V-number of an optical fiber

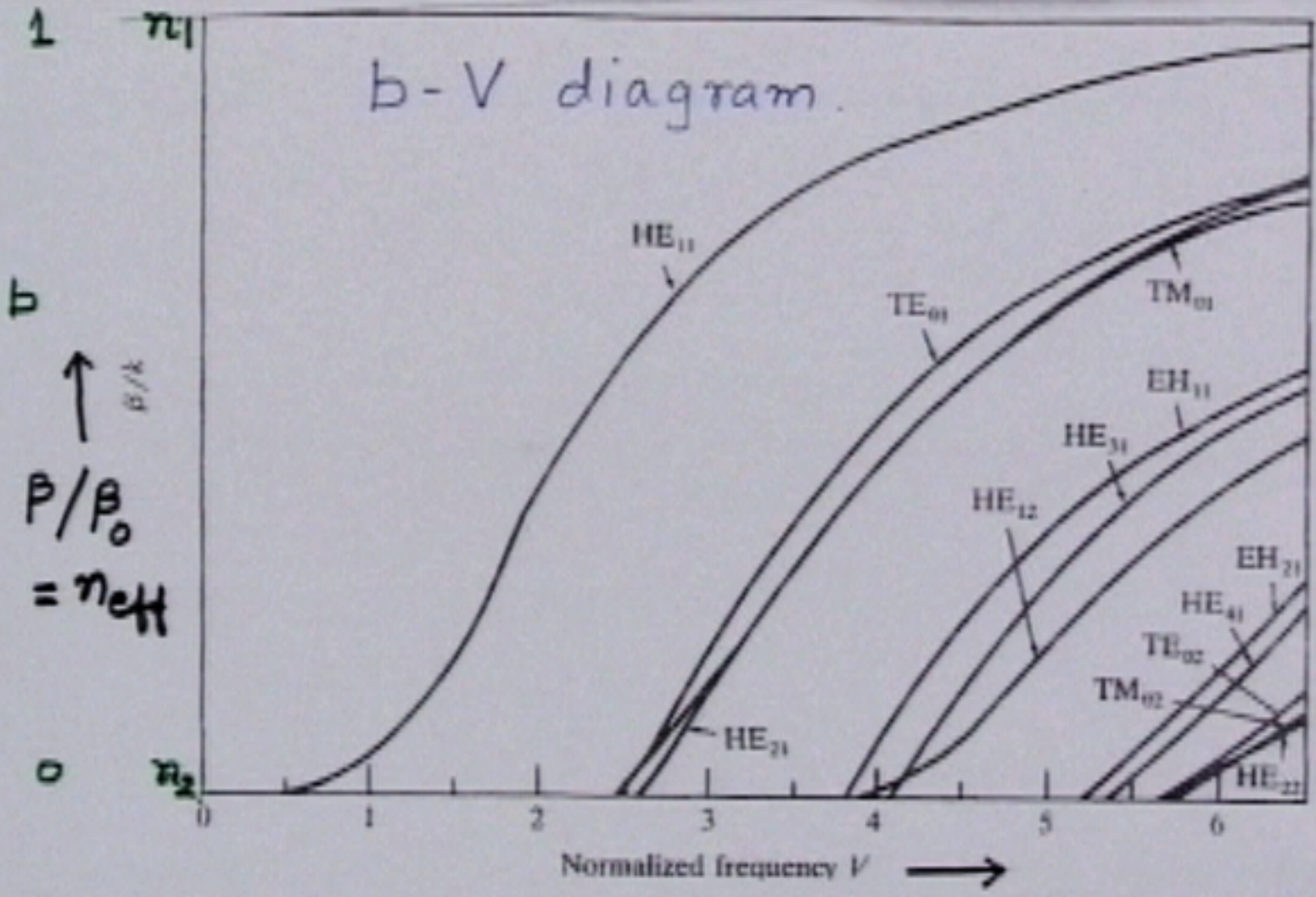
$$V = \frac{\omega a}{c}\sqrt{n_1^2 - n_2^2} = \frac{2\pi a}{\lambda}(NA)$$

Normalized Propagation constant β

$$b = \frac{n_{eff}^2 - n_2^2}{n_1^2 - n_2^2} \approx \frac{n_{eff} - n_2}{n_1 - n_2}$$

Effective index of propagation $n_{eff} = \frac{\beta}{(2\pi/\lambda)}$

0 < b < 1


b-V diagram
1
n_1
b
β/k
β/β_0
$= n_{eff}$
0
n_2
HE_{11}
TE_{01}
TM_{01}
EH_{11}
HE_{31}
HE_{12}
EH_{21}
HE_{41}
TE_{02}
TM_{02}
HE_{21}
HE_{22}
0
1
2
3
4
5
6
Normalized frequency V

$$V \leq 2.4$$

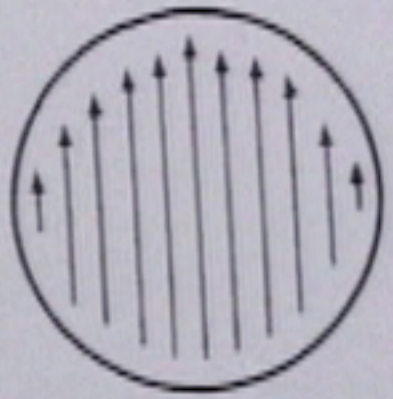
$$\rightarrow \frac{2\pi}{\lambda} a\left(n_1^2 - n_2^2\right)^{\frac{1}{2}} \leq 2.4$$

$$\rightarrow 2\pi\left(\frac{a}{\lambda}\right)0.1 = 2.4$$

$$\rightarrow \frac{a}{\lambda} \approx \frac{2.4}{0.6}$$

$$\rightarrow \frac{a}{\lambda} \approx 4$$ [redacted]

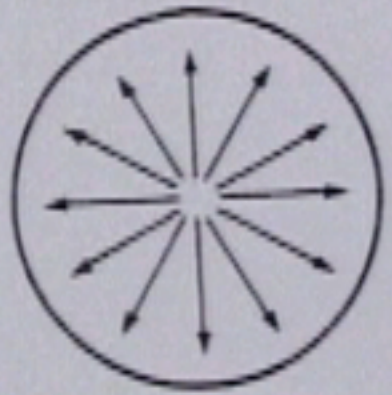
Lowest-order mode



HE_{11}

First set of higher-order modes

TE_{01}



TM_{01}

HE_{21}

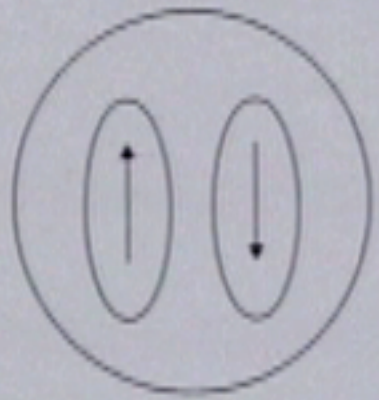
Linearly Polarized (LP) Modes

$$\Delta \equiv \frac{n_1 - n_2}{n_1} << 1$$

$$E_z, H_z \to 0$$

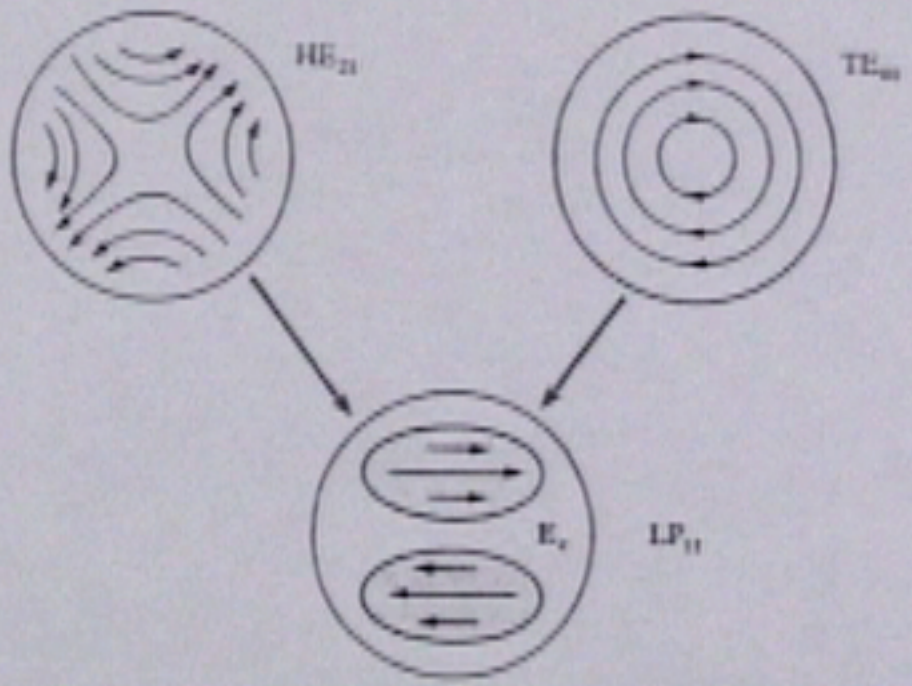
Fields are almost transverse

Fields are linearly polarized

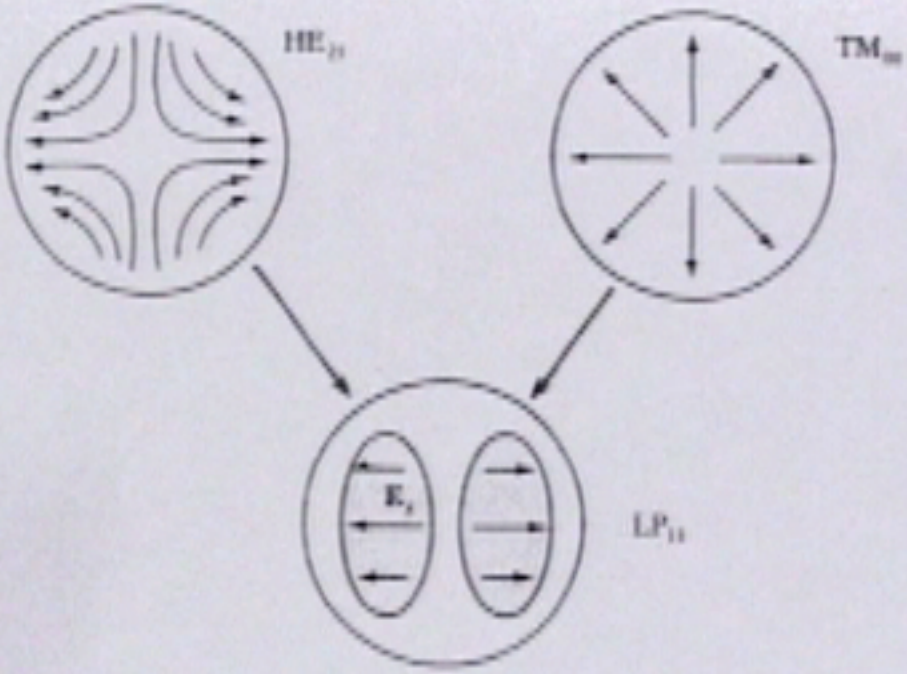


$$HE_{11} \rightarrow LP_{01}$$

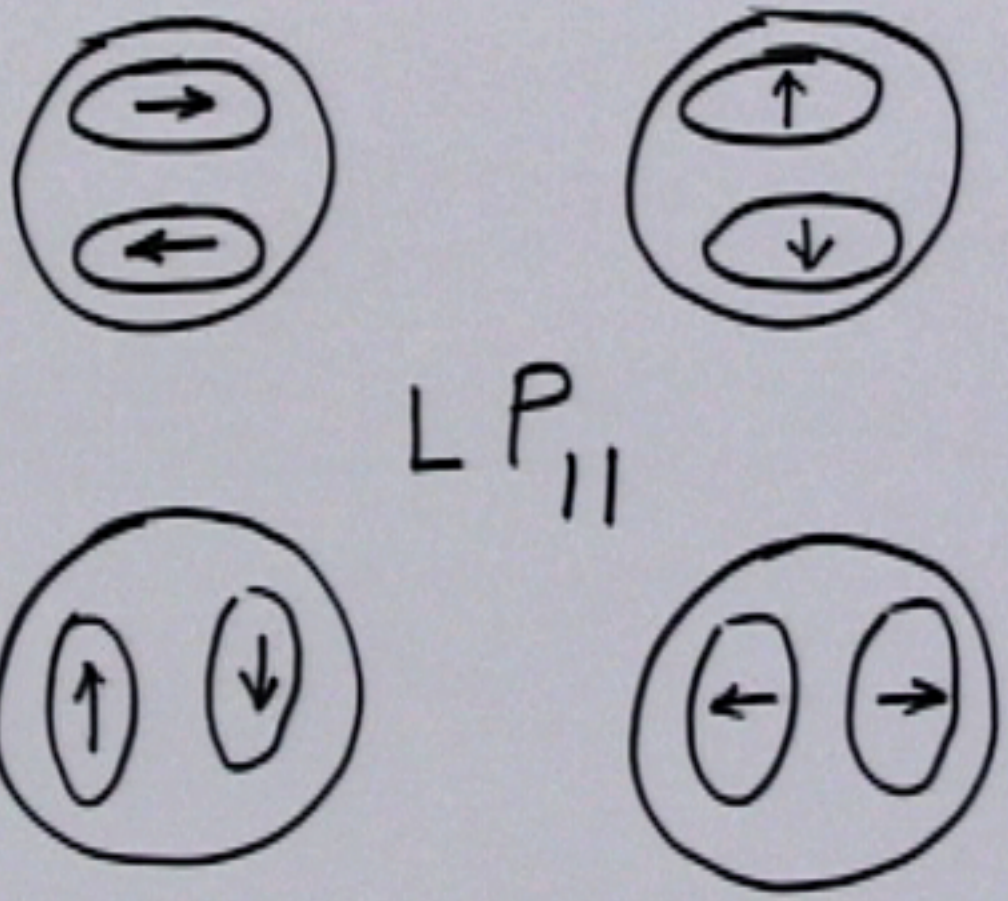
$$TE_{0m}, TM_{0m}, HE_{2m} \rightarrow LP_{1m}$$

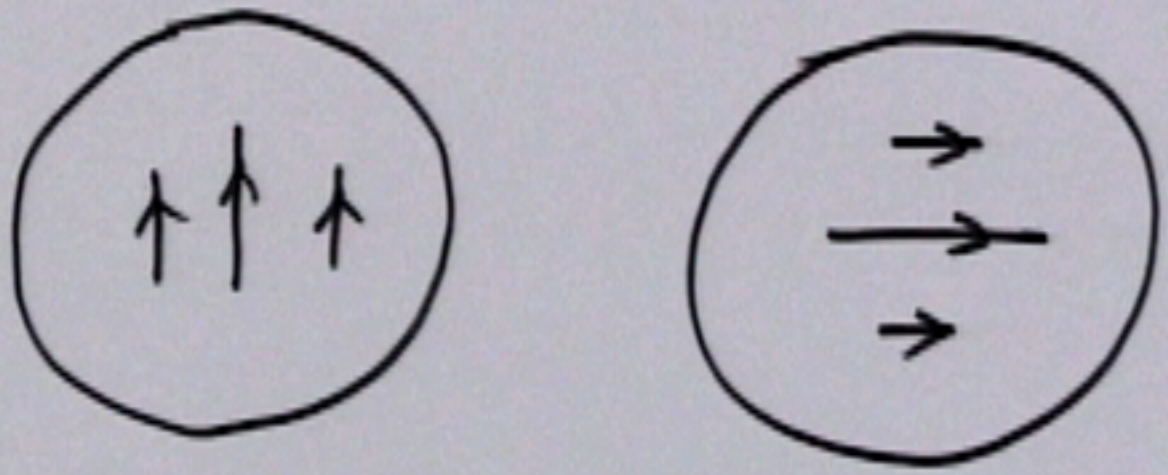


(a)



(*b*)


LP11

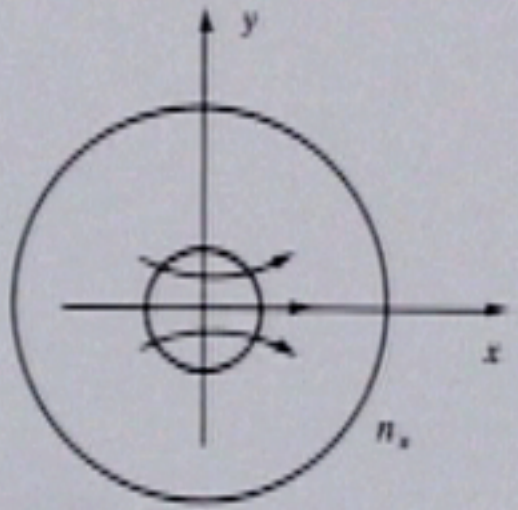


LP_{01}

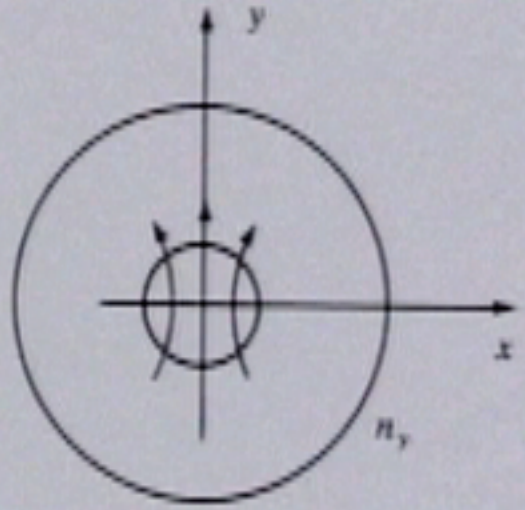
No. of Modes

$$M \approx \frac{V^2}{2}$$

Polarizations of fundamental mode

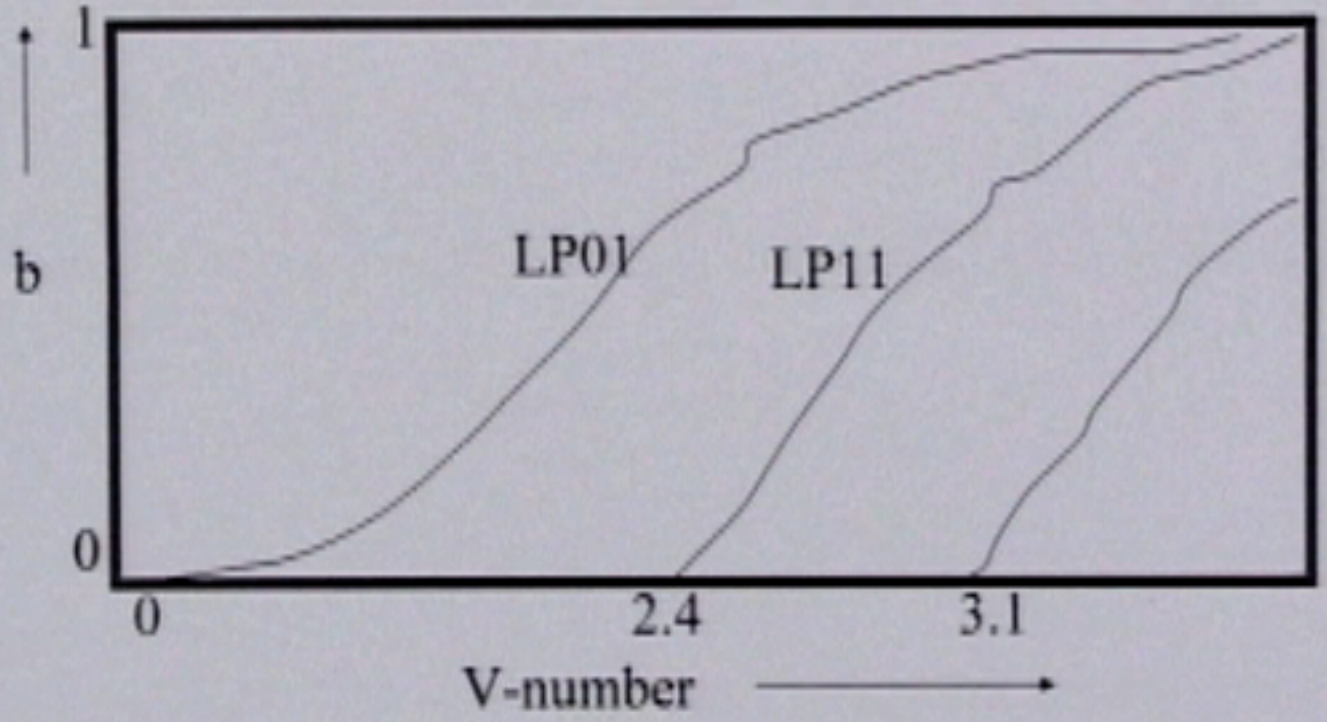


Horizontal mode

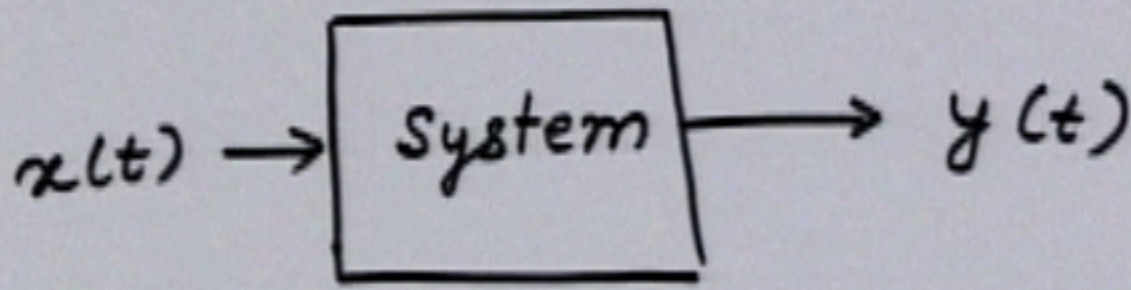


Vertical mode

b-V Diagram



Group velocity $v_g = \dfrac{\partial \omega}{\partial \beta}$ **Phase velocity** $v_p = \dfrac{\omega}{\beta}$



$$y(t) = A\, x(t-\tau)$$

$$Y(\omega) = A\, X(\omega)\, e^{j\tau\omega}$$

Amp. response constant

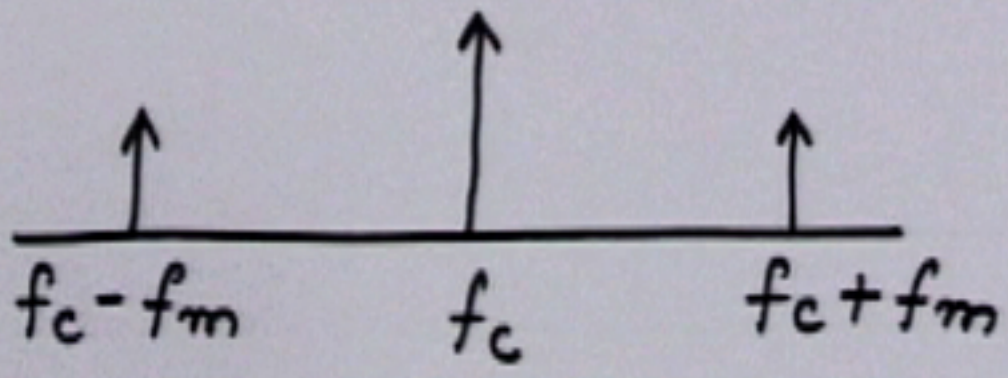
Phase response Linear.

Radio frequency :

carrier → f_c

modulating frequency f_m

AM



1 mm ~ 100 GHz