Up/Down Conversion

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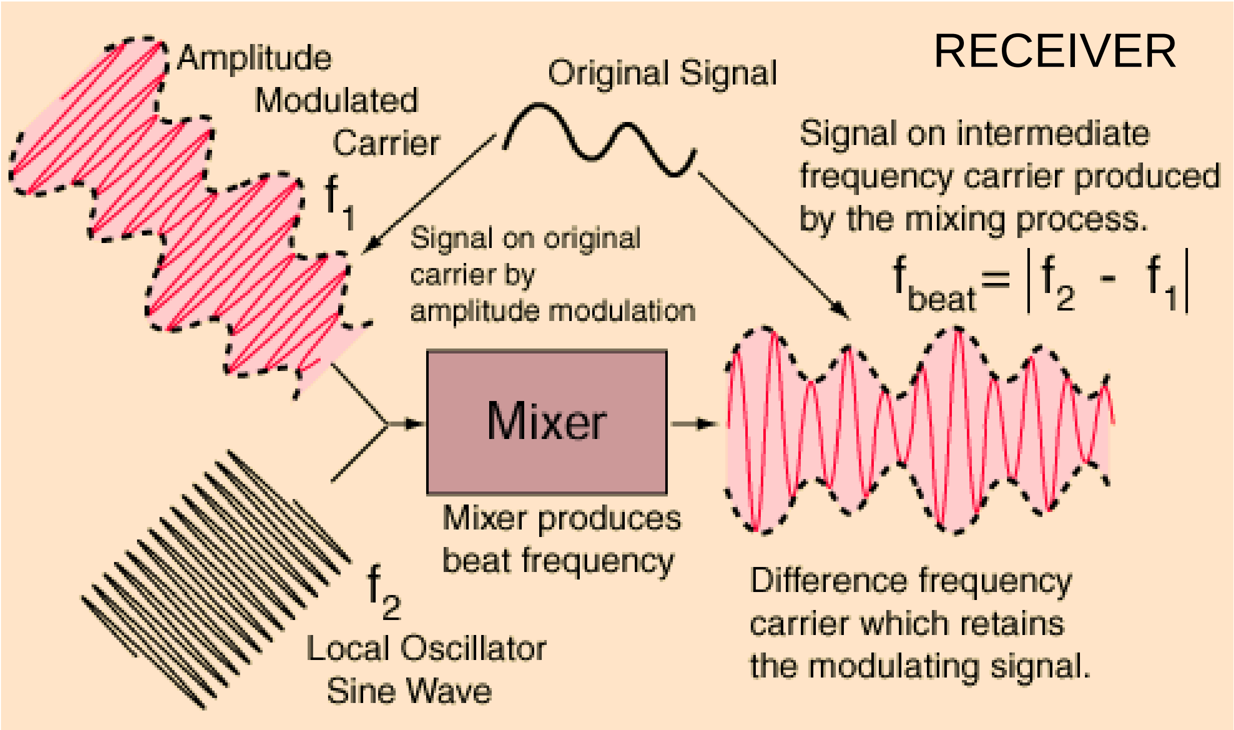
Up/Down Conversion

- 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

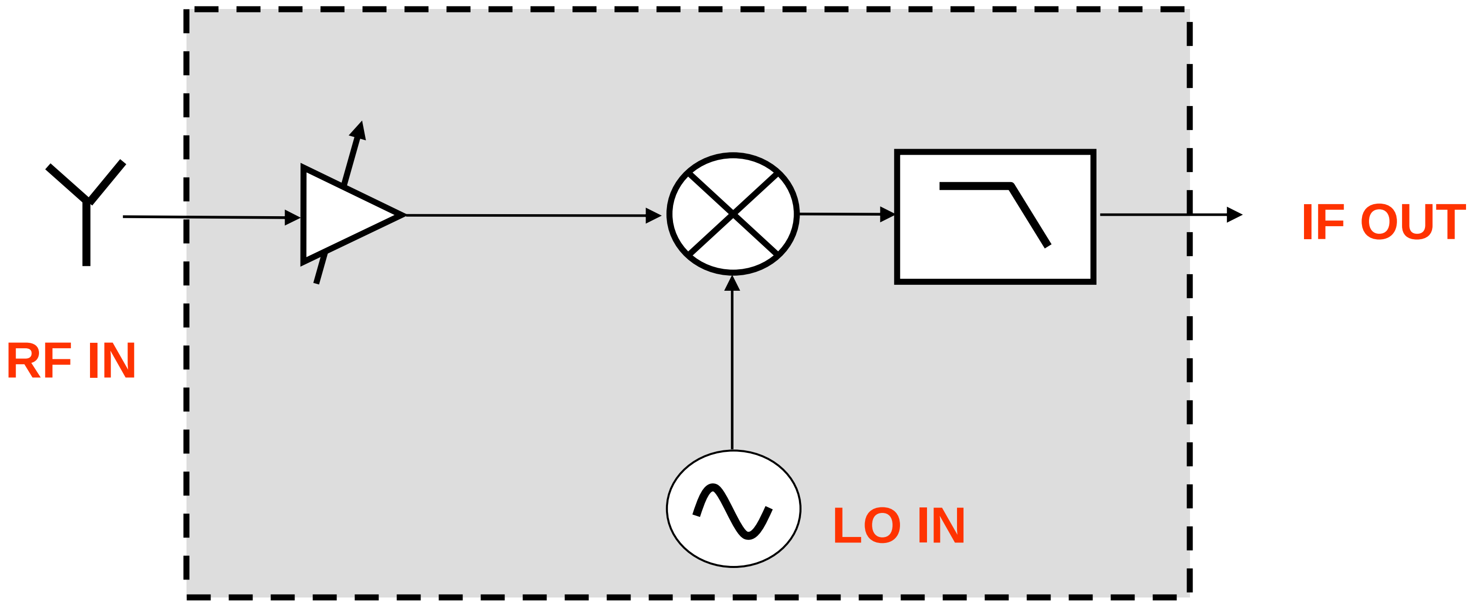


Source: http://hyperphysics.phy-astr.gsu.edu/Hbase/audio/radio.html

Functional Requirements

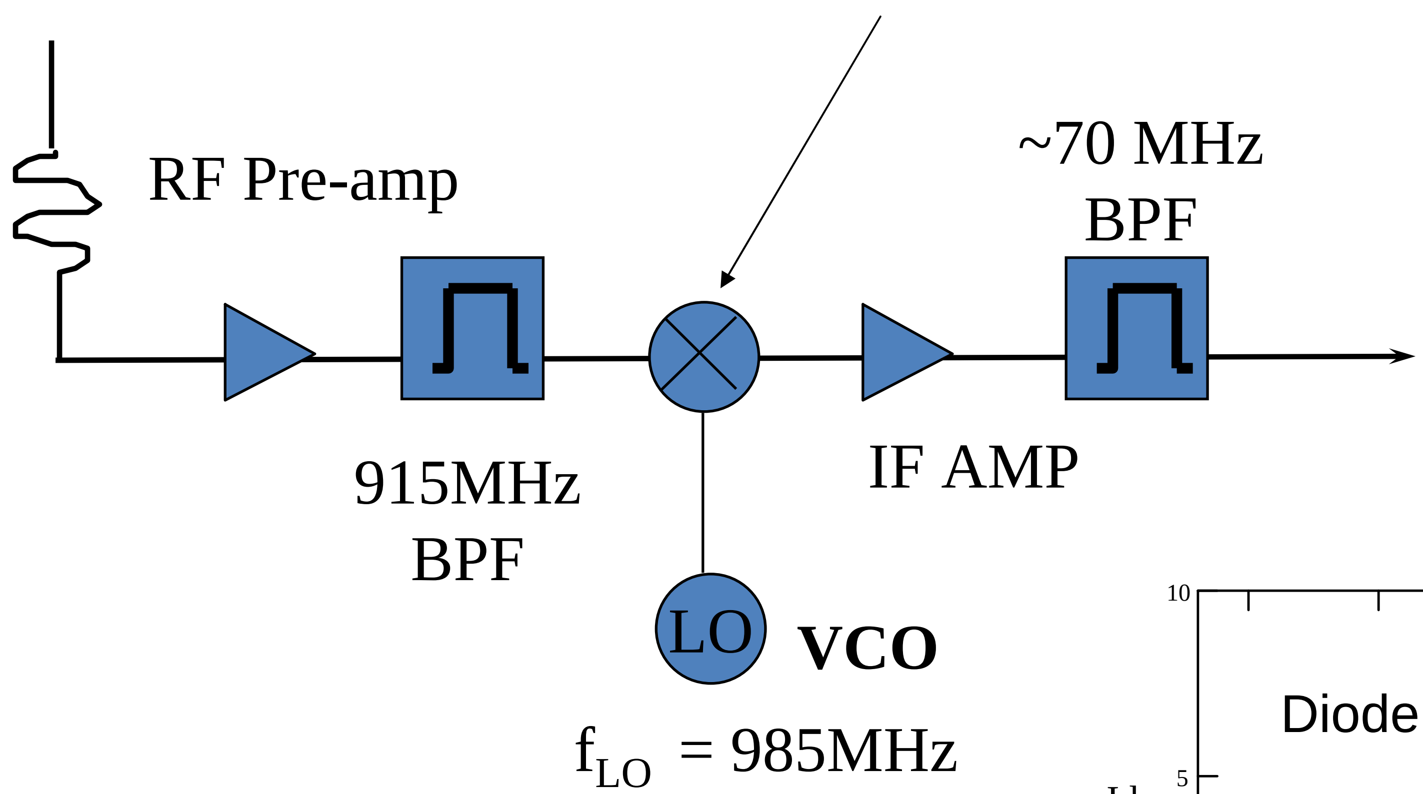
- Efficiency of frequency conversion (minimize “conversion loss” from RF ←→ IF)
- Suppression of unwanted mixing products
- Adequate operational bandwidth
- LO power needed to drive (or “pump”) the mixer

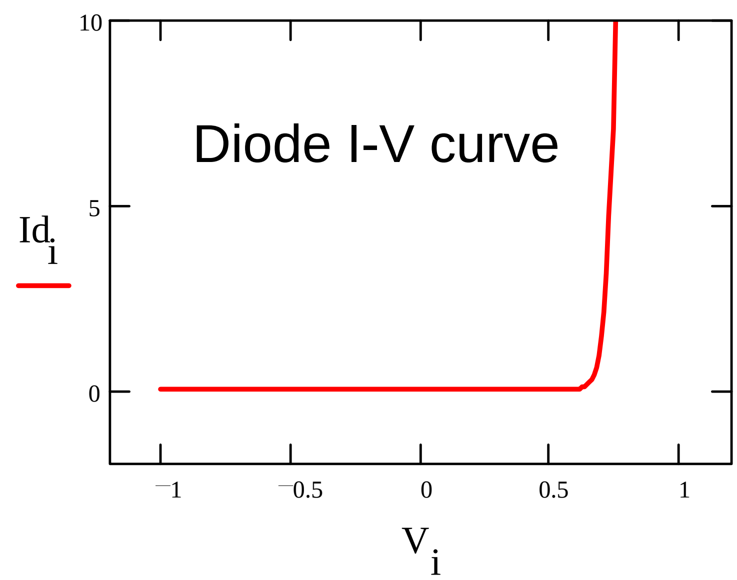
The Mixer



- A non-linear device used to <u>multiply</u> two signals and <u>produce desired harmonics</u> of the input frequencies

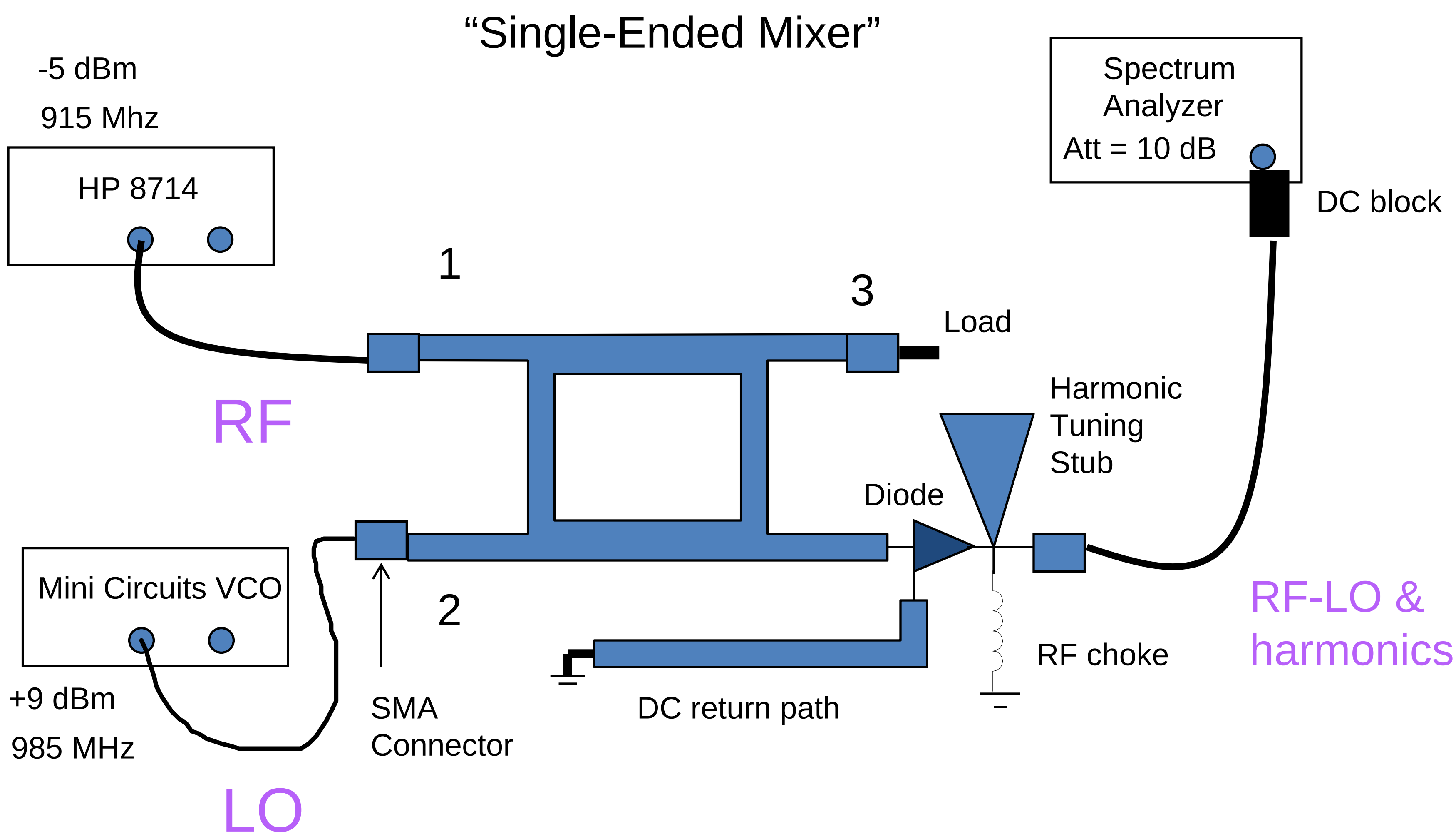
Representative Mixer Topology





Typically mixers use Schottky diodes (non-linear resistors) for the heterodyning process

Representative Mixer Topology



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

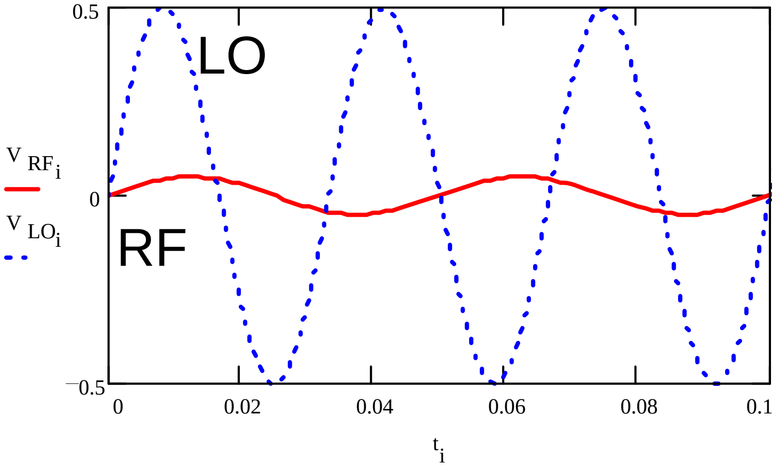
Input voltage in the time domain:

$V_{DC} = 0.2$

$V_{RF} = 0.5$ $\quad \omega_{RF} := 2\cdot\pi\cdot 20 \longleftarrow$ 20 Hz

$V_{LO} = 0.05$ $\quad \omega_{LO} := 2\cdot\pi\cdot 30 \longleftarrow$ 30 Hz

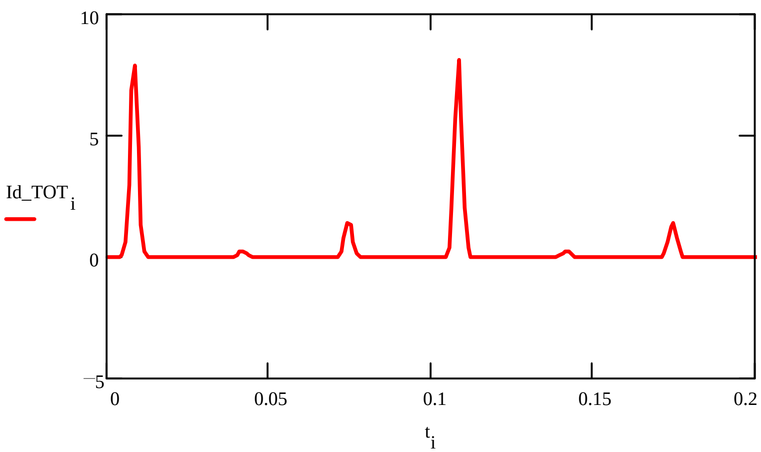
$V_{RF_i} := Vrf\cdot\sin\left(\omega_{RF}\cdot t_i\right) \quad V_{LO_i} := Vlo\cdot\sin\left(\omega_{LO}\cdot t_i\right)$



Output current in the time domain:

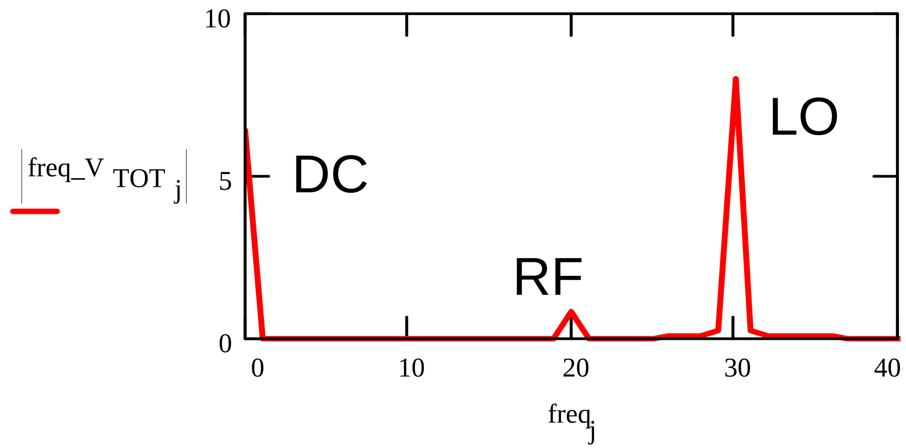
$V_{TOT_i} := V_{DC} + V_{RF_i} + V_{LO_i}$ Total input voltage

$Id\_TOT_i := Is\cdot\left(e^{\alpha\cdot V_{TOT_i}} - 1\right) \longrightarrow$ Diode current

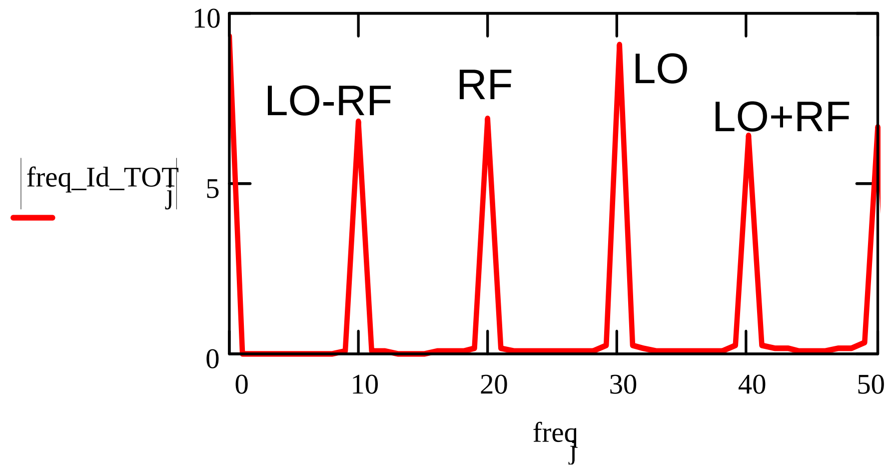


Non-Linear Mixing Process

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



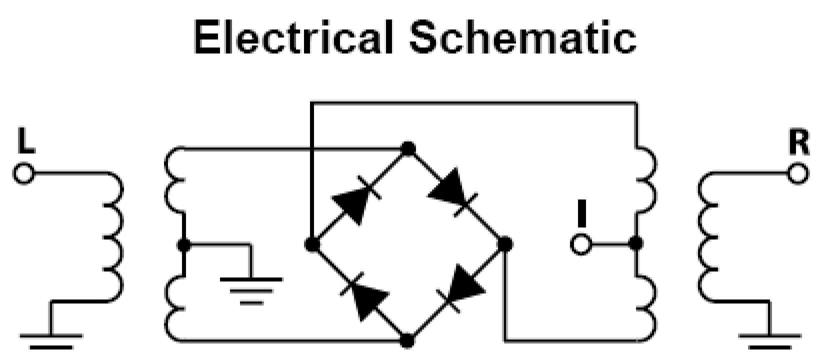
Fourier transform of the total input voltage



Fourier transform of the output diode current

Design & Technology Issues

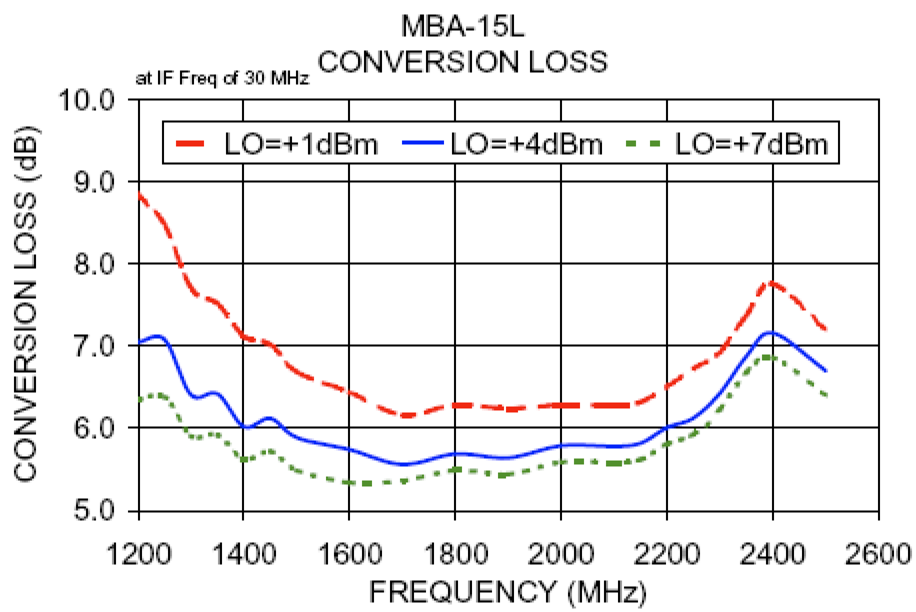
- <u>ANY</u> non-linear device (one whose transfer function depends on input level) will produce harmonics. For mixers, diodes and transistors are commonly used
- Mixer topologies can be selected to minimize certain unwanted harmonics (esp. LO feed-through)
- Combining device is often the bandwidth-limiting 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 [(available RF input power)/(IF output power)] 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.

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References

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