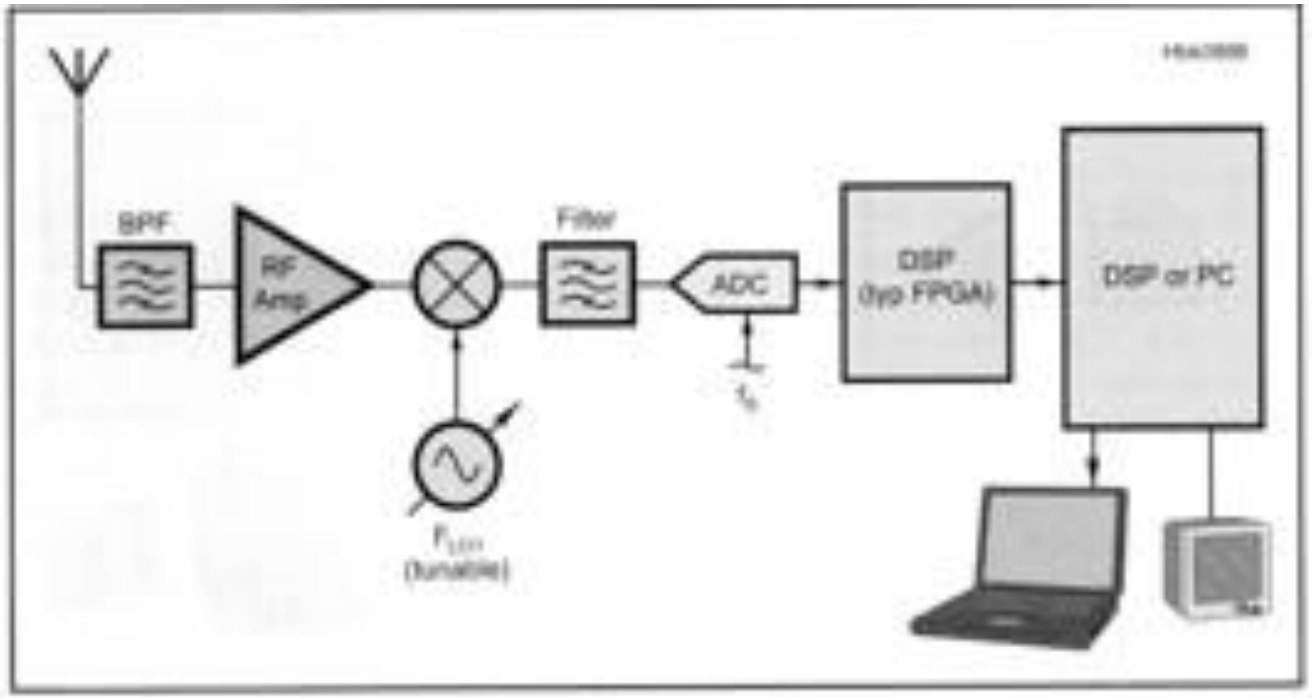
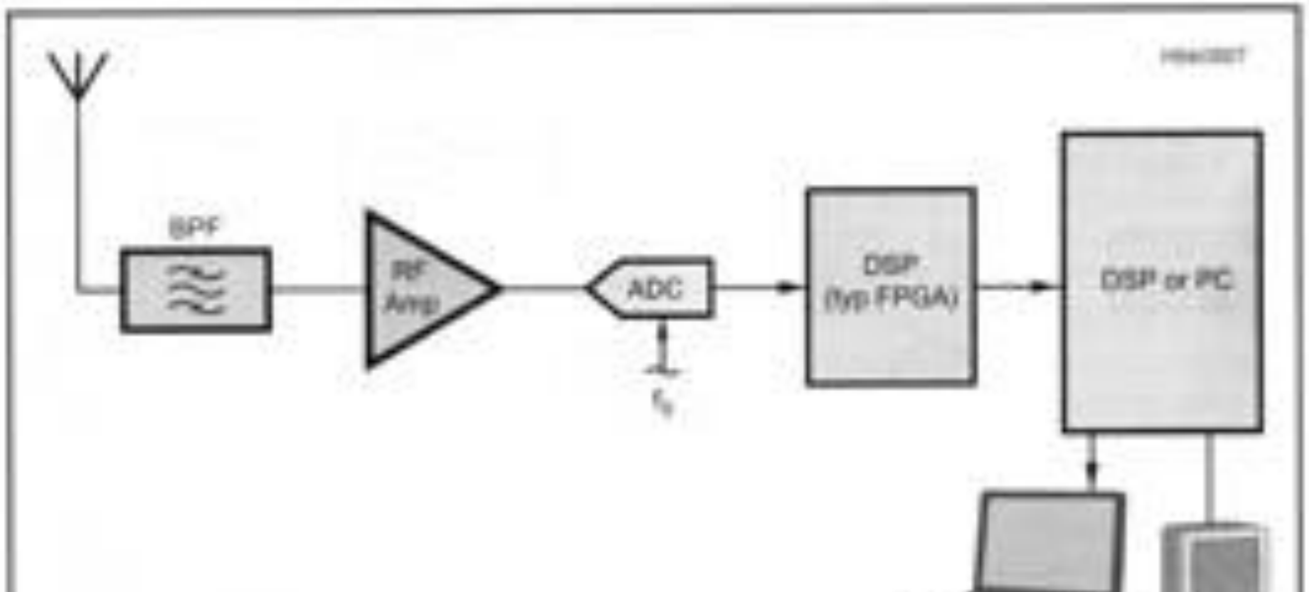


Figure 8.5 — High-IF sampling SDR receiver architecture.



Software Defined Radio Technology

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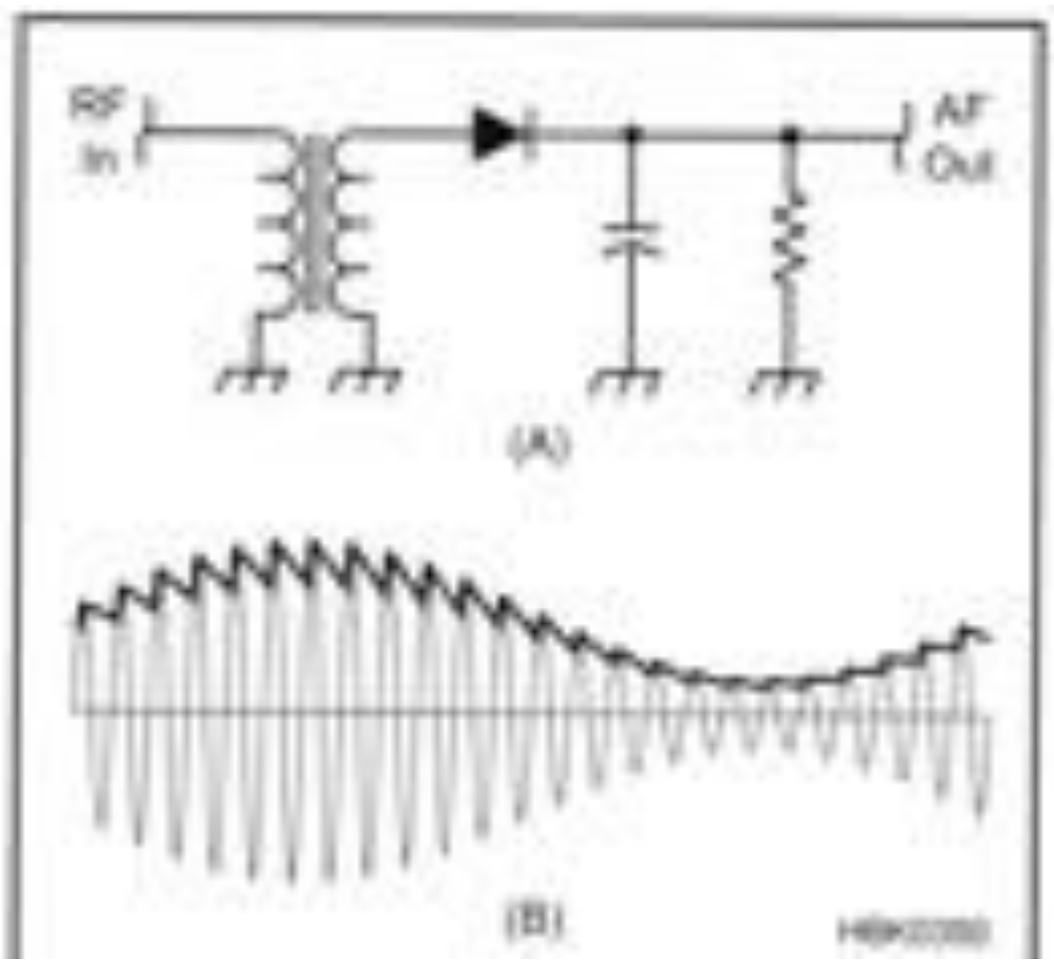
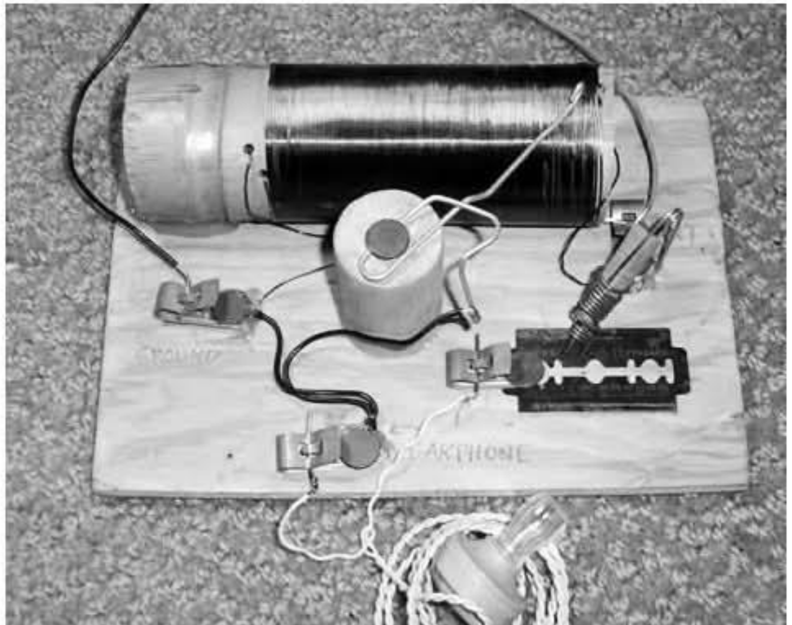
03/11/2025

1940's Sampling Radio – "Crystal Radio

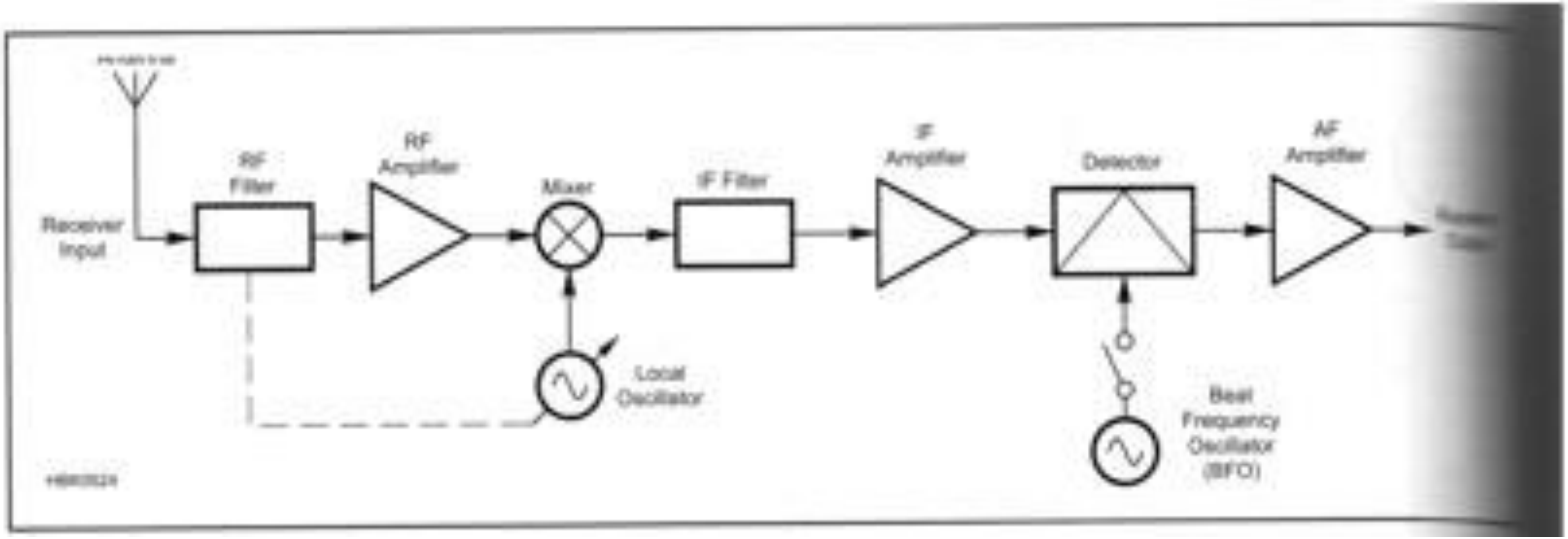


"Crystal" was a primitive form of solid state rectifier

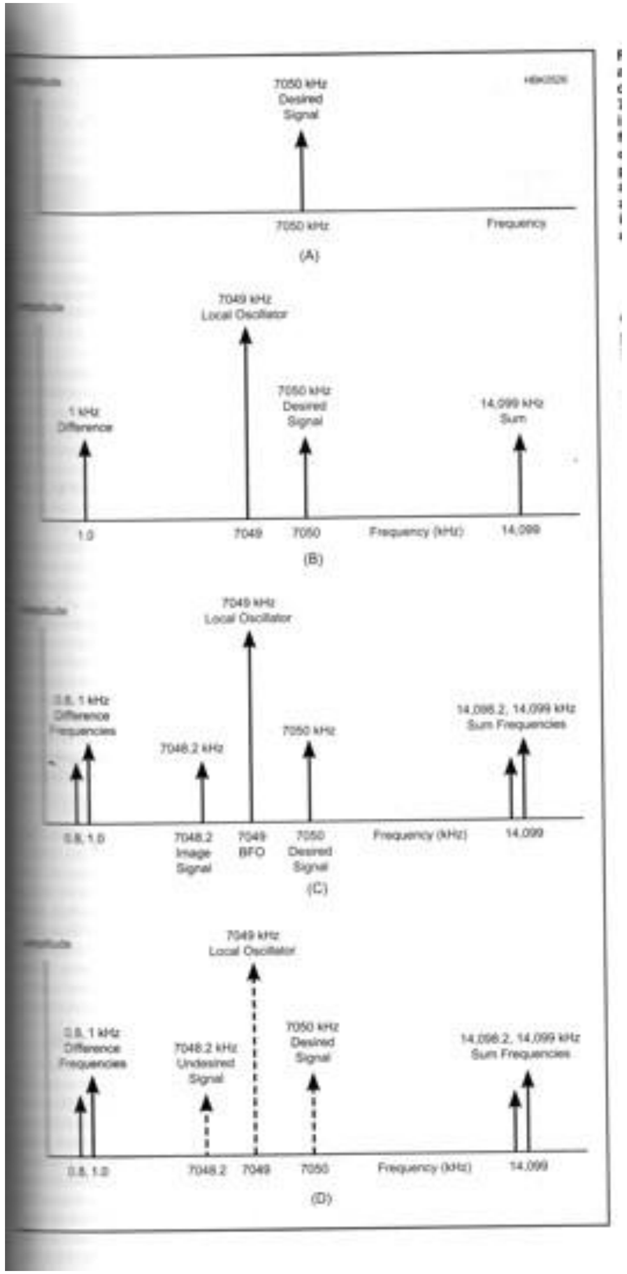
- **Some form of "tuner" might precede the "crystal"**
- **Capacitor held the charge of the most recent sample**
- **Resistor bled off the capacitor so it would charge to match the next sample**
- **High frequency sine wave is the AM carrier signal**
- **Small ups and down is the lower frequency amplitude modulation**
- **This sampling is "ancient" precursor of techniques used in modern SDRs**



Simple, Modern Analog Hetrodyne* AM Receiver

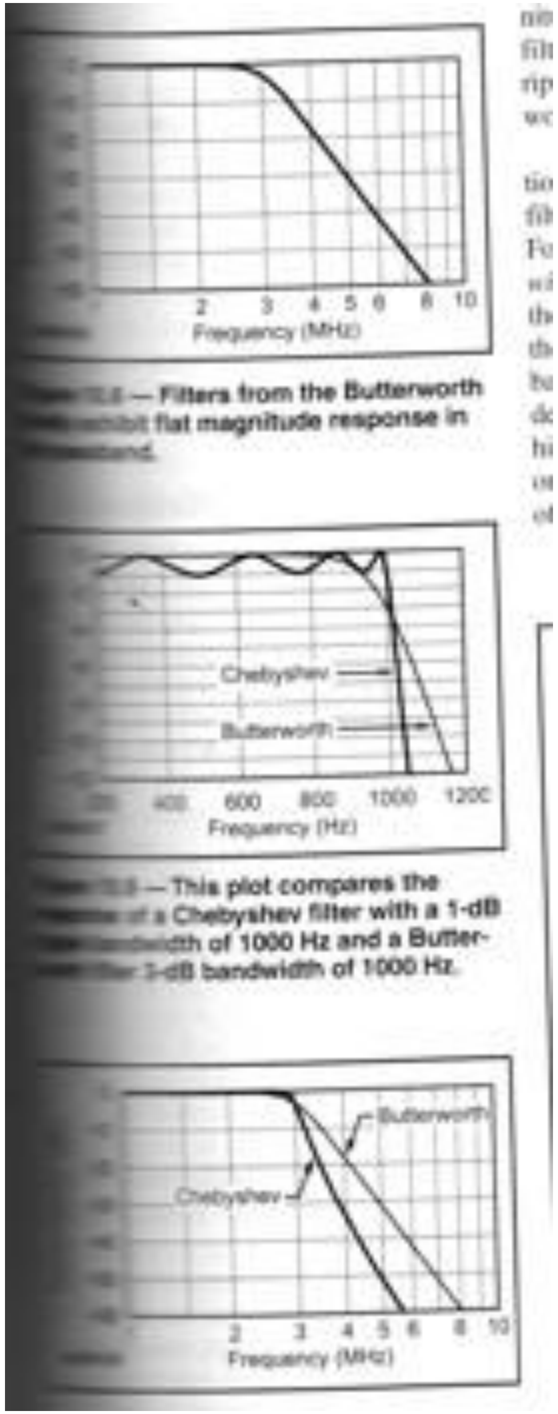


*relating to the production of a lower frequency from the combination of two almost equal high frequencies, as used in radio transmission:



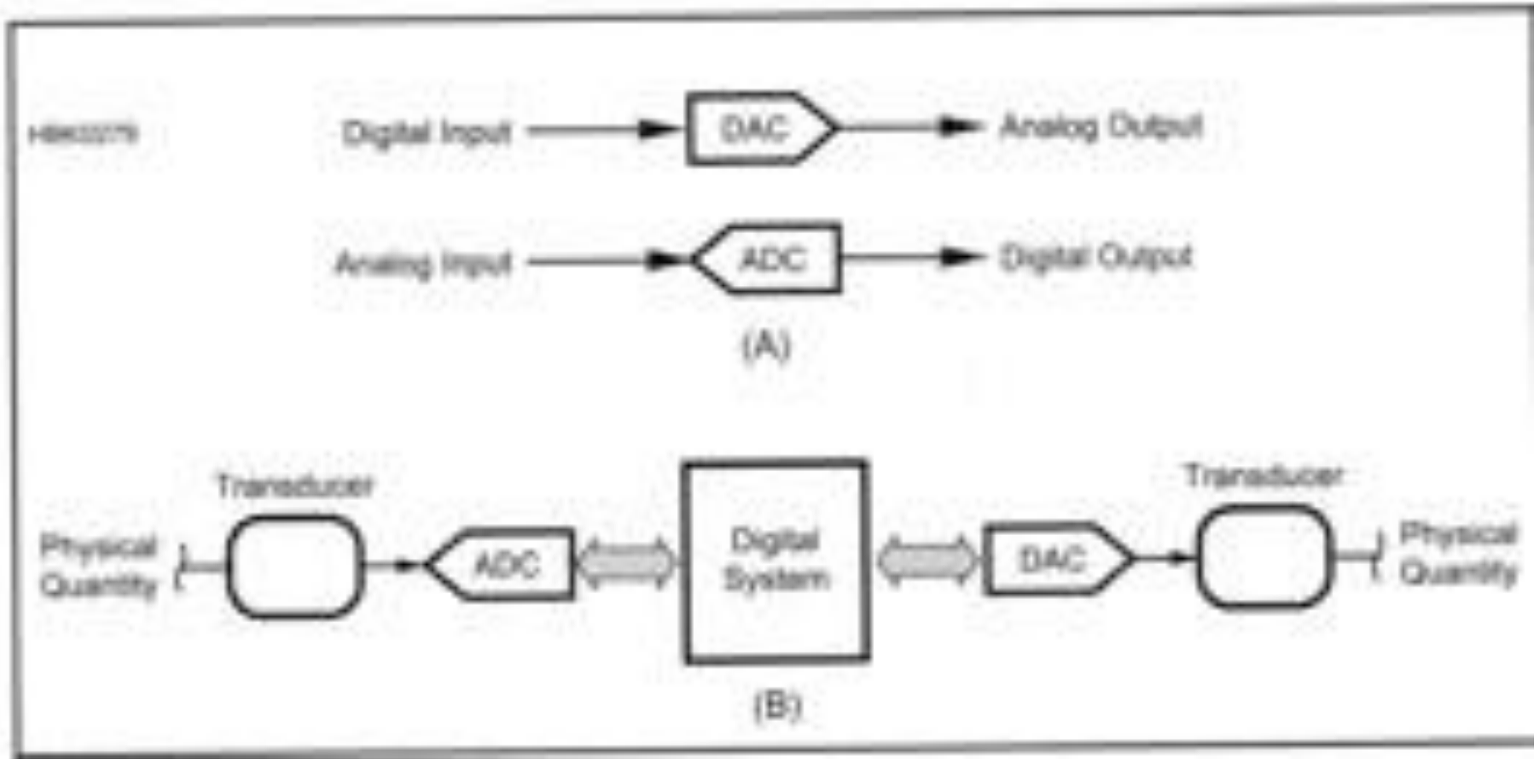
Mixing RF signal with Local Oscillator produces Sum and Difference signals

- Difference is usually the one of interest – down converting signal to Intermediate frequency (IF)
- Same IF for all bands
- Do a bunch of filtering and amplifying once for all bands
- A “Hetrodyne” becomes a “Superhetrodyne” when down coverting happens 2 or more time
- Unwanted sum and diffence signals need to be filtered out or in harmless bands “birdies”



Limits of Analog Superhetrodyne Receivers

- Lots of circuitry for Am vs Fm vs AFSK vs……
- Alignment complexity – all the stages must be on proper frequency
- Not frequency “agile” – lots of circuitry to exactly certain bands
- Filtering is broad, not narrow
  - Analog filters do not have sharp edges, they have broad slopes
  - More expensive crystal filters are better but still broad



- Digital to Analog (DAC) and Analog to Digital (ADC) are the primary components in digital processing of analog radio
- Are digital equivalents of traditional speaker and microphone (signal to sound and sound to signal)
- Such components have been around for ~50 years
- What makes them useful for modern radios is speed and accuracy

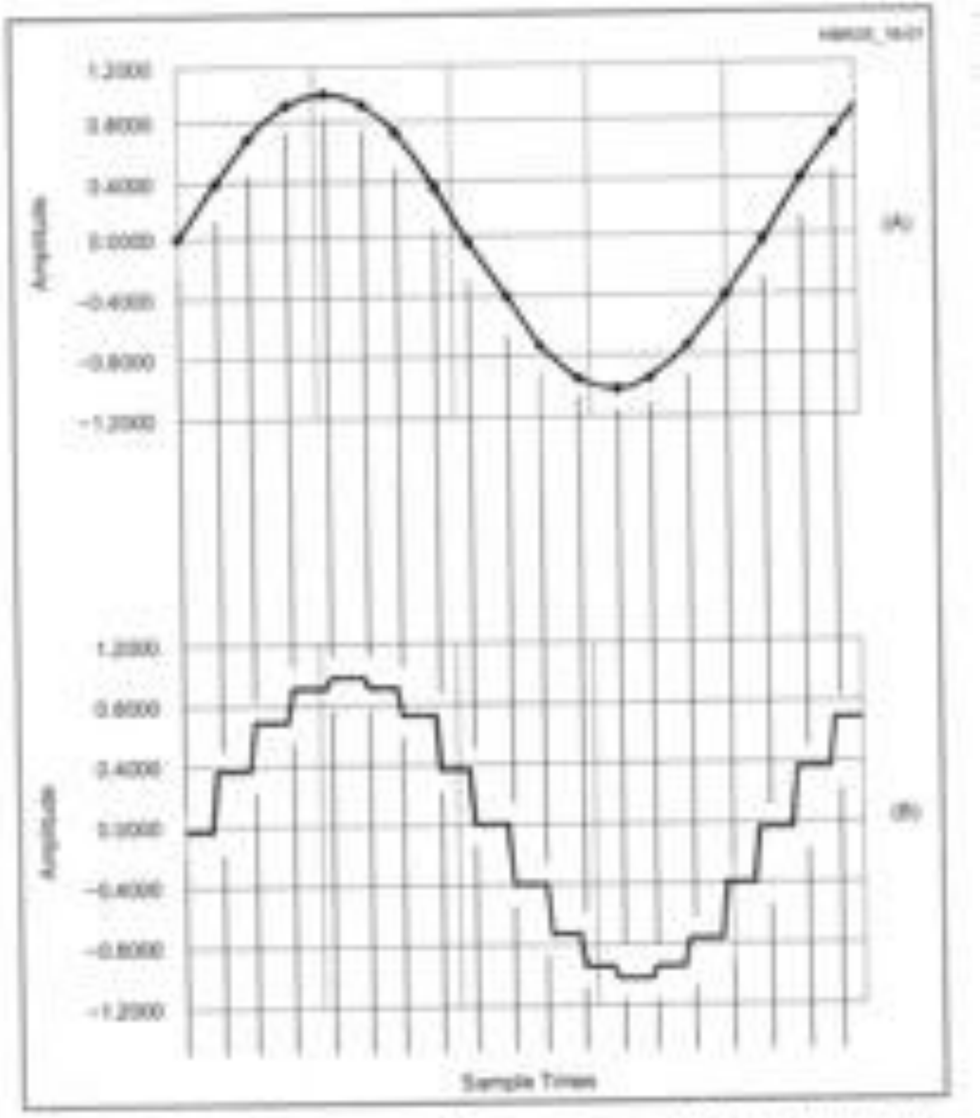


Figure 6.28 — Sine wave of frequency much less than the

- **Digitized Analog Sine Wave of frequency much lower than sampling rate**

- ADCs power is measured by
  - Sampling Rate – how many times per sine wave period is a a sample take
  - How many bits is each sample? – If you are measuring a 1V signal, is each measurement ¼ Volt? 1/8? 1/1000?
  - Lots of complex math to estimate sampling accuracy

Vocabulary of Digital Parts

- Discrete And/Or arrays
  - Parts that do a single and/or/nand function on “N inputs, single output
  - A board full of this stuff can do large combinatorial functions
- Gate Arrays (FPGA)
  - A part with a very large internal array of and/or/nand functions.
  - N inputs and M outputs
  - Many can be field programmed on a special programming fixtures
  - Very large arrays are factory fabricated with specific interconnects
- Programmable Array Logic
  - Typically contains and/or/nand arrays, adders, and registers that can be used to create state machines.

Vocabulary of Digital Parts

- Digital signal processing is the processing of digitized discrete-time sampled signals. Processing is done by general-purpose computers or by digital circuits such as ASICs, field-programmable gate arrays or specialized digital signal processors. Typical arithmetical operations include fixed-point and floating-point, real-valued and complex-valued, multiplication and addition. Other typical operations supported by the hardware are circular buffers and lookup tables. Examples of algorithms are the fast Fourier transform (FFT), finite impulse response (FIR) filter, Infinite impulse response (IIR) filter, and adaptive filters such as the Wiener and Kalman filters.

- Digital Signaling parts may contain and/or/nand logic arrays, general computing power and application specific fixed function circuits. It is not unusual that the compute power is used to configure a data path thru the logic array so that signal is processed in a certain manner until the processor logic chooses to reconfigure it

- 1980s example of signal processing – the ethernet chip. Software can't keep up with ethernet data rates. So, the compute power is used to feed the data path with a list of buffer memory addresses that are to be send or received. Data path logic runs independently from computer power until the buffer list is empty or an exception occurs.

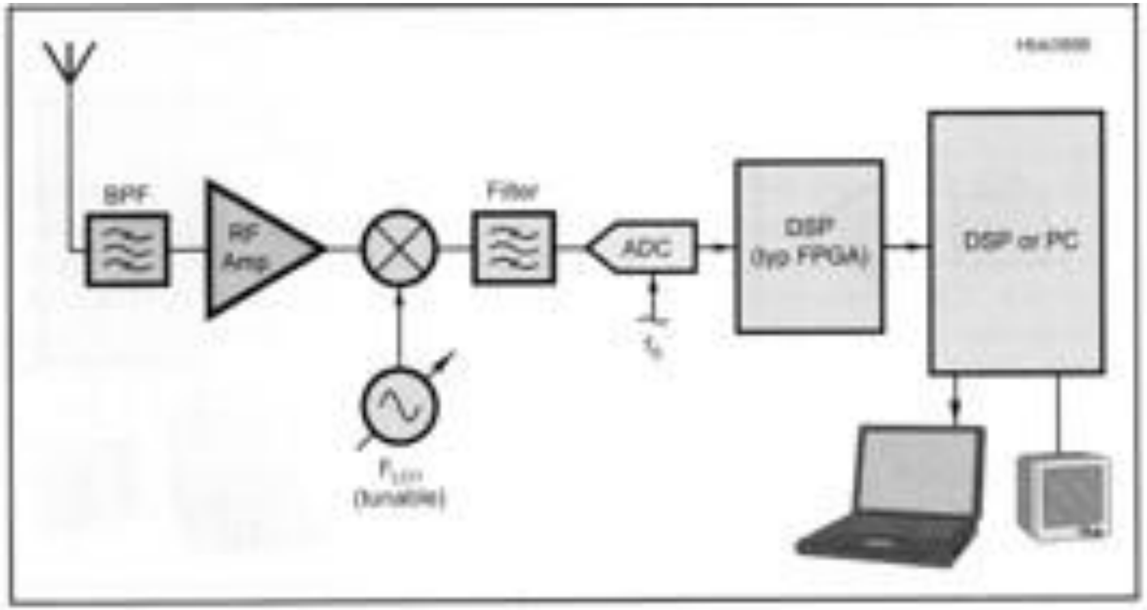


Figure 8.5 — High-IF sampling SDR receiver architecture.

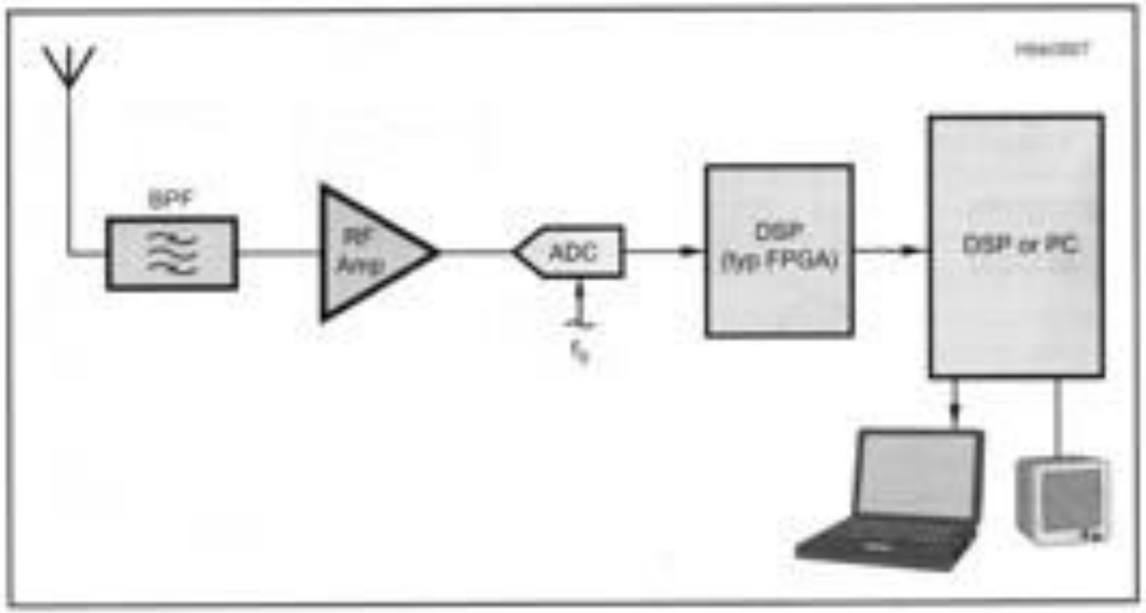
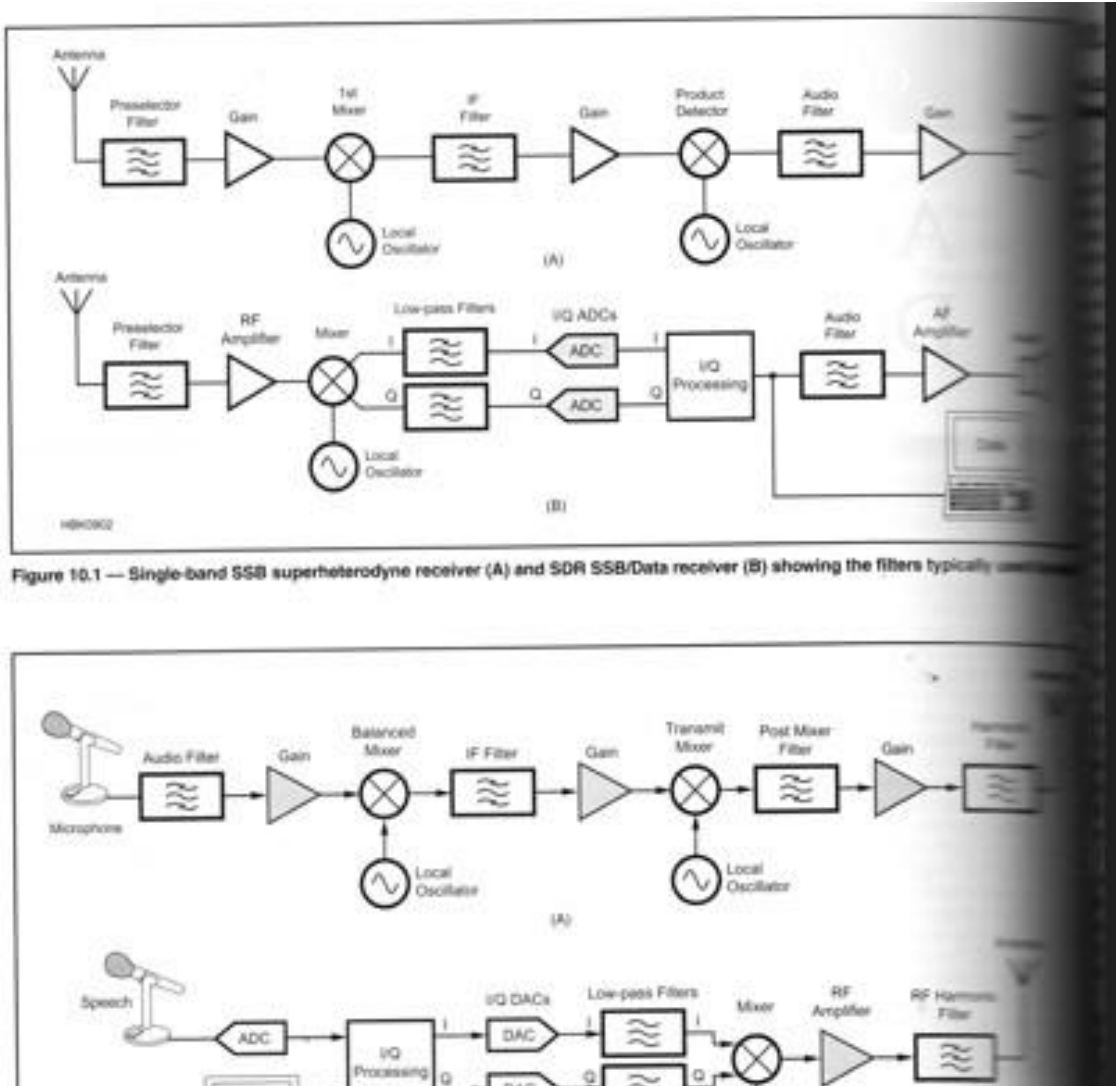


Figure 8.6 — Direct RF-sampling DSP SDR receiver architecture.

Basic SDRs

- IF Sampling
- Direct Sampling
- Compute power is used to demodulate, filter and otherwise transform the data stream
- No array for per-band receiver filters – all done in software.
- Power amplifier for transmit still needs traditional filtering for clean output signal. Computers cannot deal with 100 watt output levels



Radio Design Complexity is Beyond the ability of the average HAM

- Very deep mathematics drives most decisions.
- Nothing changes within a range of frequency changes
- No hardware changes between signaling modes
- Filtering is done in the software. Sharp edges
- Most ham transceivers are hybrid Analog/Digital

I & Q (In Phase and Quadrature) Data

A sinusoid with modulation can be decomposed into, or synthesized from, two amplitude-modulated sinusoids that are in quadrature phase, i.e., with a phase offset of one-quarter cycle (90 degrees or $\pi/2$ radians). All three sinusoids have the same center frequency. The two amplitude-modulated sinusoids are known as the **in-phase** (I) and **quadrature** (Q) components, which describes their relationships with the amplitude- and phase-modulated carrier.[A][2]

Or in other words, it is possible to create an arbitrarily phase-shifted sine wave, by mixing together two sine waves that are 90° out of phase in different proportions.

The implication is that the modulations in some signal can be treated separately from the carrier wave of the signal. This has extensive use in many radio and signal processing applications.[3] I/Q data is used to represent the modulations of some carrier, independent of that carrier's frequency.

FTDX10 SDR

Hybrid SDR configuration inherited from the FTDX101 series

In addition to the narrow band SDR receiver that boasts awesome basic performance, the FTDX hybrid SDR configuration utilizing an integrated direct sampling SDR receiver, which permits visu of the entire band spectrum in real time.
By adopting the hybrid SDR method, and utilizing the features of the direct sampling method, it is to display a wide-view of the information in the entire band in real time, and improve the perforr the complete receiving circuit with the narrow band SDR technology down conversion method.

DNR (Digital Noise Reduction) by DSP digital processing

The incorporated digital noise reduction circuit may be set to the optimal working algorithm by varying the 15 step parameters according to the noise type.

https://www.sdrplay.com/products/
https://www.sdrplay.com/sdruno/

SDRPlay & SDRUNO

Exhaustive features
Takes patience to properly configure

Commercial Motivation For All This

- Every carrier (Verizon, AT&T,…) has own set of frequencies Want one phone that works on all networks. Frequency agile
- Military radar, weapons guidance needs to do complex mathematics in real-time to weapons. Can’t tolerate old style wake up the computer and get more analysis. Analysis must occur on real-time guidance data stream
- Medical image processing requirements are similar to radar example. Doctor’s insertion of a heart valve replacement is not an old xray film. It is real time image processing.
- Ham radio is riding on the coat-tales of this technology, not driving it

Why Do I Care?

- I am a DXCC/Contest/POTA/Antenna/Computer guy, not a radio tech…….
- I buy the best commercial radio I can afford

- I want to be warned about the “buzzword generators”
- I want to pass the Extra Class exam
- I am a generally curious person and want to keep up with technology
- I understand old technology mixers, etc. Now I want to understand the mathematical basis
- I want to buy one of the low-end receivers and play with it
- I expect SDR will be increasingly dominant in “hybrid” transceivers