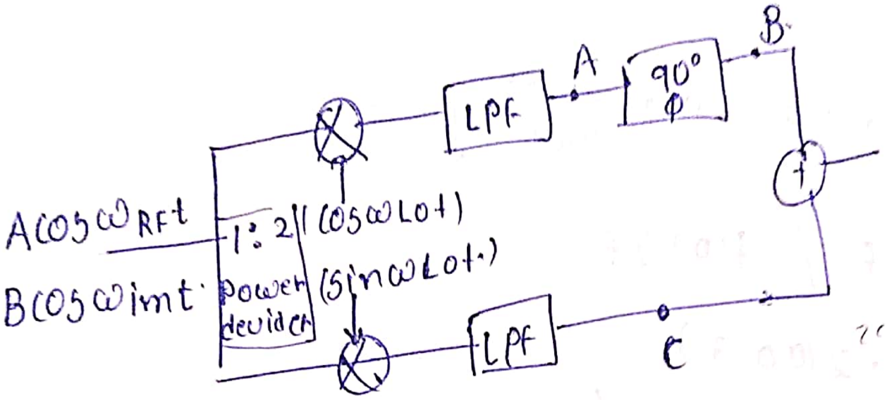
$= 88-108 - 2(109.4)$

Scanned by CamScanner

* Hartly & Weaver

DI - 02/09/2019
Friday 3rd Oct - at 12 nm.
CEP-103

* Hartly Architecture for image rejection




Signal at A after LPF

$= A\cos\omega_{RF}t \cdot \cos\omega_{LO}t + B\cos\omega_{im}t \cdot \cos\omega_{LO}t$

$= \frac{A}{2}\left(\cos(\omega_{RF}-\omega_{LO})t\right) + \cancel{\cos} + \frac{B}{2}\left(\cos(\omega_{im}-\omega_{LO})t\right)$

$= \frac{A}{2}\cos(\omega_{IF})t + \frac{B}{2}\cos(\omega_{IF})t$

Signal at B

$= \frac{A}{2}\cos(\omega_{IF}t+90°) + \frac{B}{2}\cos(\omega_{IF}+90°)$

$= -\frac{A}{2}\sin\omega_{IF}t - \frac{B}{2}\sin(\omega_{IF})t$

Signal at C

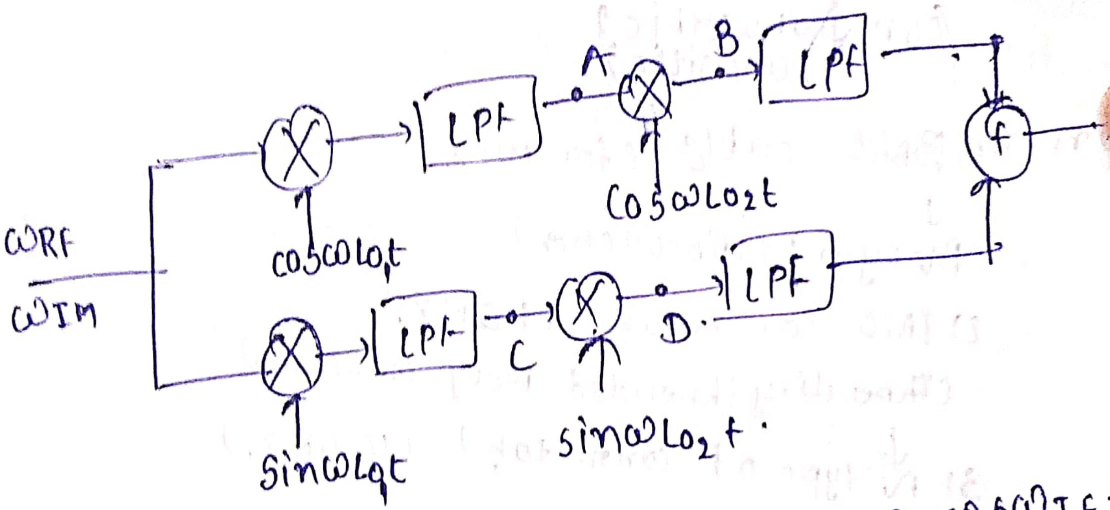
$= -\frac{A}{2}\sin(\omega_{RF}-\omega_{LO})t + \frac{B}{2}\sin(\omega_{im}-\omega_{LO})t$

$= -\frac{A}{2}\sin\omega_{IF}t + \frac{B}{2}\sin\omega_{IF}t$

signal at (x) o/p

$A + C = -A\sin\omega_{IF}t$

Weaver architecture (introduced to avoid phase shifter, as it is difficult to de




signal at A = $\frac{A}{2}\cos\omega_{IF}t + \frac{B}{2}\cos\omega_{IF}t$

signal at C = $\frac{-A}{2}\sin\omega_{IF}t + \frac{B}{2}\sin\omega_{IF}t$

signal at B = $\frac{A}{2}\cos(\omega_{IF}-\omega_{LO_2})t + \frac{B}{4}\cos(\omega_{IF}-\omega_{LO_2}$

after LPF

signal at D = $-\frac{A}{4}\cos(\omega_{IF}-\omega_{LO})t + \frac{B}{4}\cos(\omega_{IF}-\omega$

after LPF

signal at ...

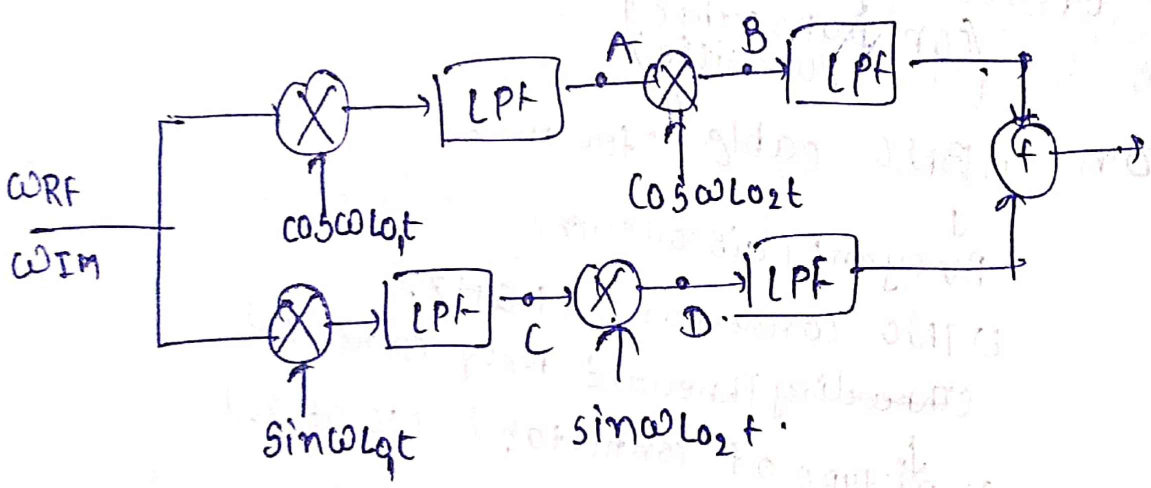
$$= -\frac{A}{2}\sin(\omega_{RF}-\omega_{LO})t + \frac{B}{2}\sin(\omega_{im}-\omega_{LO})t$$

$$= -\frac{A}{2}\sin\omega_{IF}t + \frac{B}{2}\sin\omega_{IF}t$$

signal at ② O/P

$$A + C = -A\sin\omega_{IF}t$$

Weaver architecture (introduced to avoid phase shifted, as it ... to design




signal at A $= \frac{A}{2}\cos\omega_{IF}t + \frac{B}{2}\cos\omega_{IF}t$

signal at C $= \frac{-A}{2}\sin\omega_{IF}t + \frac{B}{2}\sin\omega_{IF}t$

signal at B $= \frac{A}{2}\cos(\omega_{IF}-\omega_{LO_2})t + \frac{B}{4}\cos(\omega_{IF}-\omega_{LO_2})t$

after LPF

signal at D $= -\frac{A}{4}\cos(\omega_{IF}-\omega_{LO})t + \frac{B}{4}\cos(\omega_{IF}-\omega_{LO})t$

after LPF

at O/P ⇒ B - D

$$= \frac{A}{2} \cos(\omega_{IF} - \omega_{LO2} t)$$

1 phase shifter is replaced by 2 Mixer & 2 LPF.

1st Insem course.

* Basics of RF electronics:

1) Presence of stray elements (or ~~paraeethic~~ parasitic)

2) Radiation :

1) BNC cable (few MHz)

B — Buoyant (discoverer)

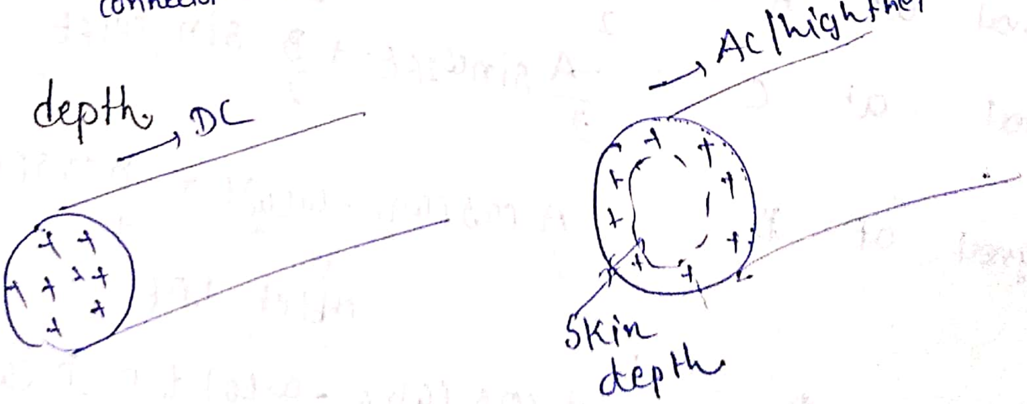
2) TNC connector (1 GHz)

(~~Threading~~ Threaded Nevy connector)

3) N type of connector) (10 GHz)

Gold connector. 4) SMA (Sub miniature A) (20 GHz)

* Skin depth

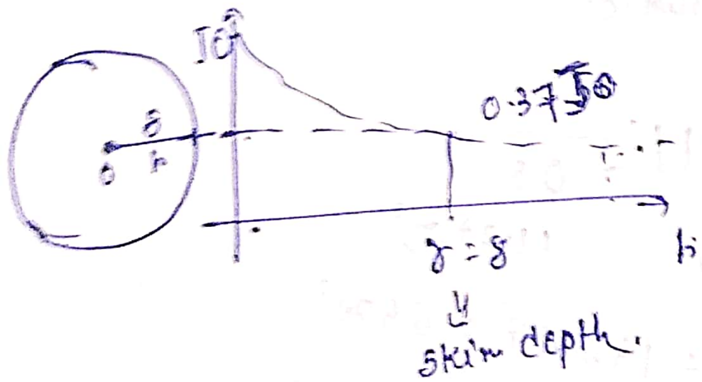


$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}} = \sqrt{\frac{1}{\pi f \mu \sigma}}$$

$f \uparrow \rightarrow \delta \downarrow$ (skin depth)

coper wire

→ For AC signals, current density falls exponentially from surface to center of the conductivity, $\delta$ called skin depth, are at critical depth, signal amplitude falls to $1/e$ or 36.8% of its maximum value.

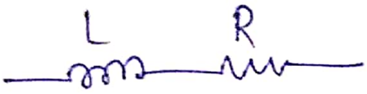



$$1 \text{ mil} \rightarrow \frac{1 \text{ inch}}{1000}$$
$$= \frac{2.54 \text{ cm}}{1000}$$
$$= \frac{25.4 \text{ m}}{1000}$$

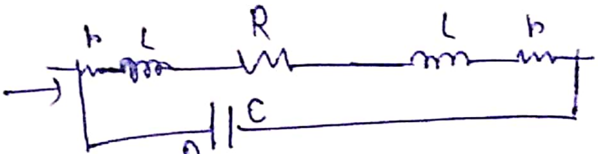
50
44

SWG
(standard wire guage.)

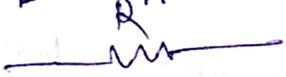
(AC equivalent circuit)
wire (circuit) -




Resistor (R)
(AC equivalant)




Resistor (R)
(DC equivalant)



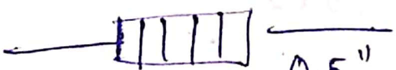

~~BB~~

10 KΩ (colour code)

d

200MHZ (~~Admittance~~)

To Measure resistance.



0.5" (1.27 cm)

0.5" (1.27cm)

~~L = 0.002.~~ d = 14 SWG = 64 mil

= × 0.254 cm

≈ 0.1628 cm.)

L (μH) = 0.002.

!

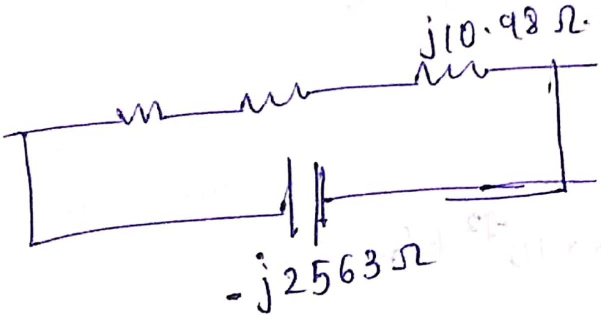
87 (nH) (nano Henry)

$X_L = j\omega L = 2\pi \times 200\times10^{-6} \times 8.7\times10^{-4}$

$= 2\pi f L = j10.93\,\Omega$

$C = 1.4\,PF \; (10^{-12})$

$$X_C = \frac{1}{j\omega C} = \frac{1}{2\pi\times200\times10^{-6}\times0.3\times10^{-12}}$$




$$Z = \frac{R\,X_C}{\sqrt{R^2+X_C^2}}$$

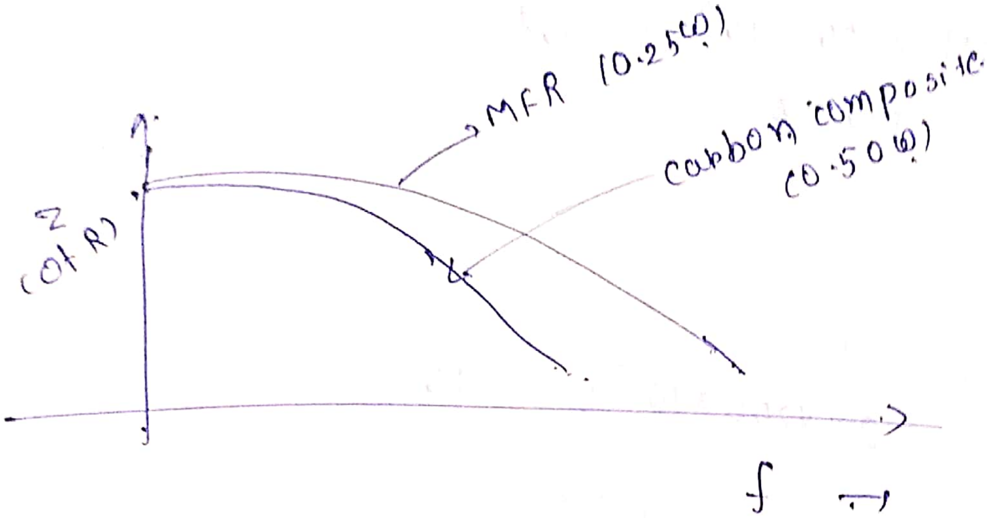
$\Downarrow$

$1890\,\Omega$

$\Downarrow$

10 kΩ resistor behaves as 2 kΩ resistor at 200MHZ

13/09/2019




* Capacitor

$\Rightarrow \quad \varepsilon = \varepsilon_r \varepsilon_0$

$\varepsilon_r$ — relative permittivity

$\varepsilon_0$ — free space $8.85 \times 10^{-12}$ F/m

$\varepsilon_r$ · dielectric constant - ability to retain the charge

$\varepsilon_r = \varepsilon_r' + j\varepsilon_r''$ (can be real / complex)

not skin depth

$\tan\delta = \dfrac{-\varepsilon_r''}{\varepsilon_r'} = \dfrac{-\varepsilon_{im}}{\varepsilon_{real}} = \dfrac{\sigma}{\ }$

↓

lost tangent

Normal PCB (FR-4) → ~~tanδ~~ .

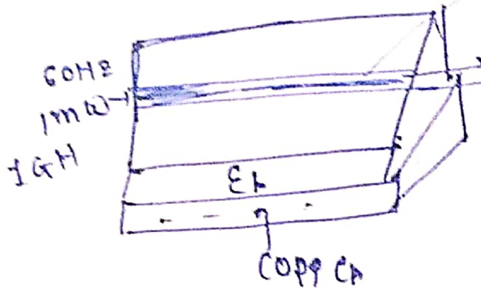
($\varepsilon_r = 4$)

CIVIL

Metal

chitching

$FeCl_3$




← at low freq$^n$

at high freq$^n$ Power loss.

at high freq$^n$ → photolithography.

⇓

use special PCB

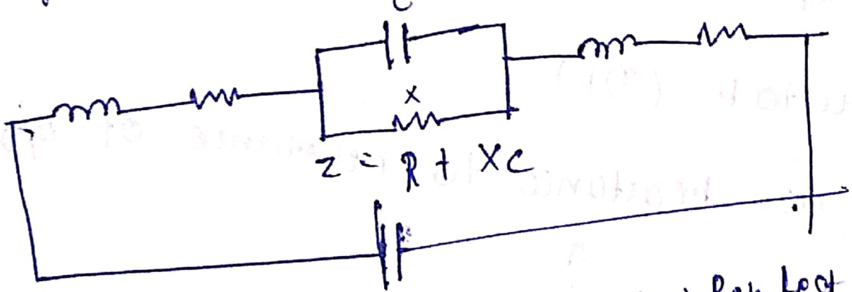
(RF substrate
μwave "
Dielectric " ) → Very costly

→ $\tan\delta = 0.0009$ at 60 Hz

$= 0.009$ at 1MHz

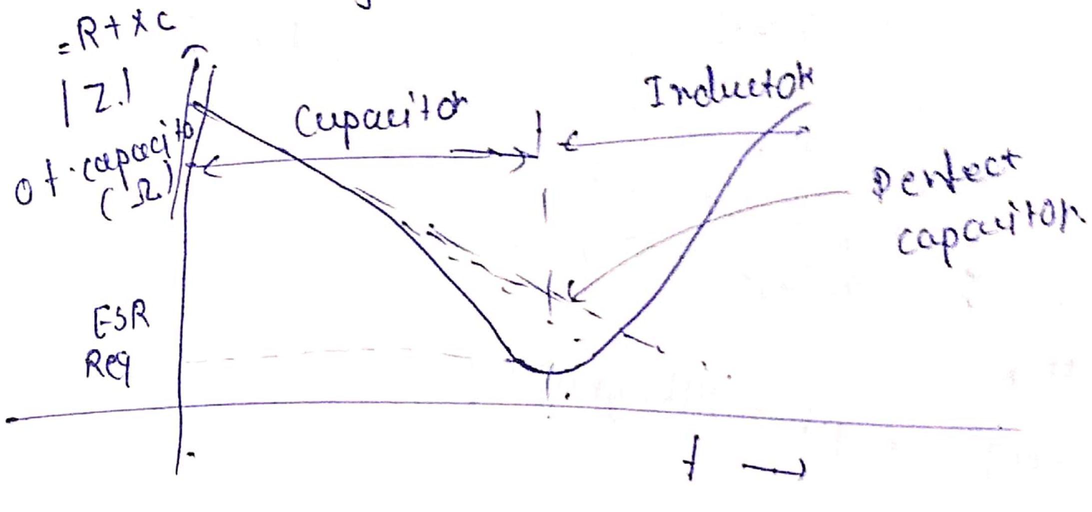
$= 0.09$ at 1GHz

capacitor → used to block dc




current leads voltage by 90° → Perfect capacitor

$X_C = \frac{1}{j\omega C}$




• ESR or Req or ac resistor of capacitor

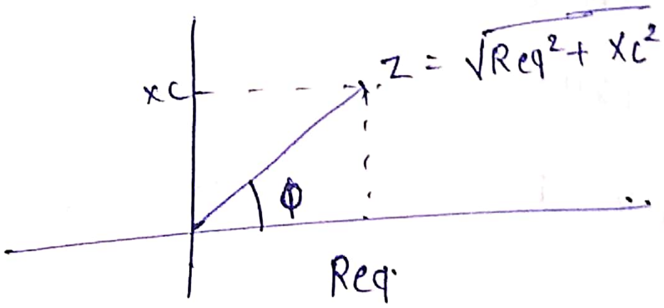
d

Effect = $R_S + R_P$

2) Power factor (PF) : $\cos\phi = \frac{Req}{X_C}$

$= \frac{Req}{\sqrt{X_C^2 + Req^2}}$

$\simeq \frac{Req}{X_C}$




3) Discipation factor (DF)

ratio of ac reactance to resistance of o/p

$= \frac{Req}{X_C}$

100 % $DF = \frac{Req}{X_C} \times 100\%$.

4) Q - factor $= \frac{X_C}{Req} = \frac{1}{\omega C Req} \approx \frac{1}{PF}$

~~for~~ perfector.

⇒ for perfect capacitor

$ESR = Req = 0$

$PF = 0$

$DF = 0$

$Q = \infty$

$\tan\delta = 0$

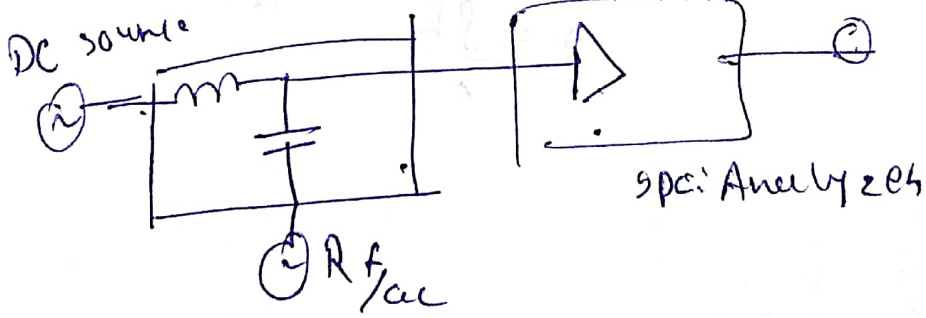
* Inductor (Inductor application)

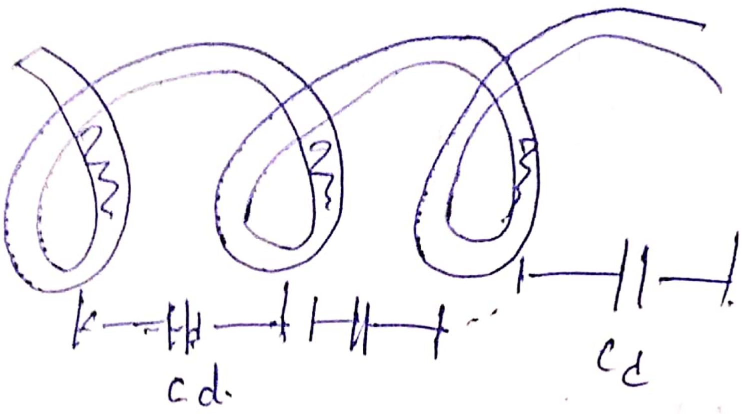
RF choke, → Inductor

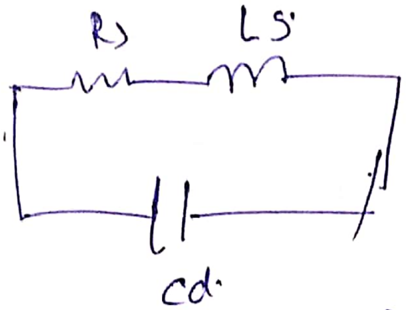
tunning,

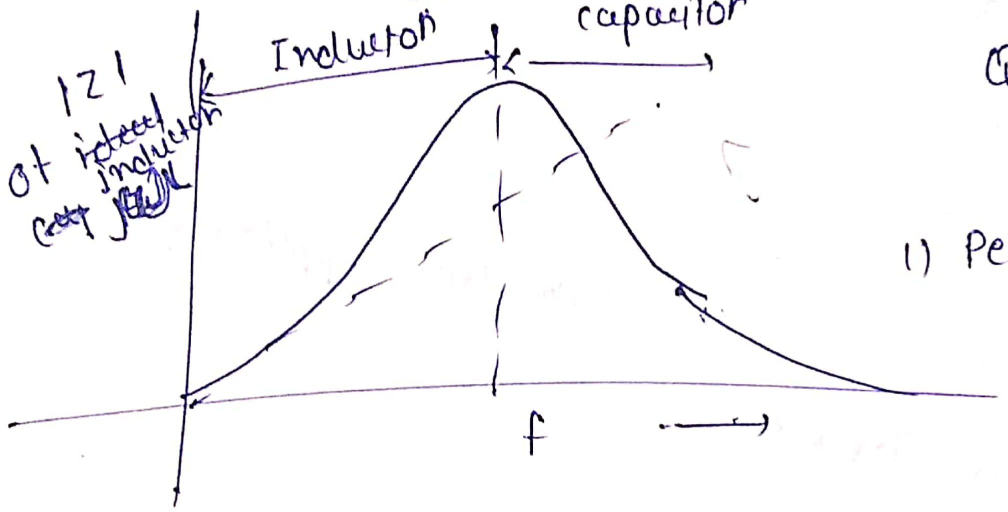
delay,

Bias Tee






$$Q = \frac{X_L}{R_S} = \frac{\omega L}{R_S}$$

1) Perfect inductor

$R_S = 0$

$Q = \infty$

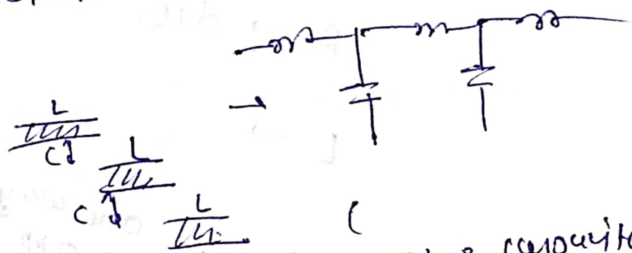
2) large diameter → large area

$$R = \frac{\rho l}{A} \qquad R \to 0$$

3)· Increase space betn ~~[illegible]~~ winding (A)

$C = \frac{\varepsilon A}{d}$ A ↑ C ↑

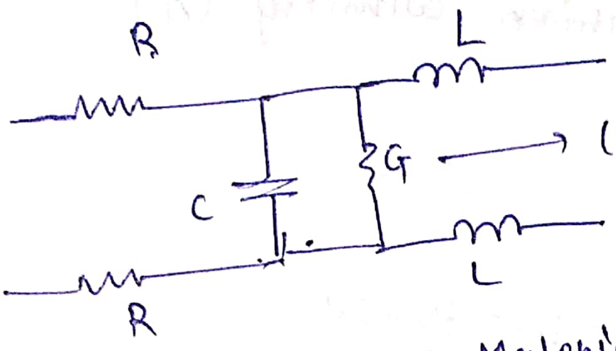
220R ← chip ~~resistance~~ resistor.




(inductor & capacitor on PCB)

| | mils | mils |
|---|---|---|
| 0402 = | 40 × | 20 |
| 0603 = | 60 × | 30 |
| 0805 = | 80 × | 50 |
| 1206 = | 120 × | 60 |
| 1218 = | 120 × | 180 |

Dt - 16/09/2019



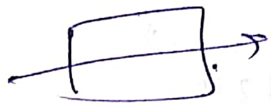

→ (conductance)

R → due to Material by conductor
(~~conductor~~)

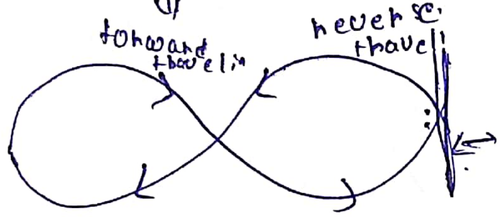
L →

one way

at low freq$^n$ → i/p → o/p



at 'RF freq$^n$



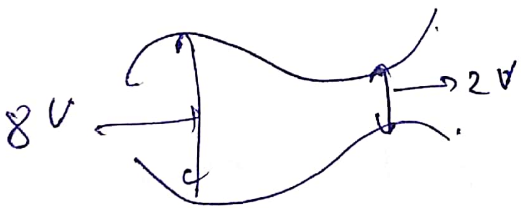

→ V & C changes → Z impedance changes

load at every point

reflection depends on

⇓

SW



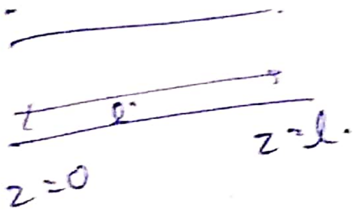

maxima
minima

⇓

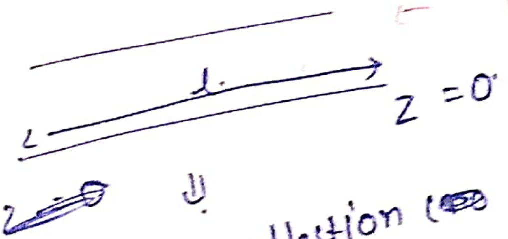
standing wave (super position of forward & reverse travelling wave)

By

at low freq^e




at RF freq^n




always talks in terms of ~~V(z)~~ V(z)

⇓

no-reflection (lossless line impossible) → bcz R, G, ...

⇓

every thing depends on load.

characteristic impedance. ( $Z_0 = 50\Omega$ ) (standard) (i/p & o/p impedance always $Z_0 = 50\Omega$ )

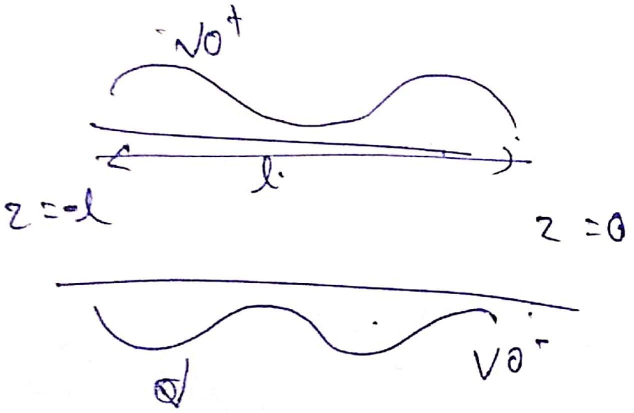
Broadcasting
↓ in
75Ω (India)

→ To avoid impedance mis match, impedance transform is used.

Voltage along transmission line

$$V(z) = V_0^+ e^{-\gamma z} + V_0^- e^{\gamma z}$$

→ forward wave



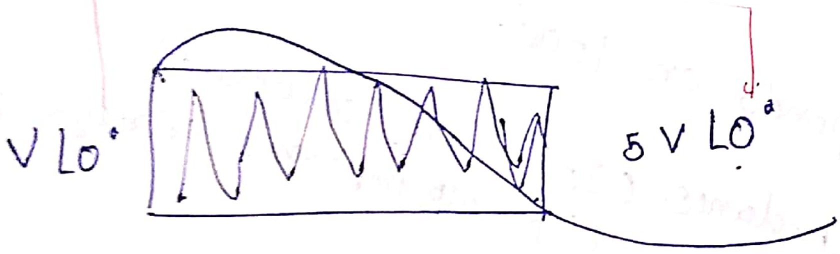

$\gamma$ = Propogation const.

$= \alpha + j\beta$ → phase constant (rad/m)

↓

attenuation constant (NP/m)

difficult to get




1 Np = 8.686 dB

$$\cancel{Z_0} = \frac{R_0 + jX_0}{\cancel{\alpha + j\beta}} = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$\Omega$

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$$

↓ m, ↓ NP/m, ↓ rad/m

Case - I lossless line (ideal), $\boxed{R = 0, \; G = 0}$

$$\gamma = j\omega\sqrt{LC} = \alpha + j\beta$$

$$\boxed{\beta = \omega\sqrt{LC}}$$

$\alpha = 0 \Rightarrow$ lossless line.

$Z_0 = R_0 + jX_0 = \sqrt{\frac{L}{C}}$

$R_0 = \sqrt{\frac{L}{C}}$

$X_0 = 0$

phase velocity $v_p$

$$\boxed{v_p = \frac{1}{\sqrt{LC}} = \frac{\omega}{\beta}}$$

case-II) Low loss line

$\boxed{(R << \omega L, \; G << \omega C)}$

$\gamma, \alpha, \beta, v_p, Z_0, R_0, X_0$

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$$

$$\approx j\omega\sqrt{LC}\left(1 + \frac{R}{j\omega L}\right)^{1/2}\left(1 + \frac{G}{j\omega C}\right)^{1/2}$$

$$(1+x)^n = 1 + nx + \ldots$$

$$= j\omega\sqrt{LC}\left(1 + \frac{R}{2j\omega L}\right)\left(1 + \frac{G}{2j\omega C}\right) + \ldots$$

$= j\omega\sqrt{LC}\,(1 + \frac{}{j}$

$$= \underbrace{j\omega\sqrt{LC}}_{\beta} + \underbrace{\frac{1}{2} R\sqrt{\frac{C}{L}} + \frac{1}{2} G\sqrt{\frac{L}{C}}}_{\alpha}$$

$$Z_0 = R_0 + jX_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$$

$$= \sqrt{\frac{\frac{R}{j\omega L}+1}{\frac{G}{j\omega C}+1} \cdot \frac{j\omega L}{j\omega C}}$$

$$= \sqrt{\frac{L}{C}}\left(1+\frac{R}{j\omega L}\right)^{1/2}\left(1+\frac{R}{j\omega L}\right)^{-1/2})$$

$$= \sqrt{\frac{L}{C}}\left(1+\frac{1}{2j\omega}\left(\frac{R}{L}-\frac{G}{C}\right)\right]$$

$$R_0 = \sqrt{\frac{L}{C}}$$

$$X_0 = \sqrt{\frac{L}{C}} \cdot \frac{1}{2j\omega}\left[\frac{R}{L}-\frac{G}{C}\right]$$

$$\approx 0$$

$v_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$

Distortionless

↓

losses of electric field = losses of magnetic field.

$\boxed{RC = GL}$

$\boxed{\frac{R}{L} = \frac{G}{C}}$

$\gamma, \alpha, \beta, R_0, Z_0, X_0, V_p$

$\gamma = \alpha + j\omega = \sqrt{(R+j\omega L)(G+j\omega C)}$

$= \sqrt{(R+j\omega L)\left(\frac{RC}{L} + j\omega C\right)}$

$= \sqrt{\frac{R^2 C}{L} + j\omega RC + j\omega RC - \omega^2 LC}$

$= \sqrt{\frac{R^2 C}{L} + -\omega^2 LC + 2j\omega RC}$

$= \sqrt{\frac{C}{L}(R^2 - \omega^2 L^2) + 2j\omega RL}$

$$= \sqrt{\frac{C}{L}(R+j\omega L)^2}$$

$$= \sqrt{\frac{C}{L}}\,(R+j\omega L) = \gamma = \alpha + j\beta$$

$$\alpha = R\sqrt{\frac{C}{L}} = \sqrt{RG} \quad \left(\because \frac{C}{G} = \frac{RC}{L}\right)$$

$$\beta = \omega\sqrt{LC}$$

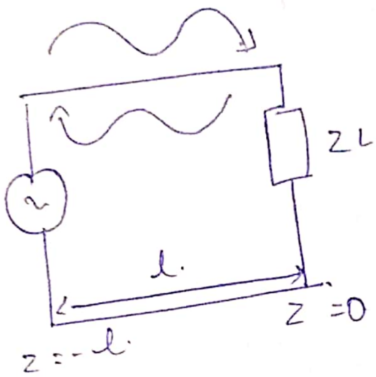
$$v_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$$

$$Z_0 = R_0 + jX_0 = \sqrt{\frac{(R+j\omega L)}{(G+j\omega C)}}$$

$$= \sqrt{\frac{R+j\omega L}{\frac{RC}{L} + j\omega C}}$$

$$R_0 = \sqrt{\frac{C}{L}} = \sqrt{\frac{R}{G}}$$

$$X_0 \simeq 0$$




$$\gamma = \underbrace{\alpha}_{\substack{\text{attenuat const} \\ (\text{Np/m})}} + j\underbrace{\beta}_{\substack{\text{phase con.} \\ (\text{rad/m})}}$$

$$V(z) = \underbrace{V_0^+ e^{-\gamma z}}_{\substack{\text{forward} \\ (\text{incident})}} + \underbrace{V_0^- e^{+\gamma z}}_{\substack{\text{backward} \\ (\text{reflected})}}$$

$$I(z) = I_0^+ e^{-\gamma z} + I_0^- e^{+\gamma z} \qquad \left( \because Z_0 = \frac{V_0^+}{I_0^+} = \frac{V_0^-}{I_0^-} \right)$$

$$= \frac{V_0^+}{Z_0} e^{-\gamma z} + \cancel{V_0} I_0^- e^{\gamma z}$$

Assumption :- line is lossless ($\alpha = 0$)

(reflection due to impedence mismatch)

$$\gamma = \alpha + j\beta = j\beta$$

$$V(z) = V_0^+ e^{-j\beta z} + V_0^- e^{j\beta z} \quad \text{——— (A)}$$

$$I(z) = \frac{V_0^+}{Z_0} e^{-j\beta z} - \frac{V_0^-}{Z_0} e^{j\beta z} \quad \text{——— (B)}$$

Voltage reflection coefficient [$\Gamma$ or $e$]

Ⓐ $V_L$ (voltage at load.) $= V(z=0)$

$$= V_0^+ + V_0^-$$

Ⓑ $I_L$ (current at load) $= I(z=0)$

$$= \frac{1}{Z_0}\left[V_0^+ - V_0^-\right]$$

$$Z_L = \frac{V_L}{I_L} = \frac{V_0^+ + V_0^-}{\frac{1}{Z_0}\left[V_0^+ - V_0^-\right]}$$

$Z_L = Z_0(V_0^+$

$$V_0^- = \left(\frac{Z_L - Z_0}{Z_L + Z_0}\right) V_0^+$$

reflection co-efficient

$$\boxed{\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0}}$$

.perfect.
$Z_0 = 50 + j0.$

complex quantity (by default take voltage co-efficient)

$$\frac{I_0^-}{I_0^+} = \frac{-V_0^-}{V_0^+} = -\Gamma$$

$\Gamma$ = complex quantity ($\because Z_L$ is complex)

$= |\Gamma| e^{j\theta_r} = |\Gamma| \angle \theta_r$

→ Matched ~~impedence~~ line ($Z_L = Z_0$)

⇓

Perfect Match

$\Gamma = 0 = \frac{Z_L - Z_0}{Z_L + Z_0}$ (no reflection)

→ short-circuited ~~impedance~~ line ($Z_L = 0$)

$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = -1 = 1 \angle 180°$ (phase reversal)

→ Open-circuited line ($Z_L = \infty$)

$\Gamma = 1 = 1 \angle 0°$ ✗ (reflection with no phase change)

OTDR (Optical Time domain Reflectometer)

⇓

measure reflected signal in time domain

$-1 < \Gamma < 1$

$0 \leq |\Gamma| \leq 1$

* VSWR (Voltage standing wave Ratio)

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$ less VSWR (for good system)

ML 1

SC $\infty$

OC $\infty$

$(1 < VSWR < \infty)$

* Standing wave (lossless $\alpha = 0$, $\gamma = j\beta$)

eqn

(A) $V(z) = V_0^+ e^{-j\beta z} + V_0^- e^{j\beta z}$

(B) $I(z) = \frac{V_0^+}{Z_0} e^{-j\beta z} - \frac{V_0^-}{Z_0} e^{+j\beta z}$

$V(z) = V_0^+ (e^{-j\beta z} + \Gamma e^{j\beta z})$

$I(z) = V_0^+ (e^{-j\beta z} - \Gamma e^{j\beta z})$

$\left( \because \frac{V_0^+}{V_0^-} = \Gamma \Rightarrow V_0^- = \Gamma V_0^+ \right)$

$|V(z)| = [V(z) \cdot V^*(z)]^{1/2}$

complex conjugate

$$= \left[V_0^+ \left(e^{-j\beta z} + \Gamma e^{j\beta z}\right) \cdot (V_0^+)^* \left(e^{j\beta z} + \Gamma e^{-j\beta z}\right)\right]^{1/2}$$

$$= \left[V_0^+ \left(e^{-j\beta z} + |\Gamma| e^{j\theta_r} e^{j\beta z}\right)\right] \cdot \left[(V_0^+)^* \left(e^{j\beta z} + |\Gamma| e^{-j\theta_r} e^{-j\beta z}\right)\right]^{1/2}$$

$(\because \Gamma = |\Gamma| e^{j\theta_r})$

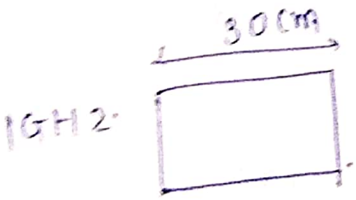
$$= |V_0^+| \left[1 + |\Gamma|^2 + |\Gamma| e^{j(2\beta z + \theta_r)} + e^{-j(2\beta z + \theta_r)}\right]^{1/2}$$

$(\because e^{jx} + e^{-jx} = 2\cos x)$

$$\boxed{|V(z)| = |V_0^+| \left[1 + |\Gamma|^2 + 2|\Gamma| \cos(2\beta z + \theta_r)\right]^{1/2}}$$

$\lambda = c/f$

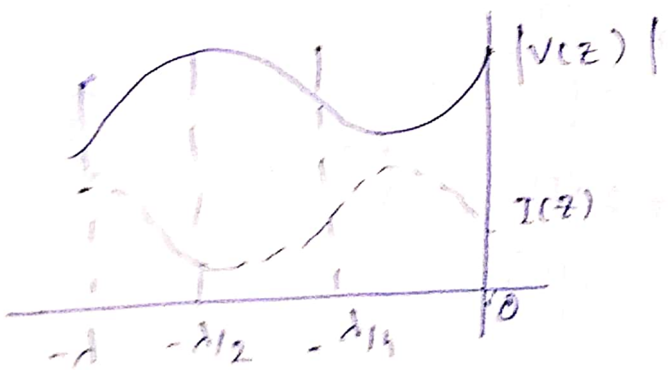
Electrical length $\rightarrow \lambda = c/f = \frac{3 \times 10^8}{1 \times 10^9} = 30\text{cm}$




$l = \lambda$ @ 1GHz

$l = 7.5 \Rightarrow \frac{\lambda}{4}$ @ 1GHz

$l = 15 \Rightarrow \frac{\lambda}{2}$ @ 1GHz



* Our objective

1) To find Position of Maxima & minima
2) " " Amp " " "

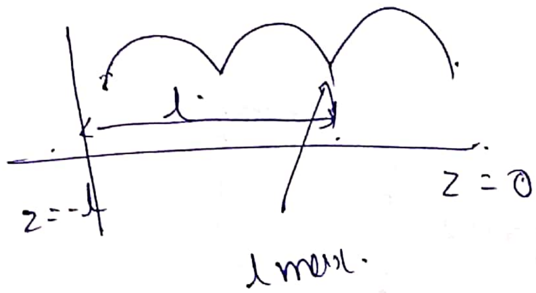
Maxima: The Maxima value of standing wave betain of $|V(z)|$ corresponds to positions on of line at which ~~inci~~ incident & reflected waves are in phase.

$(2\beta z + \theta_r) = 2n\pi$ , $n = 0$, -ve or +ve in phase.

↓

~~$z = l_{max}$~~

$z = l_{max}$ (Position of Maxi




$2\beta l_{max} = 2n\pi$

$-2\beta l_{max} + \theta_r = -2n\pi$

~~$l_{max}$~~ $l_{max} = \frac{\theta_r + 2n\pi}{2\beta}$

$= \frac{\theta_r + 2n\pi}{2\left(\frac{2\pi}{\lambda}\right)}$ $\left[\because \beta = \frac{2\pi}{\lambda}\right]$

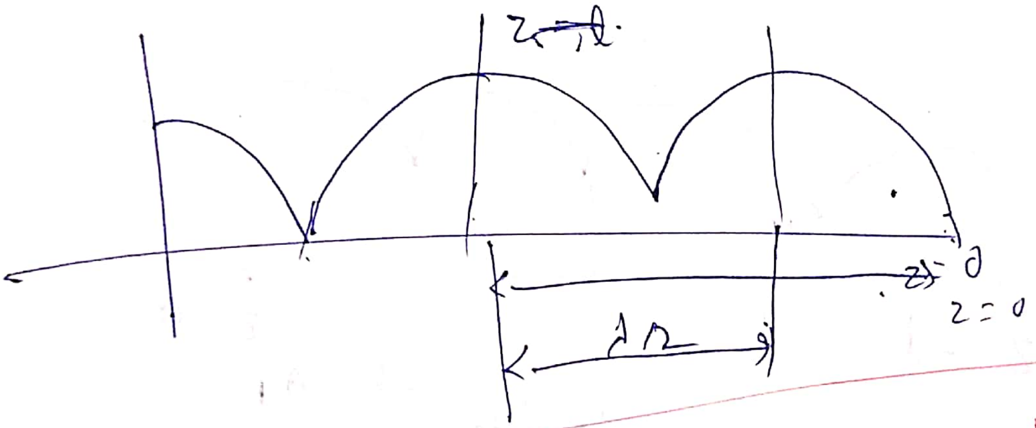
$l_{max} = \frac{\theta_r \lambda}{4\pi} + \frac{n\lambda}{2}$ ; $n = 0, 1, 2 \ldots$

First Maxima will occure at.

1st " " $\frac{\theta_r \lambda}{4\pi}$ $(n=0)$.

2nd " " $\frac{\theta_r \lambda}{4\pi} + \frac{\lambda}{2}$ $(n=1)$

3rd " " $\frac{\theta_r \lambda}{4\pi} + \lambda$ $(n=2)$




$\boxed{\text{Dest. bet}^n \text{ 2 successive Matrix } = \frac{\lambda}{2}}$

(c) $\cancel{V_0^+}$ $|V(z)| = |V_0^+| [1 + |\Gamma|^2 + 2|\Gamma| \cos(2\beta z + \theta_r)]^{1/2}$

$= |V_0^+| [(1 + |\Gamma|)^2]^{1/2}$

$|V(z)|_{max} = |V_0^+| [1 + |\Gamma|]$

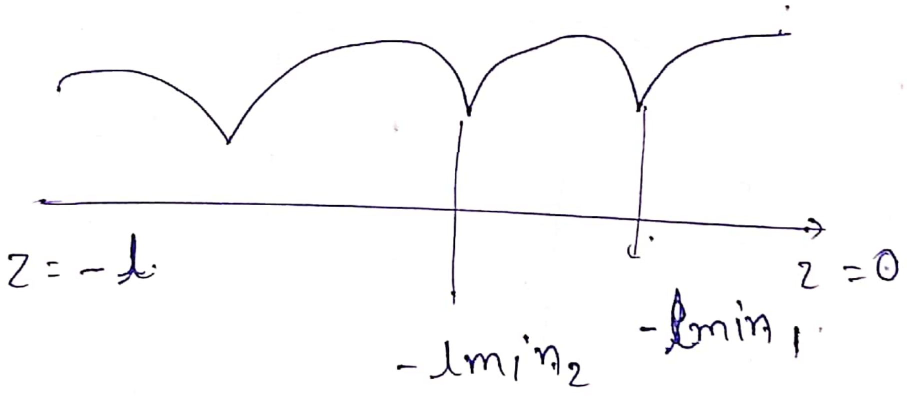
⇒ Minima.

$(2\beta z + \theta_r) = (2n+1)\pi \quad ; \; n = 0, 1, 2$

$z = l_{min}$

$-2\beta l_{min} + \theta_r = (2n+1)\pi. \quad n = 0, 1, 2 ..$

$z = -l_{min}$




$$l_{min} = \frac{\theta_r + (2n+1)\pi}{2\beta}$$

$$\boxed{l_{min} = \frac{\theta_r + (2n+1)\pi}{2\left(\frac{2\pi}{\lambda}\right)}}$$

$1^{st}$ min

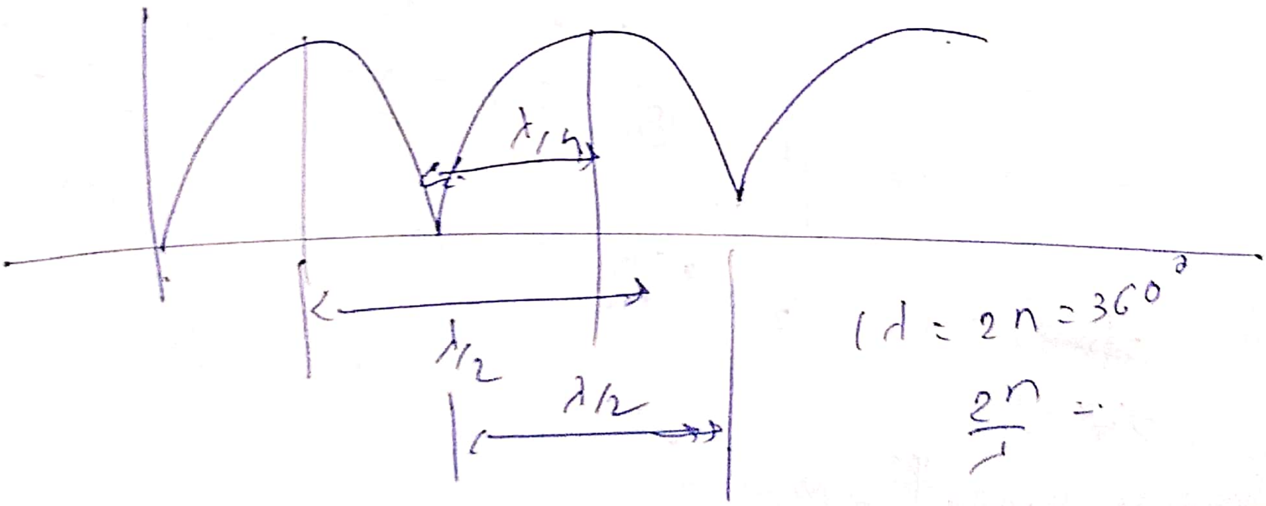
$$P_{min_1} = \frac{\theta_r \lambda}{4\pi} + \frac{\pi}{4\pi/\lambda} \quad (n=0)$$

$$P_{min_1} = \frac{\theta_r \lambda}{4\pi} + \frac{\lambda}{4} \quad (n=0)$$

$$P_{min_2} = \frac{\theta_r \lambda}{4\pi} + \frac{3\lambda}{4} \quad (n=1)$$

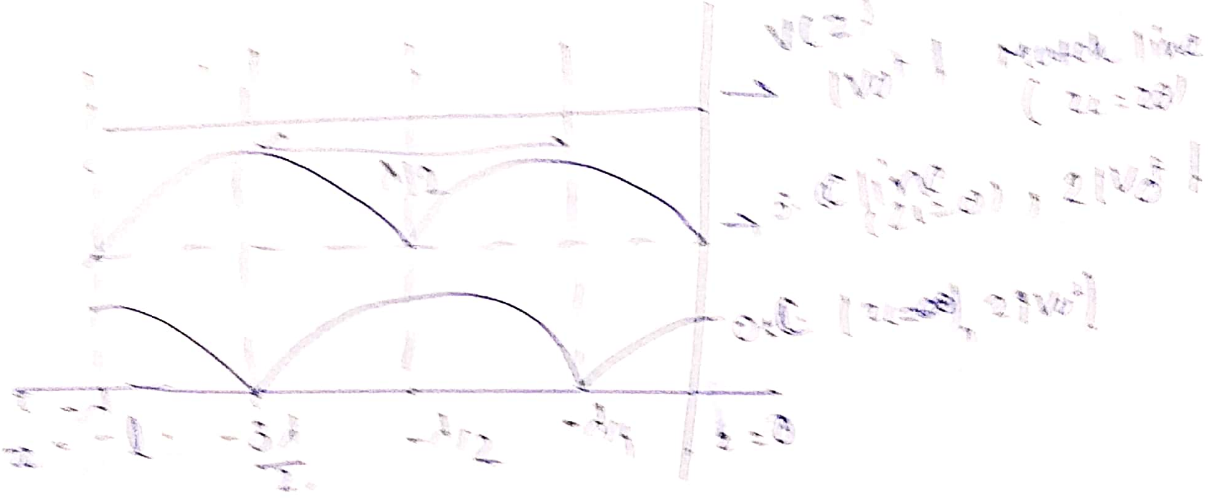
Dist. betn 2 successive minimum $= \frac{\lambda}{2}$

Dist betn max. & subsequence min $= \frac{\lambda}{4}$.




$(d = 2\pi = 360°$

$\frac{2\pi}{\lambda} =$




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

for collision avoid system


(A) $V z = V_0^+ e^{-j\beta z} + V_0^- e^{j\beta z}$

(B) $I(z) = \frac{V_0^+}{Z_0} e^{-j\beta z} - I_0^- e^{+j\beta z}$

zin ( z = -l ) from load.

$$= \frac{V(z=-l)}{I(z=-l)}$$

$Z_{in} = Z_0 \sim V_0^+ e^{j\beta z} + V_0^- e^{-j}$

$$Zin = Zo \cdot \frac{Vo^{+} e^{j\beta l} + \frac{Vo^{-}}{Vo^{+}} e^{-j\beta l}}{Vo^{+} e^{j\beta l} - \frac{Vo^{-}}{Vo^{+}} e^{-j\beta l}}$$

$\cancel{Zu \cdot e^{4j}}\ e^{GRBG}$

$$= \frac{Zo\left(e^{j\beta l} + \left(\frac{Z_L - Zo}{Z_L + Zo}\right) e^{-j\beta l}\right)}{e^{j\beta l} - \left(\frac{Z_L - Zo}{Z_L + Zo}\right) e^{-j\beta l}}$$

$$\left(\Gamma = \frac{Z_L - Zo}{Z_L + Zo}\right)$$

$$Zin = Zo \frac{(Z_L + Zo) e^{j\beta l} + (Z_L - Zo) e^{-j\beta l}}{(Z_L + Zo) e^{j\beta l} - (Z_L - Zo) e^{-j\beta l}}$$

$$= Zo \cdot \frac{Z_L\left(e^{j\beta l} + e^{-j\beta l}\right) + Zo\left(e^{j\beta l} - e^{-j\beta l}\right)}{Z_L\left(e^{j\beta l} - e^{-j\beta l}\right) + Zo\left(e^{j\beta l} + e^{-}\right)}$$

$$Z_0 \cdot \frac{Z_L\left(e^{j\beta l} + e^{-j\beta l}\right) + Z_0\left(e^{j\beta l} - e^{-j\beta l}\right)}{Z_L\left(e^{j\beta l} - e^{-j\beta l}\right) + Z_0\left(e^{j\beta l} + e^{-j\beta l}\right)}$$

$$e^{j\beta l} = \cos(\beta l) + j\sin(\beta l)$$

$$e^{-j\beta l} = \cos(\beta l) - j\sin(\beta l)$$

$$Z_{in} = Z_0 \cdot \frac{Z_L \cos(\beta l) + jZ_0 \sin(\beta l)}{jZ_L \sin(\beta l) + Z_0 \cos(\beta l)}$$

$Z_{in}$ $(z = -l$

$$Z_{in}(z = -l) = Z_0 \cdot \frac{(Z_L + jZ_0 \tan(\beta l))}{Z_0 + jZ_L \tan(\beta l)} \quad \because \beta = \frac{2\pi}{\lambda}$$

$R \rightarrow \Omega/m$

$L \rightarrow nH/m$

[$\because$ at every point elements per length value changed - so distributed element

If line is lossy ($\alpha \neq 0$, $\gamma = \alpha + j\beta$)

$$\cancel{Z_{in}(l)} = Z_0 \cdot Z_L + Z_0 \tan \cancel{h(} \beta l)$$

$$\boxed{Z_{in}(l) = Z_0 \cdot \frac{Z_L + Z_0 \tanh(\gamma l)}{Z_0 + Z_L \tanh(\gamma l)}}$$

$$\tanh(\gamma l) = \tanh(j\beta l) = j\tan(\beta l)$$

for lossless line ($\gamma = j\beta$)

Dt - 23/9/19

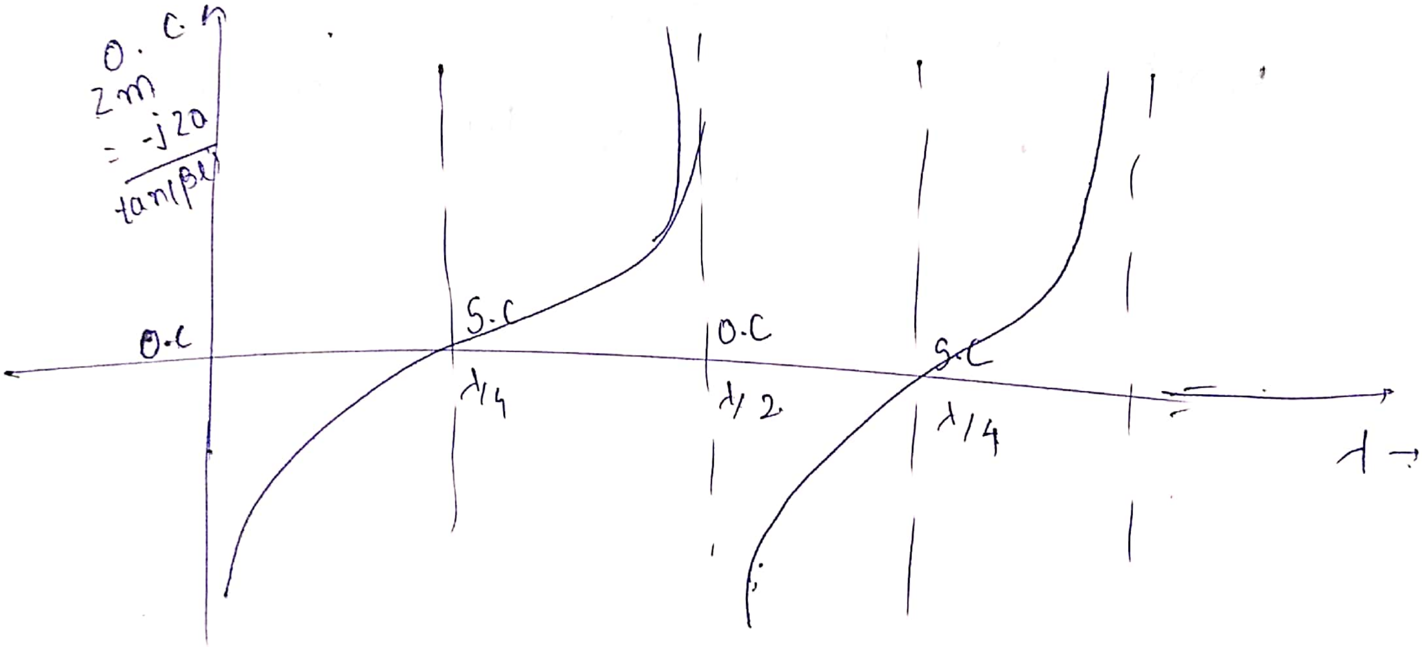
case - II lossless o.c. line.

① eqn

$$\frac{Z_L}{Z_{in}} = \infty$$

$$Z_{in}^{x} = \frac{-j z_0}{\tan(\beta l)} = -j z_0 \cot(\beta l)$$

lossless = $\coth(\gamma l)$ $(-j z_0 \cot(\beta l)$ $= \coth(\gamma l))$




case - III $l = \lambda/4$

① eqn

$$\Rightarrow \beta l = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4} = \frac{\pi}{2}$$

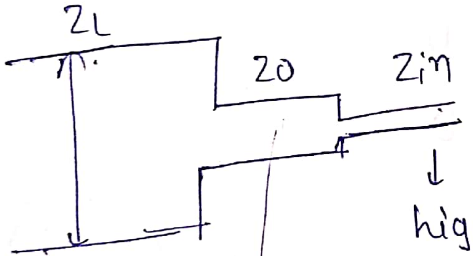
$$\tan(\beta l) = \tan\left(\frac{\pi}{2}\right) = \infty$$

(1): $Z_{in} = Z_0 \left[ \dfrac{\dfrac{Z_L}{\tan\beta l} + jZ_0}{\dfrac{Z_0}{\tan\beta l} + jZ_L} \right]$

$Z_{in}^{\lambda/4} = Z_0 \left[ \dfrac{jZ_0}{jZ_L} \right]$ $\left( \because \dfrac{1}{\tan\beta} = \dfrac{1}{\infty} \to 0 \right)$

$$\boxed{Z_{in}^{\lambda/4} = \dfrac{Z_0^2}{Z_L}}$$ → quarter wave transformer.

*




high impedance 75

Low impedence 50

$\Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0}$

$= \dfrac{75 - 50}{75 + 50}$

$= \dfrac{1}{5} = 20\%$ (power cutted disaster)

$Z_0 = \sqrt{Z_{in} Z_L}$ → This is for real impedence.

$= \sqrt{50 \times 75}$

$= 6550$ (impedance transformer)

Scanned by CamScanner

$\frac{\lambda}{4}$ → Quater wave transformer

⇓

for impedance matching

↓

impedance inverter

(after ever $\lambda/4$ SC ⟷ O.C. that's why impedance inverter)

## case - IV

$$l = \lambda/2.$$

$$\beta l = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$$

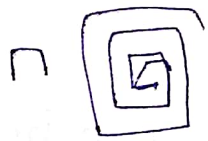
$$\tan(\beta l) = \tan\pi = 0$$

$$Z_{in}^{\lambda/2} = Z_0 \cdot \frac{Z_L + 0}{Z_L + 0}$$

$$\boxed{Z_{in}^{\lambda/2} = Z_L}$$

⇓

Half wave transformer



↑

Meander line (~~ten~~ actual wave length $= \lambda/2$)

if I wan $Z_{in} = Z_L$ then length must be $\frac{\lambda}{2}$ (depends upon frequency.)