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RFBeam radar sensors

There are many kind of sensors available on the market for movement detection for burglar or intruder alarm systems, like PIR infrared sensors or (invisible) light gates. These products are used as movement detection sensors in buildings and industrial applications, and usually have limitations, like need of using Fresnel lenses, smaller active area and need of special considerations. The last years innovation made it possible to use the microwave and radar technology for these purposes, and we show what advantages could be achieved, the speed, direction of movement and the position (presence) of objects can be also determined.

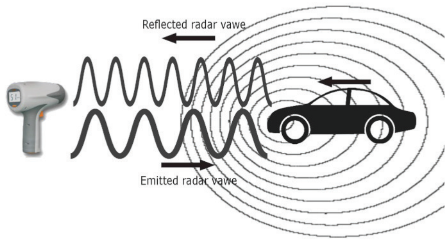
Radar sensors in general

In the past radar systems could only be set up by the use of expensive, big and heavy components like wave guides. Today, using planar technology, the sensor modules are small, cost effective and robust. The radar sensors this article is about, are used for short range radar applications covering ranges from a few centimetres to some kilometres.

Working principle

The radar modules are emitting electromagnetic radiation in the radio frequency range of 18...27GHz, the so called K-Band. A portion of this range from 24...24.250GHz is the ISM (Industrial, Science and Medical) radio band. The K-band is allowed to use nearly worldwide with no limitations. The radar radiation is reflected by solid objects and the reflected radiation is used for detecting objects.

The amount of reflected radiation, which is detected by the radar module, is not only depending on the distance of the object, but also on its size and material. A metal surface is a very good radar target due to its high radar cross-section, and even a human being is reflecting quite well because of high ε_r -value of water contained by the body.



A person can be detected at a distance of 12 meters even with smallest standard modules. Many of the plastic materials are more or less transparent for microwave radiation. Therefore the sensor module can easily be hidden behind a plastic panel which is a huge advantage for the outdoor design of the final product compared to pyroelectric detectors, which need a Fresnel lens for proper operation.

The operation of these sensors is based on the Doppler effect to calculate velocity data about objects at a certain distance. The reflected signal radiated towards a desired target has an altered frequency. This variation gives direct and highly accurate measurements of the radial component of the target's velocity relative to the radar. The difference between the observed frequency and the emitted frequency of a wave for an observer moving relative to the source of the waves is called the Doppler effect. It is commonly experienced when a vehicle equipped with a siren approaches, passes and recedes from an observer standing still. The received frequency is higher (compared to the emitted frequency) during the approach, it is identical at the instant of passing by, and it is lower during the recession. This changing of the frequency also depends on the direction the wave source is moving with respect to the observing point.

The Doppler radar is used to detect moving objects and evaluate their velocity. A reflective moving object in sight of the sensor generates a low frequency sine wave at the sensor output, that is proportional to the object speed.
The frequency transformation could be described with the following formula:

$$\mathbf{F_{reflected} = F_{emitted}\ (1+v/c) / (1-v/c)}$$

Where v is the velocity of the object, c is the speed of light. The Doppler (beat) frequency is as follows :

$$\mathbf{F_d = F_{reflected}\ - F_{emitted}\ = 2vF_{emitted} /c,}$$

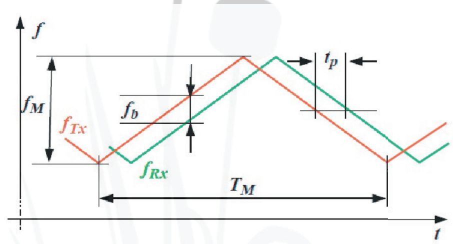
which is proportional with the speed of the moving object.

The amplitude depends on the distance and the reflectivity of the moving object. One good example is the RFBeam radar sensor distributed by Endrich, where the output frequency is 158Hz per m/s (44Hz per km/h) for a radial moving object. Some RFbeam sensors are “stereo” sensors with 2 outputs, called I (In phase) and Q (Quadrate). These sensors allow detecting the moving direction (approaching, receding).

Types of radar sensors by means of technology

There are four kinds of technologies to use for Doppler radars, the coherent pulsed (CP), pulse-Doppler radar, continuous wave (CW), or frequency modulated (FM). CW Doppler radar only provides a velocity output as the received signal from the target is compared in frequency with the original signal. Early Doppler radars were CW, but these quickly led to the development of frequency modulated continuous wave (FM-CW) radar, which sweeps the transmitter frequency to encode and determine range. FMCW is used to detect distances (ranging) of stationary and moving objects. This type of Radar uses a frequency modulated carrier. Typically, the carrier frequency is changed linearly by applying a saw tooth or a triangle waveform (see figure).

At the output of the Radar transceiver a

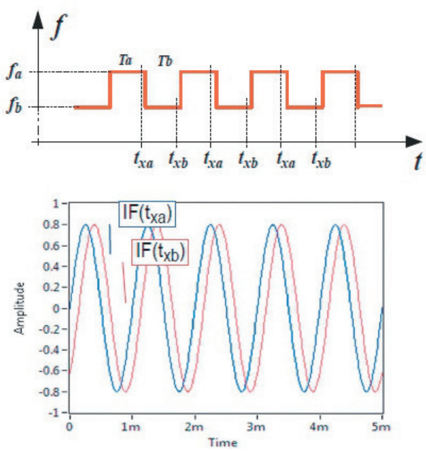


low frequency signal called beat frequency is resulted by the difference between transmitted and received frequencies. Most RFbeam sensors have an analog FM input. Some types can also be modulated under digital control. In K-Band (24GHz), maximum allowed frequency modulation depth is <250MHz, taken tolerance issues and temperature influences in account, the usable frequency shift is limited to typically 150MHz. This results in a resolution (and a minimum distance) of 1m.

The CW and FM-CW radars can normally only process one target, which limits their use. With the development of the digital signal processing technologies, Pulse-Doppler radars (PD) were introduced, and Doppler processors for coherent pulse radars were developed at the same time.

The advantage of combining Doppler processing with pulse radars is to provide accurate velocity information. An other type of the radar sensor technique, the FSK (Frequency Shift Keying) allows distance measurements (ranging) of moving objects. FSK allows a better resolution than FMCW and uses less bandwidth by means of using switching between two discrete carrier frequencies fa and fb, while FMCW uses linear ramps. This technique is also based on the Doppler signals generated by reflective moving objects.

Due to the very small step f_a - f_b a moving target will appear at the nearly the same Doppler frequency at both carriers, but with a different phase. This phase is proportional to the distance of the moving object.



It is important to mention that by both FMCW and FSK techniques it is possible to measure distance, however FMCW is usually used to measure distance of stationary objects, while FSK is used for moving objects.

FMCW makes it also possible to detect presence of a stationary object, by first learning the system to the background environment.

When a new object is present, the FMCW output will become different form the curve stored for the empty environment therefore detection is possible.

Applications

RFbeam Microwave is a leading supplier of planar Radar sensors, K-band measuring equipment and engineering services. The company usually offers radar transceivers, which are devices containing a Transmitter and a Receiver in order to send an electromagnetic wave and to receive the echo of this wave. The product range covers simple low cost.

Doppler devices as well as state-of-the-art digital and superhet transceivers and systems. Typical applications are movement and industrial sensors, traffic supervision and analyser systems, sport measurement equipment and many other uses. It is possible to get demo kits, application software and radar target simulators.