LECTURE # 22

Main Merits & Demerits of Superhetrodyne Rx.

Superhetrodyne Merits:

(i) Main merit of Superhetrodyne Rx is when compared to its pre-decessor i.e TRF-Rx which used only an RF section and not a mixer. There is no concept of fixed tuned IF section in TRF-Rxs. That is why their RF sections suffer from varying capability of Selectivity, Bandwidth and Sensitivity as Stations are tuned from one received carrier (f_{si}) to another received carrier over $f_{s_{min}}$ to $f_{s_{max}}$. It is for this reason that if at all TRF-Rx is used, it will not have a front end RF variably tuning section. On the contrary it will have a pre-defined fixed front end RF tuned section which is that carrier at which (f_s) Q curve is high and sharp with narrow BW.

(ii) Superhetrodyne offers much better stability than TRF-Rx. In the early TRF-Rx, these utilized a tuneable filter at front end whereas a superhetrodyne utilizes a tuneable Oscillator. A tuneable oscillator is more easily stabilized than a tuneable filter.

(iii) In a Superhetrodyne only the sections before mixer need to be adjusted while all sections/stages after mixer are fixed tuned to IF offering best possible Q curve. These stages do not need any adjustment. e.g After mixer IF amplifiers design, Demodulators, Audio & Power Amplifiers are all designed to perform their best around a pre-defined IF value of frequency.

Superhetrodyne Rx Demerits:-

Three main issues surface in case of Superhetrodyne Rxs namely.

(i) Insufficient Image Rejection
(ii) Double Spotting
(iii) Spurious Response.

(i) Insufficient Image Rejection Issue of Superhetrodyne Rx

A superhetrodyne Rx is said to suffer from the issue of Insufficient Image rejection if for a particular tuned position, two different stations are picked up by Rx and demodulated along with the particular desired station. In other words the tuning position is one but stations received are two - Desired as well as an unwanted station.

Let $f_s \rightarrow$ desired station.
Let $f_{LO} > f_s$ in case of down conversion.

$$\therefore \boxed{I_F = f_{LO} - f_s} \quad (1)$$

This equation (1) is the normal expected operation of a superhetrodyne Rx.

From (1) we may also write

$$\boxed{f_{LO} = I_F + f_s} \quad (2)$$

Let there be another station which is undesired designated as f_{ud} (undesired) but is covered by front end of Q curve so manages to enter the mixer. It is possible that f_{ud} is such a value so that

$$I_F = f_{ud} - f_{LO} \quad (3)$$

The above equations clearly implies that the subsequent IF fixed tuned section will not only process and detect f_s, but these stages will process and detect f_{ud} as well. At output of Rx we shall be now receiving two signals overlapped and detected — f_s (wanted) & f_{ud} (undesired) also called Image frequency.

To find f_{ud} equate (1) and (3) to eliminate IF.

$$I_F = f_{LO} - f_s = f_{ud} - f_{LO}.$$

$$\therefore \quad f_{ud} + f_s = 2f_{LO}.$$

$$\text{or} \quad f_{ud} = 2f_{LO} - f_s \quad (4)$$

Equation (4) gives f_{ud} in terms of f_{LO} & f_s.

Again we may solve equation (2) and (3) so that after substituting f_{LO} from (2) in (3) we get (ie eliminating f_{LO})

$$I_F = f_{ud} - (I_F + f_s).$$

$$\text{or} \quad f_{ud} = 2I_F + f_s \quad (5)$$

Equation (5) gives f_{ud} in terms of I_F and f_s.

Q.13

Q.(a) Let the desired $f_s = 535$ kHz when pre-defined $I_F = 455$ kHz. In case of down conversion where $f_{LO} > f_s$, use these values to calculate f_{ud} image freq.

(b) Also draw the corresponding Mixer section / block diag with all the possible inputs & o/ps at various stages of Rx

Solution

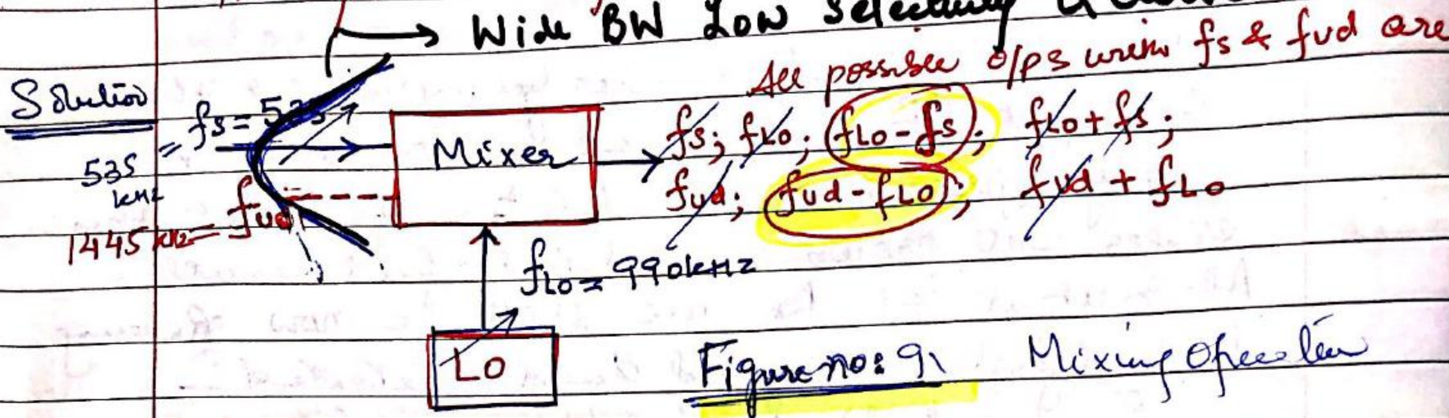

Figure no: 9: Mixing Operation

Here desired $f_s = 535$ kHz, $IF = 455$ kHz.
Since here down conversion is achieved when $f_{LO} > f_s$.

$\therefore$ $\boxed{IF = f_{LO} - f_s}$ ①

or $455\ kHz = f_{LO} - 535\ kHz$.

$\therefore$ $\boxed{f_{LO} = 990\ kHz}$

fud → undesired stage also called image frequency.
Let fud be an (image frequency) undesired station that also appears on front end along with fs as it may fall in the wide BW poor Q front end curve.

Using Eqn (4) $f_{ud} = 2f_{LO} - f_s = 2(990) - 535$ kHz

$\therefore$ $\boxed{f_{ud} = 1445\ kHz}$

fud can also be obtained from Eqn ⑤ because
$f_{ud} = 2IF + f_s = 2(455) + 535$ kHz
$f_{ud} = 1445$ kHz

$\therefore$ $\boxed{f_{ud} = 1445\ kHz}$ Ans.

(b) Using the illustration, we note the all the possible O/ps of mixer are by mixing f_{LO} with desired station f_s and also by mixing f_{LO} with undesired image freq f_{ud}.

These possible mixer o/p are.

Rejected ~~f_s~~ = 535 kHz

Rejected ~~f_{LO}~~ = 990 kHz

Selected → $f_{LO} - f_s$ ($\because f_{LO} > f_s$) = 455 kHz = IF ✓

Rejected ~~$f_{LO} + f_s$~~ = 1525 kHz

Rejected ~~f_{ud}~~ = 1445 kHz

Selected $f_{ud} - f_{LO}$ ($\because f_{ud} > f_{LO}$) = 455 kHz = IF ✓

Rejected ~~$f_{ud} + f_s$~~ = 1980 kHz

Out of all the above possible mixer o/p the subsequent IF amplifier will only pass two components

(i) IF = 455 kHz = $f_{LO} - f_s$ corresponding to f_s signal and

(ii) IF = 455 kHz = $f_{ud} - f_{LO}$ Correspond to f_{ud} image frequency

This results IF amp output to have two overlapped stations f_s and f_{ud} which causes interference of the desired f_s by the undesired image freq f_{ud}.

Q. 14) How should this problem be removed to improve the image frequency rejection capability of Rx?

Ans:- Since $f_{ud} = 2I_F + f_s$.

Remedy 1: Use large Value of I_F

Thus the Image frequency rejection (f_{ud}) capability of a Super heterodyne Rx can be removed by increase I_F.

Because if I_F is large then since f_{ud} station is at $2I_F$ above f_s then it is a high possibility that input Q curve will not provide a high response to the already weak f_{ud}.

By using high values of I_F, the f_{ud} would get positioned around the low response portion of input Q curves.

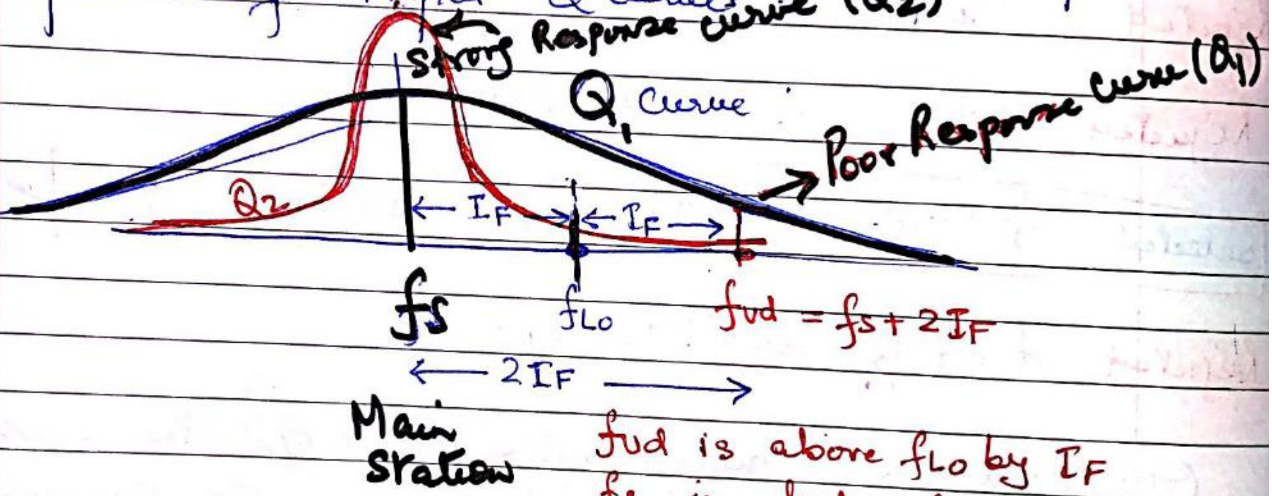

Figure 10: Response Q curve on front end before Mixer (Q_1 Curve & Q_2 Curves).

Even if f_{ud} will result in producing I_F (because it is also I_F away from f_{LO} as is f_s), still this station is so weak that overlapping is not so seriously affecting the main station reception f_s. Hence unwanted interference shall be within tolerable limits.

→ Use High Q (Curve Q_2) RF section

Remedy 2: Another possibility to avoid or minimize the influence of f_{ud} is to improve the front end selectivity. This can be achieved by employing circuitry that

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produces and offers highly sharp, narrow BW Q curves to the received stations. As shown in illustration of Figure 10, Q_1 curve offers poor rejection to fid while the sharp Q_2 curve offers excellent rejection to fid at the front end itself.

(ii) **Double Spotting issue of Superhetrodyne Rx.**

A Super-hetrodyne Rx suffers from the problem of Double spotting when for different tuning position the same station is received. In other words the signal is first received at a particular position then when front end tuner is down tuned then the same signal is again received. Even though on the second tuning position the received double spotted signal is weak.

To explain this issue of double spotting in case of a Super hetrodyne receiver (Rx) let us assume the station is at frequency f_s. Let IF be the pre-defined IF value of the radio set then in case of down conversion when $f_{LO_1} > f_s$ then $IF = f_{LO_1} - f_s$ where f_{LO_1} is the LO frequency value corresponding to first tuning position of f_s.

$\therefore$ Station tuned $= f_s$

Corresponding LO frequency $= f_{LO_1}$

So that $$IF = f_{LO_1} - f_s \quad (1)$$

Now while down tuning, f_{LO} is also changed. Let f_{LO_2} be the LO frequency so that now $\boxed{IF = f_S - f_{LO_2}}$ (2).

Solving (1) & (2) we get

$f_{LO_1} - f_S = f_S - f_{LO_2}$.

$\therefore \boxed{f_{LO_2} = 2f_S - f_{LO_1}}$ (3):

also we may write

$\boxed{f_{LO_1} + f_{LO_2} = 2f_S}$ (4).

Interpretation of above equations (3) & (4) is that while down tuning the radio set from higher to lower frequency position, f_{LO} also decreases to higher value. Then there is a possibility LO frequency is such that due to poor front end selectivity if f_S still manages to appear at mixer input, f_{LO_2} mixes with f_S again to produce I_F.

Equation (1) suggests that $f_{LO_1} > f_S$ to produce $I_F = f_{LO_1} - f_S$, while at the second tuning position $f_{LO_2} < f_S$ still to produce

$I_F = f_S - f_{LO_2}$ as given in Eqn (2).

This is a problem explained in case of down tuning because $f_{LO_2} < f_{LO_1}$.

Q.15

Q. (a) Let the desired first tuning position be for $f_S = 535$ kHz for a predefined $IF = 455$ kHz. In case of down conversion where $f_{LO_1} > f_S$, use these values to calculate f_{LO_1} and f_{LO_2} that results in Double spotting of f_S while down tuning.

(b) Also draw Corresponding Mixer Section block diagram with all possible i/ps & o/ps at various stages of Rx.

Ans

$f_s = 535\,kHz$

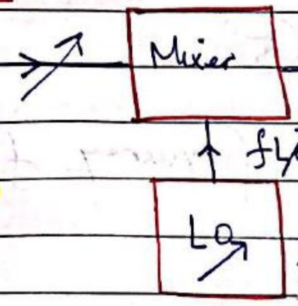

Figure no 11

→ Mixer o/ps at first tuning position with f_{LO_1} – f_s, f_{LO_1}, $(f_{LO_1} - f_s)$, $f_{LO_1} + f_s$.
→ IF

→ Mixer o/p at Second tuning position with f_{LO_2}

f_s, f_{LO_2}, $(f_s - f_{LO_2})$, $f_s + f_{LO_2}$
→ I_F

→ First tuning Position signal f_s, LO frequency $= f_{LO_1} > f_s$

Possible o/p of mixer is with $IF = 455 = f_{LO_1} - f_s$ are

Rejected $f_s = 535\,kHz$

Rejected $f_{LO_1} = 990\,kHz$

Selected $IF = f_{LO_1} - f_s = 990\,kHz - 535\,kHz = 455\,(kHz)$ ✓

Rejected $f_{LO_1} + f_s = 990\,kHz + 535\,kHz = 1525\,kHz$.

→ Second tuning Position while down tuning.

LO frequency $f_{LO_2} < f_{LO_1}$; $f_{LO_2} < f_s$ so that it mixes to produce $IF = f_s - f_{LO_2} = 455\,kHz$.

$f_{LO_2} = 535\,kHz - 455\,kHz = 80\,kHz$.

Possible mixer o/ps if f_s still manages to mix with f_{LO_2} are

Rejected $f_s = 535\,kHz$

Rejected $f_{LO_2} = 80\,kHz$

Selected $IF = f_s - f_{LO_2} = 535\,kHz - 80\,kHz = 455\,kHz$ ✓

Rejected $f_s + f_{LO_2} = 535\,kHz + 80\,kHz = 615\,kHz$

This example shows how we receive same station at two different tuning Positions. In the second case the

Signal becomes the image of itself reduced in strength when Rx is tuned to another position that results in LO frequency $f_{LO_2} = f_S - I_F$ or equivalently

$$f_{LO_2} = f_{LO_1} - 2 I_F \quad (5)$$

That is when down tuned LO frequency f_{LO_2} is 2 times IF below f_{LO_1}.

This issue in superheterodyne Rxs gives the impression that signal is located at two frequencies in the available band of frequencies.

Q.16 How should the problem of Double spotting in the Rx be removed

Remedy:- Use of large value of predefined IF

Here also it will be desirable to use a high value of IF so that f_{LO_2} is so less than f_{LO_1} that it may not be generated by the LO at all.

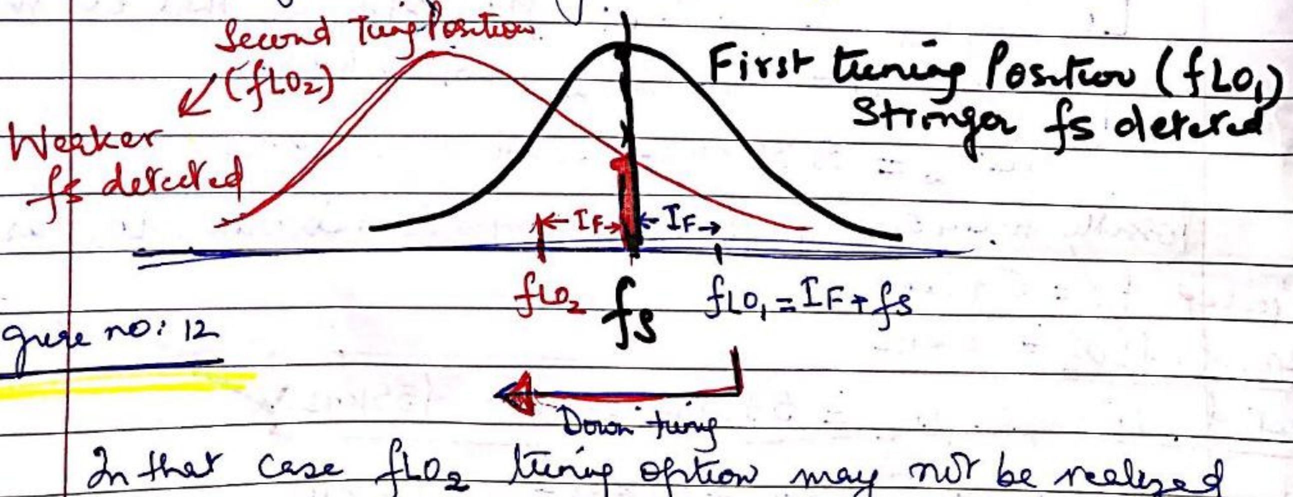

Figure no: 12

In that case f_{LO_2} tuning option may not be realized and hence we would avoid the double spotting of fs.

(iii) **Spurious Response issue of Superhetrodyne Rx.**

The Spurious Responses occur when a signal with a frequency near that of the desired frequency passes through the RF amplifier to the mixer with an appreciable amplitude. Either this signal or its harmonics mixes with LO frequency f_{LO} to produce a frequency within the bandpass of IF amplifier / Filter. A nonlinear mixer will produce these harmonics but a linear multiplier used as a mixer will not produce these harmonics.

Let f_{ud} be the unwanted signal near f_s where is the desired Signal.

Let mf_{ud} be one of its harmonics (of f_{ud})

Let nf_{LO} be one of its harmonics (of f_{LO})

The the nonlinear mixing operation takes place such that

$$IF = \pm n f_{LO} \mp m f_{ud} \quad (1)$$

Also

$$IF = f_{LO} - f_s \quad (2)$$

The above equations imply that not only is f_s passed on as desired thro' the IF section but even the mixing b/w harmonics as given in Eqn (1) is also producing IF.

Equation (1) will result in unwanted interference of Spurious response on the wanted f_s.

Q. How should the problem of Spurious Responses in Superhetrodyne Rx be avoided?

Remedy 1: Use linear mixers like linear multiplier circuits. The linear multiplier ckts do not produce these harmonics.

Remedy 2: Increase selectivity of RF amplifier by increasing Q. This could be achieved by using more that one stage of tuned circuit. Collective contribution of such successive tuned stages is to produce an overall high Q curve with small BW. This approach help in blocking fud in initial stages itself.

Q.17 This will also help in combating the problem of Insufficient Image rejection as well as Double spotting. (How?)

or

Q.17 To combat the problem of Insufficient Image Rejection issue of a Super hetrodyne Rx, IF is preferred to be used with a high value. What are the ensuing issues that result if IF value is chosen to be high?

Ans:- Referring to the problem of Insufficient Image Rejection on page 243 to pg 247, it was suggested that this problem could be avoided if IF value is high. because

- Image Frequency $\boxed{f_{ud} = 2IF + f_s}$.

But high IF poses some more related problems of its own. If IF is high, then since $Q = \frac{f_{res}}{BW}$, so $Q = \frac{IF}{BW}$

Therefor for tuning to higher IFs, for the same BW, Q required is a high selective circuit.

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But it is more difficult to design high selective, high response curves at higher frequencies. Higher value of IF would result in Q of the IF amplifier to be low and Bandpass of the IF amplifier also increases. This is shown below

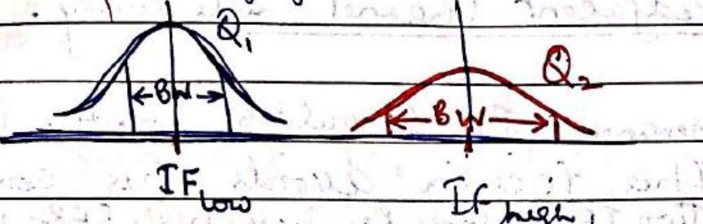

Figure 13 :- Q_1 response curve when IF_low. Q_2 response curve when IF_high.

Q_1 - Curve More selective, high response curve is possible at IF_low.
Q_2 Curve Less selective, low response curve is achieved at IF_high

So the problem with Single - Conversion Super hetrodyne Rx is that if such a Rx is operated in high frequency (HF) band where IF ≈ 30 MHZ, then it is impossible to obtain the required bandpass (BW) and image rejection using ordinary tuned Ckt. Use of high

Important: IF is more or less a theoretical solution which is very difficult to provide high Q and high selective response curve. Thus the problem of insufficient image rejection will still be unsolved.

Thus Single - Conversion Superhetrodyne Rxs are seldom used above 20 MHZ.

(PTO)