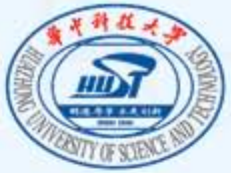

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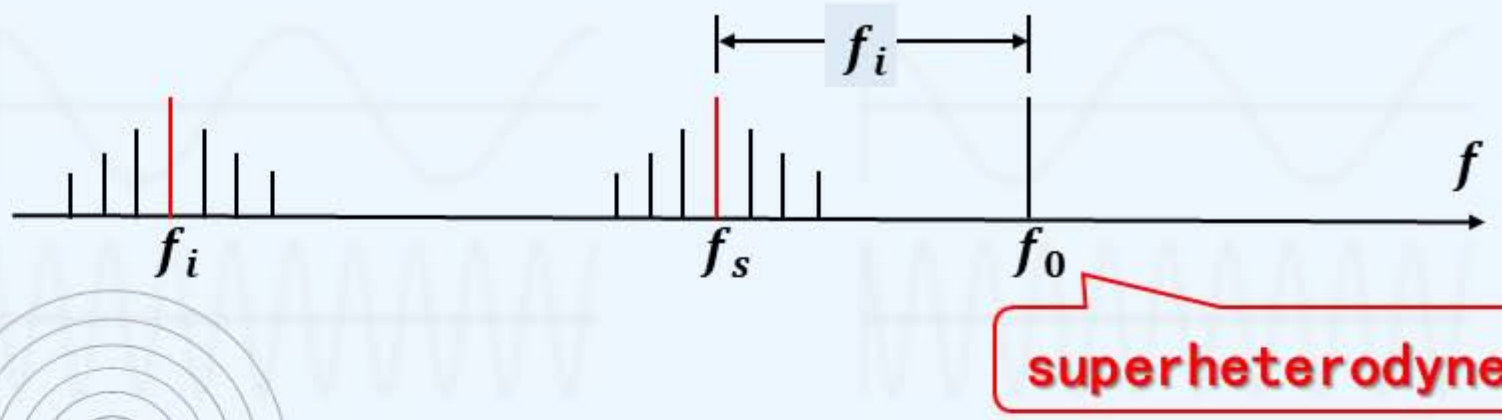
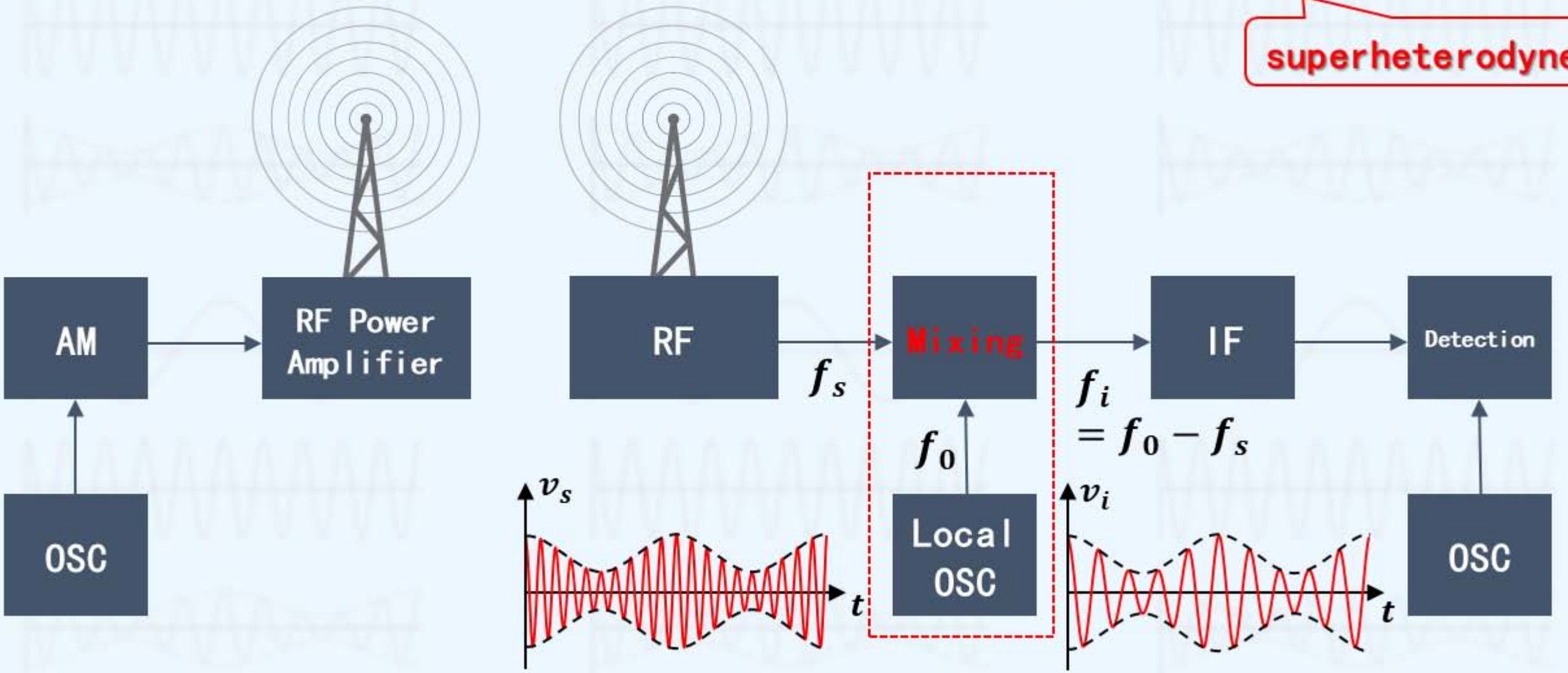
Frequency Mixing

Frequency Mixing





Frequency Mixing

- Pros:
  - Improved Sensitivity of Receiver
  - Selectivity of Receiver
  - Stability
  - Multi-band Consistency
- Cons:
  - Interference

Performance Metrics

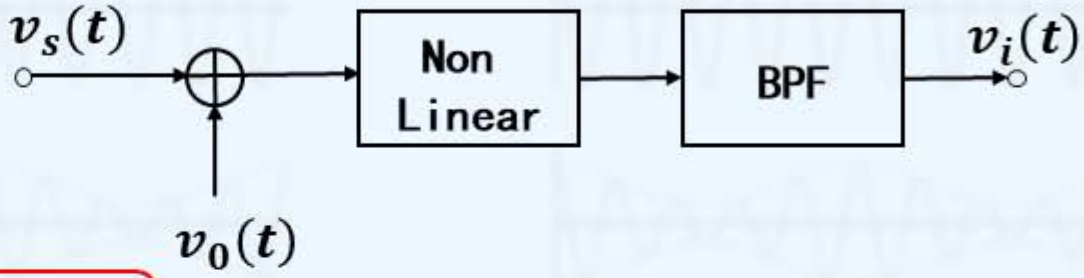
- Gain
  - V_{im}/V_{sm}
- Noise Figure
  - $\frac{(S/N)_i}{(S/N)_o}$
- Selectivity
  - Interference Suppression except for IF
- Nonlinear Interference
  - Suppression for Cross- and inter-modulation Interference
- Stability
  - Stability of Oscillator

Mixer - Classification

- Device:
  - Diode Mixer
  - BJT Mixer
  - Multplier Mixer
  - FET Mixer
- Feature:
  - Diode Mixer
  - Balanced Mixer
  - Ring Mixer
- Time domain:
  - Superposition-type
  - Multiplication-type

Superposition-type Mixer

➢ Non-linear Device



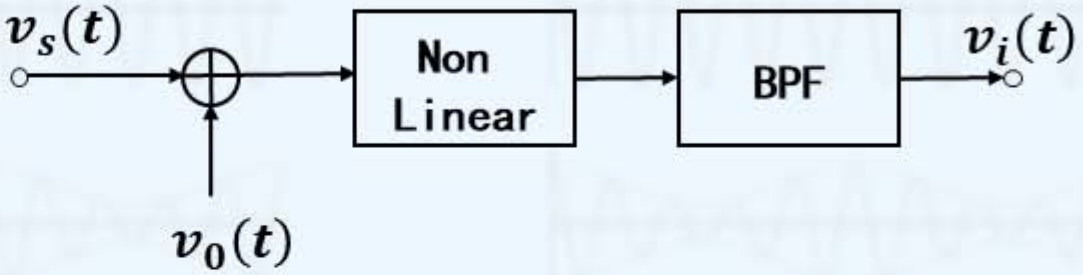
Balanced Mixer、Ring Mixer

- Diode Mixer — Dynamic range↑, Combined interference↓
- BJT Mixer — With gain
- FET Mixer — Cross-、Inter-modulation interference ↓

Superposition-type Mixer (Diode)

- Balanced Mixer
- Ring Mixer

- Principle: Non-linear (cf. AM)
  - By Power Series
  - By Switching Function



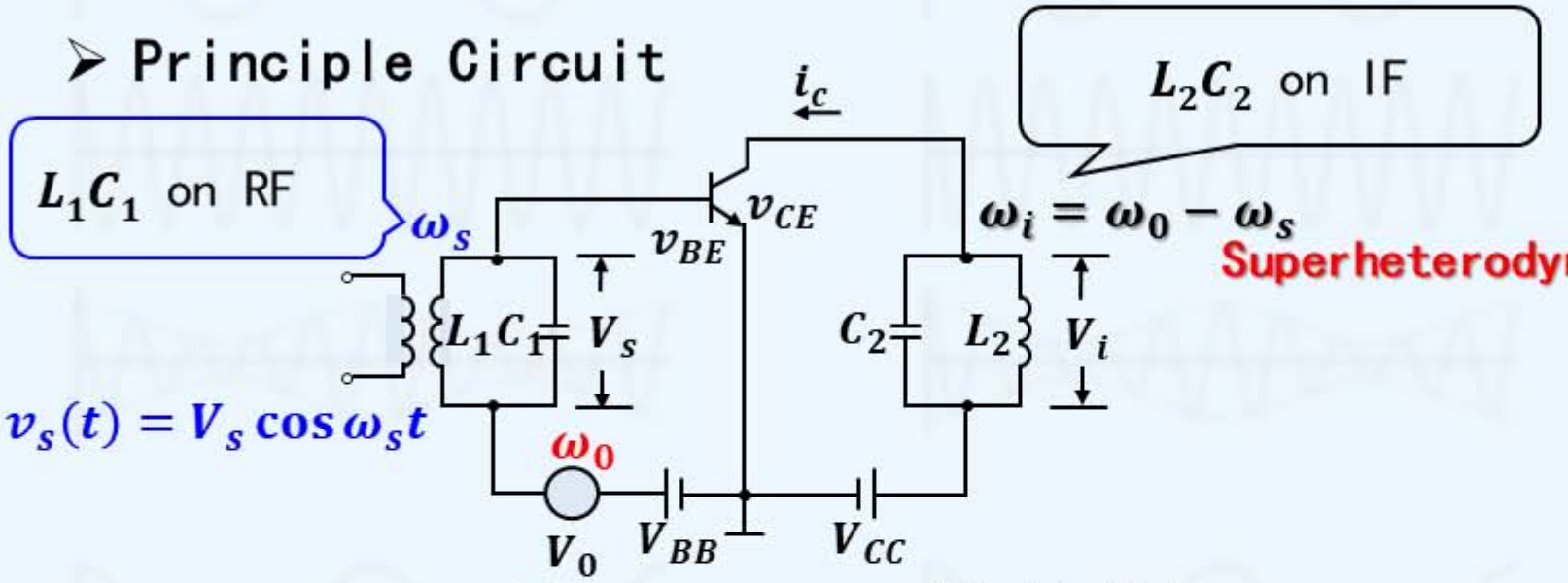
Exp: Power Series, Square law for $v_D = v_0 + v_s$

$$(v_0 + v_s)^2 = v_0^2 + v_s^2 + 2v_0v_s$$

Obtain $(\omega_0 + \omega_s)$ and $(\omega_0 - \omega_s)$

Superposition-type Mixer (Transistor)

➢ Principle Circuit



$v_s(t) = V_s \cos \omega_s t$

$\omega_i = \omega_0 - \omega_s$ Superheterodyne

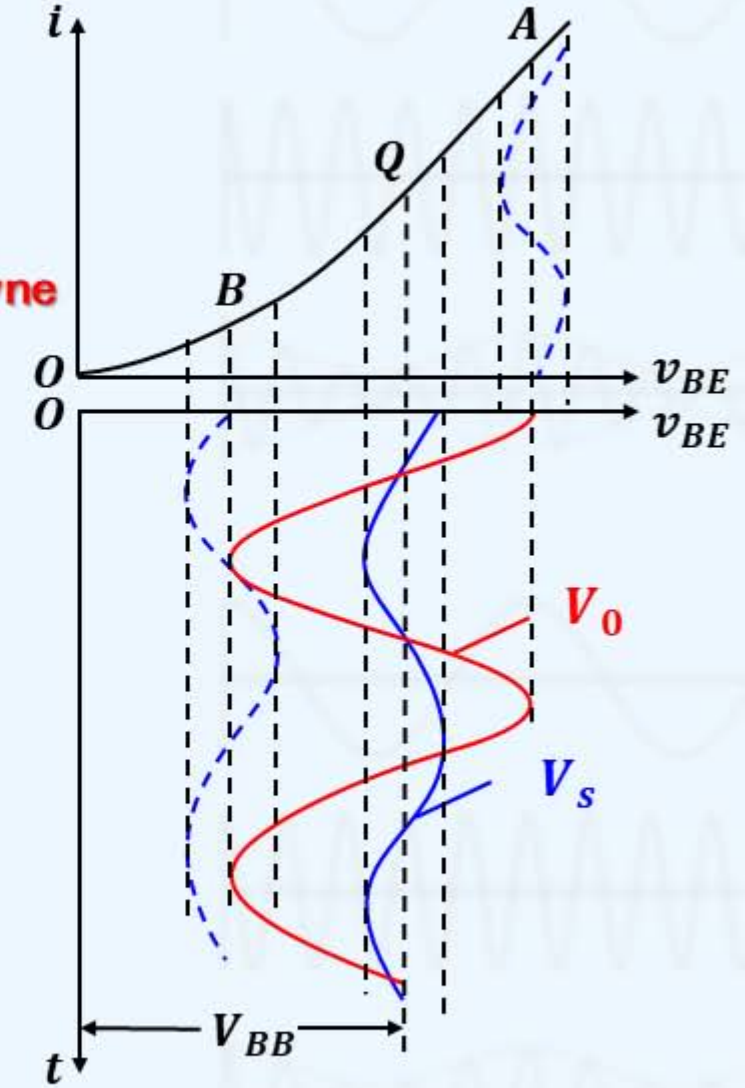
$v_0(t) = V_0 \cos \omega_0 t \quad (V_o \gg V_s)$

➢ $V_o >> V_s$ Linear Time-varying

➢ V_s Linear

➢ Transconductance changes

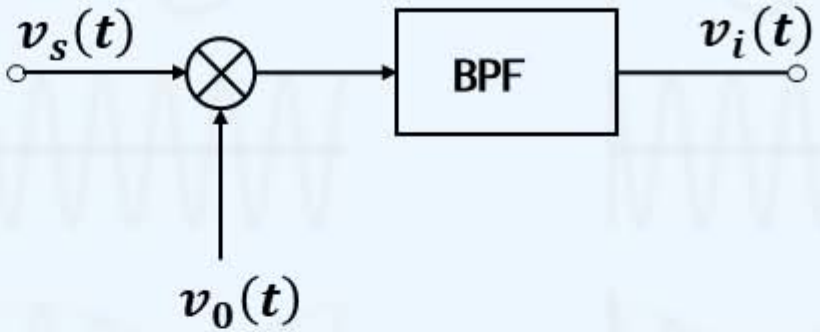
Linear Time Varying



Transistor Transcharacteristic

Multiplication-type Mixer

- Principle:



AM:

$$v_s(t) = V_s(1 + m_a \cos \Omega t) \cos \omega_s t$$

$$v_0(t) = V_0 \cos \omega_0 t$$

$$v_o v_s(t) = \frac{1}{2} V_0 V_s (1 + m_a \cos \Omega t)[\cos(\omega_o + \omega_s)t + \cos(\omega_o - \omega_s)t]$$

Obtain: $(\omega_0 + \omega_s)$ & $(\omega_0 - \omega_s)$

Mixer – Classification

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  - FET Mixer
- Feature:
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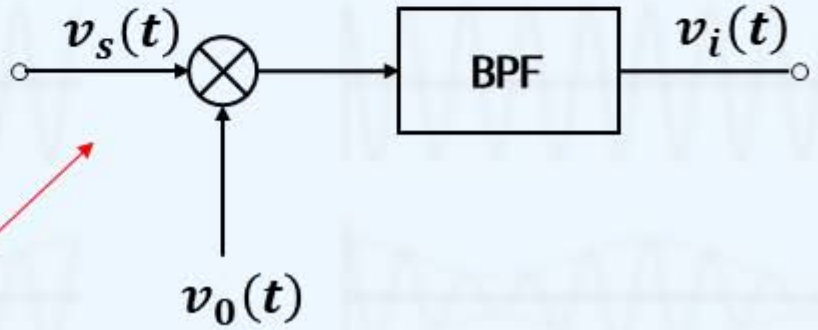
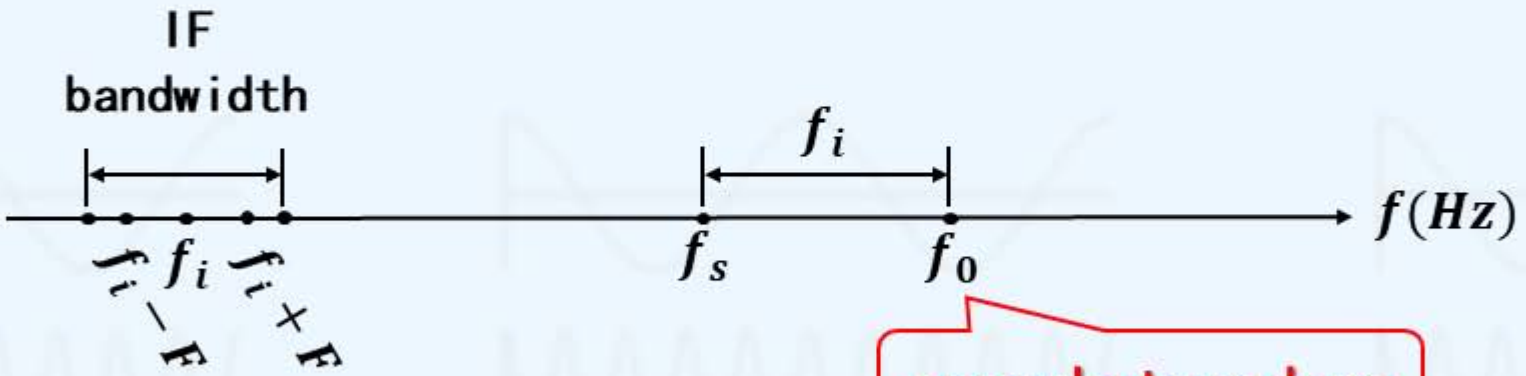


Mixing Interference

Combined Frequency Interference – f_s & f_0 (Interference Whistle)

➢ Definition: $|\pm n_s f_s \pm n_0 f_0| = f_i \pm F$

F (Whistle)

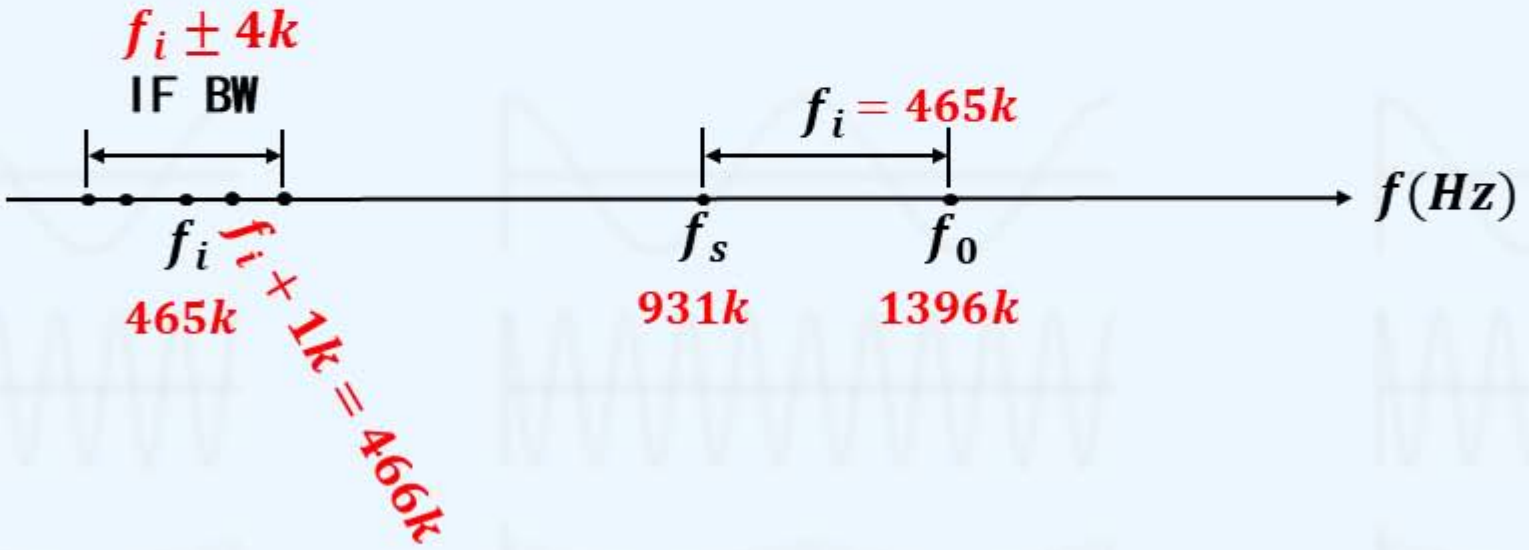


superheterodyne

Combined Frequency Interference – f_s & f_0

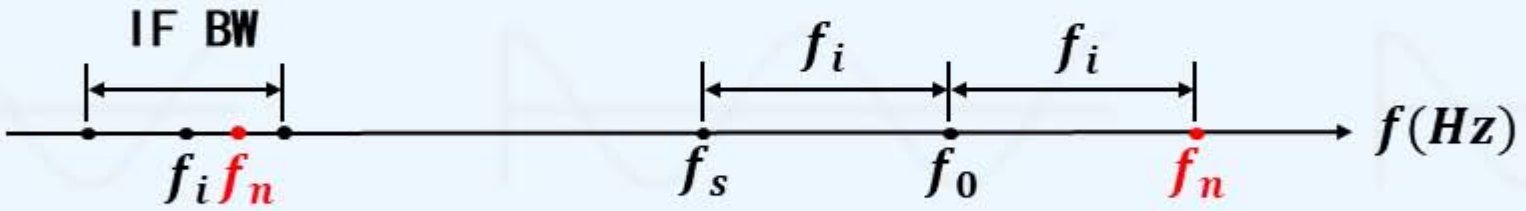
Exp: Modulated signal $f_s = 931kHz$, Local frequency $f_0 = 1396kHz$, analyze the reason to hear the whistle.

Solution: $2f_s - f_0 = 2\times931 - 1396 = 466kHz = f_i + F(F = 1kHz)$



Combined Side-Channel Interference - f_n & f_0

- Definition: $|\pm n_n f_n \pm n_0 f_0| \approx f_i$
- Special Case: Side-Channel Interference
  - IF Interference $f_n \approx f_i$
  - Mirror Frequency Interference $f_n - f_0 = f_i$



Cross-Modulation Interference - f_n & f_0

- Interference: Signal & Interference Co-exist (Multiplicative)
- Reason: Non-linear (Cube)

- Comparison:

  Combined Side-Channel Interference : Additive

Inter-Modulation Interference - f_{n1} f_{n2} & f_0

- Definition: $|\pm n_{n1}f_{n1} \pm n_{n2}f_{n2} \pm n_0 f_0| \approx f_i$
- Reason: Non-linear (Square & above)

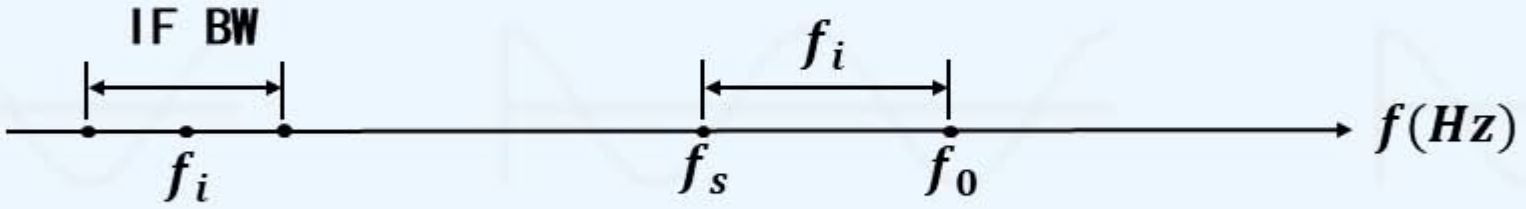
- Comparison:

  Cross-Modulation Interference: One f_n, Multiplicative

Inverse Mixing Interference – f_0

- Reason:

  Oscillator has interference



Blocking Interference

- Reason:

  Srong interference makes transistor into non-linear state

  with degrading output SNR

Summary

$$f_i \approx |\pm n_0 f_0 \pm n_s f_s \pm n_n f_n|$$

$$f_n \quad \overbrace{\qquad}^{f_{n1} \quad f_{n2}}$$