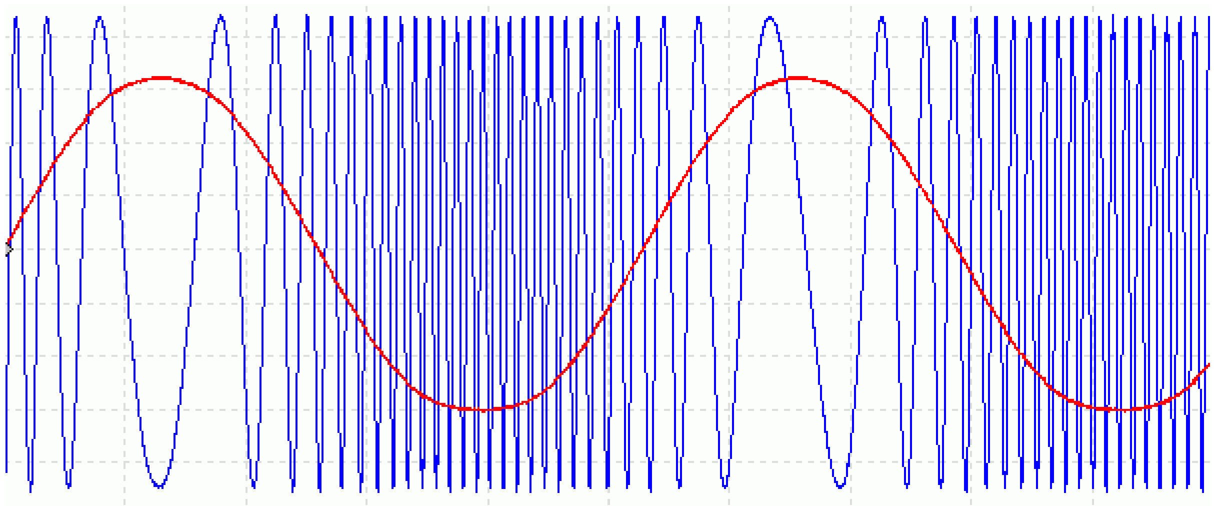
ASEN3300 Aerospace Electronics and Communications

Frequency Modulation



Frequency/phase Modulation

- **AM:** $S(t) = B\,[1+m\sin(2\pi f_m t)]\cos(2\pi f_c t)$
- **FM:** $S(t) = B\cos[2\pi f_c t + f_\Delta/f_m \cos(2\pi f_m t)]$

$x(t)=\sin(2\pi f_m t)$

$B = 1$

$f_c = 20$ kHz

$D = f_\Delta / f_m$

$f_m = 2$ kHz

$f_\Delta = 5$ kHz

$A(t)$, $\phi(t)$ $= B \cdot A(t) \cdot \cos(\phi(t))$

$A(t) = 1 + m\sin(2\pi f_m t)$

$\phi(t) = 2\pi f_c t$

$B \cdot A(t) \cdot \cos(\phi(t))$

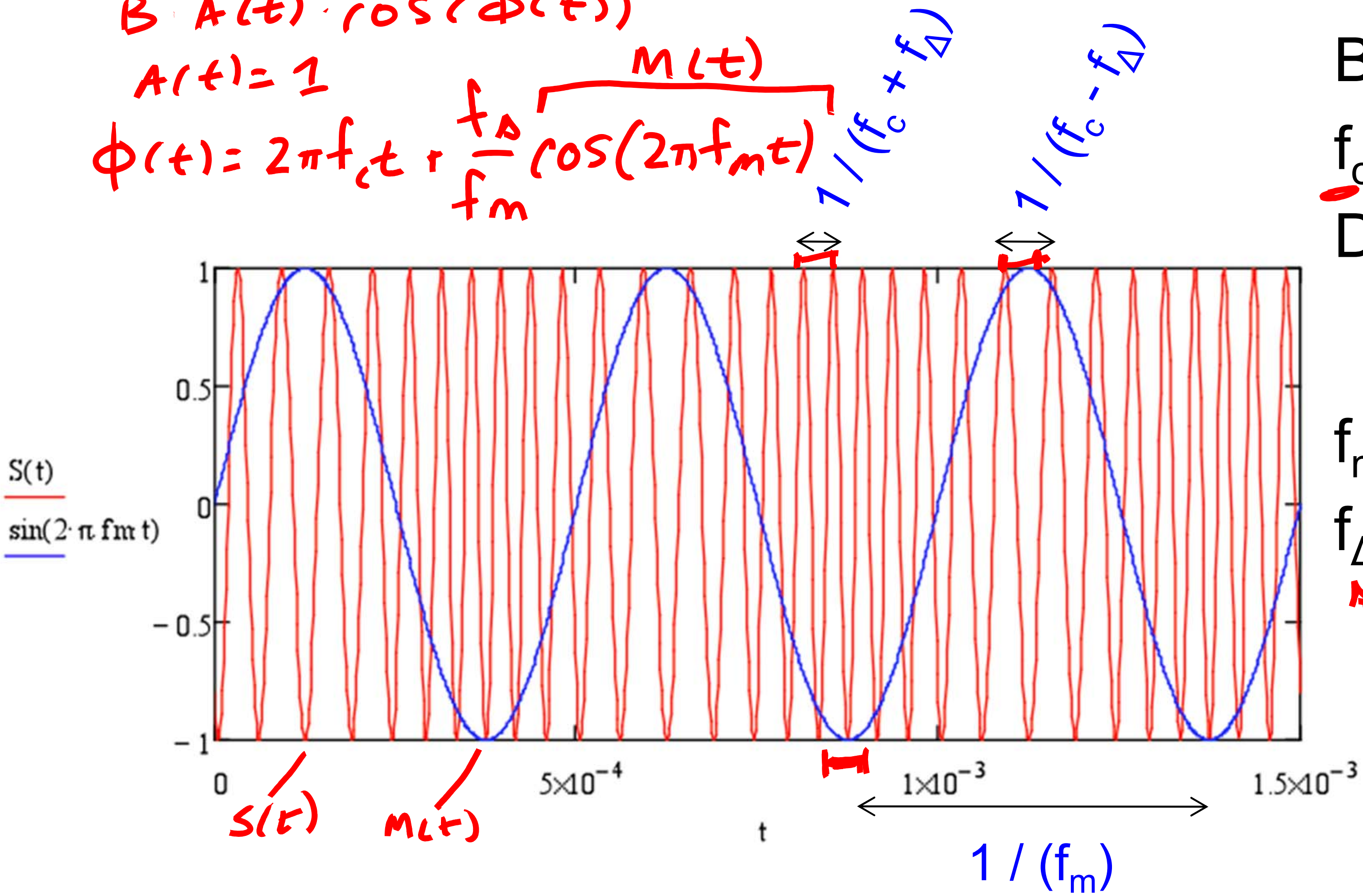
$A(t) = 1$

$\phi(t) = 2\pi f_c t + \frac{f_\Delta}{f_m}\cos(2\pi f_m t)$ ($m(t)$)

carrier

– modulating frequency

frequency deviation



Frequency/phase Modulation

$S(t) = B\cos[2\pi f_c t + f_\Delta/f_m \cos(2\pi f_m t)]$

$= B\cos[\Phi(t)]$

$m(t) = \cos(2\pi f_m t)$

$\Phi(t) = 2\pi f_c t + f_\Delta/f_m \cos(2\pi f_m t)$

$f = \frac{1}{2\pi}\frac{d}{dt}\Phi(t)$

$\Phi(t) = 2\pi f_0 t + \phi$

$\frac{1}{2\pi}\frac{d}{dt}\Phi(t) = f_0$

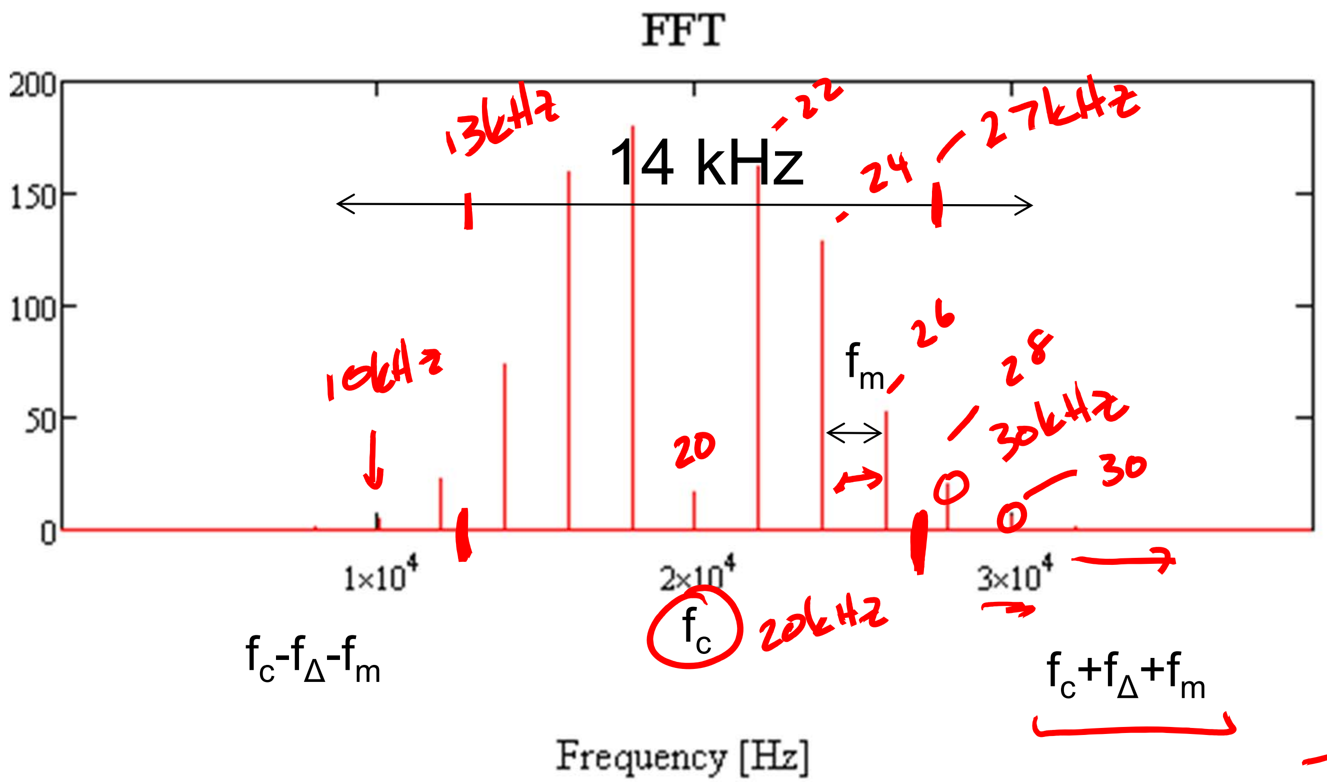
Instantaneous frequency:

$f = d\,\Phi(t)/(2\pi\, dt) = f_c + (f_m)^* f_\Delta/f_m \sin(2\pi f_m t)$

$f(t)$

$f = f_c + f_\Delta \sin(2\pi f_m t)$; $[f_c - f_\Delta\ ;\ f_c + f_\Delta]$

FM bandwidth



$x(t)=\sin(2\pi f_m t)$

B = 1

f_c = 20 kHz

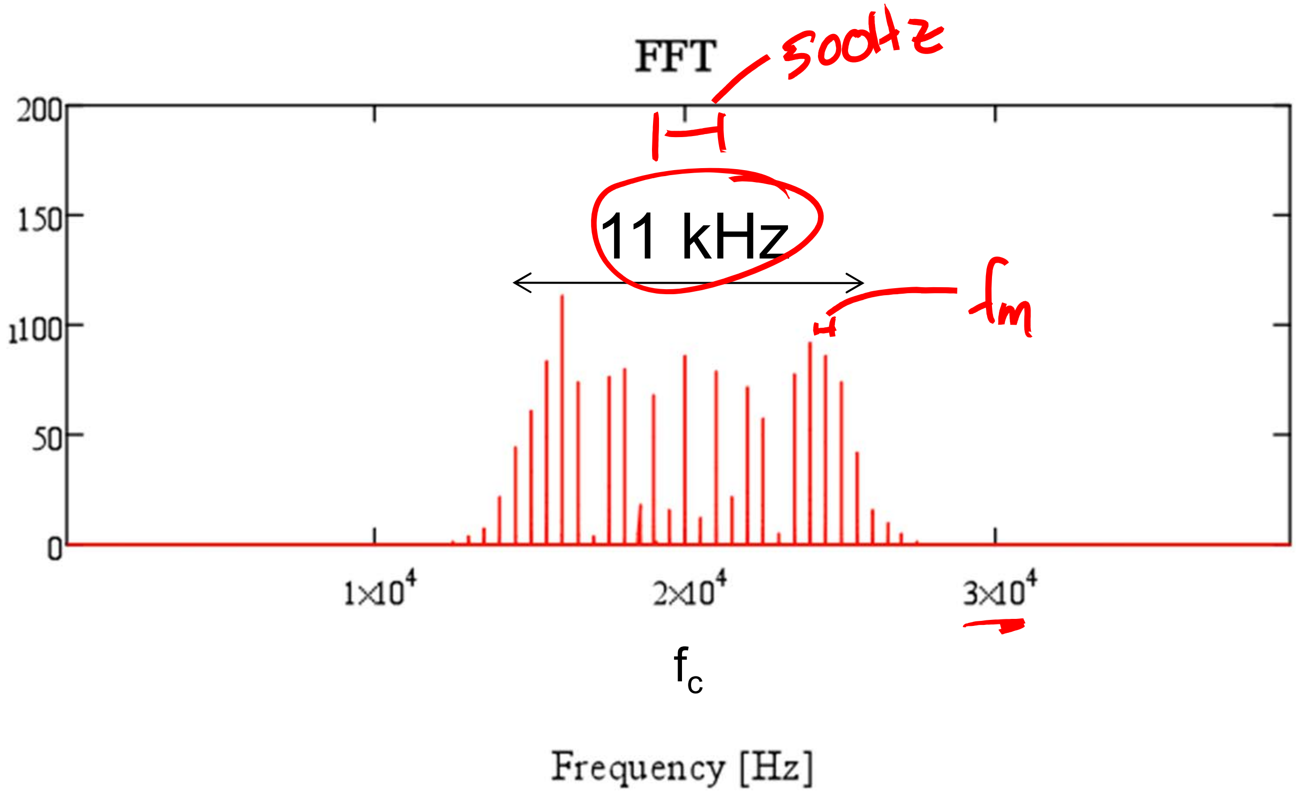
f_m =2 kHz

f_Δ = 5 kHz

BW ≈ 2(f_Δ + f_m) = 2(5kHz + 2kHz) = 14 kHz

(Carson rule – approximation of the BW (~98%) for FM signal)

FM bandwidth



$x(t)=\sin(2\pi f_m t)$

$B = 1$

$f_c = 20$ kHz

$f_m = 500$ Hz

$f_\Delta = 5$ kHz

AM signal f_m 500Hz

$\mathbf{BW \approx 2(f_\Delta + f_m)} = 2(5\text{kHz} + 0.5\text{kHz}) = 11$ kHz

$f_\Delta \gg f_m \quad BW \sim 2 f_\Delta$

FM Theory

$$S(t) = B\cos\left[2\pi f_c t + \frac{f_\Delta}{f_m}\cos(2\pi f_m t)\right]$$

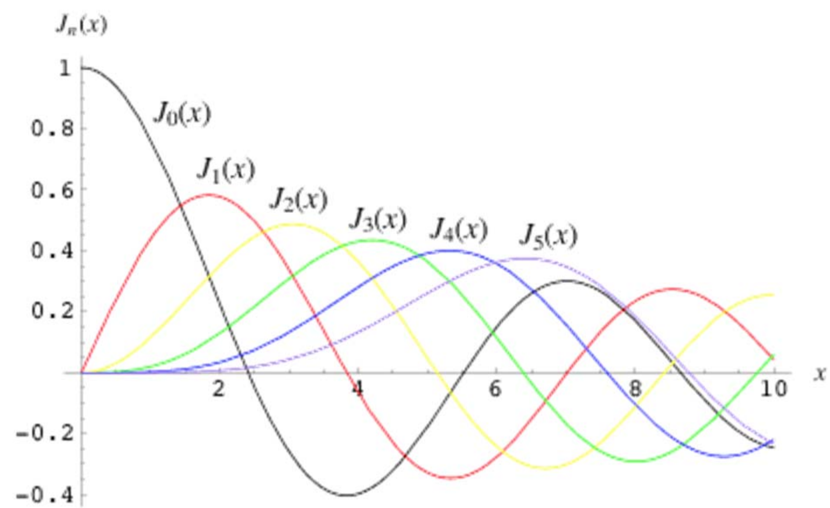
$$S(t) = AJ_0(x)\cos(2\pi f_c t)$$
$$+ A\sum_{n=1}^{\infty} J_{2n}(x)\sin[2\pi(f_c + 2nf_m)t]$$
$$+ A\sum_{n=1}^{\infty} J_{2n}(x)\sin[2\pi(f_c - 2nf_m)t]$$
$$+ A\sum_{n=1}^{\infty} J_{2n-1}(x)\cos[2\pi(f_c + (2n-1)f_m)t]$$
$$+ A\sum_{n=1}^{\infty} J_{2n-1}(x)\cos[2\pi(f_c - (2n-1)f_m)t]$$

even multiples of fm

Fourier Series

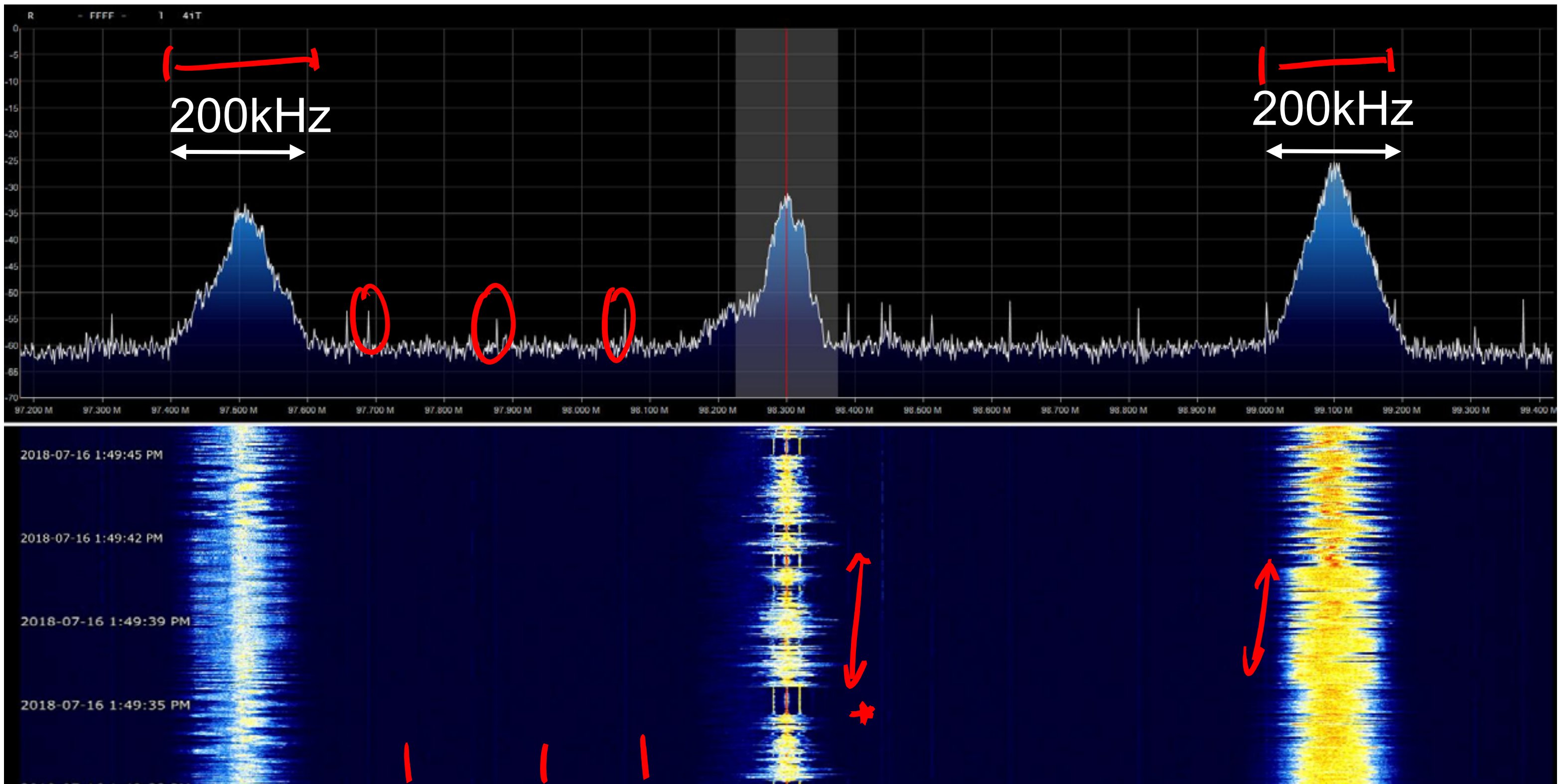
odd multiples of fm

Jn(x) is a Bessel Function of the first kind



Bandwidth defines channel spacing

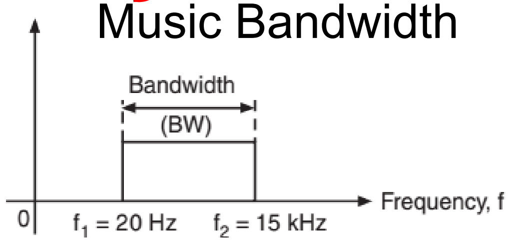
Waterfall Chart



97.4MHz 98.3MHz 99.1MHz

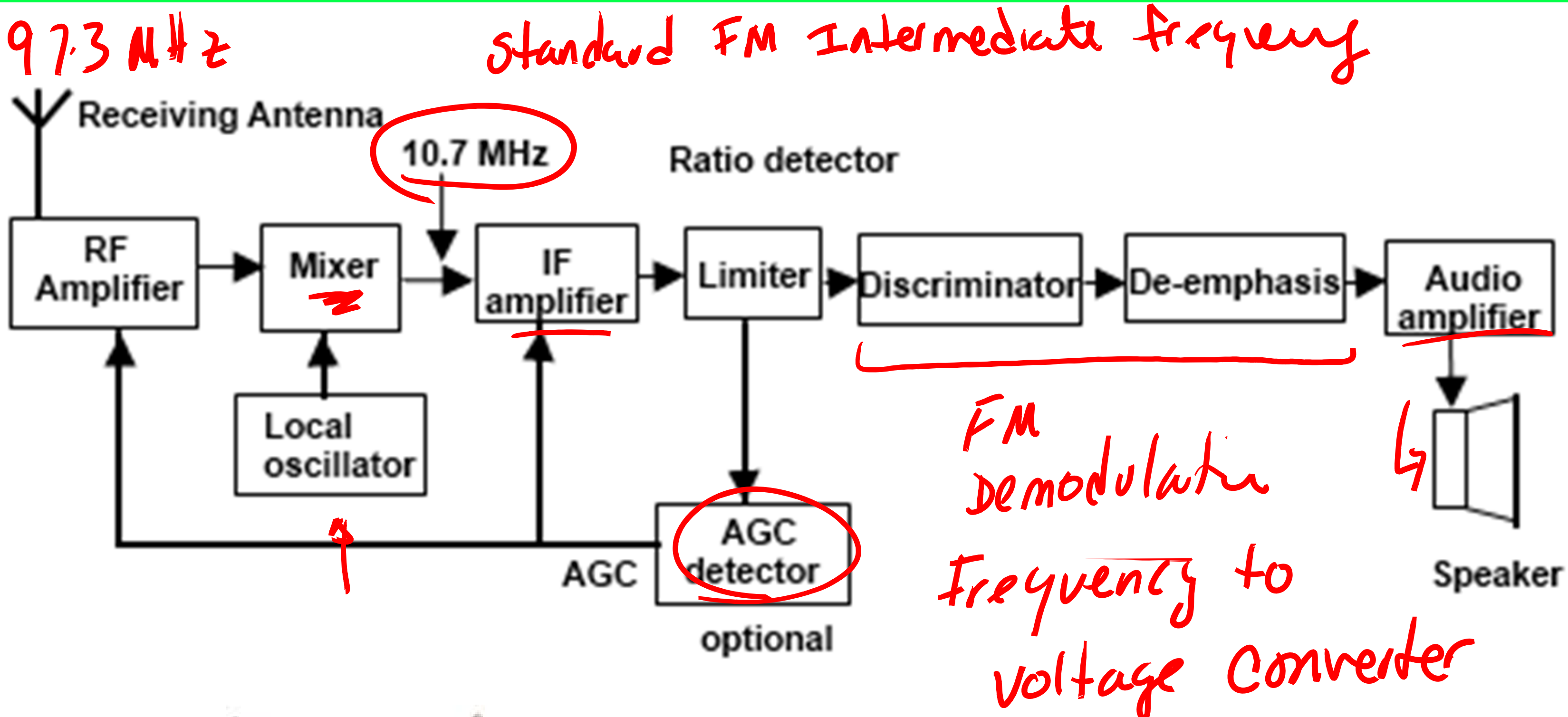
Example
KBCO
f_c = 97.3MHz
f_m = 20 kHz
f_Δ = 200 kHz

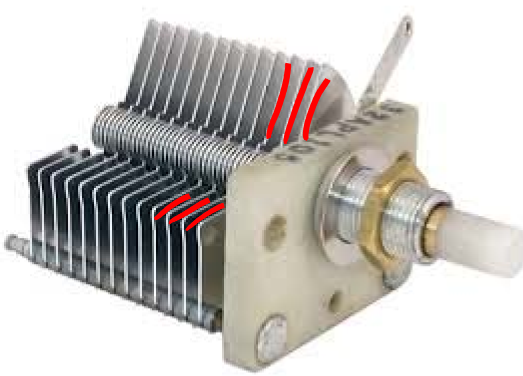
Music Bandwidth



S.No.	Type of the signal	Range of frequency in Hz	Bandwidth in Hz
1.	Voice signal (speech) for telephony	300 – 3400	3,100
2.	Music signal	20 – 15000	14, 980
3.	TV signals (picture)	0 – 5 MHz	5 MHz
4.	Digital data	300 – 3400 (If it is using the telephone line for its transmission)	3,100

FM Receiver





Air variable capacitor used for tuning