Up/Down Conversion
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- Functional Requirements
- Representative Mixer Topology
- Nonlinear “Mixing” Process
- Design and Technology Issues
- System Implications
Functional Requirements

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.

Source: http://hyperphysics.phy-astr.gsu.edu/Hbase/audio/radio.html
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
A non-linear device used to multiply two signals and produce desired harmonics of the input frequencies
Representative Mixer Topology

Typically mixers use Schottky diodes (non-linear resistors) for the heterodyning process.
Representative Mixer Topology

“Single-Ended Mixer”

RF

Mini Circuits VCO

+9 dBm
985 MHz

LO

HP 8714

-5 dBm
915 Mhz

DC block

SMA Connector

Harmonic Tuning Stub

RF choke

Load

RF-LO & harmonics

Spectrum Analyzer
Att = 10 dB

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:

\[ V_{DC} = 0.2 \]
\[ V_{RF} = 0.5 \quad \omega_{RF} := 2\pi \cdot 20 \quad \rightarrow \quad 20 \text{ Hz} \]
\[ V_{LO} = 0.05 \quad \omega_{LO} := 2\pi \cdot 30 \quad \rightarrow \quad 30 \text{ Hz} \]

\[ V_{RF_i} := V_{RF} \sin(\omega_{RF} t_i) \quad V_{LO_i} := V_{LO} \sin(\omega_{LO} t_i) \]

Output current in the time domain:

\[ V_{TOT_i} := V_{DC} + V_{RF_i} + V_{LO_i} \quad \text{Total input voltage} \]

\[ I_{d\_TOT_i} := I_{s} \cdot \left( e^{\alpha V_{TOT_i}} - 1 \right) \quad \text{Diode current} \]
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