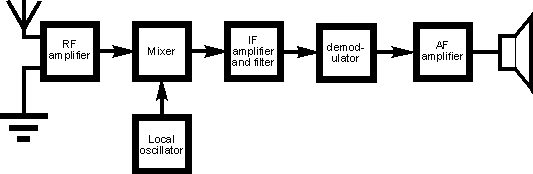
I figured we need a place to start, so that we can understand a little more about how the SDR radios work - I still think it’s magic.

A very simple conventional radio receiver - “modern” radios are typically much more complex than this simple block diagram, but all the important stages are here, and that is the important part.



<http://www.radio-electronics.com/info/rf-technology-design/superheterodyne-radio-receiver/block-diagram.php>

Basic Block Diagram of Basic Superheterodyne Radio Receiver

***Front end amplifier and tuning block:*** Signals enter the front end circuitry from the antenna. This circuit block performs two main functions:

* *Tuning:* Broadband tuning is applied to the RF stage. The purpose of this is to reject the signals on the image frequency and accept those on the wanted frequency. It must also be able to track the local oscillator so that as the receiver is tuned, so the RF tuning remains on the required frequency. Typically the selectivity provided at this stage is not high. Its main purpose is to reject signals on the image frequency which is at a frequency equal to twice that of the IF away from the wanted frequency. As the tuning within this block provides all the rejection for the image response, it must be at a sufficiently sharp to reduce the image to an acceptable level. However the RF tuning may also help in preventing strong off-channel signals from entering the receiver and overloading elements of the receiver, in particular the mixer or possibly even the RF amplifier.
* *Amplification:* In terms of amplification, the level is carefully chosen so that it does not overload the mixer when strong signals are present, but enables the signals to be amplified sufficiently to ensure a good signal to noise ratio is achieved. The amplifier must also be a low noise design. Any noise introduced in this block will be amplified later in the receiver
* ***Mixer / frequency translator block:*** The tuned and amplified signal then enters one port of the mixer. The local oscillator signal enters the other port. The performance of the mixer is crucial to many elements of the overall receiver performance. It should eb as linear as possible. If not, then spurious signals will be generated and these may appear as 'phantom' received signals.
* ***Local oscillator:*** The local oscillator may consist of a variable frequency oscillator that can be tuned by altering the setting on a variable capacitor. Alternatively it may be a frequency synthesizer that will enable greater levels of stability and setting accuracy.
* ***Intermediate frequency amplifier, IF block :*** Once the signals leave the mixer they enter the IF stages. These stages contain most of the amplification in the receiver as well as the filtering that enables signals on one frequency to be separated from those on the next. Filters may consist simply of LC tuned transformers providing inter-stage coupling, or they may be much higher performance ceramic or even crystal filters, dependent upon what is required.
* ***Detector / demodulator stage:*** Once the signals have passed through the IF stages of the superheterodyne receiver, they need to be demodulated. Different demodulators are required for different types of transmission, and as a result some receivers may have a variety of demodulators that can be switched in to accommodate the different types of transmission that are to be encountered. Different demodulators used may include:
  + *AM diode detector:* This is the most basic form of detector and this circuit block would simple consist of a diode and possibly a small capacitor to remove any remaining RF. The detector is cheap and its performance is adequate, requiring a sufficient voltage to overcome the diode forward drop. It is also not particularly linear, and finally it is subject to the effects of selective fading that can be apparent, especially on the HF bands.
  + *Synchronous AM detector:* This form of AM detector block is used in where improved performance is needed. It mixes the incoming AM signal with another on the same frequency as the carrier. This second signal can be developed by passing the whole signal through a squaring amplifier. The advantages of the synchronous AM detector are that it provides a far more linear demodulation performance and it is far less subject to the problems of selective fading.
  + *SSB product detector:* The SSB product detector block consists of a mixer and a local oscillator, often termed a beat frequency oscillator, BFO or carrier insertion oscillator, CIO. This form of detector is used for Morse code transmissions where the BFO is used to create an audible tone in line with the on-off keying of the transmitted carrier. Without this the carrier without modulation is difficult to detect. For SSB, the CIO re-inserts the carrier to make the modulation comprehensible.
  + *Basic FM detector:* As an FM signal carries no amplitude variations a demodulator block that senses frequency variations is required. It should also be insensitive to amplitude variations as these could add extra noise. Simple FM detectors such as the Foster Seeley or ratio detectors can be made from discrete components although they do require the use of transformers.
  + *PLL FM detector:* A phase locked loop can be used to make a very good FM demodulator. The incoming FM signal can be fed into the reference input, and the VCO drive voltage used to provide the detected audio output.
  + *Quadrature FM detector:* This form of FM detector block is widely used within ICs. IT is simple to implement and provides a good linear output.
* ***Audio amplifier:*** The output from the demodulator is the recovered audio. This is passed into the audio stages where they are amplified and presented to the headphones or loudspeake

This is a somewhat simplified block diagram of a typical Software Defined Radio, again, from what I read, there is a little more going on, but all of the important parts are here.

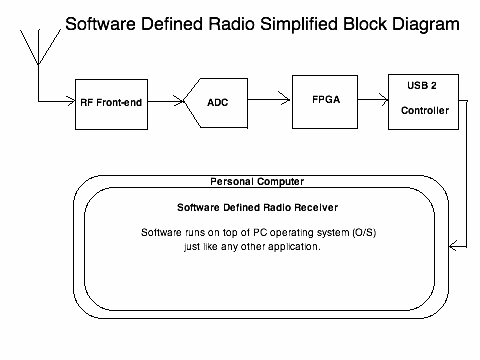
and in a true SDR you are left with an antenna, a front end, and at least one A2D - and (maybe) at least one D2A converter. -- The mixer, IF amp, demodulator, and AF amp are all done in software

I did find a site that explained the A2D pretty well, but I’ve since lost that site, have no idea where it went.

It explained of course the sine wave on the antenna - gets converted to a digital representation, of lines, the lines are put together to form something that looks like a modulated square wave.

The information contained in the sine wave is still present in the square wave. and that is how it works - like I said - Magic.

<http://www.hamradiosecrets.com/ham-radio-receiver.html>



First, as with any other radio receiver, the antenna is connected to the SDR's "hardware" **RF front-end**. Its purpose is to...

1. Interface *physically* with the antenna for optimum RF energy transfer to the receiver.
2. Serve as low-pass or band-pass filter.
3. Amplify the signals.
4. Convert the frequency of signals down to an intermediate frequency (IF) suitable for the ADC stage that follows.

The amplified IF analog signal produced by the RF front-end is fed to an analog-to-digital-converter (ADC).

The digital output of the ADC is then fed to a *Field Programmable Gate Array* (FPGA).

1. The FPGA extracts the "I" and "Q" components of the signal.
2. The "I" and "Q" signal pair is called a *complex signal*. It is produced in the FPGA by two frequency mixers having a phase shift of 90° between them.
3. The I/Q output of the FPGA is then fed to the USB 2 programmable controller.
4. The *software defined radio*, running on the PC, takes its I/Q data from the USB 2 controller. The SDR software...
5. a) extracts the information from the signal for audio output;
6. b) displays a graphical user interface giving the user access to control functions and a variety of selectable visual outputs.

All of the signal demodulation and spectral functions are done **by the SDR software on your PC**.

Most SDR ham radio receiver implementations will usually (at least) support AM, WFM, USB, LSB, N-FM, DSB and CW with fully adjustable DSP filter bandwidths ... down to below 1 Hz in some cases!

The SDR is hosted by the O/S of your computer, just like any other application. The majority of the SDR implementations run on some flavor of Microsoft Windows®.

However, an increasing number of SDR projects are now turning to the ***Linux open source operating system*** which offers...

* much faster signal handling and process-to-process communications,
* far greater stability,
* much more flexibility.

Different Info found here, basically the same, but explains SDR as a Dual SuperHetr (so it shows where I and Q come from)

<http://www.cvarc.org/new-wp/download/technical/IntroToSDR.pdf>

Terms to Know:

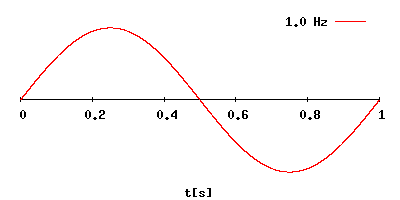
Intermediate-Frequency (IF) - frequency to which a carrier frequency is shifted as an intermediate step in transmission or reception. Created by mixing the carrier signal with a local oscillator.

Audio Frequency (AF) - an Audible Frequency - something we can hear usually 20 to 20,000 Hz

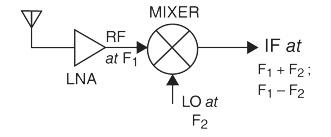
Hertz - Unit of frequency defined as one cycle per second. Named after Heinrich Rudolf Hertz, the first person to provide conclusive proof of the existence of electromagnetic waves.

(Kilohertz kHz 10^3Hz), (Megahertz MHz 10^6Hz), (Gigahertz GHz 10^9Hz) and (Terahertz THz 10^12Hz)

One hertz simply means "one cycle per [second](http://en.wikipedia.org/wiki/Second)" (typically that which is being counted is a complete cycle); 100 Hz means "one hundred cycles per second", and so on. The unit may be applied to any periodic event—for example, a clock might be said to tick at 1 Hz, or a human heart might be said to [beat](http://en.wikipedia.org/wiki/Heart_rate) at 1.2 Hz. The rate at which aperiodic or [stochastic](http://en.wikipedia.org/wiki/Stochastic) events (such as [radioactive decay](http://en.wikipedia.org/wiki/Radioactive_decay)) occur is expressed in [becquerels](http://en.wikipedia.org/wiki/Becquerel), not hertz. Whereas 1 Hz is 1 [cycle per second](http://en.wikipedia.org/wiki/Cycle_per_second), 1 Bq is 1 aperiodic event per second. The phrase **inverse second** (1/s or s−1) is associated with both.



Mixer - Critical stage of RF signal chain in a Superheterodyne receiver, it allows the receiver to be tuned across a wide band of interest, then translates the desired, arbitrary received signal frequency to a known, fixed frequency, allowing the signal of interest to be processed, filtered and demodulated.



BFO (Beat Frequency oscillator) - dedicated oscillator used to create an audio frequency signal from Morse code (CW) transmissions to make them audible. They are also used in SSB, being able to replace the missing carrier wave

VFO

Modulation - process of varying one or more properties of a periodic waveform called the carrier signal, with a modulating signal that typically contains information to be transmitted.

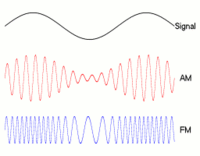
Modulator - a device that performs modulation.

Demodulator/Detector - a device that performs demodulation (The inverse of modulation)

(In computer world we would think of a MoDeM or Modulator/DeModulator - It converts signals that can’t be heard or sent over wires, to signals that can be heard and sent over wires. In radio - remove the wires)

AM - Amplitude Modulations a type of Analog modulation - defined by the Amplitude of the carrier signal. Looks like a sine wave.

FM - Frequency Modulation - The Frequency of the carrier signal is varied in accordance to the instantaneous amplitude of the modulation signal - type of Analog modulation



Side Band (or Single Sideband) SSB - two types with a carrier (SSB) or without a carrier (SSB-SC) - type of AM, that uses transmitter power and bandwidth more efficiently, But does make the transmitter and receiver more complex. I couldn’t find a simple explanation of this, I couldn’t find the way it was explained to me a very long time ago - what I did find was a bunch of complicated math - that comes down to how it was explained to me years ago.

AM - Sinewave - most useful information is in the TOP or BOTTOM of the wave - send the signal through a bunch of filters to drop either the lower or the upper portion of the sine, then send to more filters so you just are left with the peak. Send to the final, and do the reverse to demodulate it. (Upper Side Band USB, Lower Side Band LSB) with the peaks containing the most useful information.

CW - Continuous Wave, Morse Code, Telegraphy (Radio Telegraphy) Earliest forms of digital communications with it being either on or off (1 or Zero), it constant of both a amplitude and a frequency. There is also a Modulated CW which has a tone modulated with the signal.

Local oscillator (LO) - electronic **oscillator** used with a mixer to change the frequency of a signal. This frequency conversion process, also called heterodyning, produces the sum and difference frequencies from the frequency of the **local oscillator** and frequency of the input signal.

I Signal - In-Phase components of a signal

Q Signal - Quadrature components of a signal

x(t) = I(t) + jQ(t)

x(t) can therefore be represented as a vector with magnitude and phase angle.

Phase angle is not absolute, but relates to some arbitrary reference

(DSP relies heavily on I and Q signals for processing)

and Here is some more of that math/radio theory we all love

<http://www.csun.edu/~skatz/katzpage/sdr_project/sdr/IandQ%20_and_Sideband_7_10.pdf>

Digital Controlled Oscillator (DCO) - combination of a voltage-controlled oscillator driven by a control signal from a digital to analog converter. VCO - is an electronic oscillator whose oscillation frequency is controlled by a volltage. The applied input voltage determines the instantaneous oscillation frequency. Consequently modulating signals applied to control input may cause FM or (PM) phase modulation. A VCO may also be part of a phase-locked loop.

DSP Digital Signal Processor - (math) mathematical manipulation of an inormation signal to modify or improve it in some way. It is characterized by the representation of discrete time, discrete frequency, or other discrete domain signals by a sequence of numbers or symbols and the processing of these signals.

The goal of DSP is usually to measure, filter and/or compress continuous real-world analog signals.

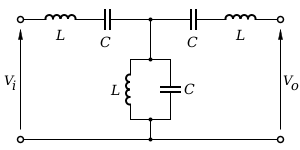
Carrier Signal - or Carrier Wave - sometimes just carrier - is a waveform (usually sinusoidal) that is modulated with an input signal for the purpose of conveying information. Carrier waves is usually a much higher frequency that the input signal. The purpose of the carrier is usually to transmit information through space as an electromagnetic wave (radio communication), or to allow serveral carriers at different frequencies to share a common physical transmission medium by frequency division multiplexing (cable TV). Could also be used for an unmodulated emission. The frequency of a radio or television station is actually the carrier waves center frequency

Center Frequency -

<http://en.wikipedia.org/wiki/Center_frequency>

Band Pass Filter - Filter that passes frequencies within a certain range and rejects frequencies outside that range.

Here comes that magic Q again - A band-pass filter can be characterised by its Q factor. The Q-factor is the inverse of the fractional bandwidth. A high-Q filter will have a narrow passband and a low-Q filter will have a wide passband. These are respectively referred to as narrow-band and wide-band filters.



High Pass Filter - filter that passes signals with a frequency higher than a certain cutoff frequency and attenuates signals with frequencies lower than the cutoff frequency.

Low Pass Filter - filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency.

Narrow Band - In radio, **narrowband** describes a channel in which the bandwidth of the message does not significantly exceed the channel's coherence bandwidth.

In the study of wired channels, *narrowband* implies that the channel over consideration is sufficiently narrow that its frequency response can be considered flat. The message bandwidth will therefore be less than the coherence bandwidth of the channel. That is, no channel has perfectly flat fading, but the analysis of many aspects of wireless systems is greatly simplified if flat fading can be assumed.

<http://en.wikipedia.org/wiki/Narrowband>

Wide Band - when the message bandwidth significantly exceeds the coherence bandwidth of the channel. Some communication links have such a high data rate that they are forced to use a wide bandwidth; other links may have relatively low data rates, but deliberately use a wider bandwidth than "necessary" for that data rate in order to gain other advantages

Bandwidth - difference between the upper and lower frequencies in a continuous set of frequencies. It is typically measured in hertz, and may sometimes refer to *passband bandwidth*, sometimes to *baseband bandwidth*, depending on context. **Passband bandwidth** is the difference between the upper and lower cutoff frequencies of, for example, a bandpass filter, a communication channel, or a signal spectrum. In the case of a low-pass filter or baseband signal, the bandwidth is equal to its upper cutoff frequency.

phase-lock loop (PLL) -is a control system that generates an output signal whose phase is related to the phase of an input signal. While there are several differing types, it is easy to initially visualize as an electronic circuit consisting of a variable frequency oscillator and a phase detector. The oscillator generates a periodic signal. The phase detector compares the phase of that signal with the phase of the input periodic signal and adjusts the oscillator to keep the phases matched. Bringing the output signal back toward the input signal for comparison is called a feedback loop since the output is 'fed back' toward the input forming a loop.

Types of Modulation: AM, FM, CW, USB, LSB, Pulse Modulation, PSK, FSK, ASK, QAM and more)

Hertz Conversion

<http://www.rapidtables.com/convert/frequency/hz-to-mhz.htm>

## How to convert hertz to megahertz

1Hz = 0.000001MHz

or

1MHz = 1000000Hz

#### **Hertz to megahertz formula**

The frequency *f* in megahertz (MHz) is equal to the frequency *f* in hertz (Hz) divided by 1000000:

*f*(MHz) = *f*(Hz) / 1000000

#### **Example**

Convert 300 hertz to megahertz:

*f*(MHz) = 300Hz / 1000000 = 0.0003MHz

More SDR Stuff

<http://www.jlrg.org/docs/presentations/Intro%20to%20the%20RTL-SDR%20-%20KF4OD.pdf>

What can SDR do for me?

Perform the modulation/demodulation for ALL the modes (Including NEW Modes not even thought of yet - the software handles it all) NFM, WFM, AM, SSB, CW, etc

Work Satellites with auto adjustment for Doppler, receive Images from weather satellites

Visually see a large portion of the RF spectrum.

Support any future mod/demod with just a software update, can help with various experiments/advances without having to physically build circuits.

And a whole lot more - Ham’s have found a bunch of different uses for low cost SDR radios, everything from getting pictures from space to tracking a aircraft, boat or car

and stuff in between.

Many of the current radios on the market have at least some component of a SDR in them.

Read a bit on this subject I found that software has been used for radio (at least in some way or another) since the late 70s. Reading I realized that both my hand-held radios, and probably my car stereo are more software that I first thought. Thou, in all those cases the software doesn’t define them, but controls the hardware. In otherwords, I could not pull my car stereo out and reprogram it for a different band, or to receive SSB. It’s hardware defines what it can and cant do. The Software just makes it work.

Both of my hand-held radios are the same way, I can’t modified the software to say add a new mode, or add need frequency to the radios. The D-Star radio probably is much closer to a software defined radio, and yet it still relies heavy on the hardware that is in it.

I see as the price of these cheap (Under $100 - $200 dollar) SDRs continue to drop, more and more handheld radios will be made that are full SDR radios.

That’s my 2 cents.