

## Frequency and Phase Modulation (Ch. 5)

7A-1

Why? (noise and interference reduction)

"instantaneous frequency" - (5.1)

bandwidth (5.2)

Generation (5.3)

Demodulation (5.4) (+ 5.6)

interference (5.5)

Problems with AM, etc--

Prone to interference

" " noise (static)

Receiver output varies with signal strength.

For good S/N ratio - need VERY strong signal.

FM (and PM) gives us-

Noise immunity

a "capture" effect - noise drops sharply with signal

Receiver output is not dependent on signal strength.

But costs:

Bandwidth  $\Delta f$

(it takes LOTS of bandwidth)

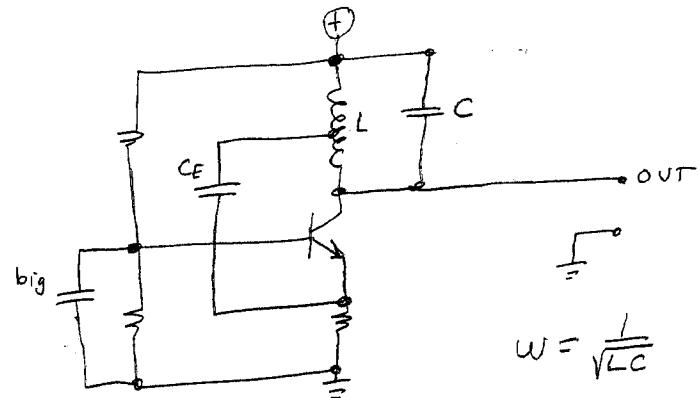
Basic concept -

Instead of varying the amplitude of  
a carrier, vary its frequency.

## A Simple way to generate FM:

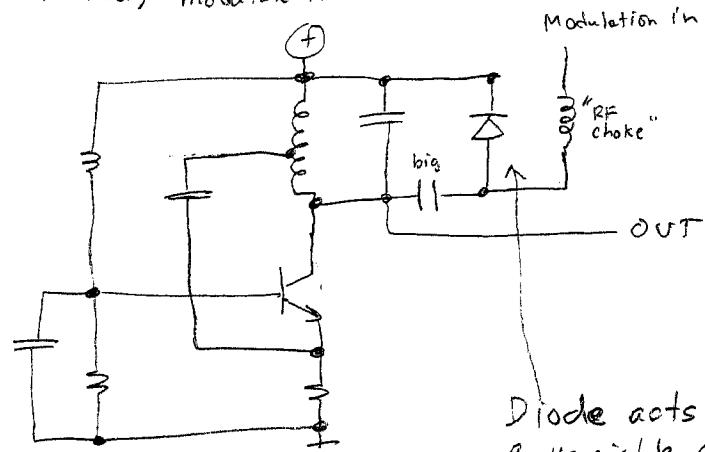
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Here's an oscillator: (basic "Hartley" oscillator)



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

Now, modulate it:



Modulation in

"RF choke"

OUT

Diode acts like  
a variable capacitor,  
controlled by the  
"modulation in".

### Concept of instantaneous frequency

7A-3

Book says -- think of instantaneous velocity.

Practically-- The carrier frequency is much higher than the modulation, so you can look at one cycle.

Consider a generalized sinusoidal signal --

$$\phi(t) = A \cos(\underline{\theta(t)})$$

↑  
"generalized angle."

The "generalized angle" for

$$A \cos(w_c t + \theta_0)$$

$$\text{is } w_c t + \theta_0$$

Instantaneous frequency:

$$\omega_i(t) = \frac{d\theta}{dt}$$

$$\theta(t) = \int_{-\infty}^t \omega_i(\alpha) d\alpha \quad \leftarrow \begin{array}{l} \text{integrating,} \\ \text{and swapping sides.} \end{array}$$

### Phase modulation

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$\theta(t)$  is a function of  $m(t)$

modulation by varying the phase angle of a carrier

$$\theta(t) = \underline{w_c t + \theta_0} + \underline{k_p m(t)}$$

unmodulated  
Carrier

Component due to  
modulation

$w_c$  = carrier frequency

$\theta_0$  = reference phase ( $=0$ ) drop it

$k_p$  = some constant = modulation index

resulting PM wave is:

$$\phi_{pm} = A \cos(w_c t + k_p m(t))$$

instantaneous frequency is:

$$\omega_i(t) = \frac{d\theta}{dt} = w_c + k_p \dot{m}(t) \quad \leftarrow \begin{array}{l} \text{phase} \\ \text{modulation} \end{array}$$

$\dot{m}(t)$  = derivative of  $m(t)$

Instantaneous frequency varies linearly with derivative of  $m(t)$

FM is almost the same --

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instantaneous frequency varies linearly  
with  $m(t)$

$$\omega_i(t) = \omega_c + k_f m(t)$$

$k_f$  = some constant = modulation index

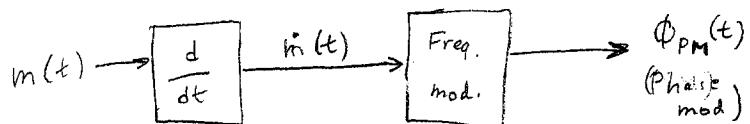
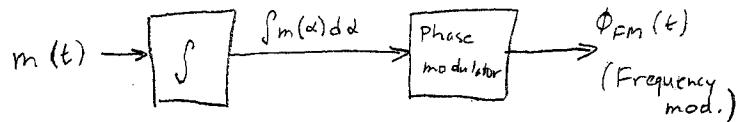
$$\theta(t) = \int_{-\infty}^t [\omega_c + k_f m(\alpha)] d\alpha$$

$$= \omega_c t + k_f \int_{-\infty}^t m(\alpha) d\alpha$$

$$\phi_{FM} = A \cos(\omega_c t + k_f \int_{-\infty}^t m(\alpha) d\alpha)$$

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Frequency & Phase modulation are really the same,  
Phase is the derivative of frequency.



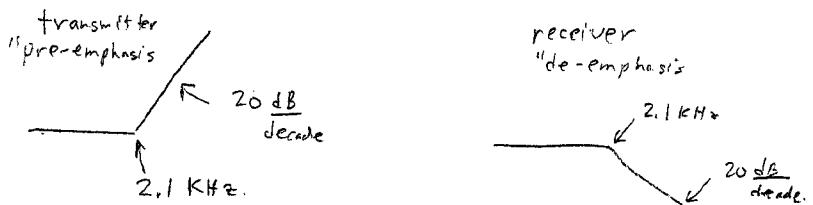
Which is "better"? - Whichever (or what combination)  
makes better use of bandwidth. The difference is only  
an equalization network

Which is "better"?

Whichever makes better use of bandwidth.

The difference is only an equalization network.

FM broadcast - uses this equalization:

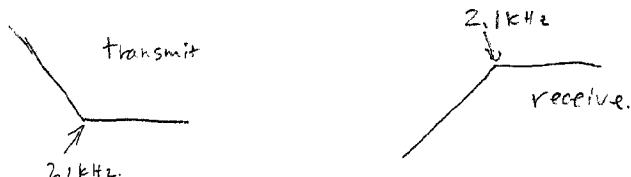


This is like PM above 2.1 kHz, FM below.

The rising slope is like differentiation (transmit)

The falling slope is like integration (receive).

it could have used:



and Phase modulation,

with exactly the same result.