Continuous Wave Radar

CW radar sets transmit a high-frequency signal continuously. The echo signal is received and processed permanently. One has to resolve two problems with this principle:

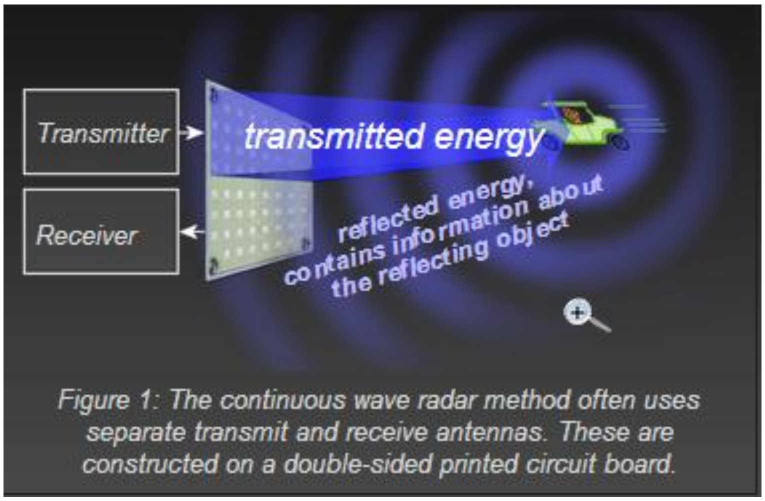

Figure 1: The continuous wave radar method often uses separate transmit and receive antennas. These are constructed on a double-sided printed circuit board.

- prevent a direct connection of the transmitted energy into the receiver (feedback connection),
- assign the received echoes to a time system to be able to do run time measurements.

A direct connection of the transmitted energy into the receiver can be prevented by:

- spatial separation of the transmitting antenna and the receiving antenna, e.g. the aim is illuminated by a strong transmitter and the receiver is located in the missile flying direction towards the aim;

- Frequency dependent separation by the Doppler-frequency during the measurement of speeds.

A run time measurement isn't necessary for speed gauges, the actual range of the delinquent car doesn't have a consequence. If you need range information, then the time measurement can be realized by a frequency modulation or phase keying of the transmitted power.

A CW-radar transmitting a unmodulated power can measure the speed only by using the Doppler- effect. It cannot measure a range and it cannot differ between two or more reflecting objects.

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When an echo signal is received, then that is the proof that there is an obstacle in the propagation direction of the electromagnetic waves. Specific properties of the obstacle can be concluded on properties of the received echo signal. For example, the echo signal is dependent in its strength of how big is the obstacle. In addition, the strength of the echo signal is an indication whether this obstacle is far away or is close to the radar.

(Unfortunately, in this context, a measurement result of the distance is not possible, since the strength of the echo signal depends on many factors.) A change in the frequency spectrum, however, is a more secure characteristic for specific properties. Thus, in the reflection at certain materials may occur even harmonics of the carrier frequency. This is specifically exploited in a so-called “harmonic radar”. Based on these materials, which are incorporated, for example, in protective clothing or shoes, spilled persons can be found in snow avalanches. The most widely used spectral change however, is caused by the Doppler Effect.

Doppler Radar

An unmodulated continuous wave radar transmits a constant frequency with constant amplitude. The received echo signal has either also exactly this frequency, or the echo signal is reflected on a moving with a radial velocity of reflector and is then shifted by the amount of Doppler frequency. CW radar devices that are dedicated to the processing of these Doppler frequency, referred to Doppler radar.

A runtime measurement is not required for a speed measurement using a Doppler radar because no distance determination is made. When a runtime measurement is required then it can be made by modulating the transmit signal to get a time reference of the received echoes. This modulation, i.e. the time of the change of the transmit signal in frequency or amplitude may be registered after the runtime in the receiver. Thus, a time measurement is possible. By such a modulation, however, arise other radar classes that use completely different measuring principles (for example, by frequency modulation, CW radar changes to FMCW Radar). Amplitude modulation is likewise conceivable, and would lead to a pulse radar with a modulation depth of 100%. CW-radar which radiates a non-modulated oscillation can only detect the velocity of an object using the Doppler effect. It can not determine distances or distinguish different aims.

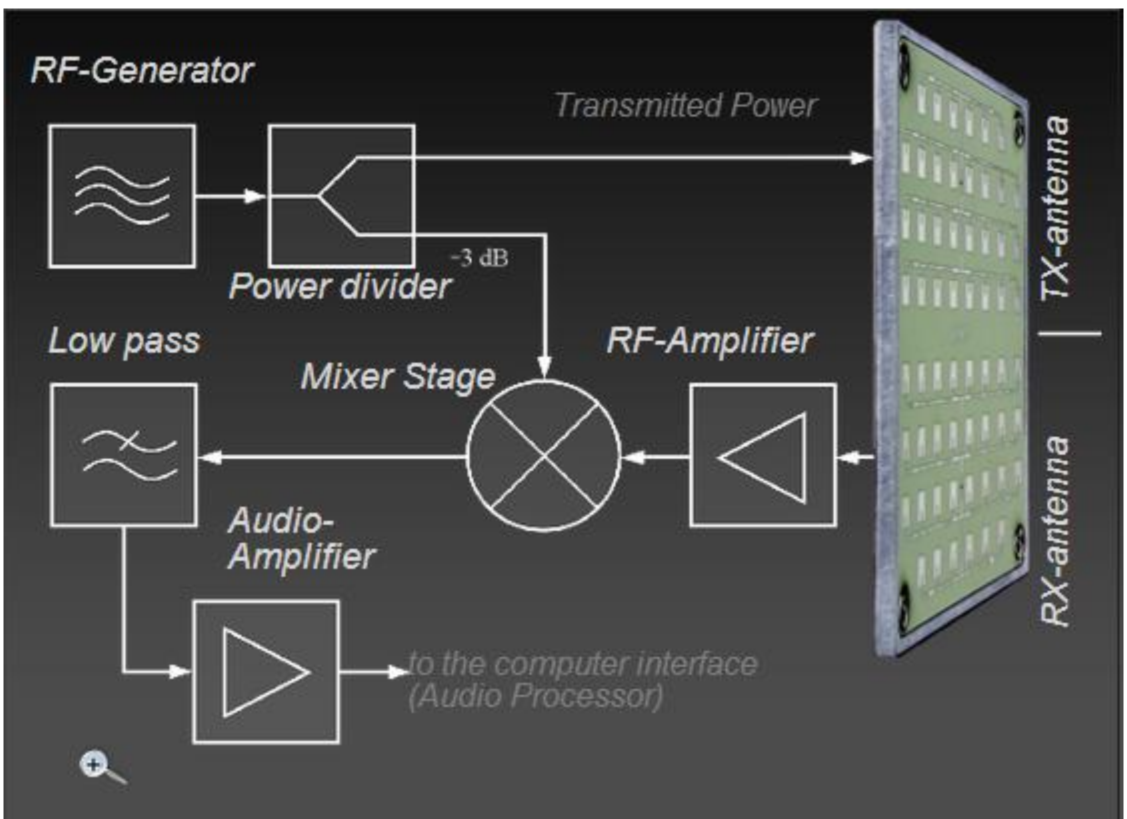

Figure 2: Block diagram of a simple radar transceiver using direct downconversion (interactive picture)

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Block diagram of CW radar

Direct conversion receiver

The structure of a Doppler radar for velocity measurements is very simple. The whole circuit of transmitter and receiver can be made with semiconductor devices on a substrate as an integrated component. This device is usually called transceiver, a portmanteau of the words Transmitter and Receiver. In many cases, this transceiver is already provided with the needed antennae. Mostly these antennas are on a double sided printed circuit board realized patch antennas, or (for larger bandwidths) small horn antennas.

In a direct conversion receiver (or referred to homodyne receiver), the echo signal is not converted to an intermediate frequency, but the high frequency generated in the transmitter is also used directly for downconversion. The output of the mixer stage is then located in the baseband, and is therefore free from any carrier frequency. In order to downconvert the echo signal, the used mixers require a local oscillator power of about 7 dBm usually. Thus here the power of the RF generator is set of 10 dBm. Since the power divider has a minimum attenuation of -3 dB, the transmission power of at least 6 dBm is given for the entire module then. Though the output signal is now at baseband, the output is often still referred to as the “IF”, which suggests an intermediate frequency. The Doppler frequency is but mostly in the audible range. Strong fixed target echoes appear at this output as a DC voltage, when this DC voltage is not blocked by, for example, coupling capacitors as a high pass. Usually such circuitry action is carried out also for the prevention of cross-talk from the transmitting antenna to the receiving antenna.

The maximum possible radial velocity v shall be calculated for a Doppler radar in K–Band, ($\lambda \approx$ 12 mm) used as motion detector. How quickly may be moved a reflector in order to process the echo signal with a stereo audio processor a commercial sound card? (f_{cut}= 18 kHz = maximum f_D)

In radar, the Doppler frequency is calculated according to:

$$f_D = 2 \cdot v / \lambda$$

fD = Doppler frequency [Hz]

λ = the wavelength of the transmitted frequency [m]

v = radial velocity [m/s]

This equation converted after v and entered the given values:

v = λ · fD / 2 = 12 mm· 18 kHz / 2 = 108 m/s ≈ 380 km/h

With this configuration, a maximum of 380 km/h can be measured, which includes most use cases for a simple motion detector.

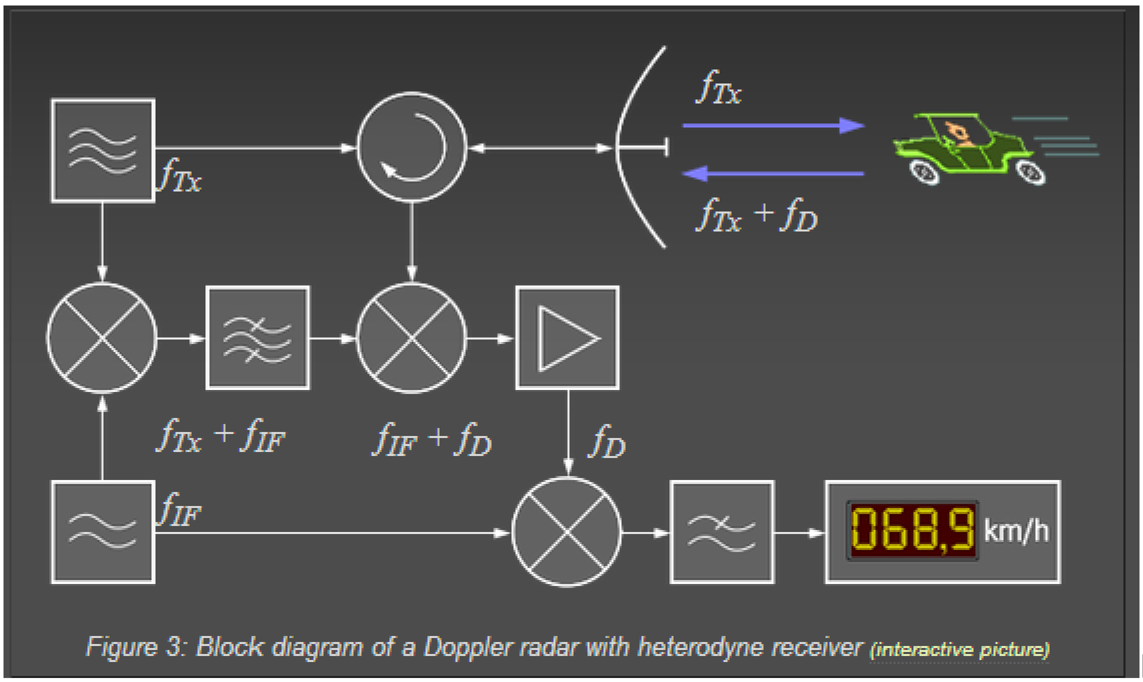

Figure 3: Block diagram of a Doppler radar with heterodyne receiver (interactive picture)

Superheterodyne

By direct mixing, the sensitivity is limited. Thus, the flicker noise of the mixer is given along with the output signal, ie, the Doppler frequency is superimposed with a random distribution of low-frequency noise. Very weak signals and low Doppler frequencies cannot be evaluated so often.

A significant improvement in sensitivity may provide at this point a superheterodyne receiver. The echo signals are converted first in a region which is well above the flicker noise. This flicker noise of the first mixer stage cannot pass through the band-pass filter of the intermediate frequency amplifier. Simultaneously, the echo signal is amplified by about 30…40 dB. Only in the second mixer, the echo signal is converted into the baseband. Since the amplified echo signal is now much larger than the flicker noise of the second mixing stage, this noise of the second mixer can be ignored.

In this example, only a single antenna for transmission and reception is used. The separation of the transmission energy of the received energy is performed with a circulator. The local oscillator frequency for the superheterodyne receiver is generated here by an upward mixing followed by narrow-band filter. As an evaluation of the velocity, a counter is used herein. So that only a single reflective object may be displayed. (Which is usually the one with the highest amplitude.) If the radar observes a plurality of moving reflectors, then the overlapping Doppler frequencies need to be selected by a bank of filters, or a tunable filter. Nevertheless, several Doppler frequencies are possible to be measured, there is no way to attribute the simultaneously measured values to a particular object without any doubt.

Applications of unmodulated continuous wave radar

Figure 4: TRAFFIPAX SpeedoPhot, a German speed gauge (© 2000 ROBOT Visual Systems GmbH)

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- Traffic control radar (Speed gauges)

Speed gauges are very specialized CW-radars. A speed gauge uses the Doppler- frequency for measurement of the speed. Since the value of the Doppler- frequency depends on the wavelength, these radar sets use a very high frequency band. The figure shows the speed gauge „Traffipax Speedophot” produced by ROBOT Visual Systems GmbH. This radar uses a frequency of 24.125 gigahertz.

It can measure the speed of the incoming and the outgoing traffic, from the right or left border of the street. The radar can be mounted in a car or on a tripod. The traffic offence can be circumstantiated by a photo camera with high resolution.

- Doppler radar motion sensor

Simple and inexpensive Doppler radar sensors with a circuitry as shown in Figure 2 can trigger switching functions such as alarms or simply be used as a door opener or switch for lighting.

- Motion monitoring

If the output of the mixer stage is DC coupled in Figure 2 (ie: in the mixing stage no inductive transformer or coupling capacitors are used) and the subsequent amplifiers are also all DC coupled, then this non-modulated continuous wave radar can monitors also distances to fixed targets with an accuracy in the order of about $\lambda/16$. Here no Doppler frequency is measured, it is compared the phase angle between the transmitted signal and the received signal. The way from the radar to the reflector and the way back is a multiple of the used wavelength. If this distance changes only by fractions of a millimeter, then the phase angle between the two signals also changes.

The measuring range is ambiguous: how many full wavelengths must be additionally added to the measured fraction, this can not be determined. The radar can monitor only a changing to a previous value.

By this measurement method, for example, a non-contact monitoring of heart rate and respiratory activity of intensive care patients can be performed. The radar is aligned on the chest of the patient and monitors the distance to an accuracy of fractions of a millimeter. The changes of the phase angle between the transmitted signal and the received signal is displayed on an oscilloscope as a function of time. A connected to the radar computer counts the periodic changes, and outputs the heart rate of the patient numerically. If no more changes are registered, an alarm is triggered.

Source: http://www.radartutorial.eu/02.basics/Continuous%20Wave%20Radar.en.html