Up/Down Conversion
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- Functional Requirements
- Representative Mixer Topology
- Nonlinear “Mixing” Process
- Design and Technology Issues
- System Implications
Heterodyning - method for transferring a broadcast signal from its carrier to a fixed intermediate frequency (IF) so that most of the receiver does not have to be retuned when you change channels.
Functional Requirements

• Efficiency of frequency conversion (minimize “conversion loss” from RF $\leftrightarrow$ IF)
• Suppression of unwanted mixing products
• Adequate operational bandwidth
• LO power needed to drive (or “pump”) the mixer
The Mixer

- A non-linear device used to **multiply** two signals and **produce desired harmonics** of the input frequencies
Typically mixers use Schottky diodes (non-linear resistors) for the heterodyning process.
Representative Mixer Topology

- Mini Circuits VCO
  - SMA Connector
  - +9 dBm 985 MHz

- HP 8714
  - -5 dBm 915 Mhz

- RF Spectrum Analyzer
  - Att = 10 dB

- DC block

- Load

- Diode

- Harmonic Tuning Stub

- RF choke

- RF-LO & harmonics

“Single-Ended Mixer”

1. RF
2. SMA Connector
3. DC return path
Non-Linear Mixing Process

• In the following slides a mixer demonstration is given using the following parameters:
  – LO frequency at 30 Hz, with a peak voltage of 0.5 V
  – RF frequency at 20 Hz, with a peak voltage of 0.05 V
  – A DC bias voltage of 0.2 V (typically not used)
• The demonstration shows the input voltages in the time and frequency domain, and the resulting diode current (assuming all three voltages are simultaneously applied) in the time and frequency domain
• The generation of output harmonic signals at the following frequencies is shown:
  – LO (1st LO harmonic)
  – RF (1st RF harmonic)
  – LO-RF and LO+RF
  – DC
Non-Linear Mixing Process

Input voltage in the time domain:

\[ V_{DC} = 0.2 \]
\[ V_{RF} = 0.5 \]
\[ V_{LO} = 0.05 \]
\[ \omega_{RF} := 2 \cdot \pi \cdot 20 \leftarrow 20 \text{ Hz} \]
\[ \omega_{LO} := 2 \cdot \pi \cdot 30 \leftarrow 30 \text{ Hz} \]
\[ V_{RF_i} := V_{RF} \sin(\omega_{RF}t_i) \]
\[ V_{LO_i} := V_{LO} \sin(\omega_{LO}t_i) \]

Output current in the time domain:

\[ V_{TOT_i} := V_{DC} + V_{RF_i} + V_{LO_i} \quad \text{Total input voltage} \]
\[ \text{Total input voltage} \]
\[ Id_{TOT_i} := I_s \cdot \left( e^{\alpha \cdot V_{TOT_i}} - 1 \right) \quad \text{Diode current} \]
Non-Linear Mixing Process

Now, the same input and output data in the frequency domain:

- **Fourier transform of the total input voltage**
- **Fourier transform of the output diode current**
Design & Technology Issues

- **ANY** non-linear device (one whose transfer function depends on input level) will produce harmonics. For mixers, diodes and transistors are commonly used.
- Mixer topologies can be selected to minimize certain unwanted harmonics (esp. LO feed-through).
- Combining device is often the bandwidth-limiting elements. Couplers and transformers are commonly used.
Design & Technology Issues

- LO signal must have enough power to operate mixer with low conversion loss

\[ L_C = 10 \log \left( \frac{\text{available RF input power}}{\text{IF output power}} \right) \text{ dB} \]
System Implications

- Conversion loss can affect the amount of gain that is required in the amplification stages
- Level of unwanted mixing products and RF/LO feed-through can affect filter requirements
- Poor impedance match causes signal reflection and will degrade overall transceiver performance
- LO signal generation consumes DC energy
Up/Down Conversion – Conclusions

• The frequency conversion, or heterodyning process, is central to the design of wireless systems. Internal parts of the radio can operate at a frequency that is different from the frequency broadcast across the wireless channel.

• Heterodyning occurs in mixers, which require devices with non-linear current-voltage behavior.

• Mixer performance influences requirements for amplifiers, filters, and DC supply.
References

• Microwave and RF Design of Wireless Systems, David M. Pozar, Wiley, 0-471-32282-2
• http://www.minicircuits.com/pages/app_notes.html