Receivers: Translates RF signals to baseband.

* Because of the interference and noise, it is not easy to recover the message.
* Hence, the receiver must be able to handle a very wide range of signal powers.
* occasionally, noise and interference can be much stronger than the desired signal.
* Noise sets the threshold for minimum detectable signal power.
* While Distortion sets the maximum signal power level.

Power	$-174\,dB_m$	$-130\,dB_m$	$-80\,dB_m$	$+10\,dB_m$
	4×10^{-12} W	10^{-16} W	10^{-11} W	10^{-2} W
Volts (rms) in 50Ω	0.6 nV	0.1 μV	32 μV	1 V
	Thermal noise of resistor in 1 Hz bandwidth	minimum detectable signal for good communication receiver in 3 KHz bandwidth	minimum detectable signal for cell phones	strong Local signal at input of the receiver

* To detect a transmitted signal, i.e., to achieve conversion from RF (station frequency-called RF frequency) to baseband frequency, two main methods are available:

(1) Direct conversion (2) superheterodyne method.

⇒ A sensitive and selective receiver can be made using only amplifiers, selective filters, and a demodulator.

⇒ This is called Tuned Radio Frequency (TRF) receiver.

* Early Radios used TRF receivers.

⇛ However: such a receiver does not usually deliver the kind of performance expected in modern communications applications.

* One type of receiver that can provide that performance is the superheterodyne receiver.

* Superheterodyne receivers convert all incoming signals to a Lower frequency, known as the intermediate frequency (IF),

* at which a single set of amplifiers and filters is used to provide a fixed Level of sensitivity and Selectivity.

* The Key circuit is the mixer, which produces sum and difference frequencies.

* The incoming signal to the antenna will pass through RF amplifier then to the mixer.

* The mixer will mix the incoming signal with a Local oscillator to produce either sum or difference frequencies.

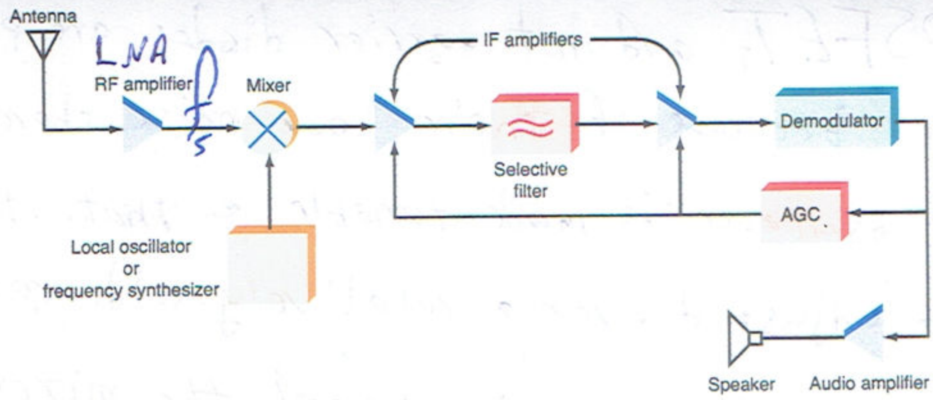


Figure 9-5 Block diagram of a superheterodyne receiver.

RF Amplifiers:

+ The antenna picks up the weak signal and feeds it to the RF amplifier, Also called Low Noise Amplifier (LNA).
+ RF-Amplifier (LNA) provides gain and selectivity, therefore, LNA is also called preselector.

Mixers and Local Oscillators:

* The output of the RF-Amplifier is applied to the input of the mixer.
* The mixer also receives an input from a Local oscillator or frequency synthesizer.
* Usually a tuned circuit at the output of the mixer selects the difference frequency, or it is called intermediate frequency (IF).
* The sum frequency may also be selected as the IF in some applications.
* The mixer maybe a diode, a balanced modulator, or a transistor.

* MOSFETs and hot carrier diodes are preferred as mixers because of their Low-noise characteristics.

* Local oscillator is made tunable so that its frequency can be adjusted over a relatively wide range.

* As the LO frequency is changed, the mixer translates a wide range of input frequencies to the fixed IF.

IF Amplifiers :- The output of the mixer is amplified by one or more IF amplifier stages.

* Most of the receiver gain is obtained in these stages.
* since The IF is usually much Lower than the input signal frequency, IF amplifiers are easier to design and good selectivity is easier to obtain.

* Crystal, ceramic filters are used in most IF sections to obtain good selectivity.

* Some forms of receivers use DSP filters for Selectivity.

Demodulators :- Demodulator or detector.

* Diode detector for AM, quadrature detector for FM, or product detector for SSB.
* The output from demodulator is usually fed to audio amplifier.
* For non-voice signals, the output sent to a TV, tablet, Cell Phone screen, Computer, or some other devices.

Automatic Gain Control :- (AGC)

* The output of the demodulator is usually the original modulating signal.
* The amplitude of the modulating signal is proportional to the amplitude of the received signal.
* The recovered signal, which is usually ac, is rectified and filtered into a dc voltage by a circuit known as the AGC.
* AGC helps maintain a constant output voltage level over a wide range of RF input signal levels.
* AGC also helps the receiver to function over a wide range so that strong signals do not produce performance-degrading distortion.
* The amplitude of the RF signal at the antenna of a receiver can range from uvolts to thousands of microvolts;
* This wide signal range is known as the dynamic range.
* However, applying a very high-amplitude signal to a receiver causes the circuits to be overdriven, producing distortion and reducing intelligibility.

* with AGC, the overall gain of the receiver is automatically adjusted depending on the input signal level.

* The signal amplitude at the output of the detector is proportional to the amplitude of the input signal:

→ if it is very high: the AGC produces a high dc output voltage, thereby reducing the gain of the IF amplifiers.

∴ → This reduction in gain eliminates the distortion produced by a high-voltage input signal.

→ when the incoming signal is weak: The detector output is low.

∴ → The output of the AGC is then a small dc voltage. This causes the gain of the IF amplifiers to remain high, providing maximum amplification.

Frequency Conversion:

frequency conversion is the process of translating a modulated signal to a higher or Lower frequency while retaining all the originally transmitted information.

* In radio receivers, high-frequency radio signals are regularly converted to a lower; intermediate frequency, where improved gain and selectivity can be obtained.

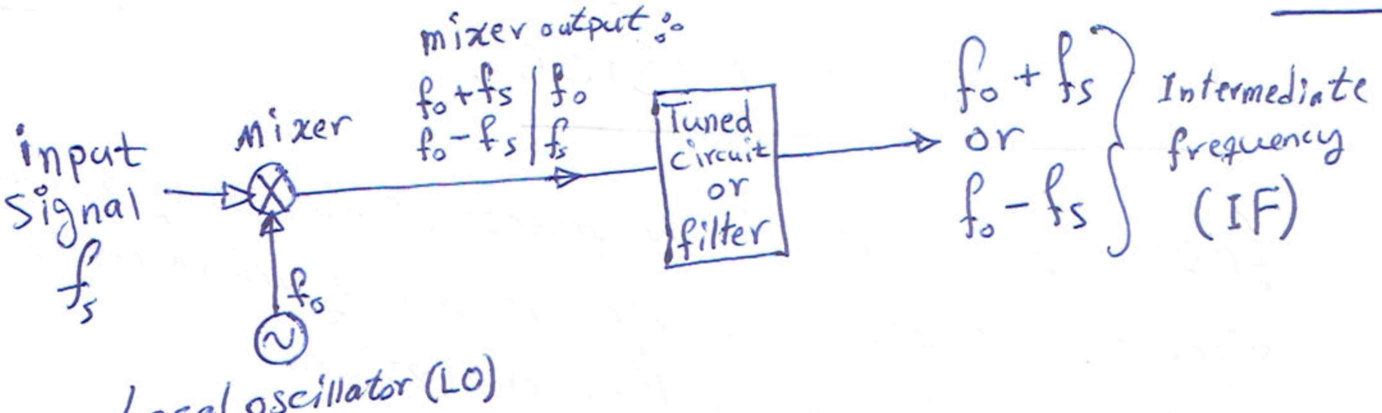
{This is called Down Conversion}

* In Satellite communications, the original signal is generated at a Lower frequency and then converted to a higher frequency for transmission.

{This is called UP Conversion}

Mixing Principles:

* Frequency conversion is a form of amplitude modulation or analog multiplication carried out by a mixer circuit or converter.
* The function performed by the mixer is called heterodyning.



* The output of the mixer, therefore consists of signals : f_o , f_s , f_o+f_s , and f_o-f_s or f_s-f_o.

* The tuned circuit filters out : f_o, f_s.
* Only the sum or the difference frequency in the output is the desired signal.

EX.1 For an FM radio receiver to translate an FM signal at 107.1 MHz to an intermediate frequency of 10.7MHz for amplification and detection,

→ Local oscillator frequency $f_o = 96.4$ MHz is used

→ The mixer output signals are :-

$f_s = 107.1$ MHz,

$f_o = 96.4$ MHz,

$f_o + f_s = 96.4 + 107.1 = 203.5$ MHz,

$f_s - f_o = 107.1 - 96.4 = 10.7$ MHz.

→ The filter designed to selects the 10.7 MHz (the IF) and rejects the others.

EX. 2 Suppose a Local oscillator frequency is needed that will produce an IF (f_{IF}) of 70 MHz for a signal frequency of 880 MHz.

→ since the IF frequency (f_{IF}) is the difference between the input signal and Local oscillator frequencies, there are two possibilities:

$$f_o = f_s + f_{IF} = 880 + 70 = 950 \text{ MHz}$$

$$f_o = f_s - f_{IF} = 880 - 70 = 810 \text{ MHz}$$

---

* There are many mixer circuits:

i - Diode Mixer,
ii - Doubly Balanced mixer,
iii - FET Mixers,
iv - IC Mixers, and
v - Image Reject mixers

IF-Frequency & Image Problem:

* The choice of f_{IF} is usually a design compromise.
* f_{IF} is made as high as possible for effective elimination of the image problem.
* Yet Low enough to prevent design problems.

For instance:

1. AM Broadcast stations: $f_{IF} = 455$ KHz,
2. FM Radios (88-108 MHz): $f_{IF} = 10.7$ MHz,
3. TV Receivers: $f_{IF} = 40$- to 50- MHz,
4. Radar Receivers: $f_{IF} = 60$ MHz, and
5. Satellite Communications: $f_{IF} = 70$- and 140- MHz.

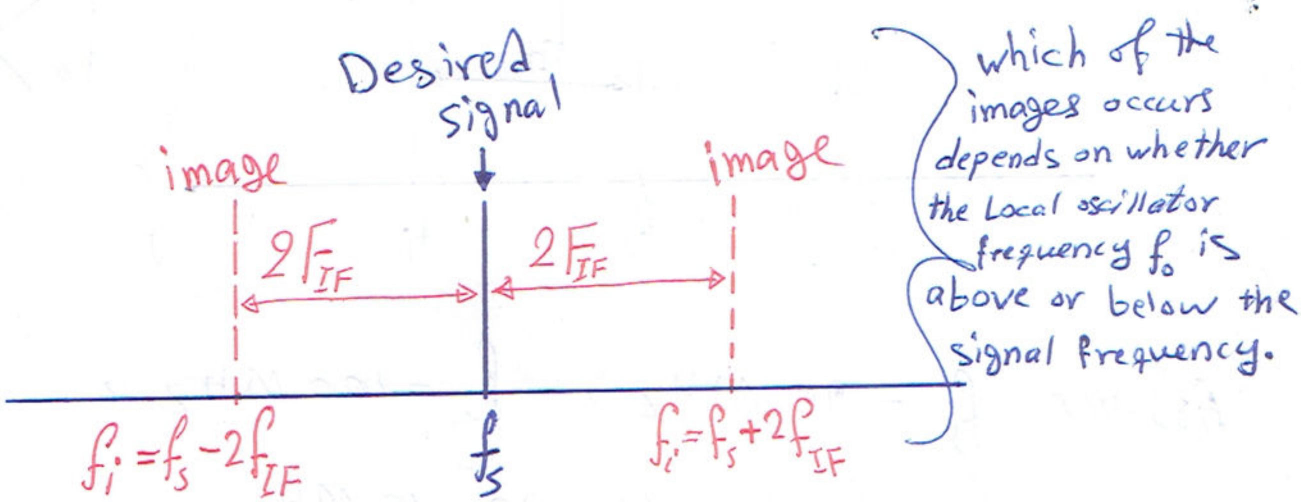
* The primary objective is to obtain good selectivity.
* Narrowband selectivity is best obtained at lower frequencies.
* At low frequencies, the circuits are far more stable with high gain.

But, But, But !!!

* However, when Low IFs are selected, a different sort of problem is faced, particularly if the signal to be received is very high in frequency.

⇒ This is the problem of images.

* An Image is a potentially interfering RF signal that is spaced from the desired incoming signal by a frequency that is two times the IF frequency above or below the incoming frequency,



Hence $\boxed{f_i = f_s + 2f_{IF}}$ and $\boxed{f_i = f_s - 2f_{IF}}$

where:

f_i = image frequency,

f_s = desired signal frequency (station frequency),

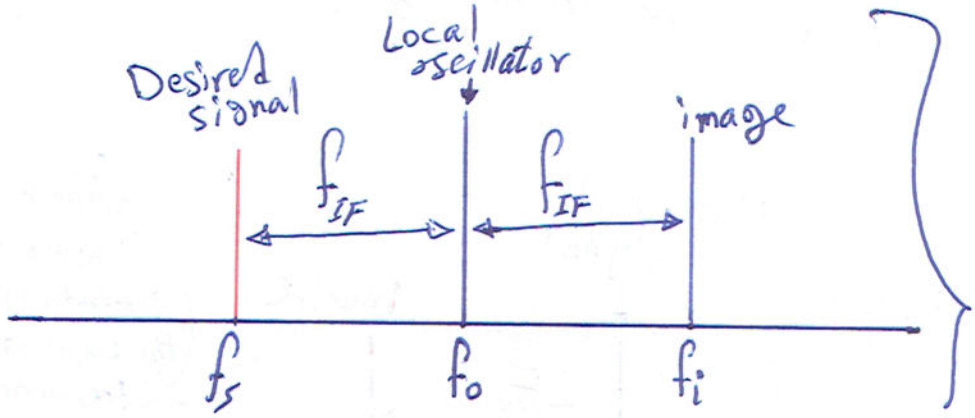
f_{IF} = intermediate frequency.

⟹ Note that the frequency of the Local oscillator is usually chosen to be higher in frequency than the incoming signal by the IF.

$$f_o > f_s$$

⟹ Local oscillator may also be $f_o < f_s$!!!

* either cases, the result is the difference frequency



case when: $f_o > f_s$

Assume $f_s = 90$ MHz, $f_o = 100$ MHz,

$$f_{IF} = f_o - f_s = 100 - 90 = 10 \text{ MHz}$$

$$f_i = f_s + 2f_{IF} = 90 + 2(10) = 110 \text{ MHz}$$

* To solve the image problem, a high quality filter must be used before the mixer's input.

* Dual Conversion Receiver :

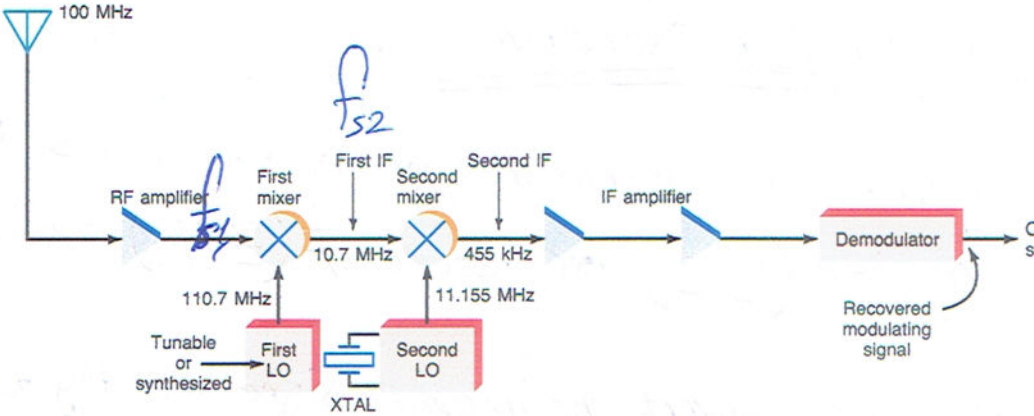


Figure 9-18 A dual-conversion superheterodyne.

GOOD TO KNOW

For a dual-conversion superheterodyne, if you have an input value f_s and the two local oscillator values f_{LO_1} and f_{LO_2}, you can determine what the two intermediate frequencies (IFs) are. First, determine the difference between the input and the first local oscillator: $f_s - f_{LO_1} = IF_1$. Now the IF_1 value is the input for the second mixer. To determine the second intermediate frequency, find the difference between the first intermediate frequency and the second local oscillator: $IF_1 - f_{LO_2} = IF_2$.

* It is another way to obtain selectivity while eliminating the image problem.
* Most shortwave receiven (SW) uses dual conversion.
* Many at VHF, UHF and microwave uses dual conversion.
* Triple conversion is also avilable practically.

EX. A superheterodyne receiver must cover the range from 220 MHz to 224 MHz. The first IF is 10.7 MHz; the second is 1.5 MHz. Find : ⓐ The local oscillator tuning range, ⓑ the frequency of the second local oscillator, and ⓒ The first IF image frequency range. (Assume a local oscillator frequency higher than the input by the IF.)

Solution

a) $220 + 10.7 = 230.7$ MHz , $224 + 10.7 = 234.7$ MHz

The tuning range is 230.7 to 234.7 MHz.

b) The second local oscillator frequency is 1.5 MHz higher than the first IF.

$10.7 + 1.5 = 12.2$ MHz

c) The first IF image range is 214.4 to 245.4 MHz.

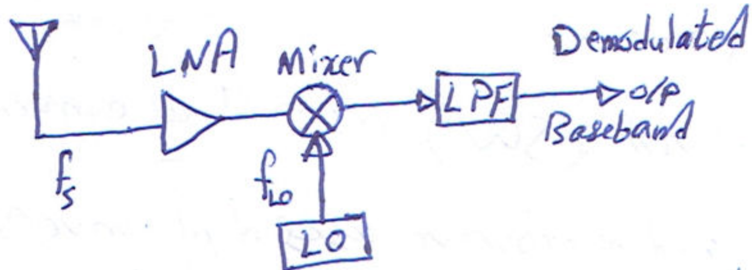
$230.7 + 10.7 = 241.4$ MHz

$234.7 + 10.7 = 245.4$ MHz

Direct Conversion Receivers

* A special version of the superheterodyne is known as the Direct conversion (DC) or Zero IF (ZIF) receiver.

* DC or ZIF receivers convert the incoming signal directly to baseband.



* The LO usually from PLL, hence $\boxed{f_s = f_{LO}}$,

* The sum and difference frequencies as a result of mixing are:

$f_{LO} - f_s = 0$ } mixer is doing demodulation as well.

$f_{LO} + f_s = 2f_{LO} = 2f_s$ } filtered out by the LPF

EX: Assume a carrier of 21 MHz, a voice modulation from 300 to 3000 Hz and AM.

→ The sidebands extend from 20,997,000 Hz to 21,003,000 Hz.

→ At the receivers the LO is set to 21 MHz. The mixer produces

21,000,000 − 20,997,000 = 3000 Hz } passed
21,003,000 − 21,000,000 = 3000 Hz }
21,000,000 + 21,003,000 = 42,003,000 Hz } filtered out
21,000,000 + 20,997,000 = 41,997,000 Hz }

* DC or ZIF receivers can be used with CW, AM, SSB, or DSB formats.

Quiz
* DC or ZIF receivers cannot recognize phase or frequency variations.

* To use DC or ZIF receivers with FM, FSK, PM, or PSK, or any other form of digital modulation, two mixers are required along with a quadrature LO arrangement.

* Such designs are used in most cell phones and other wireless receivers.

EX.1 A radio receiver used in AM system is shown below. The mixer translates the carrier frequency f_c to a fixed IF of 455 KHz by LO. The broadcast-band frequencies ranging from 540 KHz to 1600 KHz. a) Determine the range of tuning that must be provided in the Local oscillator i) when $F_{LO} > f_c$ and ii) when $F_{LO} < f_c$.
b) Based on the results of ⓐ, explain why the usual AM radio receiver uses a superheterodyne system.

Solution

a) when $f_{LO} > f_c$ Note:- f_c also called f_s (station)

tuning range of LO is 995 KHz — 2055 KHz.

when $F_{LO} < f_c$, tuning range of LO is

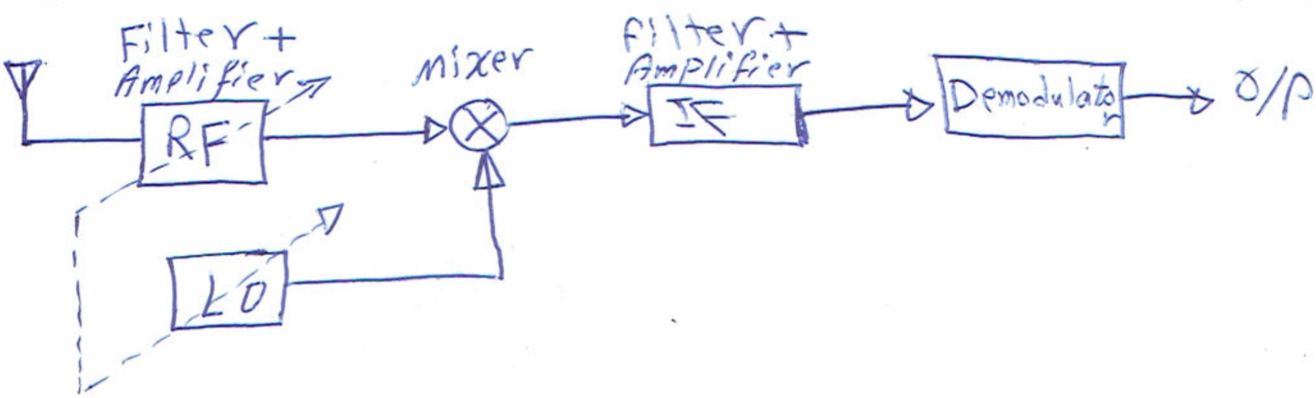
85 KHz − 1145 KHz.

b) The frequency Ratio of highest-to-Lowest LO is

i) $FR_{LO} = \frac{2055}{995} \simeq 2$ (when $F_{LO} > f_c$)

ii) $FR_{LO} = \frac{1145}{85} \simeq 13.5$ (when $F_{LO} < f_c$)

Hence, the first ratio $FR_{LO} \simeq 2$ can be easily designed and implemented practically.



EX.2 Consider an incoming signal carried on 850 KHz's from AM-Broadcasting station, where F_{IF} is 455 KHz. Calculate the Local oscillator frequency and the image frequency. Assume up-side injection.

Solution.

$f_c = 850$ KHz.

$F_{IF} = 455$ KHz.

$F_{LO} = F_c + F_{IF} = 850$ KHz $+ 455$ KHz

$F_{LO} = 1305$ KHz.

$F_{IM} = F_{LO} + F_{IF} = F_c + 2F_{IF}$

$= 1305 + 455 = 1760$ KHz.

EX.3 If you wish to listen to a station at the lower end of the dial, in other words $f_c = 540\,KHz$. Assume the upper conversion, what will be the Local oscillator frequency and the image frequency?

solution. $f_c = 540\ KHz$. $F_{IF} = 455\ KHz$.

upside conversion or injection: $F_{LO} = f_c + F_{IF} = 540 + 455$

$\therefore F_{LO} = 995\,KHz$.

$F_{IM} = f_c + 2F_{IF} = 540 + 2 \times 455 = 1450\ KHz$ [inside the AM-Broadcast range]

EX.4: If you wish to listen to the mirror of the image signal which is $F_{IM} = 1510\,KHz$ of an AM Broadcasting. What is your desired station's frequency? Assuming upperside conversion.

solution. $F_{IF} = 455\ KHz$ (AM-Broadcast)

$F_{IM} = 1510\,KHz$

$F_{IM} = F_{Station} + 2F_{IF}$

$1510 = F_{Station} + 2 \times 455 = F_{Station} + 910$

$\therefore F_{Station} = 600\ KHz$.

EX.5 In order to convert 870 KHz carrier down to 455 KHz IF-frequency, what will be the local oscillator frequency F_{LO} in ① Low side injection, and ② high side injection?

Solution $F_{IF} = 455$ KHz, $F_c = 870$ KHz.

① Low side injection

$$F_{LO} = F_c - F_{IF} = 870\text{ KHz} - 455 = 415\text{ KHz}.$$

② High side injection

$$F_{LO} = F_c + F_{IF} = 870 + 455 = 1325\text{ KHz}.$$

EX. 6 A given radar receiver operating at a frequency of 2.8 GHz and it uses the superheterodyne principle. It has a LO frequency of 2.86 GHz. A second radar receiver operates at the image frequency of the first and interference results.

a) Determine the intermediate frequency of the first radar receiver.

b) What is the carrier frequency of the second receiver?

c) If you were to re-design the radar receiver, what is the minimum intermediate frequency you would chose to prevent image frequency problem in the 2.8 − 3 GHz radar band?

Solution

a) $F_{IF} = F_{LO} - F_c = 2.86 - 2.8 = 0.06\ GHz = 60\ MHz.$

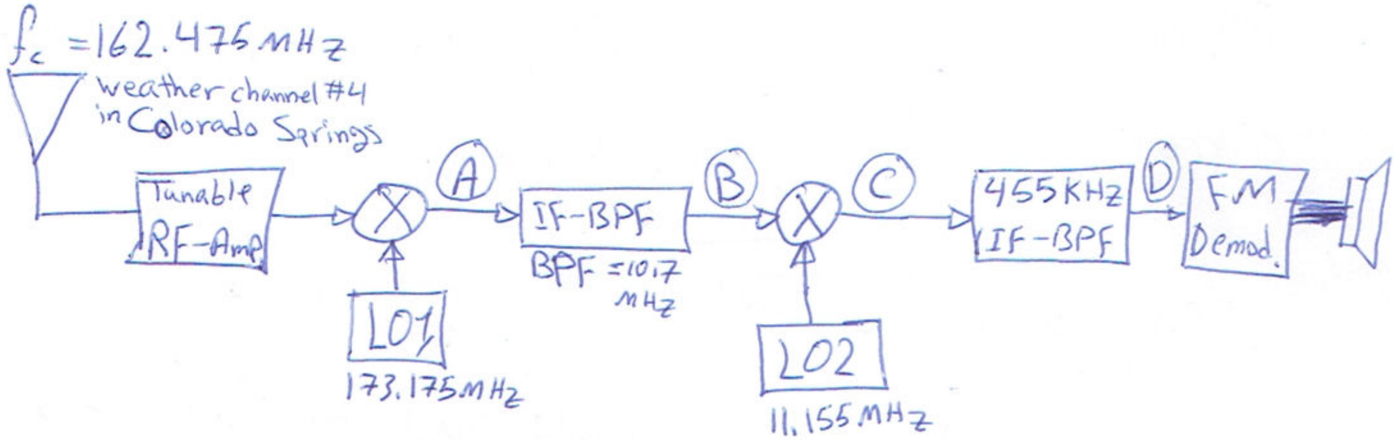
b) $F_{im} = F_c + 2F_{IF} = 2.8 + 2(0.06) = 2.92\ GHz.$

c) $2F_{IF} \geq (f_{max} - f_{min}) = 3 - 2.8 = 0.2\ GHz$

$\therefore\ 2F_{IF} \geq 200\ MHz$

Hence $F_{IF} \geq 100\ MHz$

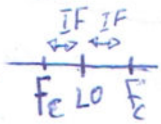
EX.7 What are the frequencies at points A, B, C, and point D using all cases of conversion (injection)?



Solution

At point (A)

In the above case, the carrier frequency is lower than the LO frequency.



$F_{LO} = F_{IF} \mp F_c$

① $F_{LO} = F_{IF} - F_c \Rightarrow F_{IF} = F_{LO} + F_c = 335.65$ MHz

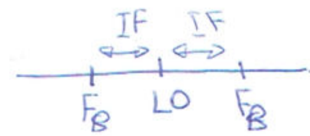
② $F_{LO} = F_c - F_{IF} \Rightarrow F_{IF} = F_{LO} - F_c = 10.7$ MHz

At point (B)

Because of BPF = 10.7 MHz

$\therefore F_B = 10.7$ MHz.

✱ At point (C)



$F_{LO} = F_{IF} \mp F_c$

① $F_{LO} = F_{IF} - F_c$

$F_B = F_c \Rightarrow F_{LO} = F_{IF} - F_B$

$\therefore F_{IF} = F_{LO} + F_B = 11.155 + 10.7 = 21.855$ MHz

② $F_{LO} = F_B - F_{IF}$

$\therefore F_{IF} = F_{LO} - F_B = 11.155 - 10.7$

$F_{IF} = 0.455$ MHz $= 455$ KHz

✱ At point (D)

Because of BPF = 455 KHz

$\therefore F_D = 455$ KHz.

Image Rejection Ratio

Image Rejection Ratio (IRR) is dependent on the circuitry of the tuned circuit.

$$IRR = \alpha = \sqrt{1+Q^2\rho^2}$$

where Q is the tuned circuit quality factor, ρ can be calculated from

$$\rho = \frac{F_{IM}}{F_c} - \frac{F_c}{F_{IM}}$$

Some references uses f_{si} for F_{IM}

* In the receiver, there is an RF-stage which has a tuned circuit.
* Further, in the mixer, there is another tuned circuit which also can reject image frequency.
* The overall IRR α is the product of both:-

$$\alpha_{total} = \alpha_{RF} \cdot \alpha_{MIXER}$$

EX.1 A superheterodyne receiver having no RF amplifier, the Q of the antenna coupling circuit (at the input of the mixer) is 90.

Calculate :-

1. F_{IM} & IRR (α) at $f_c = 950$ KHz.
2. F_{IM} & IRR(α) at $F_c = 10$ MHz.
3. what do you conclude?

solution ① $Q = 90$, $F_{IF} = 455$ KHz, $F_c = 950$ KHz.

$$F_{im} = F_c + 2F_{IF} = 950 + 2 \times 455 = 1860 \text{ KHz}.$$

$$\rho = \frac{F_{im}}{F_c} - \frac{F_c}{f_{im}} = \frac{1860}{950} - \frac{950}{1860} \simeq 1.447.$$

$$\alpha = \sqrt{1 + 90^2 (1.447)^2} \simeq 130.247.$$

② $Q = 90$, $F_{IF} = 455$ KHz $= 0.455$ MHz, $F_c = 10$ MHz.

$$F_{im} = F_c + 2F_{IF} = 10 + 2 \times 0.455 = 10.91 \text{ MHz}.$$

$$\rho = \frac{F_{im}}{f_c} - \frac{f_c}{f_{im}} = \frac{10.91}{10} - \frac{10}{10.91} = 1.091 - 0.91659 \simeq 0.1744.$$

$$\alpha = \sqrt{1 + 90^2 (0.1744)^2} \simeq 15.729.$$

③ We conclude that at low frequencies, IRR or the image can be rejected better than at high frequencies.

EX. 2 For a broadcast superheterodyne AM receiver having no RF amplifier, the Loaded Quality factor Q of the antenna coupling circuit is 100. Having $F_{IF} = 455$ KHz, find:

① the F_{IM} and its rejection ratio at a carrier of $f_c = 1000$ KHz.

② the F_{IM} and its rejection ratio at a carrier of $f_c = 25$ MHz.

solution we have given $Q = 100$, $f_{if} = 455$ KHz, $f_c = 1000$ KHz.

①

$$F_{im} = f_c + 2 f_{if} = 1000 + 2 \times 455 = 1910 \text{ KHz}.$$

$$\rho = \frac{F_{im}}{f_c} - \frac{f_c}{f_{im}} = \frac{1910}{1000} - \frac{1000}{1910} \cong 1.386$$

For single tuned circuit $\alpha = \sqrt{1 + (Q\rho)^2} = \sqrt{1 + (100 \times 1.386)^2} = 138.6$

② $F_c = 25$ MHz.

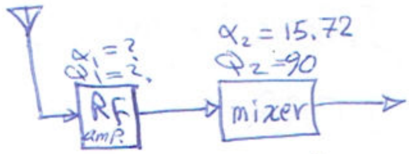
$$f_{im} = f_c + 2 f_{iF} = 25 + 2 \times 0.455 = 25.91 \text{ MHz}.$$

$$\rho = \frac{f_{im}}{f_c} - \frac{f_c}{f_{im}} \cong 0.0715$$

$$\therefore \quad \alpha = \sqrt{1 + Q^2 \rho^2} = \sqrt{1 + (7.15)^2} = 5.22.$$

Hence, IRR is better at low frequencies i.e., the image Frequency can be rejected better at low frequencies.

EX.3 In order to make the Image frequency rejection of the receiver, which is superheterodyne AM receiver, good at high frequency, say, $f_c = 10\ MHz$, see Figure below, we need to add an RF amplifier with BPF. Calculate:



① The Quality factor of the RF-amplifier.

② If the RF-amplifier removed, what is the f_{IF}? where $\rho = 1.45$.

| $\alpha_t = \alpha_1 \alpha_2 = 130.5$ |

Solution ① $\alpha_t = 130.5$, $f_c = 10\ MHz$ $\qquad f_{IF} \leftarrow$ هذا السؤال به نقص

$\alpha_t = \alpha_1 \alpha_2 = \alpha_1 \cdot 15.72 = 130.5 \Rightarrow \alpha_1 = 8.3$, $f_{im} = 10 + 0.91 = 10.91\ MHz$

$$\alpha_1 = \sqrt{1 + Q_1^2 \rho_1^2} \Big\} \ \rho_1 = \frac{f_{im}}{f_c} - \frac{f_c}{f_{im}} = \frac{10.91}{10} - \frac{10}{10.91} = 0.1744.$$

$$8.3^2 = 1 + Q_1^2 (0.1744)^2$$

$$67.89 = Q_1^2 (0.030418) \Rightarrow Q_1^2 = 2231.842 \Rightarrow \boxed{Q_1 = 47.24}$$

② Given $\rho = 1.45$, $f_c = 10\ MHz$

$$\rho = \frac{f_{im}}{f_c} - \frac{f_c}{f_{im}} \Rightarrow 1.45 = \frac{f_{im}}{10 MHz} - \frac{10 MHz}{f_{im}} = \frac{f_{im}^2 - 100 * 10^{12}}{10 * 10^6 f_{im}}$$

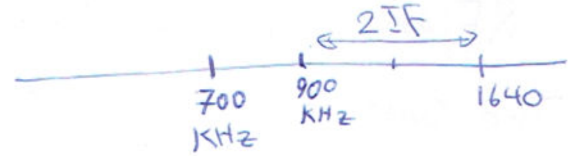
thus $f_{im} = 19.578\ MHz$.

$$f_{im} = f_c + 2 f_{IF} = 10\ MHz + 2 f_{IF} = 19.578\ MHz$$

$$2 f_{IF} = 9.578\ MHz \Rightarrow \boxed{f_{IF} = 4.789\ MHz}$$

EX.4 For a receiver with IF and RF frequencies of 455 KHz and 900 KHz respectively, determine the following:

1. The Local oscillator frequency.
2. Image frequency,
3. IFRR for a pre-selector Q of 80.



Solution

① $F_{LO} = F_c + F_{IF} = 900 + 455 = 1355 \text{ KHz}$

② $F_{Im} = F_c + 2F_{IF} = 900 + 910 = 1810 \text{ KHz}$

③ IFRR :- Q = 80.

$$\rho = \frac{f_{im}}{f_c} - \frac{f_c}{f_{im}} = \frac{1810}{900} - \frac{900}{1810} \simeq 1.514$$

$$\alpha = \sqrt{1 + 6400(1.514)^2} = 121.114$$

Ex.5 In a broadcast superheterodyne AM receiver having no RF section. The Loaded Q factor of the serial coupling circuit (at the input of the mixer) is 125. If the intermediate frequency is 465 kHz. Calculate:

1. The image frequency and its rejection ratio at 1 MHz and 30 MHz.
2. The IF-frequency required to make the image rejection ratio as good at 30 MHz as it is at 1 MHz.

Solution Given: $Q = 125$, $F_{IF} = 465\ kHz$, $F_{c1} = 1\ MHz$, $F_{c2} = 30\ MHz$.

① consider $F_{c1} = 1\ MHz$:-

$$f_{im} = f_c + 2 f_{IF} = 1000 + 2 \times 465 = 1930\ KHz$$

$$\rho = \frac{f_{im}}{f_c} - \frac{f_c}{f_{im}} = \frac{1930}{1000} - \frac{1000}{1930} = 1.93 - 0.518 = 1.4119.$$

$$\alpha = \sqrt{1 + (125 \times 1.4119)^2} \cong 176.486. \text{ Better}$$

consider $f_{c2} = 30\ MHz$. $F_{im} = 30\ MHz + 2 \times 465\ kHz = 30 + 0.93 = 30.93\ MHz$.

$$\rho = \frac{30.93}{30} - \frac{30}{30.93} \cong 0.0611$$

$$\alpha = \sqrt{1 + (125 \times 0.0611)^2} \cong 7.699$$

② It is needed IRR $\alpha_n = 176.486$ @ $f_c = 30\ MHz$.

$$\rho = 1.4119 = \frac{f_{im}}{f_c} - \frac{f_c}{f_{im}} = \frac{f_{im}}{30\,MHz} - \frac{30\,MHz}{f_{im}}$$

$$f_{im} = 57\ MHz$$

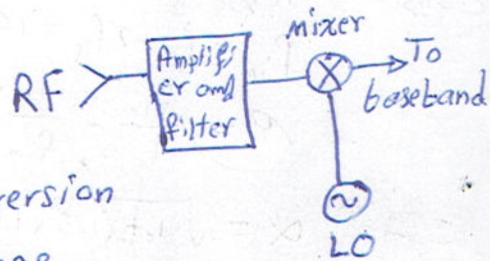
$$f_{im} = f_c + 2 f_{IF} \Rightarrow 57 = 30 + 2 f_{IF}$$

$$\therefore F_{IF} = 13.5\ MHz$$

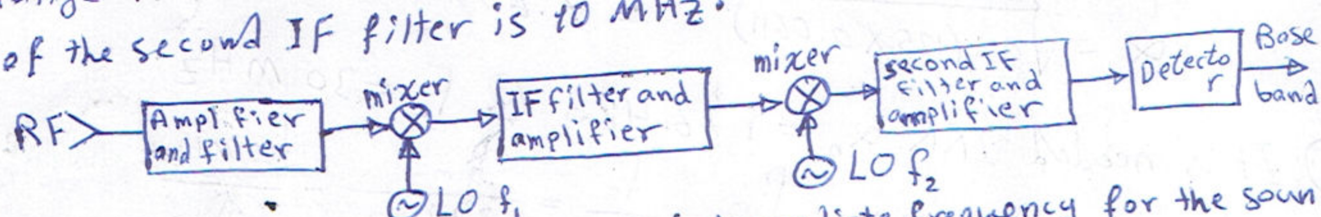
P.1 A receiver is to be designed to cover the frequencies of 20 to 40 MHz using an IF filter centered at 10 MHz. Specify two different Local oscillator frequencies for each input frequency, and determine the corresponding image frequency for each input frequency.

P.2 Select the Local oscillator frequencies and specify the preselector frequency response for an up-converter receiver covering the 2 – 30 MHz frequency range. The center frequency of the IF filter is 50 MHz.

P.3 The Figure shown aside illusterates a direct conversion receiver in which the input signal is converted directly to an audio signal. specify the Local oscillator frequencies and the corresponding image frequencies for a direct conversion receiver covering the 2-to-30 MHz range.



P.4 The double-conversion receiver shown below employs two IF filters. Specify the LO frequencies (f_1 & f_2) for a receiver covering the 2–30 MHz range. The center frequency of the first IF filter is 50 MHz, and that of the second IF filter is 10 MHz.



P.5 NTSC television uses a 41.25 MHz intermediate frequency for the sound carrier and 45.75 MHz for the picture carrier. The Local oscillator operates at 45.75 MHz above the desired incoming picture frequency. The VHF band has channels 2 to 6 covering 54 to 88 MHz and channels 7 to 13 covering 174 to 216 MHz. Determine the local oscillator frequency and image frequency for each VHF channel. The bandwidth of each channel is 6 MHz.