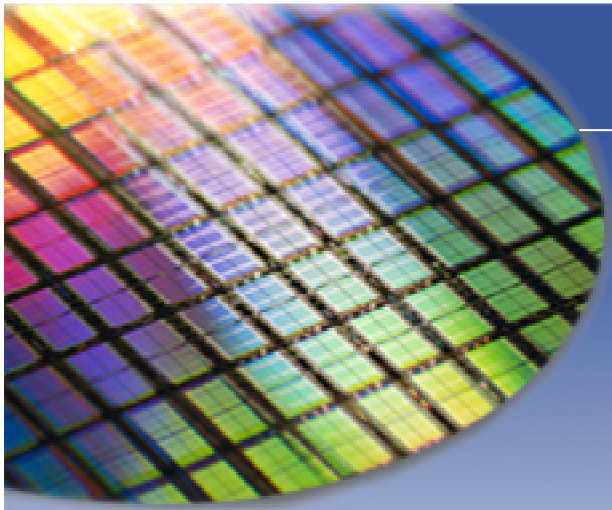


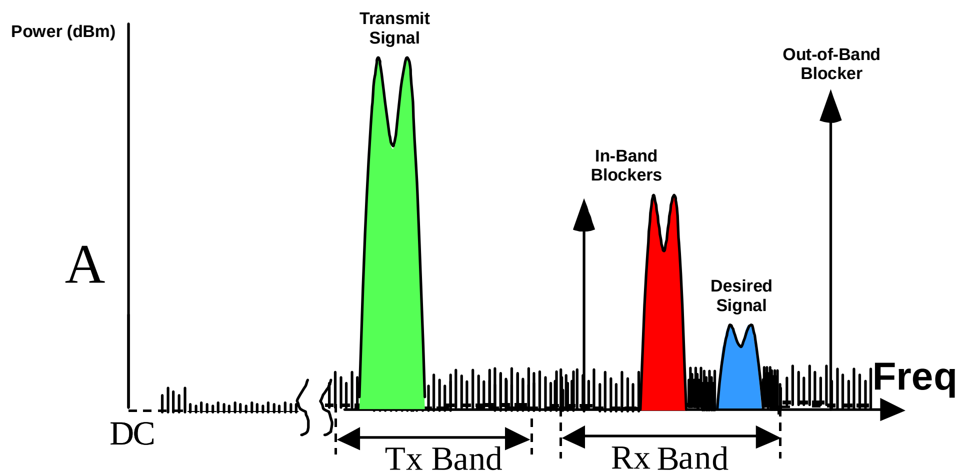
ADI 2006 RF Seminar

Chapter VI
A Detailed Look at Wireless Signal Chain Architectures

Receiver Architectures

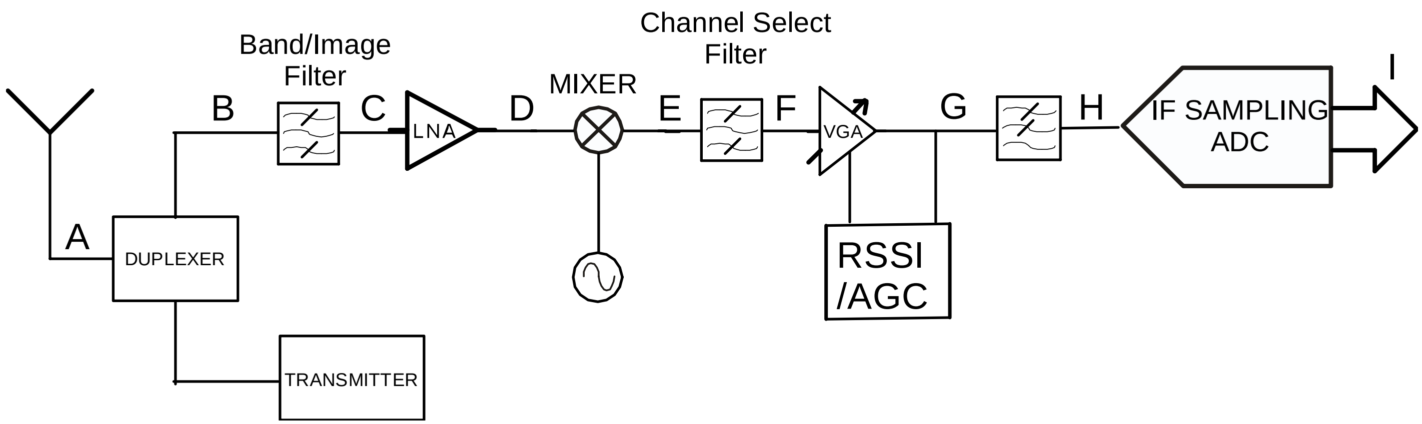
- Receivers are designed to detect and demodulate the desired signal and remove unwanted blockers
- Receiver must also get rid of unwanted signals that it generates (e.g. mixer spurs)
- Receiver uses variable gain and power detection
- Most Receivers will have some form of Automatic Gain Control
- Diversity: Some Receiver Systems have two separate Receive Paths (Antennas separated by a quarter wavelength).
- A Diversity Receiver will either pick the strongest signal or “intelligently” combine both signals to increase signal power

Blockers – a closer look



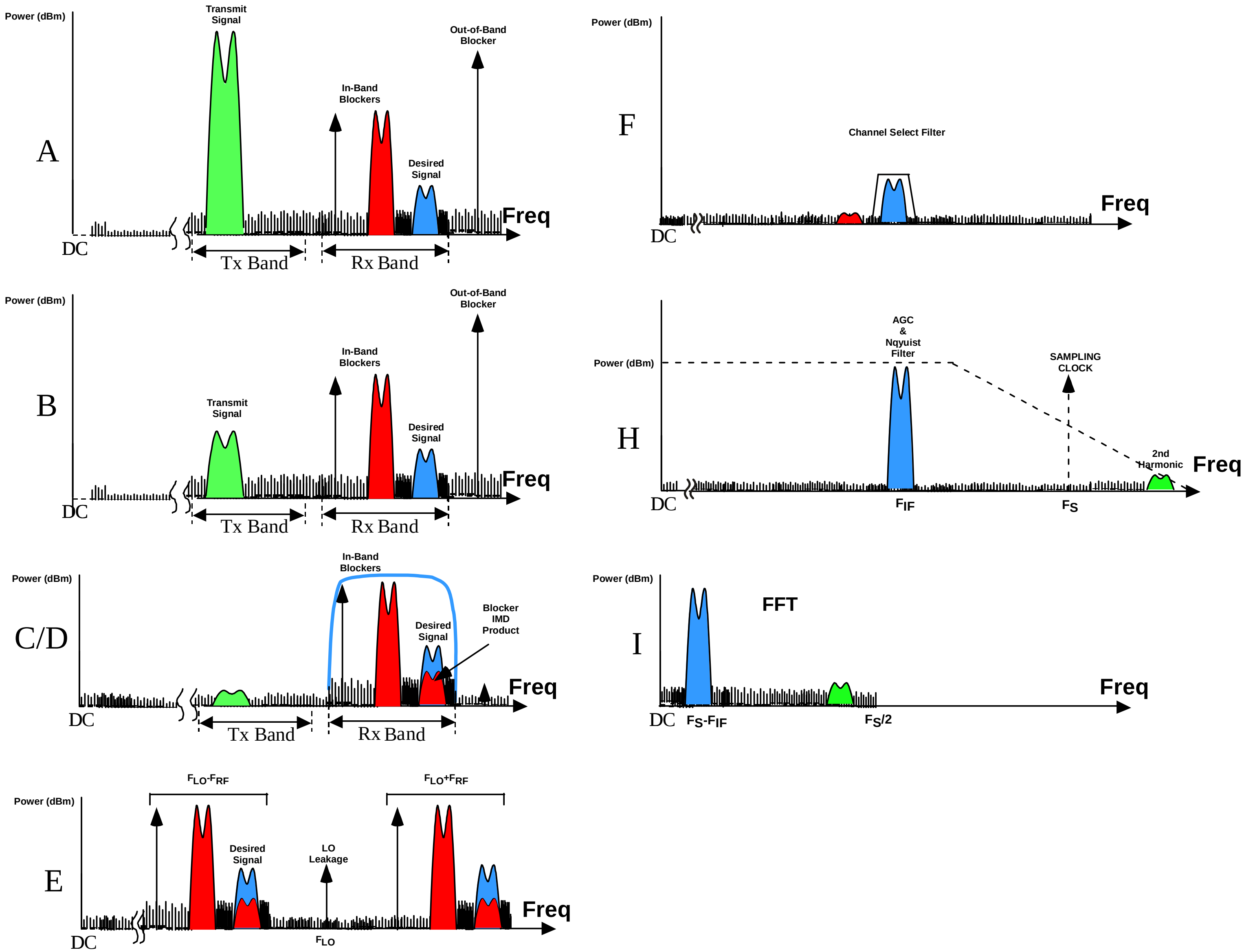
- Blockers can be orders of magnitude larger than the desired signal
- Large Blockers can jam a receiver
- Blockers can inter-modulate with each other and produce IMD products right at the frequency of the desired signal
- Some Blockers can be filtered (e.g. out-of-band) but others must be tolerated.

A Superheterodyne (Single Conversion) IF Sampling Receiver



- Mixes the received signal from RF down to a single IF
- Uses SAW filters to remove blockers and unwanted mixing components
- Detects signal power and implements AGC at the IF
- Reduces number of down-conversions by sampling the spectrum at an Intermediate Frequency but requires a high performance ADC
- Is the most popular architecture in non-cellular applications

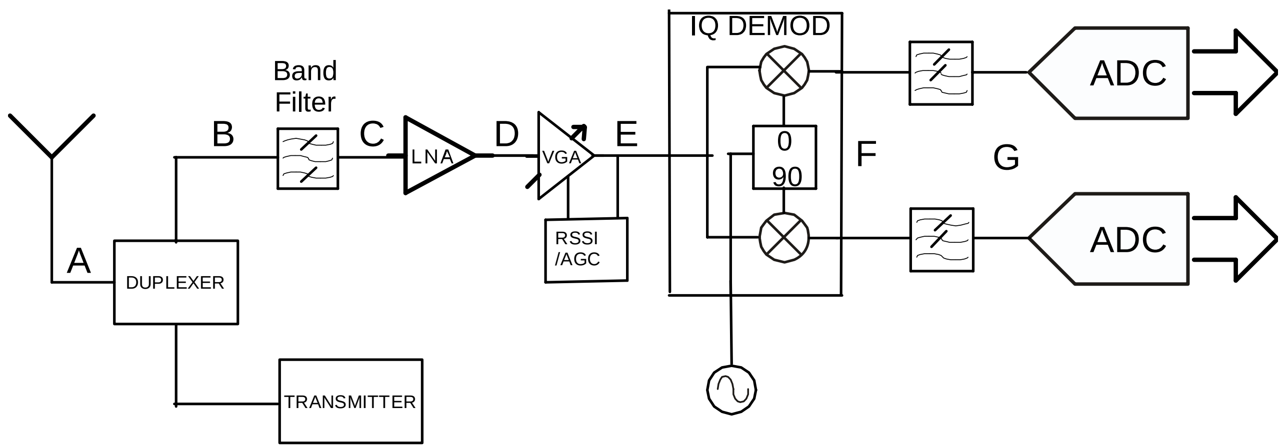
IF Sampling Signal Flow



How IF sampling works

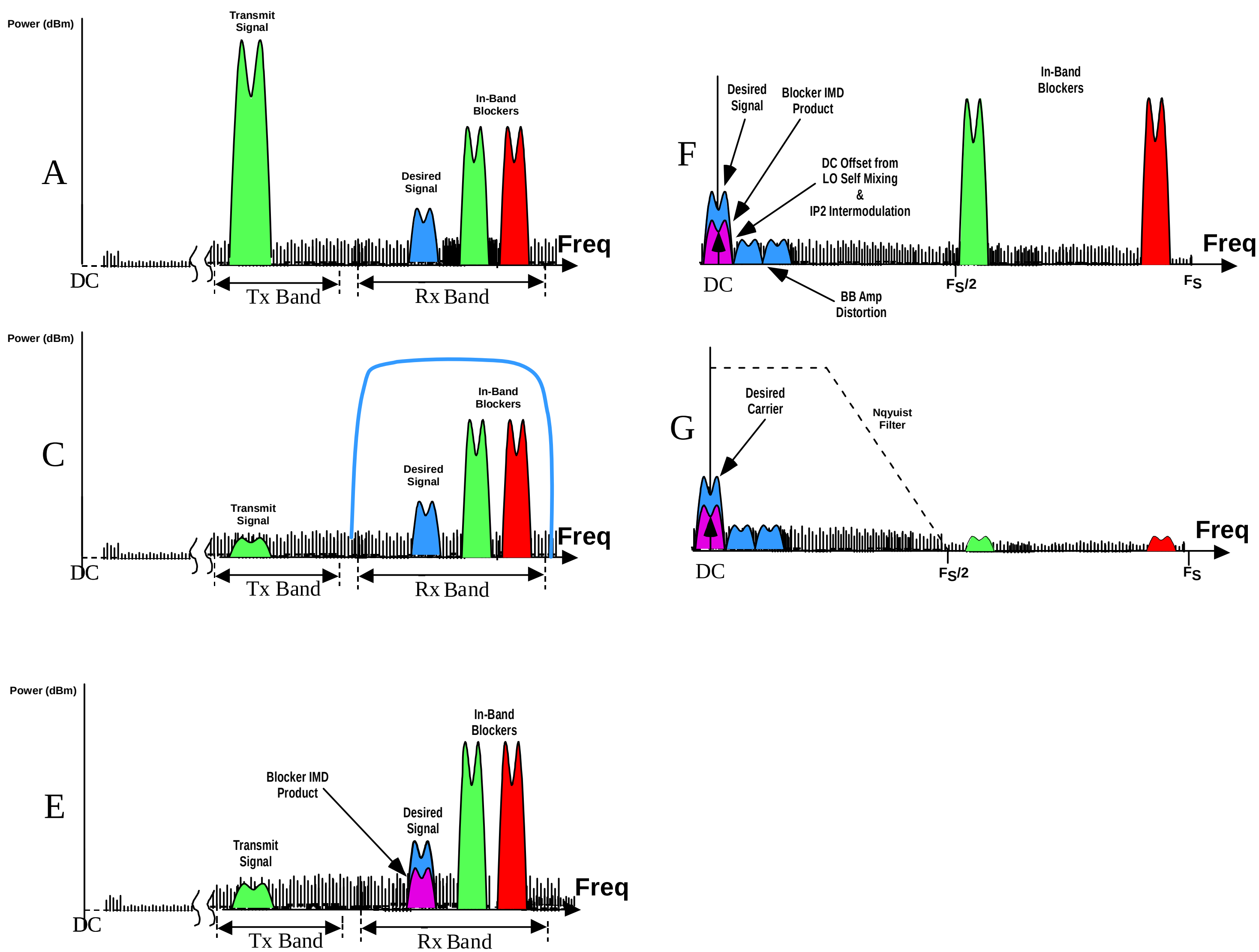
- The receiver uses RF and IF filters to eliminate the transmit signal and blockers so that only the desired signal is sampled
- The ADC must sample at twice the signal bandwidth to meet Nyquist criteria
- Oversampling can be used to improve the signal to noise ratio by 3 dB for each doubling of the sample frequency
- Harmonics of ADC driver amp that are not filtered will degrade performance
- There is usually a clock recovery loop in an FPGA or DSP or both that locks the sampling rate to a multiple of the symbol rate

Direct Conversion Receiver



- **Saves money by mixing RF spectrum to baseband in a single step**
- **Reduces component count and eliminates IF SAW filters**
- **There is a reason why RF engineers have not tried this sooner – removing DC offsets at baseband**

Direct Conversion Receiver



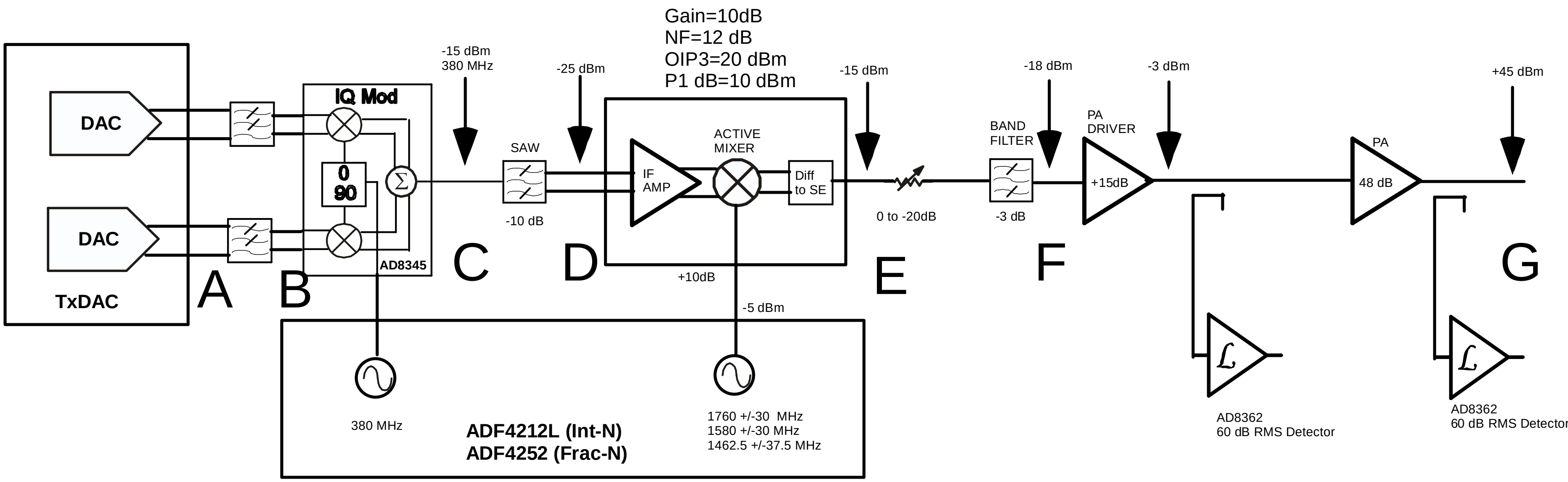
Direct Conversion Receiver

- In-Band Blockers can only be eliminated at the end of the signal chain or in the digital domain.
- In-Band Blockers can mix in the Front End (before mixer) to produce an unwanted product at baseband
- LO leakage to the RF input causes self-mixing and produces an unwanted dc offset at dc (right in the middle of the desired signal)
- Non-Ideal 90 degree balance in the Demodulator produces unwanted images of blockers which can be close to the carrier
- Direct Conversion Receivers are cheaper and smaller (no IF SAW filters, cheaper ADCs, only one mixer)

Transmitter Architectures

- Super Heterodyne with IQ Modulator
- Super Heterodyne with Real IF DAC Synthesis
- Direct Conversion
- Low IF to RF Conversion

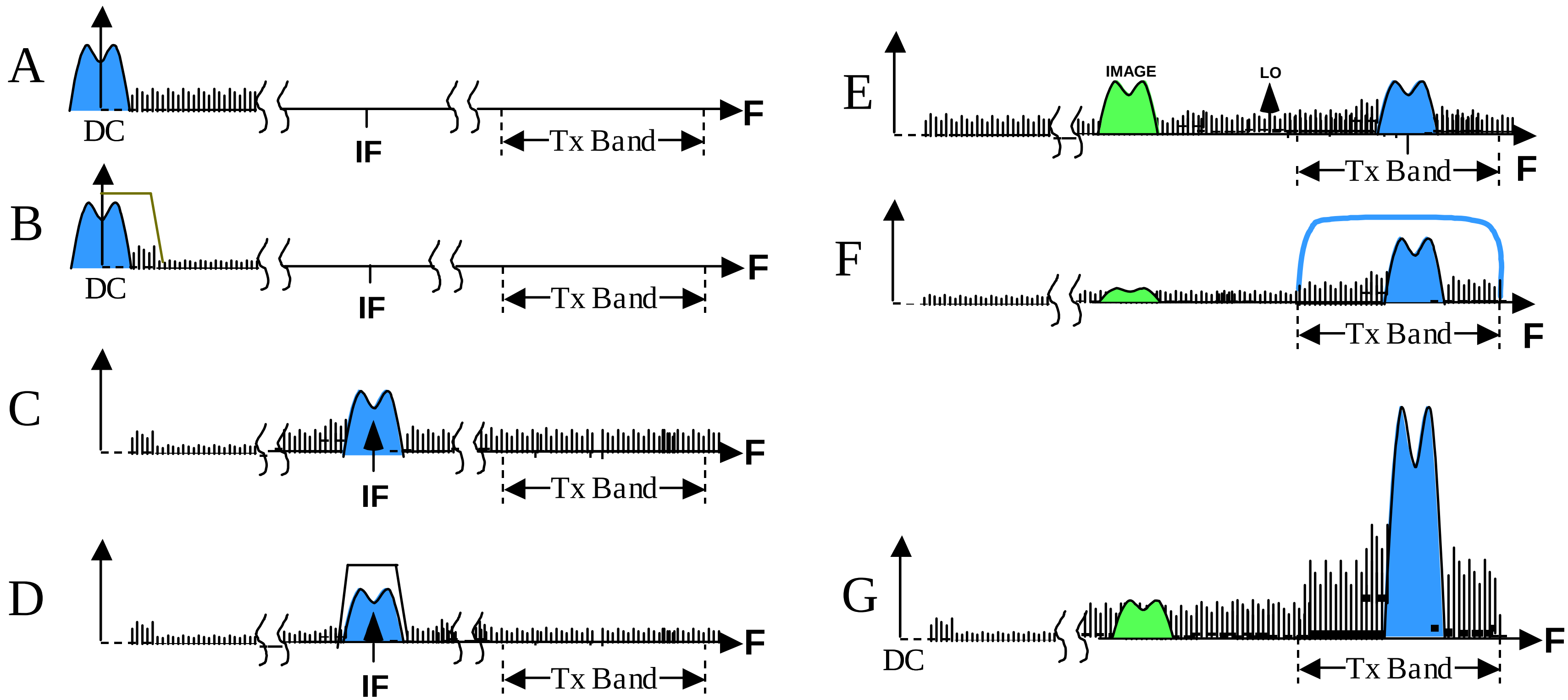
Superheterodyne Transmitter using IQ Modulator



- **Superheterodyne Transmitter uses one or more Intermediate Frequencies.**
- **DAC constructs the baseband signal, centered either at dc or at a low Intermediate Frequency (IF)**
- **Gain control and filtering may be implemented at RF, IF, and baseband.**
- **Lots of power back-off to avoid distortion in non-constant envelope systems**

ANALOG DEVICES

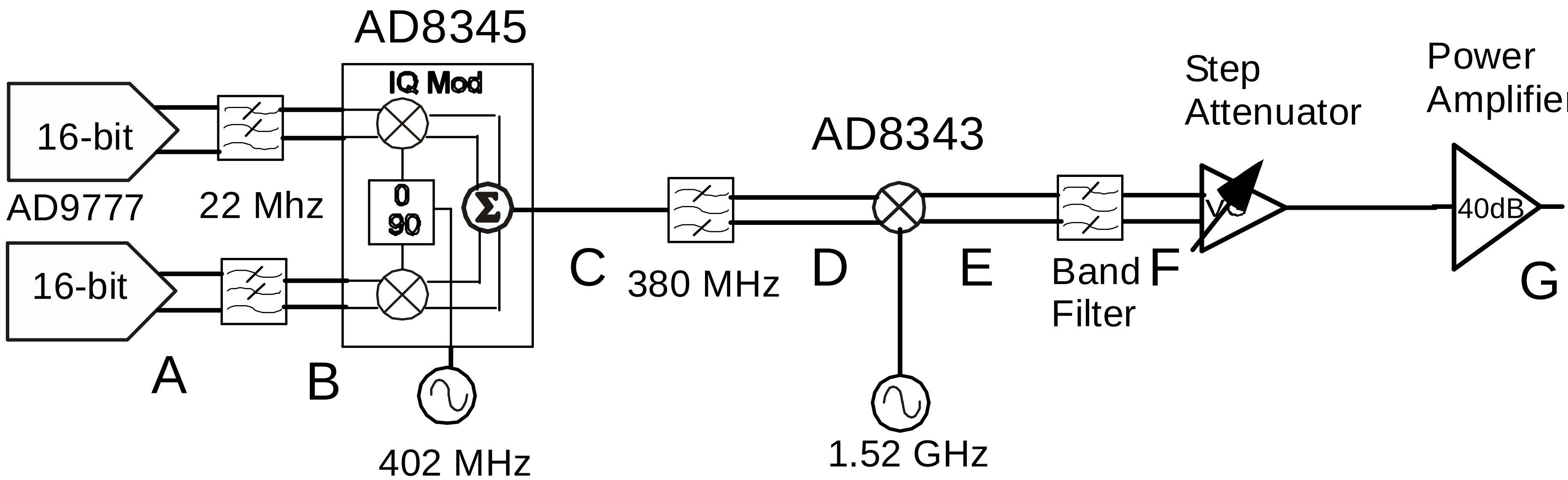
Superheterodyne Transmitter using IQ Modulator



Superheterodyne Transmitter using IQ Modulator

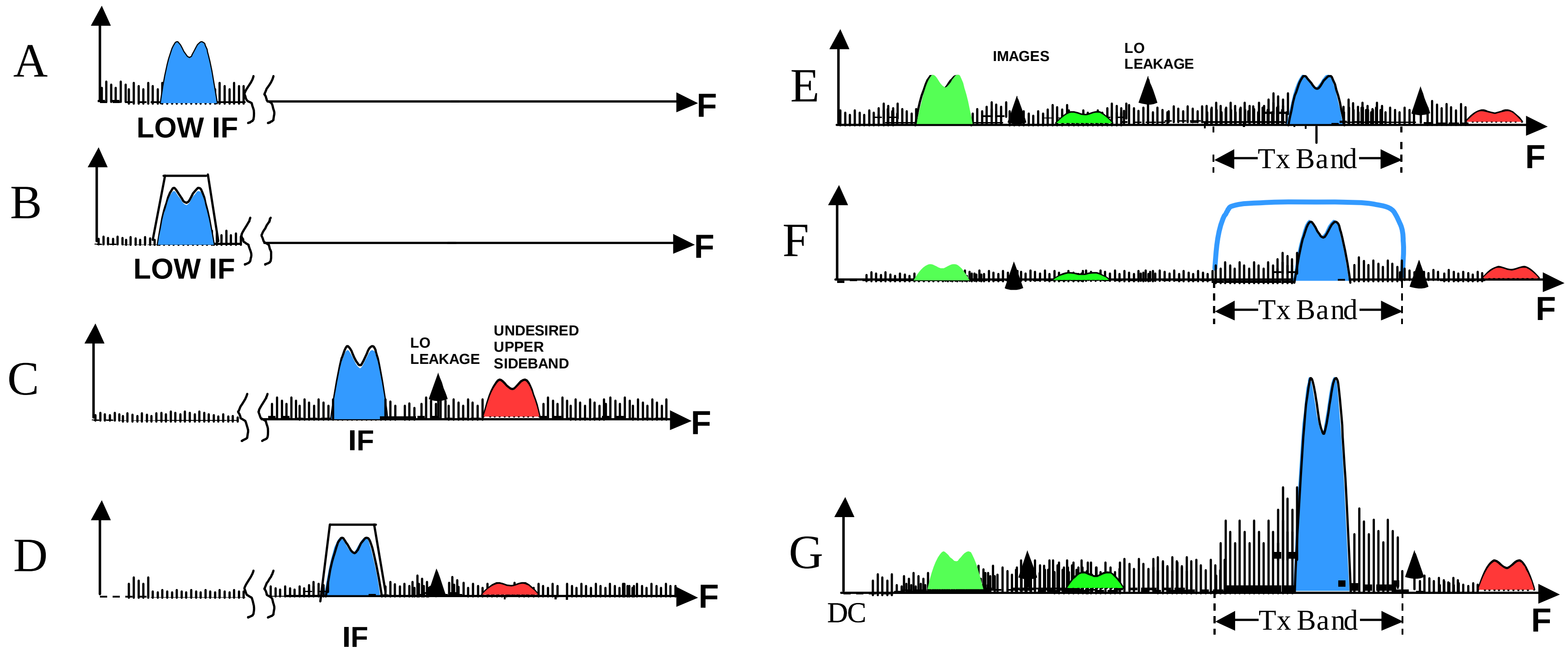
- **Noise and Spurs generated in the IF stage can be filtered**
- **After mix to RF, band filtering removes out of band noise along with the image**
- **In-Band noise generated in mix to RF cannot be removed**

Example: Superhet with IF Synthesis of signal in IQ format



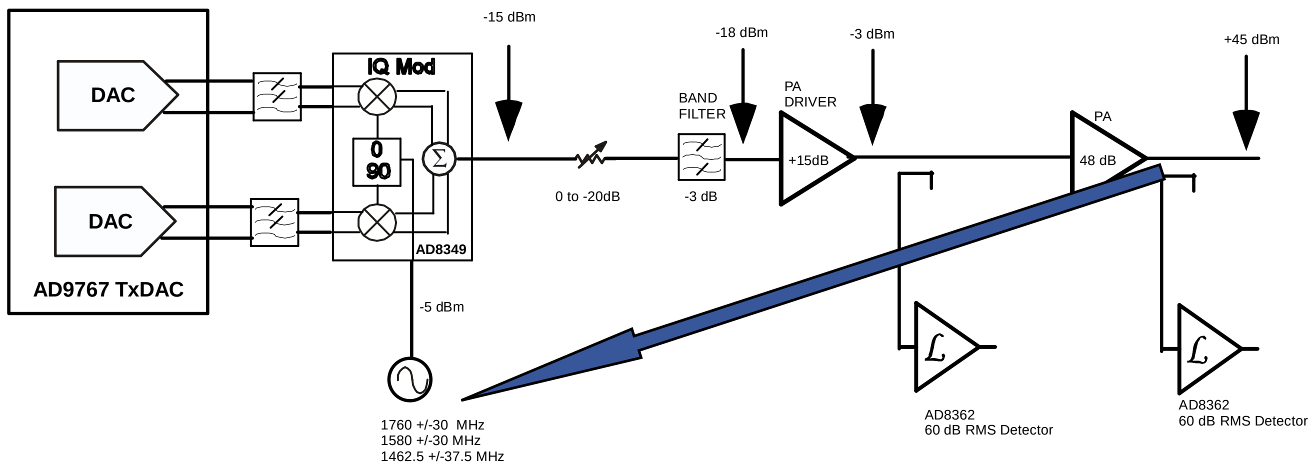
- Driving IQ mod with a low IF creates a single-sideband-like spectrum at the modulator output.
- Once IF has been filtered (removing unwanted sideband and LO), modulation quality (EVM) is excellent.

Example: Superheterodyne Receiver with IF Synthesis of signal in IQ format



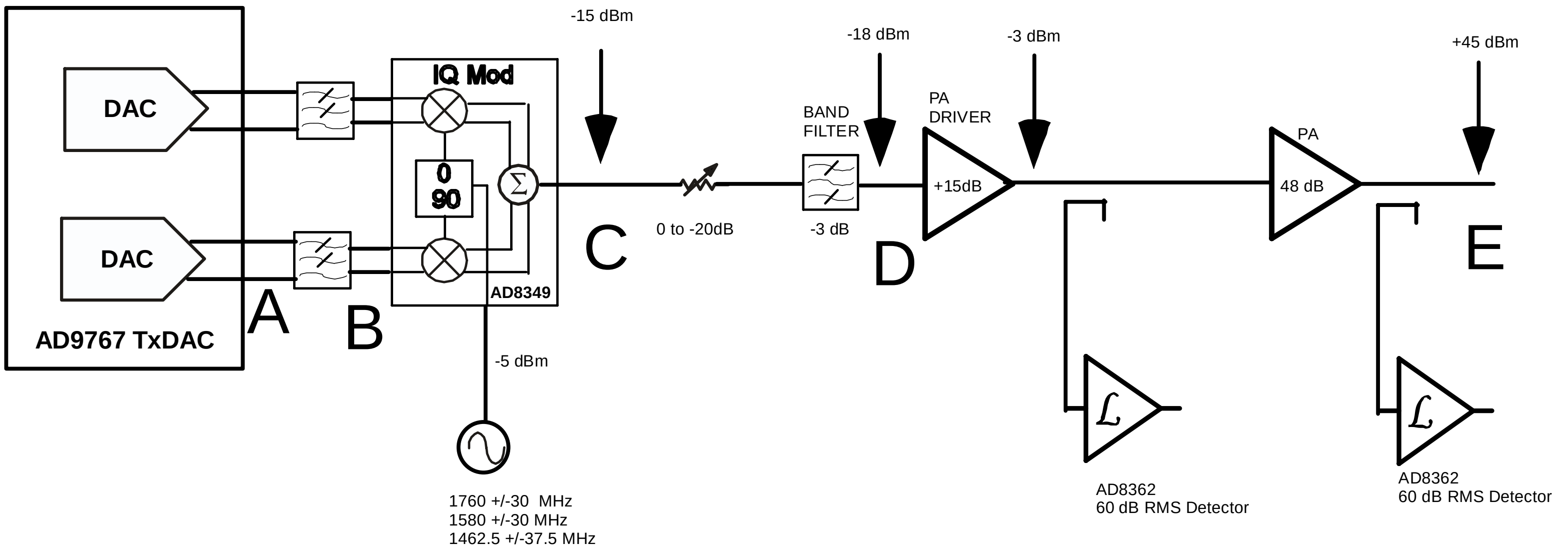
- Unwanted LO leakage and Upper Sideband are filtered at IF, resulting in excellent EVM
- If low IF is high enough, do a single up-conversion to RF

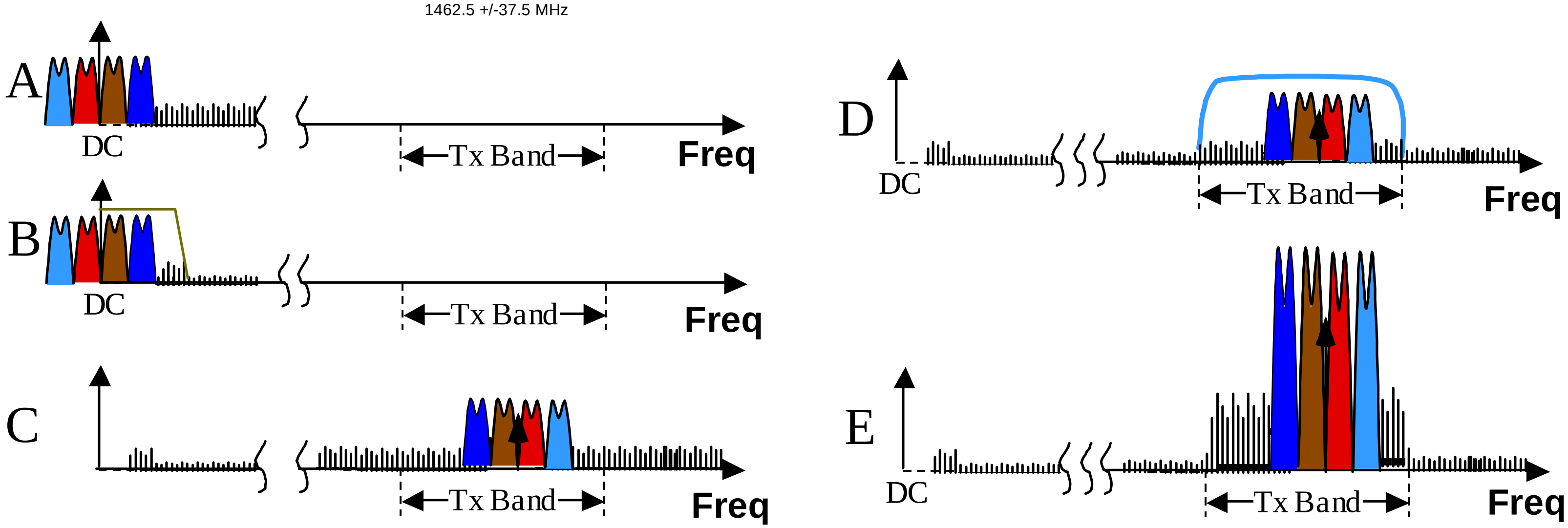
Direct Conversion Zero IF Architecture



- Direct Conversion mixes a base-band signal from a dual DAC up to the transmission frequency in a single step.
- With no IF, gain control, filtering, and equalization must be performed either in the digital backend, at the reconstructed analog base-band output or at RF.
- Effects of LO leakage and Upper Sideband Leakage occur in-band potentially interfering with the signal's EVM.
- Dual channels are required to generate the complex signal, any channel mismatch causes In-band distortion which cannot be filtered.
- High quality components are required to generate an accurate signal
- In-Band Modulator Noise cannot be filtered
- Calibration of LO leakage and Quadrature balance is generally necessary
- PA to LO leakage can modulate or "pull" the PLL

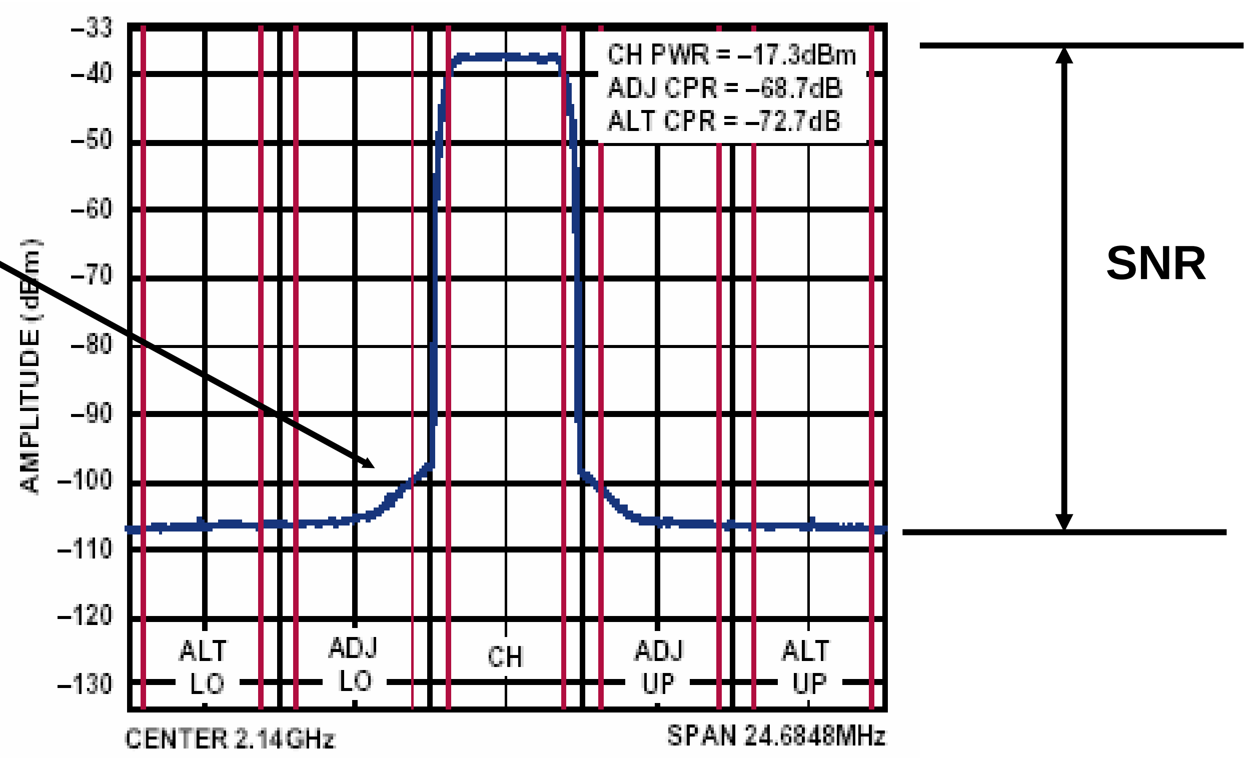
Example: Direct Conversion Transmitter





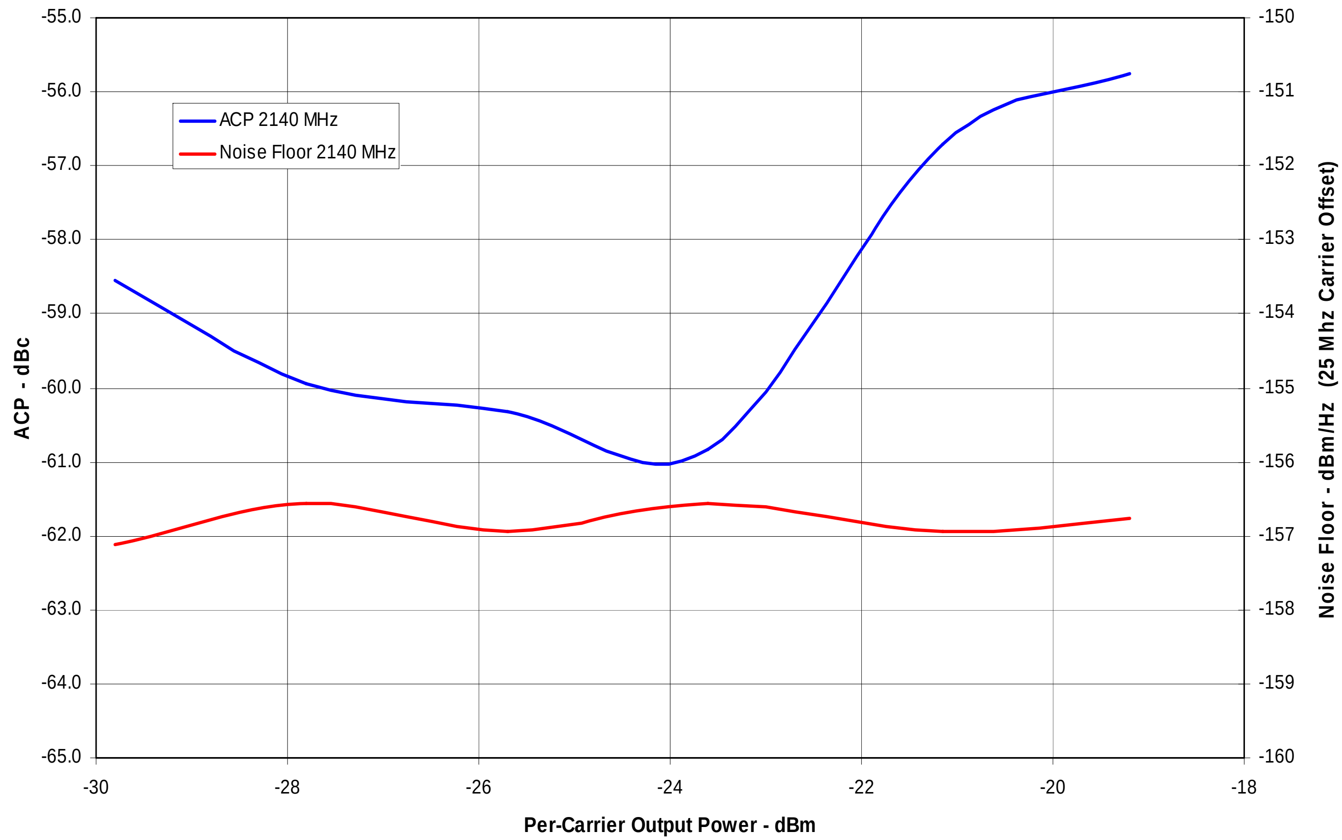
Poor OIP3 causes Adjacent Channel Leakage

Adjacent Channel Leakage



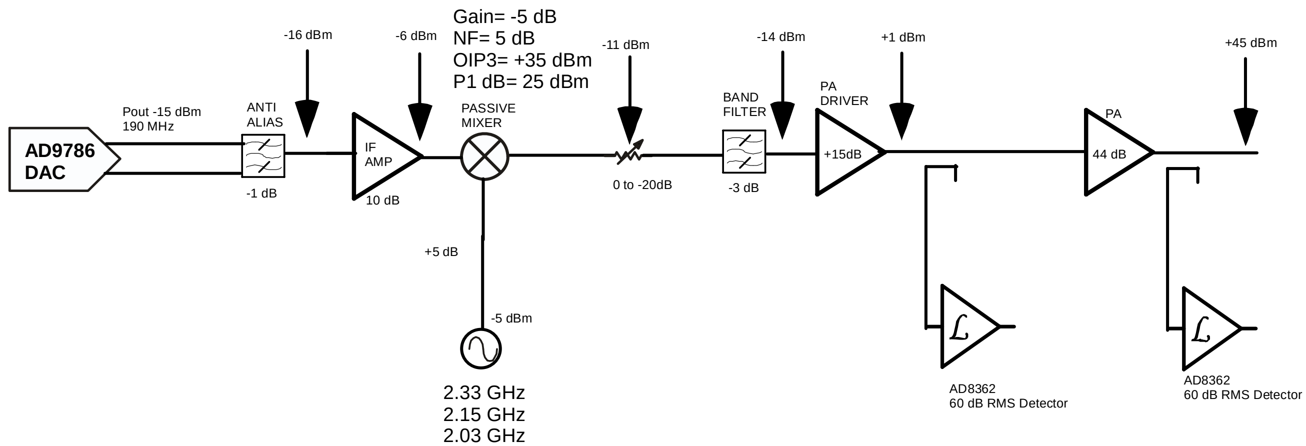
- **Think of a broadband spectrum multiple tones inter-modulating with each other**
- **IM3 products produce Adjacent Channel Power/Leakage/Distortion**
- **Use 3-to-1 decay of IMD products to reduce dBc IMD but this degrades SNR**

ACPR and Noise vs. Output Power



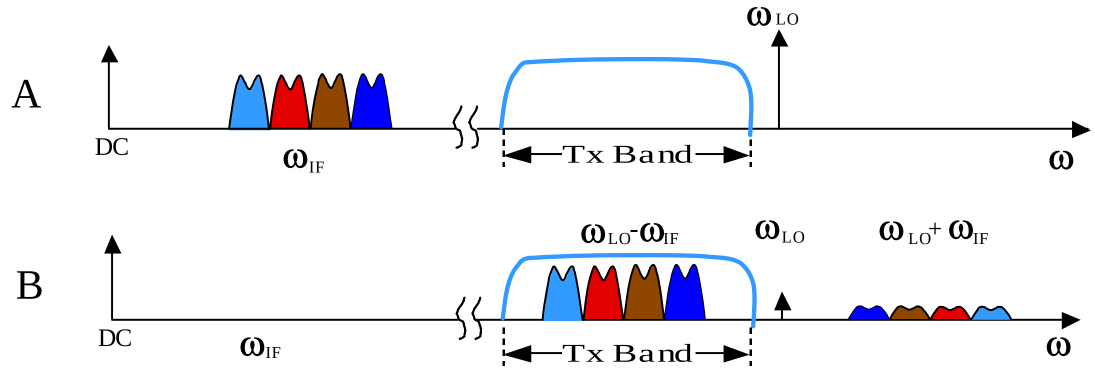
- ❑ **ACP degrades with increased output power due to IMD**
- ❑ **Noise is independent of input and output power**
- ❑ **At low power levels ACP degrades because of falling SNR**

Example: Low IF to RF Transmitter using IF Synthesizing DAC and Passive Mixer



- Baseband DAC, IQ Modulator and PLL are replaced by an IF Synthesizing DAC or DDS modulator
- Trade Off: High Performance DDS/DAC + SAW + Mixer + PLL vs. IQ DAC + Modulator + PLL
- None of the problems typically associated with Direct Conversion
- Probably more expensive than Direct Conversion

Low IF to RF Architecture



- High Performance DAC generates “real” IF at a low IF (100-200 MHz)
- Mixer performs Double Sideband Modulation
- Advantage: Unwanted LO and Sideband are removed -> excellent EVM
- Challenge: To move unwanted LO and upper sideband out of band means that the IF must be quite high