

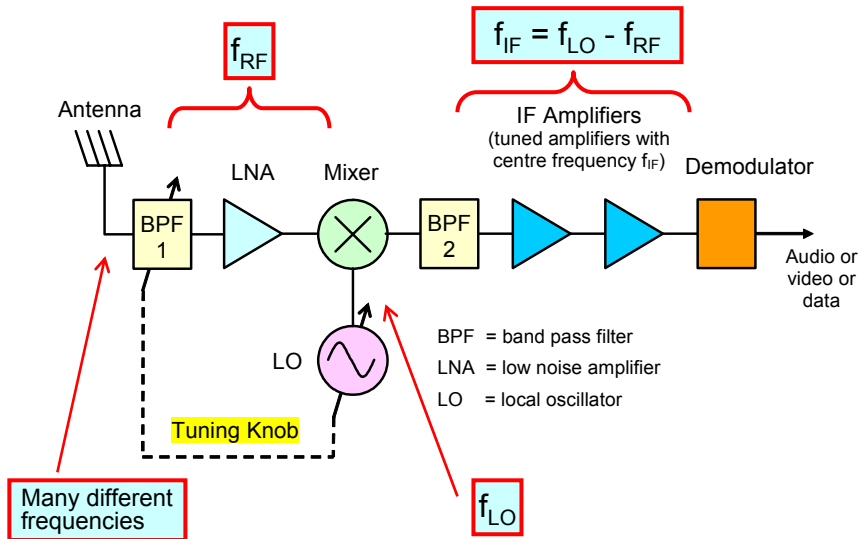
## **2. RECEIVER ARCHITECTURES**

### **ENEL434 Electronics 2**

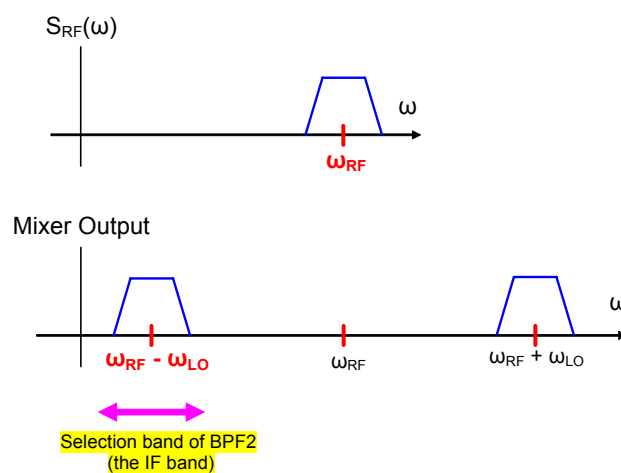
### **Summary**

- 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

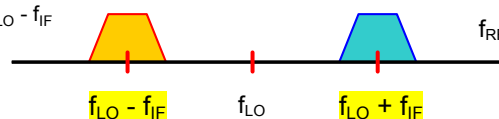
Some variations:

- 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**:

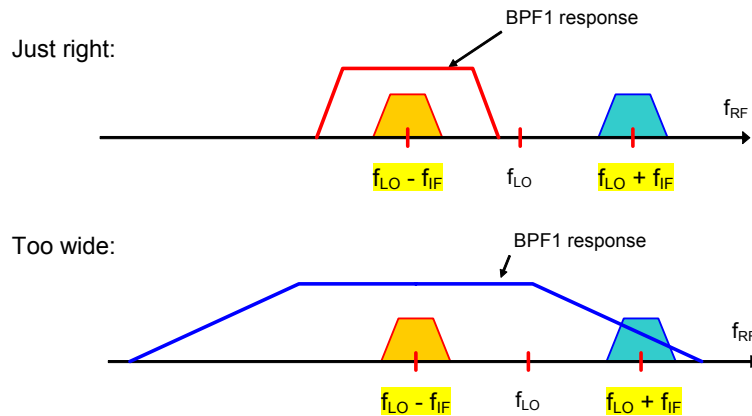
1. Band centred at  $f_{LO} + f_{IF}$
2. Band centred at  $f_{LO} - f_{IF}$



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

## Image of a Superhet Receiver

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



## 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.

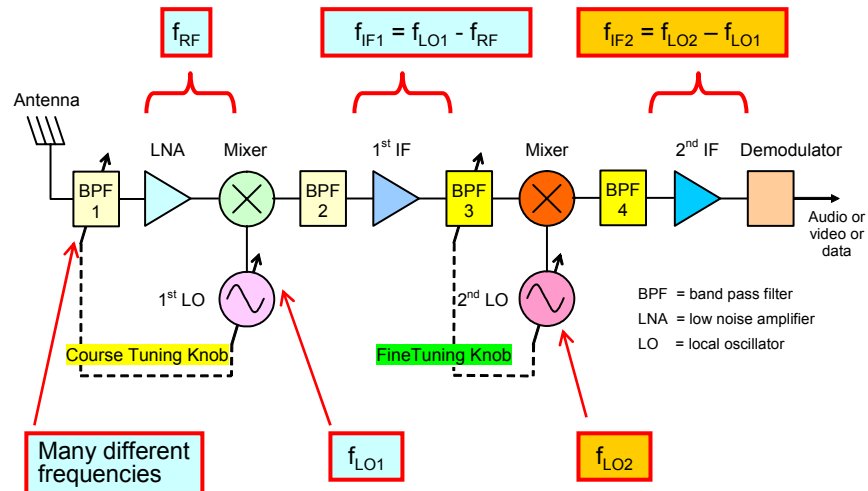
## Selectivity

- The **ability to suppress undesired channels**
- Predominantly **determined by the bandpass response of the IF amplifiers.**
- BPF1 only provides coarse 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.

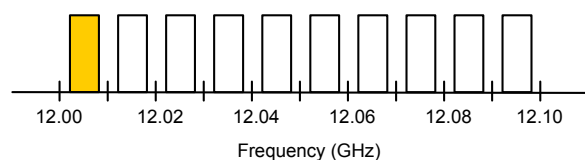
## Double Conversion Superhet Receiver



## Double-Conversion Superhet

**eg. Microwave satellite TV receiver.**

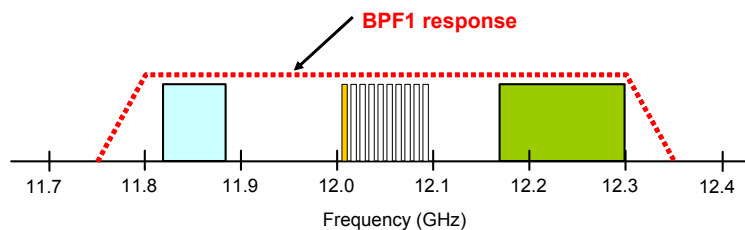
- There are 10 TV channels in the range 12 – 12.1 GHz
- Each TV channel has a bandwidth of 6 MHz
- The channels are spaced 10 MHz
- We want to receive the 1<sup>st</sup> channel which is centred at 12.005 GHz



## Double-Conversion Superhet

**eg. Microwave satellite TV receiver.**

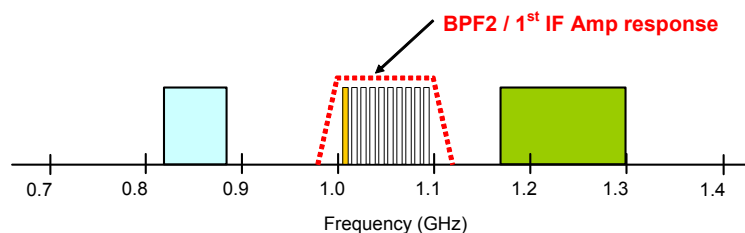
- Suppose the **1<sup>st</sup> IF band is 1 – 1.1 GHz**.
- This means  **$f_{LO1} = 11$  GHz**. L01 and BPF1 are fixed.
- The image band will therefore be 9.9 – 10 GHz.
- If the bandwidth of **BPF1** is 600 MHz, then it will be able to pass the desired band AND reject the image band.
- The percentage 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 **1<sup>st</sup> IF band is 1 – 1.1 GHz**. And this means that these unwanted channels will be suppressed.
- The percentage bandwidth of the 1<sup>st</sup> IF amplifier is 10% - again very reasonable.

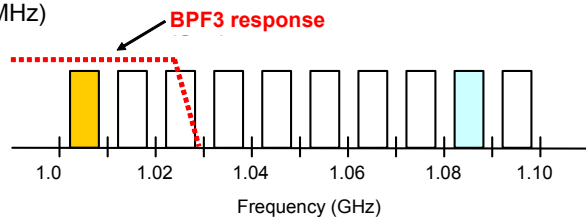




## Double-Conversion Superhet

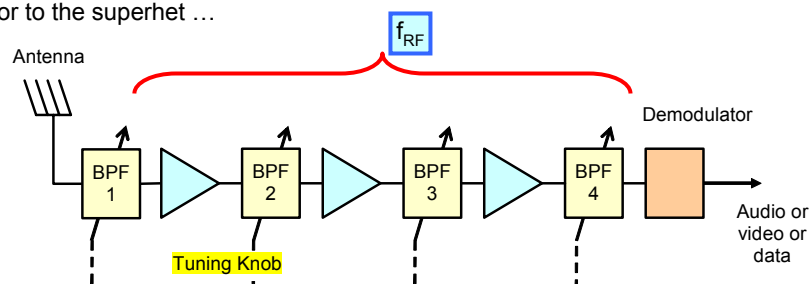
**eg. Microwave satellite TV receiver.**

- The 1<sup>st</sup> TV channel has been down-converted to 1005 MHz.
- Suppose the **2<sup>nd</sup> 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 2<sup>nd</sup> IF frequency to say 60 MHz
- Ch 2 and some of Ch 3 pass BPF3 but NOT the 2<sup>nd</sup> IF amplifier (whose bandwidth is 10 MHz)



## Tuned Radio Frequency (TRF) Receiver

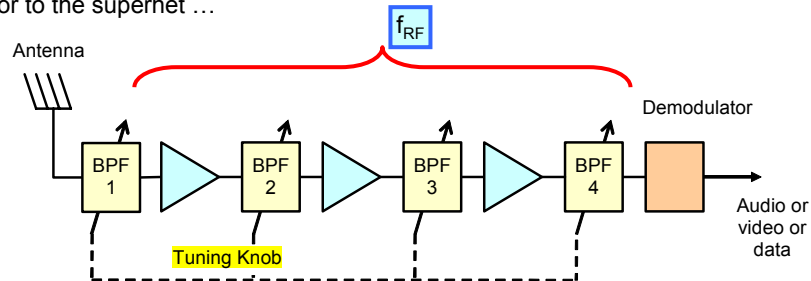
Prior to the superhet ...



- 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

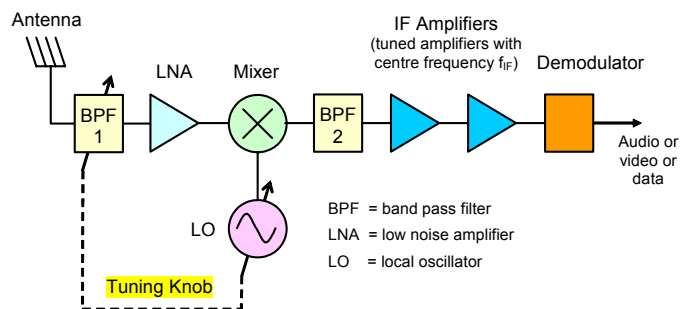
Prior to the superhet ...



- 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.

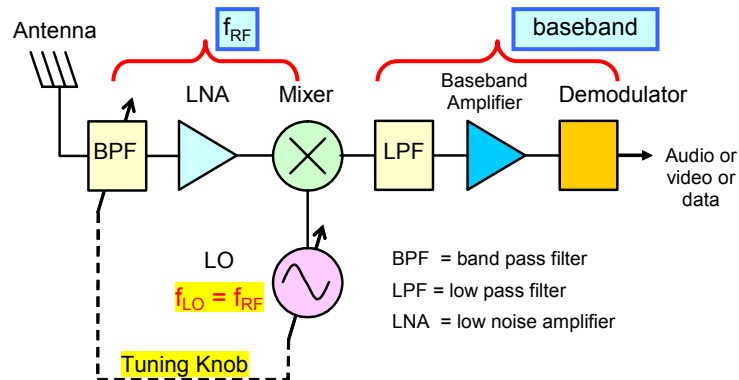
## Superheterodyne Receiver

The next stage of evolution ...



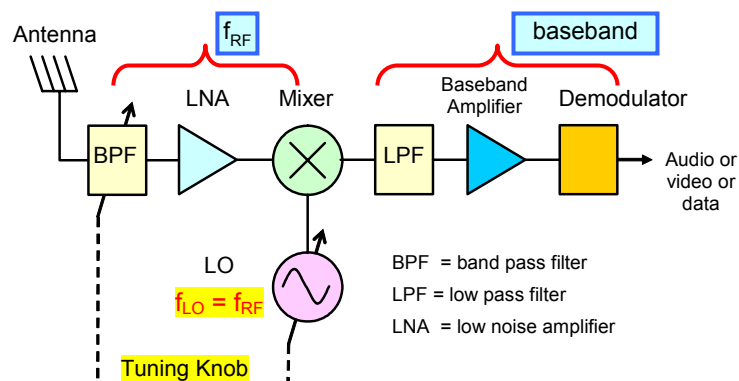
- Eliminated the need for aligned tunable BPFs.
- Filters within IF Amplifier need to be aligned – but they are fixed.

## 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

### Cellular CDMA single-band chipset

The Philips two-chip solution for Cellular CDMA uses a Zero-IF architecture to take advantage of Direct Conversion technology. Designed for single-band CDMA2000 1X and TDD applications, this compact chipset delivers superior performance, reduces the number of external passive components, shrinks board size, and lowers overall cost.



**Compact Zero-IF solution for CDMA2000 1x**

The Philips Cellular CDMA single-band chipset, composed of the SPS22 Direct Conversion Receiver and the SPS21 Direct Conversion Transmitter, is a highly integrated and cost-effective solution for CDMA2000 applications. Featuring the SPS22 Direct Conversion Receiver and SPS21 Direct Conversion Transmitter, the chipset provides superior performance in the Cellular CDMA 2000 1x frequency band. The chipset requires fewer than 30 external components and offers a low BOM cost.

To save time and resources, the chipset is available in a reference design supported by RF. This design consists of an RF front end module, an antenna, a duplexer, a power amplifier, a coupler, a balun, and a power divider. The implementation of the reference design, the SPS22 Direct Conversion Receiver, is a compact Zero-IF architecture that offers a low BOM cost and a high level of integration. The chipset is available in a compact package of 30 pins and an LGA package of 30 pins.

**Compact two-chip solution**

- Zero-IF architecture for improved performance, reduced board size, lower BOM cost
- Low power supply voltage (2.8 to 3.3V) for low power operation
- Fast start-up time
- Advanced QPSK/BPSK/FSK modulation
- Full-rate CDMA2000 1x and TDD applications

**SPS22 Direct Conversion Receiver**

- Integrated Cellular CDMA single-band receiver, digital gain control, and automatic gain control (AGC) for variable gain
- Full-rate CDMA2000 1x and TDD applications
- Low power consumption
- Full-rate CDMA2000 1x and TDD applications


**SPS21 Direct Conversion Transmitter**

- Integrated Cellular CDMA single-band transmitter, digital gain control, and automatic gain control (AGC) for variable gain
- Full-rate CDMA2000 1x and TDD applications
- Low power consumption
- Full-rate CDMA2000 1x and TDD applications

**PHILIPS**

### Cellular CDMA single-band chipset

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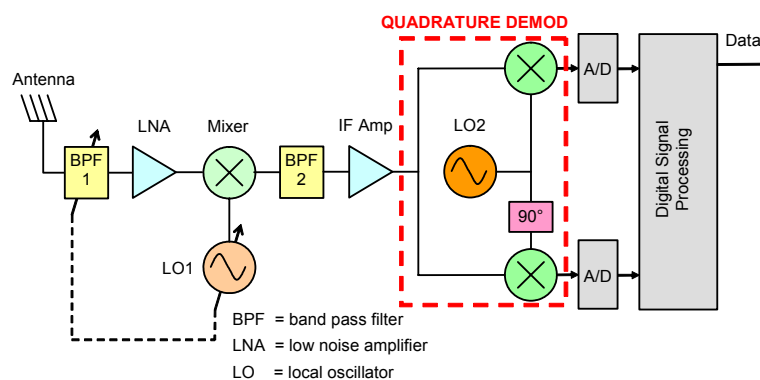
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**PHILIPS**

## 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