Department of Communications Engineering

Communication Systems

Third Year Class

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Lecture 15

Super heterodyne Receivers IV, Image Rejection Ratio

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:-

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

Q/ 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.1 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

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

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

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

② $F_c = 25$ MHz.

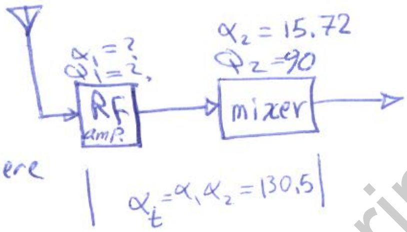
$$f_{im} = f_c + 2 f_{if} = 25 + 2 \times 0.455 = 25.91 \text{ MHz}.$$

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

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

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

Q/ 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 $\rho = 1.45$.

Solution ① $\alpha_t = 130.5$, $f_c = 10\ MHz$

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

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

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

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

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 $f_{im} = 19.578\ MHz$.

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

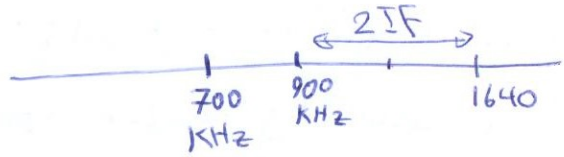
$2 f_{IF} = 9.578\ MHz \Rightarrow \boxed{f_{IF} = 4.789\ MHz}$

Q/ 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:- $Q = 80$.

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

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

Q/ 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 $F_{c1} = 1\ MHz$:-

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

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

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

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

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

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

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

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

$f_{im} = 57\ MHz$.

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

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

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