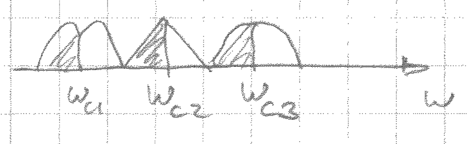
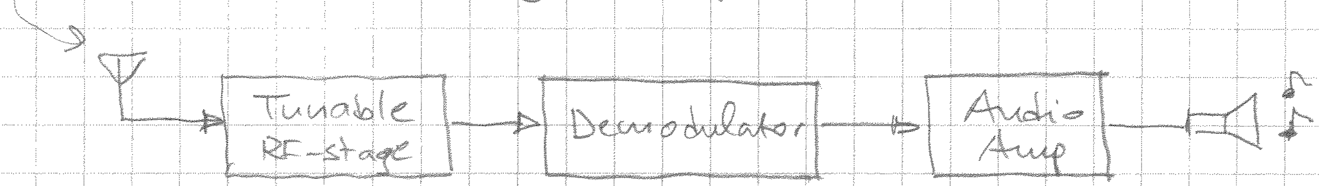
SUPERHETERODYNE RECEIVER

Motivation:

Consider a FDM signal



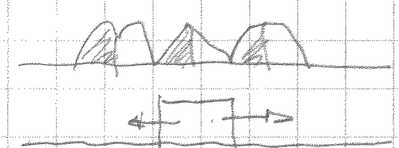
To receive this signal and to tune in to a particular "channel" we we may require a receiver with the follow up structure.



The above system will function as required. However, the design and implementation of a tunable front end, the RF stage with sharp cut-off (i.e. high selectivity) and high-gain over a wide-range of frequencies, is a difficult task.

Consider the following alternative scenario.

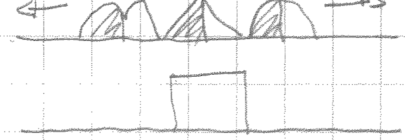
What we had?



Signal is FIXED

tunable RF-stage — move over the entire spectrum [540, 1600] kHz.

Instead, let us



Signal — move over the spectrum by MIXING

RF stage — FIXED!

* We know how to "mix" the input signal, i.e., how to move the spectrum up and down the spectrum band ($\Rightarrow$ multiply the input signal with the output of a local oscillator)

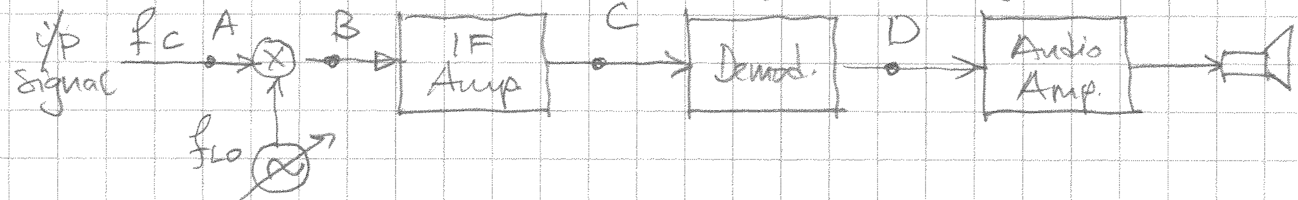
* We can also design a fixed frequency RF stage which has all the desired filtering and amplification properties.

HETERODYNING : translating / shifting in frequency.

The concept which we described in very general terms above is called heterodyning. This technique consists of either down- or up-converting the input signal to some convenient frequency band.

<u>Definition</u> This frequency is called the INTERMEDIATE FREQUENCY (IF) band. The IF is fixed and is independent of the f_c of the signal we receive

If f_c is within a range ([540, 1600]) and f_{IF} is fixed, then we need a variable frequency local oscillator.



Commercial AM Receivers use the standard $f_{IF} = 455$ kHz with $f_c \in [540, 1600]$ kHz.

Let us consider an AM station broadcasting at $f_c = 600$ kHz with transmission bandwidth of 10 kHz.

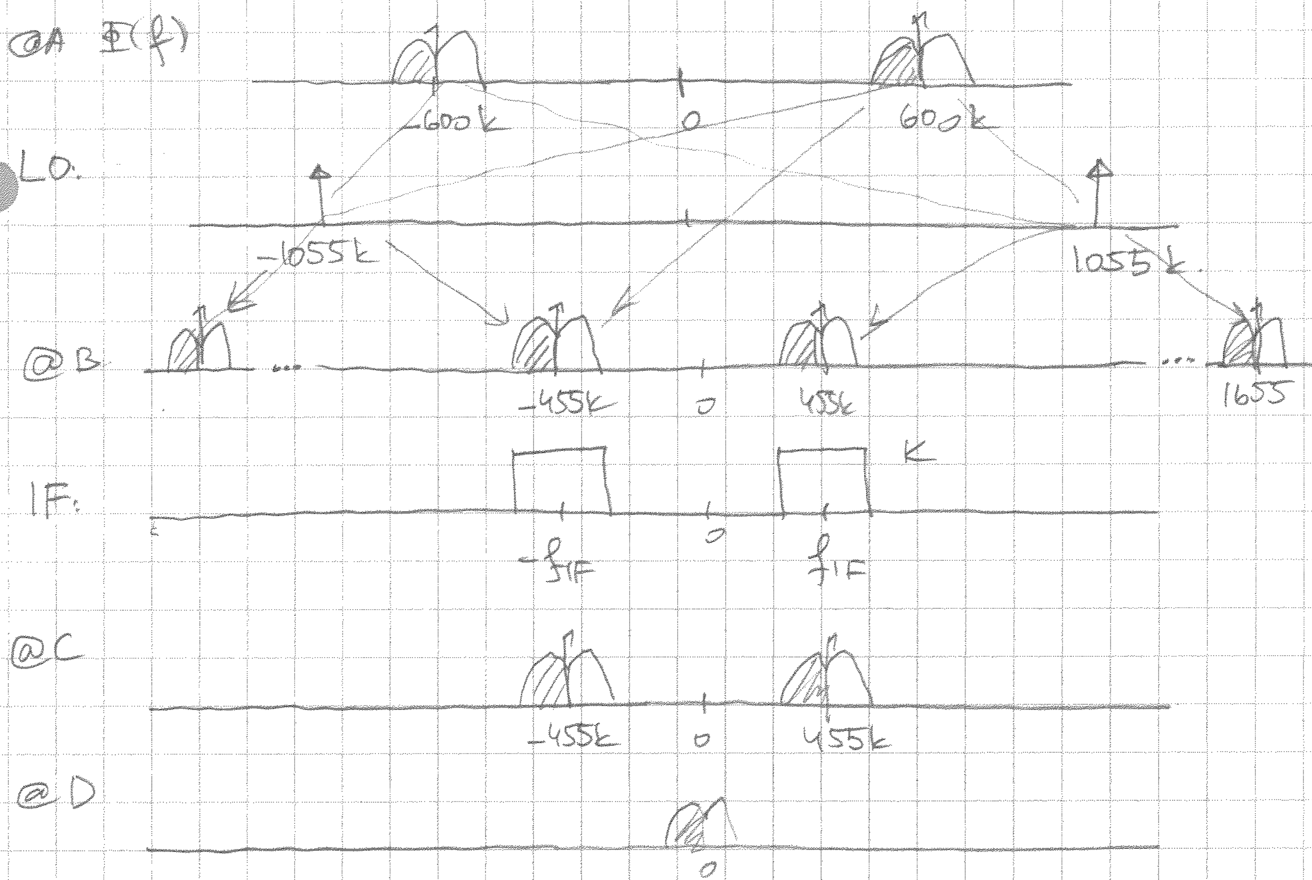
@ point A : the signal is centered about $\pm f_c$

@ point B : $\pm f_c \pm f_{LO} = \begin{cases} f_{LO} - f_c & f_{LO} + f_c \\ f_c - f_{LO} & -f_{LO} - f_c \end{cases}$ Assume $f_{LO} > f_c$

superheterodyning we want $f_c \downarrow$: down-conversion i.e.

$$f_c \longrightarrow f_{LO} - f_c \text{ such that } f_{LO} - f_c = f_{IF}$$

In other words we need $f_{LO} = 455 + 600 = 1055$ kHz. We can illustrate what is happening in the SH (superheterodyne) receiver by the following series of spectral displays.

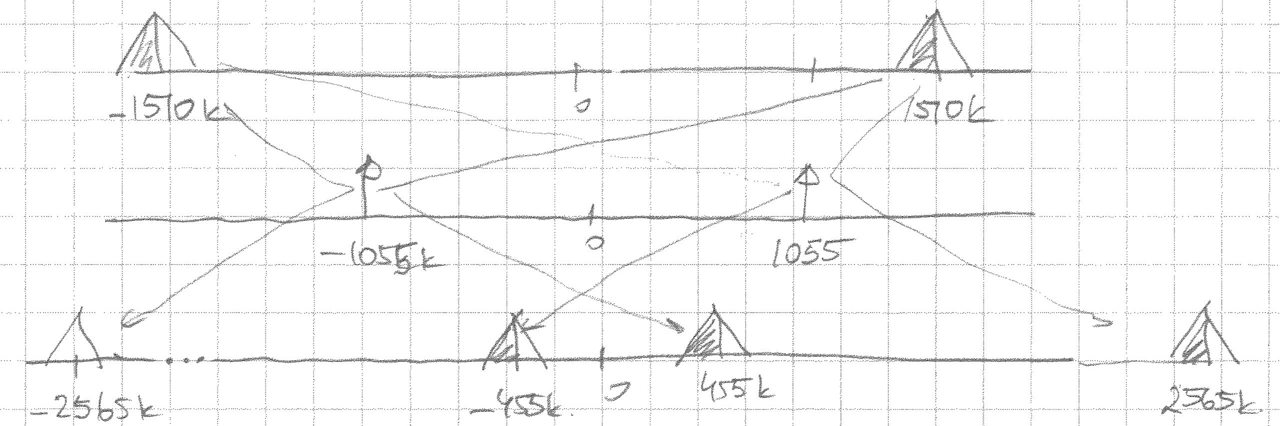


If we want to receive another station, let's say one that is broadcasting with $f_c = 1000$ kHz, then we adjust the LO such that $f_{LO} = (1000 + 455)$ kHz $= 1.455$ MHz and we can receive this new signal without having to change the rest of the receive/demodulation scheme

The implicit assumption we are making is that the IF filter is selective enough to reject signals from adjacent bands.

There is another potential hazard, we should be aware of: Let us recall that to receive $f_c = 600$ kHz we have adjusted f_{LO} to $f_{LO} = f_{IF} + f_c = 1055$ kHz. What happens to the radio signal which is broadcast using f_c

$$f_c' = f_{LO} + f_{IF} = 1055 + 455 = 1510 \text{ kHz}$$



Thus the radio signal with f_c' will be downconverted by the f_{LO} (adjusted to receive f_c) to the IF band. If this signal (downconverted from f_c' to f_{IF} by f_{LO}) is at the same strength as the f_c signal, the at the IF stage we will not be able to differentiate them.

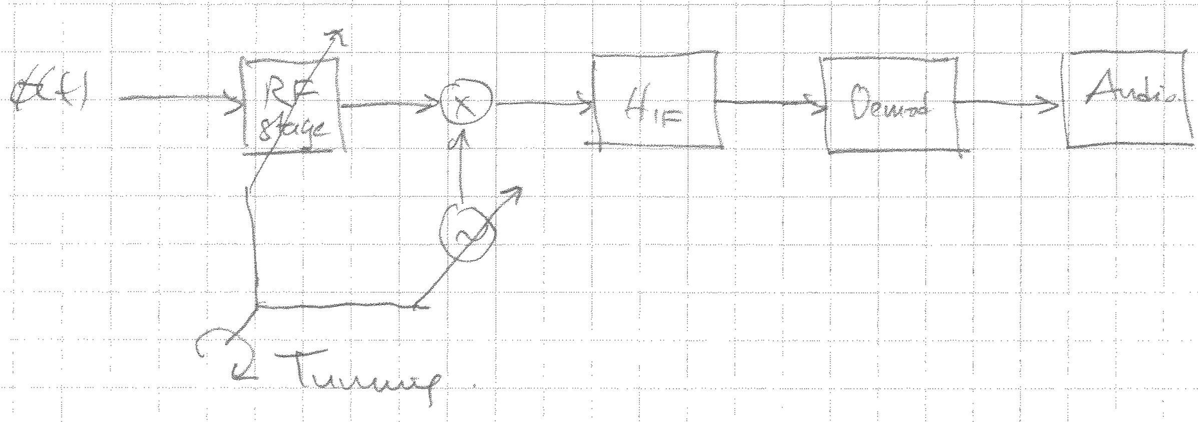
This "trouble causing" frequency is known as the IMAGE FREQUENCY.

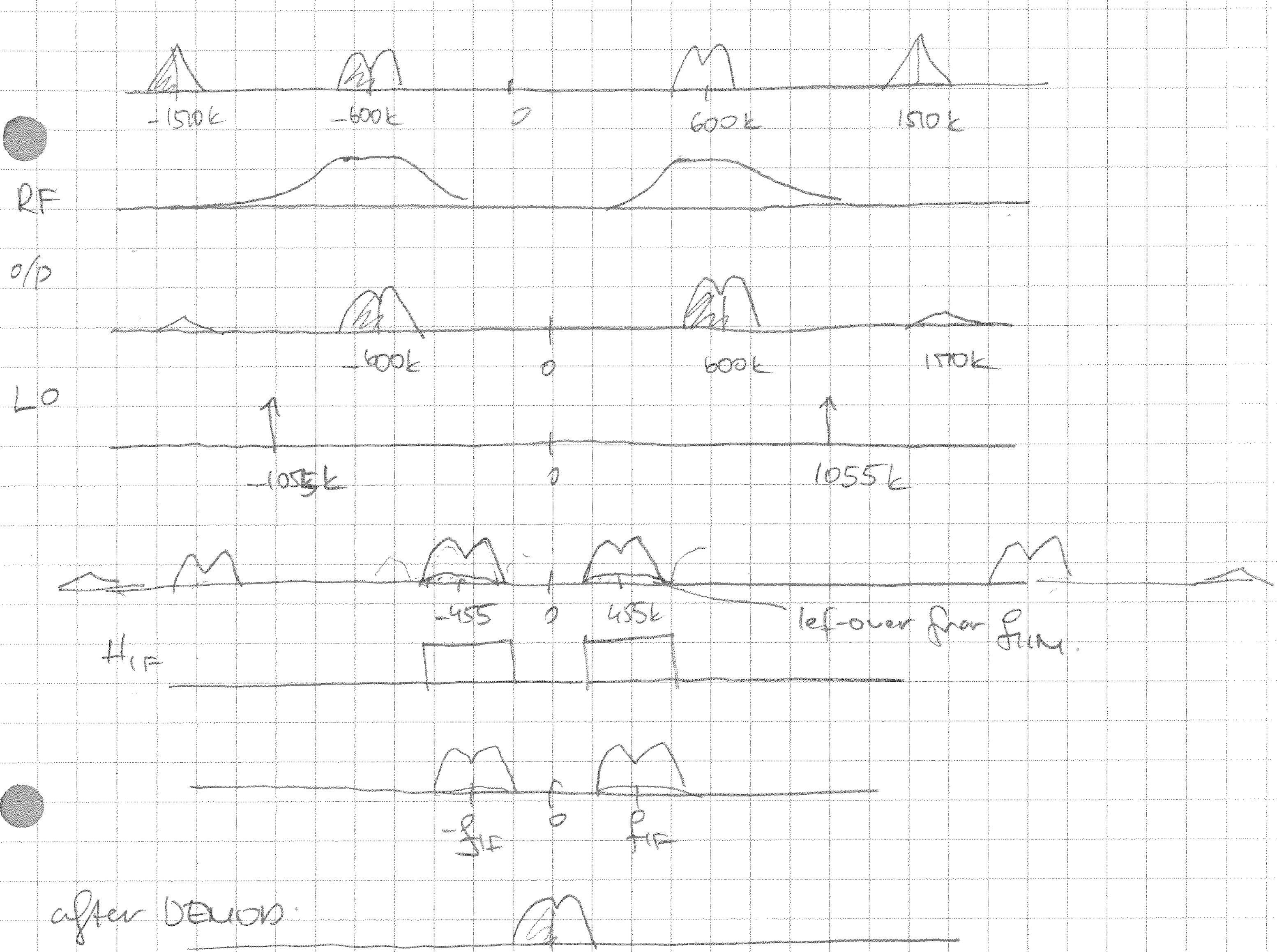
$$f_{IMAGE} = \begin{cases} f_{LO} + f_{IF} = f_c + 2f_{IF}, & \text{if } f_{LO} > f_c \\ f_c - 2f_{IF}, & \text{if } f_{LO} < f_c \end{cases}$$

where $f_{LO} = f_c + f_{IF}$ (or $f_c - f_{IF}$)

Since both f_c and f_{IMAGE} will be converted by f_{LO} to f_{IF}, what can we do?

$\Rightarrow$ **Introduce a tunable RF-Stage(s) that precedes the heterodyning process**





Since $f_{IM} = f_c + 2f_{IF}$, increasing f_{IF} allows further attenuation of f_{IM} as it is filtered by the RF-stage. Hence, we want f_{IF} as high as possible (practically feasible). There are other conflicting requirements. Is it practical to design a tunable LO which can cover the required frequency range

For example: Since $f_{LO} > f_c \in [540, 1600] \Rightarrow f_{LO} \in [995, 2055]$ kHz

~~Ratio~~ of $\frac{2055}{955} = 2.045$

or

If $f_{LO} < f_c \in [540, 1600] \Rightarrow f_{LO} \in [85, 1145] \Rightarrow 12.05$

much more difficult to achieve.

Some popular IF Frequencies

AM radio : 455 kHz
FM " : 10.7 MHz.
Radar 30-60 MHz
TV 43.75 MHz.
Sat. Receiver: 70 MHz.

- To improve performance of radioreceiver, high-perf. receivers have multiple IF stages.

- The RF section is typically rated by its image rejection performance.