Department of Communications Engineering

Communication Systems

Third Year Class

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Lecture 13

Super heterodyne Receivers II

* If we need to receive <u>only</u> one station, homodyne receiver is excellent.

* If we need to design a radio station receiver that operates in the frequency band of

$$108\ MHz - 88\ MHz = 20\ MHz$$

with a channel spacing of 200 KHz

$\therefore$ There will be $\frac{20 \times 10^6}{200 \times 10^3} = 100$ channels !!!

* in other words, we need to design a homodyne FM radio receiver with 100 homodyne internal receivers !!!

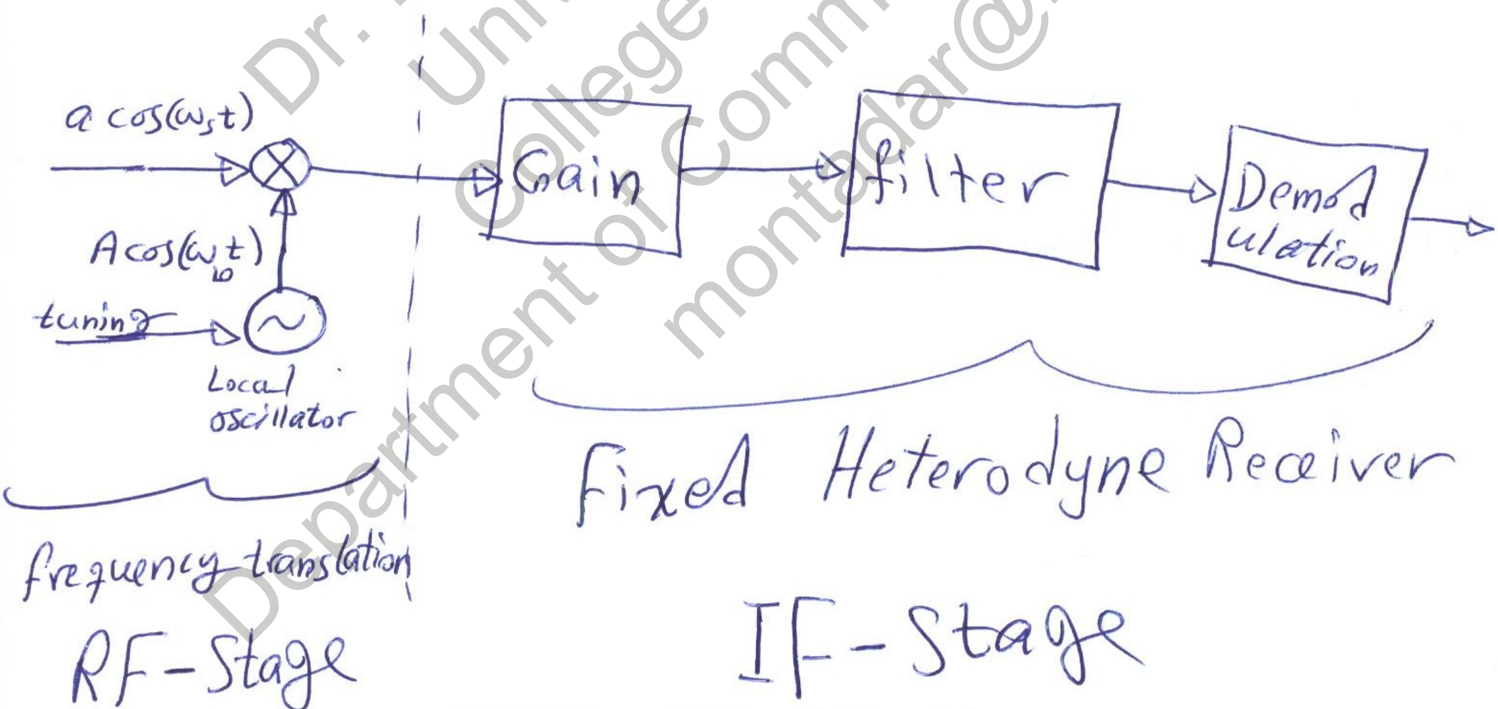
There are important problems in such receiver design

① cost ② size ③ power

* Edwin Howard Armstrong (during world war in 1918) invented a radio receiver that is widely used even in our days.

* Armstrong's device called super-Heterodyne receiver.

* Armstrong suggested not to change the hardware (chanallized receiver radio), instead, changing the Local oscillator frequency.



$$F_{IF} = |f_s - f_{LO}|$$

* For instance, we need to receive a station transmits at 103.3 MHz, then we tune the Local oscillator to $103.3 - f_{IF}$, let $f_{IF} = 10.7$ MHz, then we tune the Local oscillator to $103.3 - 10.7 = 92.6$ MHz

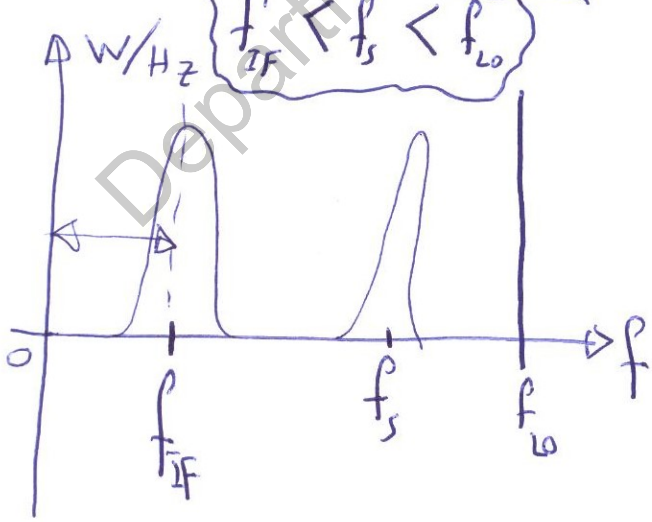
Thus $|f_s - f_{Lo}| = f_{IF}$ must satisfied in down conversion

Hence $f_s - f_{Lo} = \pm f_{IF}$

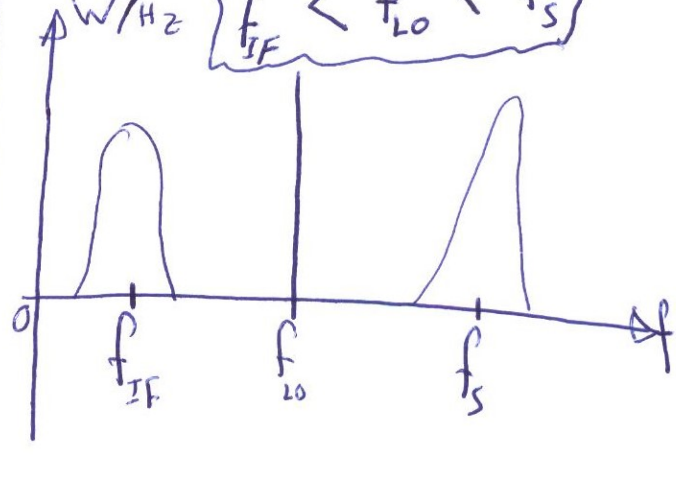
Or

$$f_{Lo} = f_s + f_{IF}$$ OR $$f_{Lo} = f_s - f_{IF}$$

$f_{IF} < f_s < f_{Lo}$



$f_{IF} < f_{Lo} < f_s$



*Consider the FM band with IF frequency $f_{IF} = 30\,MHz$, or the FM band extend from 88 MHz to 108 MHz

$$88\,MHz \leq f_s \leq 108\,MHz$$

Hence, Local oscillator bandwidth for high conversion must be 30 MHz higher than RF Bandwidth

$$88\,MHz + f_{IF} \leq f_{LO} \leq 108 + f_{IF}$$

$$= 118\,MHz \leq f_{LO} \leq 138\,MHz$$

While, for low side conversion, the Local oscillator bandwidth is

$$88\,MHz - f_{IF} < f_{LO} < 108\,MHz - f_{IF}$$

$$58\,MHz < f_{LO} < 78\,MHz$$

* If we choose low-side tuning, LO operates at Lower frequency, then we get

① Lower cost ② better output power

③ Less phase-noise ④ Frequency accuracy is better.

* If we select high-side tuning, LO bandwidth would be very high compared with Low-side tuning, and generally, Less bandwidth is better.

* In practice, mixers are implemented such as this equation

$y(x) = x^3 + x^2 + x + c$ and maybe higher order.

* Then, the input, which is x, maybe $\cos(\omega_1 t) + \cos(\omega_2 t)$

then
$$y(x) = (\cos(\omega_1 t) + \cos(\omega_2 t))^3 + (\cos(\omega_1 t) + \cos(\omega_2 t))^2 + \cos(\omega_1 t) + \cos(\omega_2 t) + c$$

* Then we have 1^{st}, 2^{nd}, and 3^{rd} orders of products, and maybe higher.

* For Third order product ① $|2f_{RF} - f_{LO}|$

$$|2f_{RF} - f_{LO}| = F_{IF}$$

for example: $F_{LO} = 130$ MHz

$F_{IF} = 30$ MHz

$$\therefore \quad |2F_{RF} - 130| = 30$$

$$2F_{RF} - 130 = \mp 30$$

$$2F_{RF} = 130 \mp 30$$

$$F_{RF} = \frac{130 \mp 30}{2} = 50 \text{ OR } 80 \text{ [MHz]}$$

in other words, if we need to listen to a radio station at 100 MHz, then stations at 50 MHz and 80 MHz also appears !!!

$|2f_{RF} - 130| \Rightarrow |2 \times 50 - 130| = 30$ & $|2 \times 80 - 130| = 30$

* ② $|2F_{LO} - F_{RF}| = F_{IF}$

assume $F_{IF} = 30\ MHz$, $F_{LO} = 130\ MHz$, then

$$|2F_{LO} - F_{RF}| = F_{IF} \Rightarrow |2(130) - F_{RF}| = 30$$

$$F_{RF} = 260 \mp 30 = 290 \text{ OR } 230\ [MHz]$$

* Also ③ $|2F_{LO} + F_{RF}| = F_{IF}$ } Gives negative frequency! ignore

* ④ $|2F_{RF} + F_{LO}| = F_{IF}$ } Gives negative frequency ignore

* ⑤ $3F_{RF} \Rightarrow 3F_{RF} = F_{IF} \Rightarrow F_{RF} = 10\ MHz$

* For Second order terms:

① $|F_{LO} - F_{RF}| = F_{IF} \Rightarrow 100\ \&\ 160\ MHz$ for the same example

② $|F_{LO} + F_{RF}| = F_{IF} \Rightarrow$ gives negative frequency. Ignore

③ $2F_{RF} = F_{IF} \Rightarrow F_{RF} = 15\ MHz$ For the same example above

* For First order terms:

* there is only $F_{RF} = F_{IF} = 30$ for the same example above.

As a conclussion, if we need to listen to a radio station at 100 MHz with $F_{IF} = 30$ MHz then we will listen to all the stations at frequencies 30 MHz, 15 MHz, 160 MHz, 10 MHz, 50 MHz, 80 MHz, 230 MHz, 290 MHz

1st order terms (30 MHz); 2nd order terms (15 MHz, 160 MHz); 3rd order terms (10 MHz, 50 MHz, 80 MHz, 230 MHz, 290 MHz)

So! Can We Listen to our Station or NO?

Yes, by inserting a pre-selector filter between the antenna and the mixer :)