2. RECEIVER ARCHITECTURES

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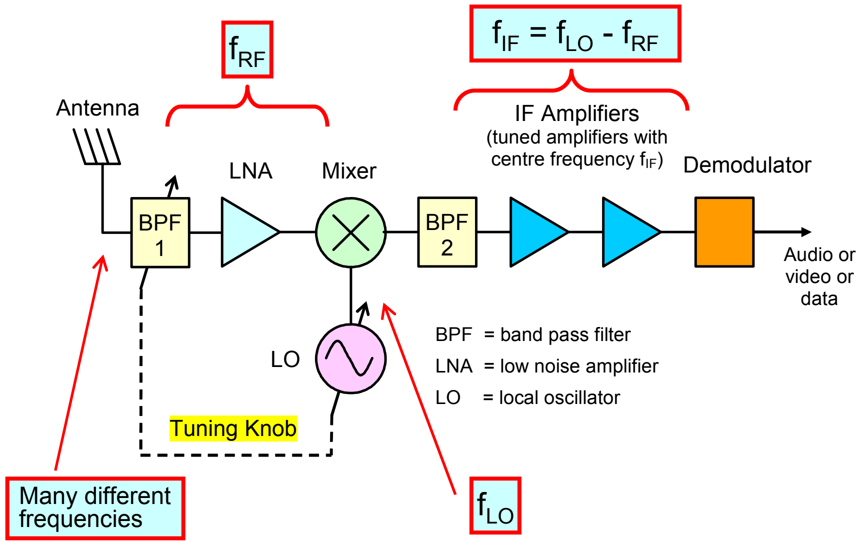
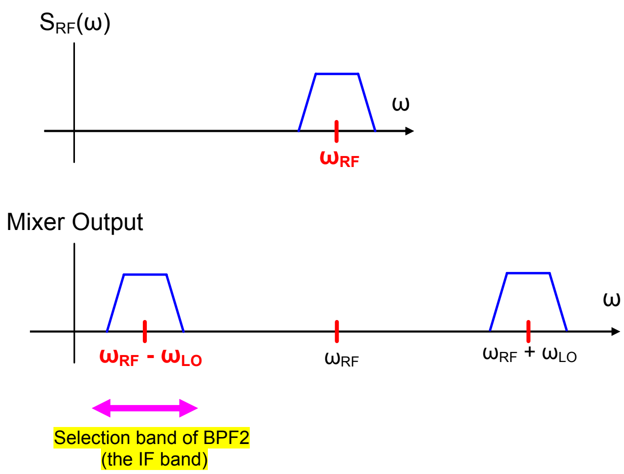
Summary

- Review of the superhet receiver
- Image
- Sensitivity
- Selectivity
- Dynamic Range
- Double conversion superhet receiver
- Tuned Radio Frequency receiver
- Homodyne receiver
- Recent Advances

Superheterodyne Receiver



Superheterodyne Receiver



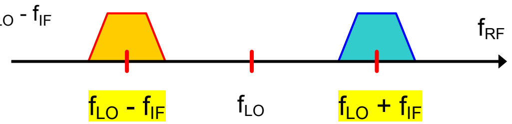
Superheterodyne Receiver

Some variations:

- The LNA may not be present
- The tuning may be fixed
- The IF amplifier may incorporate a piezo-electric filter such as a ceramic filter or a surface acoustic-wave (SAW) filter
- The detector may be analogue or digitally implemented (DSP)
- The IF strip could be digitally implemented (DSP)

Image of a Superhet Receiver

- Let us assume that the bandwidth of the IF strip is B and is less than f_{IF}.
- A band of frequencies entering the mixer will be received provided it is centred at an RF frequency that differs from f_{LO} by f_{IF}.
- Unfortunately there are **two bands that satisfy this**:
  1. Band centred at $f_{LO} + f_{IF}$
  2. Band centred at $f_{LO} - f_{IF}$



- One of these bands is desired (the RF band centred on $f_{RF} = f_{RF}$) and the other is undesired (**image band** – centred on $f_{RF} = \mathbf{f_{image}}$)
- **BPF1** needs to be **wide enough** to **pass the desired** band **but narrow enough** to **reject the other**.

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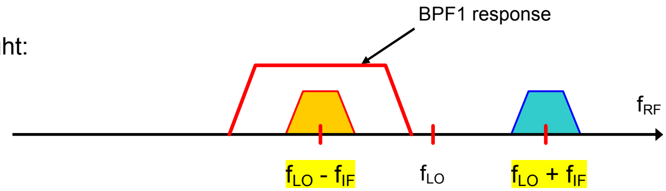
Image of a Superhet Receiver

- **BPF1** is also known as an **image-reject filter**

Just right:



Too wide:

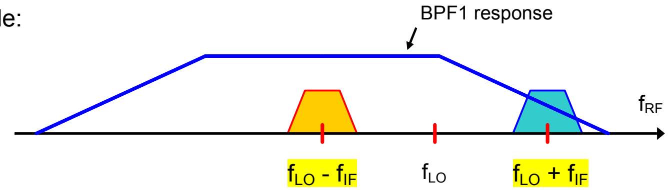


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Image of a Superhet Receiver

eg 1. AM broadcast receiver (modulation bandwidth = 9 kHz).

- Say the IF frequency is 465 kHz
- The IF bandwidth would be about 18 kHz
- To receive a station at 1080 kHz, then the LO frequency needs to be 1545 kHz
- The image frequency will be 2010 kHz [= 1545 kHz + 465 kHz]
- If the bandwidth of BPF1 is 50 kHz, then it will be able to pass the selected channel AND reject the image
- The percentage bandwidth of BPF1 is 50 / 1080 = 5 %. This would be a very reasonable specification for BPF1.

Image of a Superhet Receiver

eg 2. Microwave satellite TV receiver.

- Suppose that the IF frequency is 50 MHz
- The IF bandwidth is 10 MHz (assume TV channel bandwidth < 10 MHz)
- To receive a TV channel at 12 GHz the LO frequency needs to be 12.05 GHz
- The image frequency will be 12.1 GHz [= 12.05 GHz + 50 MHz]
- If the bandwidth of BPF1 is 30 MHz, then it will be able to pass the selected channel AND reject the image
- However, the percentage bandwidth of BPF1 is 30 / 12,000 = **0.25 %**. It would be **unreasonable** to specify such a narrow bandwidth.

Sensitivity

- The **ability to receive weak signals** is determined by the noise behaviour and gain of the first stage.
- We shall see that the first stage should contribute minimal noise to the signal AND have high gain.
- This is the main reason why an LNA appears as the first stage.
- A mixer does not provide gain – but rather a loss – called conversion loss.

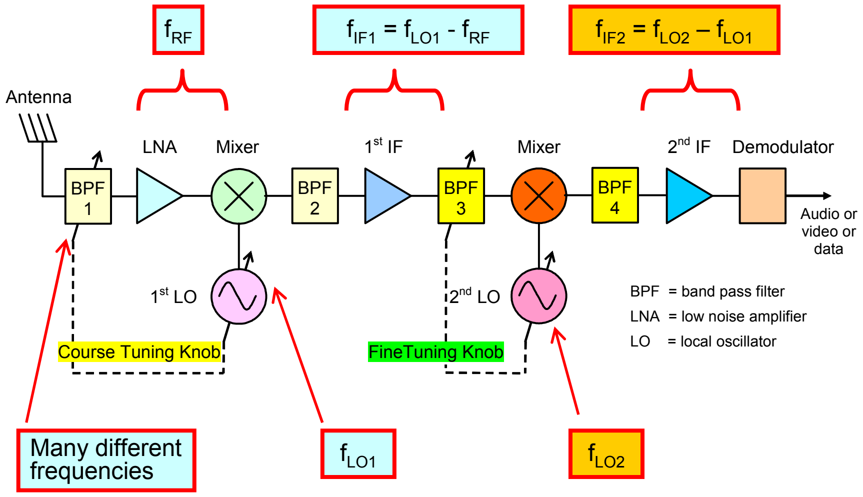
Selectivity

- The **ability to suppress undesired channels**
- Predominantly **determined** by the **bandpass response of the IF amplifiers**.
- BPF1 only provides course selectivity.
- BPF2 only needs to suppress the mixer product around $f_{LO} + f_{RF}$

Dynamic Range

The range of input power level from the lowest detectable signal to the highest that can be tolerated without distortion, is determined by many blocks in the chain.

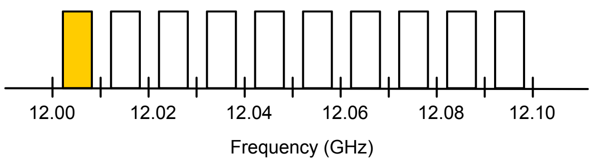
Double Conversion Superhet Receiver



Double-Conversion Superhet

eg. Microwave satellite TV receiver.

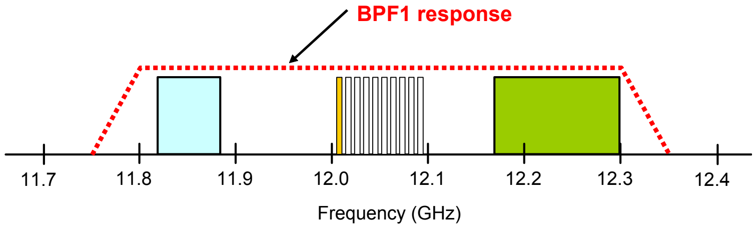
- There are 10 TV channels are in the range 12 – 12.1 GHz
- Each TV channel has a bandwidth of 6 MHz
- The channels are spaced 10 MHz
- We want to receive the 1st channel which is centred at 12.005 GHz



Double-Conversion Superhet

eg. Microwave satellite TV receiver.

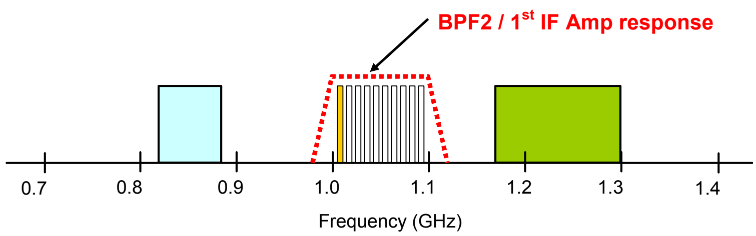
- Suppose the **1st IF band is 1 – 1.1 GHz**.
- This means **f_{LO1} = 11 GHz**. L01 and BPF1 are fixed.
- The image band will therefore be 9.9 – 10 GHz.
- If the bandwidth of **BPF1** is 600 MHz, then it will be able to pass the desired band AND reject the image band.
- The percentage bandwidth of BPF1 is 0.6 / 12.25 = **5 %**. This is a reasonable specification.



Double-Conversion Superhet

eg. Microwave satellite TV receiver.

- As you can see other unwanted signals are passed by BPF1 and will be down converted.
- However the **1st IF band is 1 – 1.1 GHz**. And this means that these unwanted channels will be suppressed.
- The percentage bandwidth of the 1st IF amplifier is 10% - again very reasonable.



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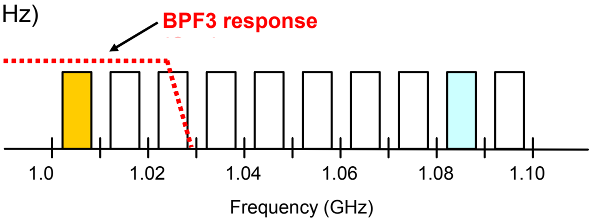
Double-Conversion Superhet

eg. Microwave satellite TV receiver.

- The 1st TV channel has been down-converted to 1005 MHz.
- Suppose the **2nd IF frequency is 40 MHz**. This means **f_{LO2} = 1045 MHz**.
- The image band centred at 1085 MHz corresponds to Ch 9.
- If the bandwidth of BPF3 is say 50 MHz (5 % bandwidth), then it can pass the desired channel (Ch 1) and suppress the image (Ch 9)
- Alternatively, increase 2nd IF frequency to say 60 MHz
- Ch 2 and some of Ch 3 pass BPF3 but NOT the 2nd IF amplifier (whose bandwidth is 10 MHz)



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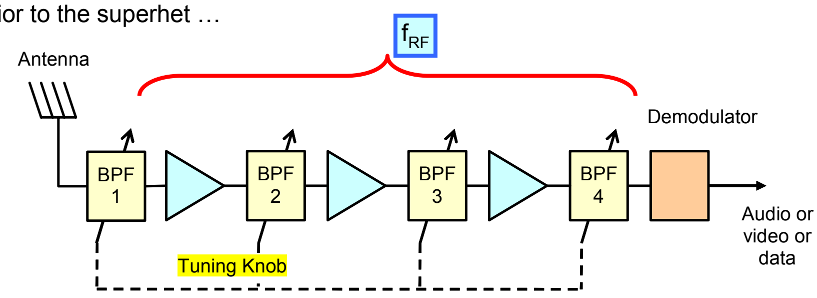
Tuned Radio Frequency (TRF) Receiver

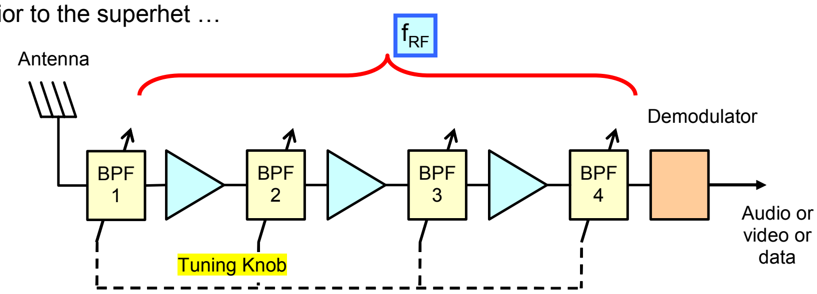
Prior to the superhet …



- Several tuned stages in cascade provide extra selectivity
- Amplifying stages prior to detection provide significantly increased sensitivity
- Variations include – different number of RF amplifiers and BPFs

Tuned Radio Frequency (TRF) Receiver

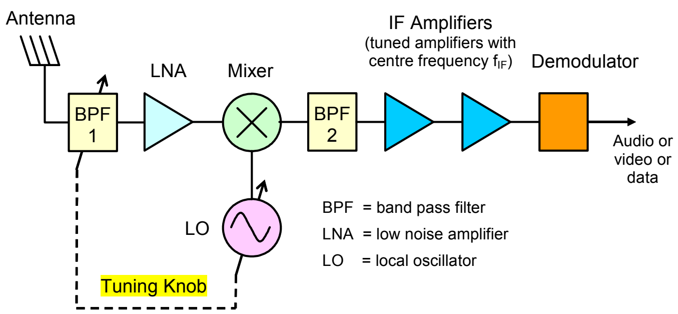
Prior to the superhet …



- Compared to the Superhet – it has the advantages of no LO and mixer, and no image.
- The problem is all BPFs need to be accurately aligned and remain this way after the tuning knob is adjusted - this is very hard to achieve.

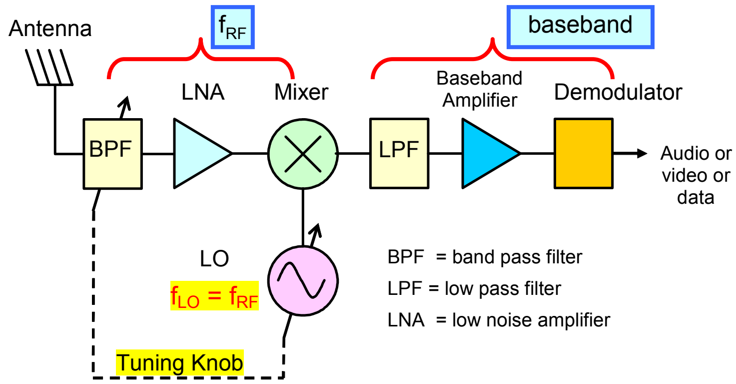
Superheterodyne Receiver

The next stage of evolution …



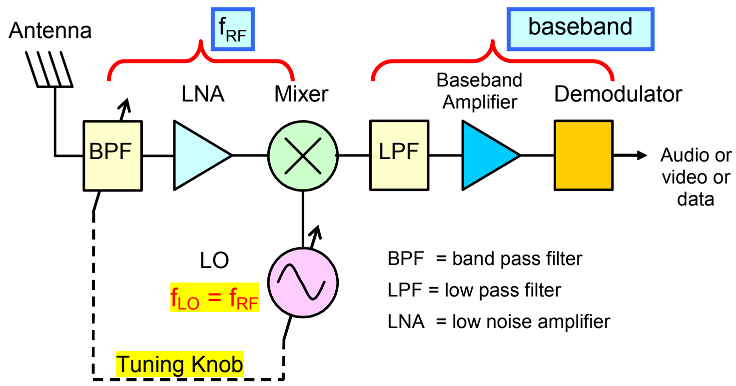
- Eliminated the need for aligned tunable BPFs.
- Filters within IF Amplifier need to be aligned – but they are fixed.

Homodyne Receiver Architecture



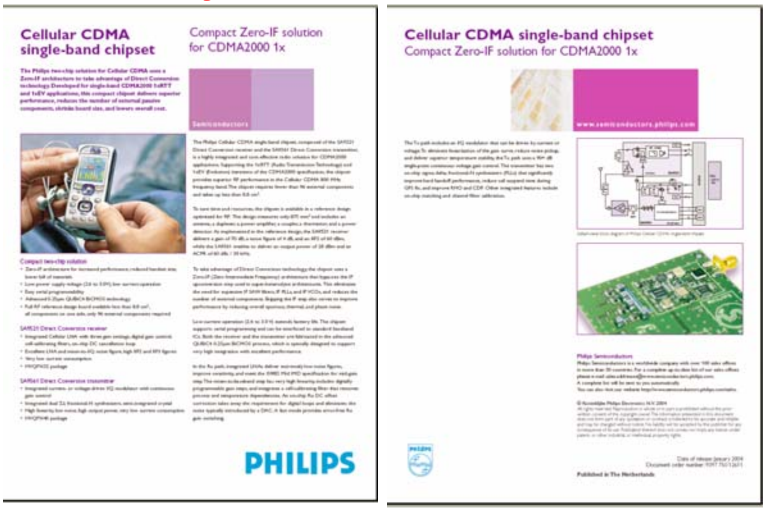
- RF is directly converted to baseband without IF stages
- Often called “Direct Conversion” or “Zero IF” receiver
- No additional detector is required for AM

Homodyne Receiver Architecture



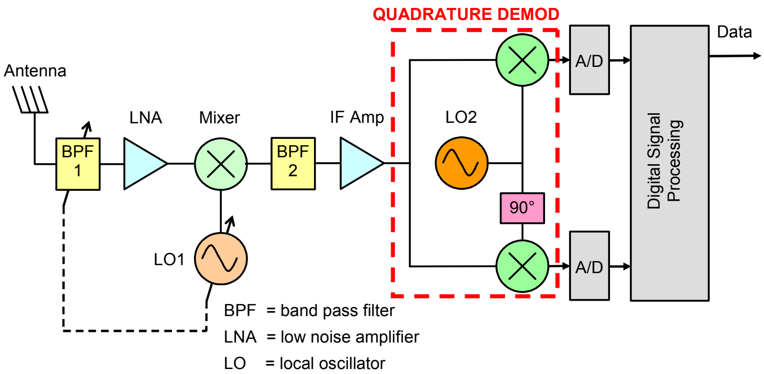
- Advantages: no image and selectivity determined by LPF (easier to design than IF BPFs).
- The challenge is to ensure that the f_{LO} is precisely f_{RF}.

Homodyne Receiver Architecture



Quadrature Detection Receiver

Can distinguish in-phase and out-phase components of the received signal ...



- Quadrature detector necessary for demodulation QAM, QPSK etc
- Cell-phones typically used the quadrature detector