



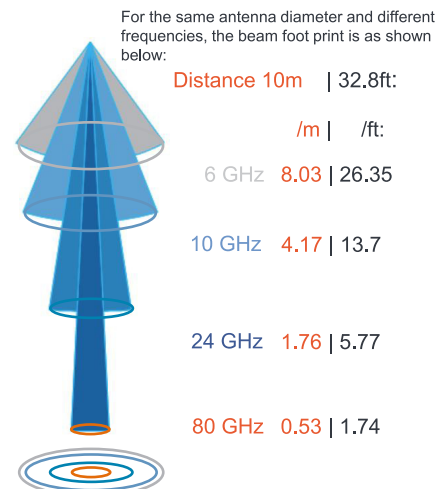
What is the Difference Between Frequency-Modulated Continuous-Wave (FMCW) and Pulsed Wave or Pulsed Width Radar?

FMCW vs. Pulse Radar

Introduction

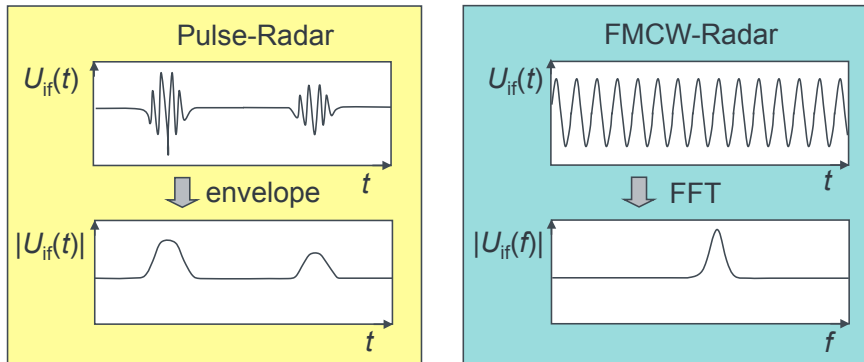
Radar (or radio detection and ranging) was first demonstrated in 1935 by Sir Robert Watson-Watt. Subsequently, it became of major importance for detecting aircraft in World War II, a fact which did much to accelerate its development. The principle is simple. A transmitter sends out a series of very short pulses of microwaves. These travel outward from the antenna, being reflected off any object that they strike. Part of the radiation is reflected back to the location of the transmitter, where there is a receiver. Electronic circuitry measures the time passing between transmission of a pulse and the reception of its echo. The time taken is proportional to the distance of the object, so the distance of the object can then be calculated. Today, we call this time proportional to distance of the object, Time of Flight.

Radar, as mentioned above, sends out very short pluses of microwaves. These microwaves operate in the electromagnetic spectrum between 19 MHz to 300 GHz for typical radar frequencies. The range of frequencies have different usage. For instance, 30 to 300 MHz radar frequencies are used today to very-long-range surveillance. This band designation is VHF. 4 to 8 GHz frequencies are used for long-range tracking of airborne weather detection, which on the C band designation. 27 to 40 GHz frequency range is used for very-high-resolution mapping for airport surveillance, and the band designation is K_a band. As you can see, Radar has many uses and has a long history of functional applications. Beside technical restrictions regarding the utilized bandwidth of a radar system, special frequency bands in the 6 GHz range (C-band), 10 GHz range (X-band), 24 GHz range (K-band), and 80 GHz range (W-band) have been designated to industrial radar systems in the framework of the worldwide harmonization of radio frequencies. Radio regulations distinguish between 'tank level probing radar' (TLPR) inside closed metallic tanks or silos and 'level probing radar' (LPR) outside with larger restrictions.



Technology

RADAR technology has proven itself to be one of the most reliable, non-contacting forms of technologies used for measuring tank level. Microwaves pass seamlessly through thick, condensing humidity in the airspace of the tank. Dust, high pressure and high temperature, and even full vacuum, Radar provides accurate, reliable measurements. This cannot be said for other forms of through-the-air measuring technologies like ultrasonic or laser. Today there are 2 main forms of normal radar functions; Pulsed Wave and Frequency-Modulated Continuous Wave.



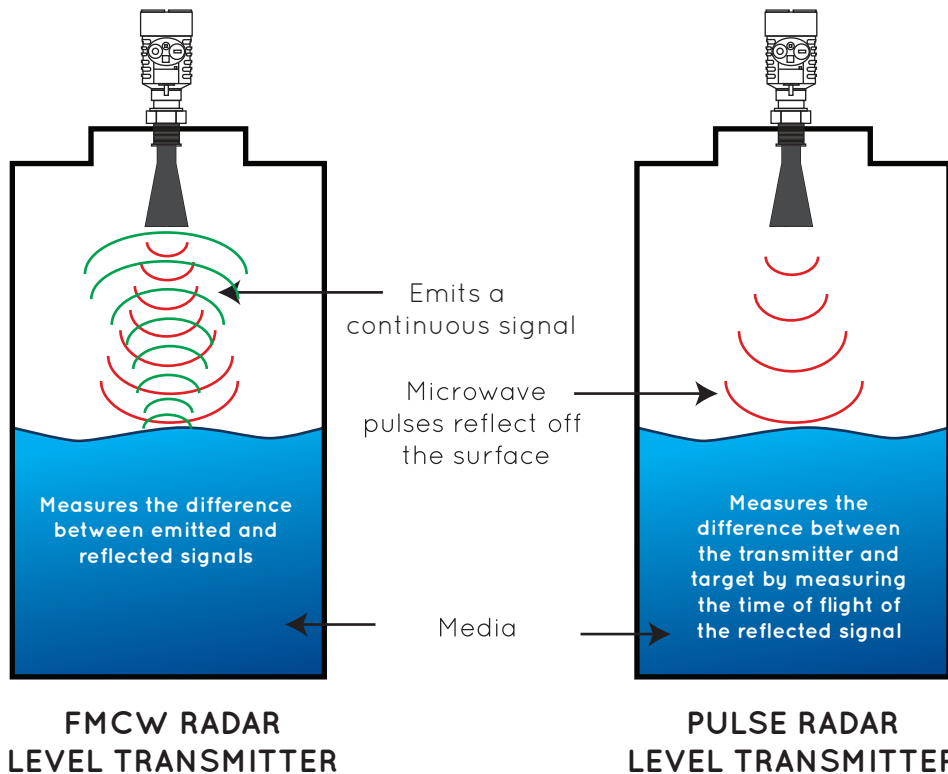
Pulsed Wave Radar

Pulsed Wave Radar uses electromagnetic waves that are emitted from the antenna in short bursts. The waves are interrupted for a period of time so that the wave can reach a reflecting target or surface and a portion of the energy can return to the same antenna before the next burst of waves are transmitted. If appropriate timing devices are employed, it is possible to determine the distance to the target in suitable units of measure. These units are measured in time increments, but since the waves travel at a known velocity, we can easily convert the time measured into distance. The pulse duration is called the "pulse length", and is measured in micro-seconds. The pulse length is usually called Pulse Width in radar systems. These listening times represent one pulsed radar cycle time, normally called the interpulse period or (IPP) or pulse repetition interval (PRI). Pulsed Wave Radar typically operates at frequencies between 6 and 28 GHz. This form usually functions with no single pulse being emitted but a sequence of periodically repeated pulses and the echo signal is sampled using a second sequence of pulses with a slightly different repetition time period. The energy of each transmitted pulse is relatively small because the peak amplitude is very limited. Along with the sequential sampling, this generally results in a relatively small dynamic range of pulse radars and a relatively bad signal-to-noise ratio (SNR). Generally, conductive liquids such as water and other water-based liquids can be measured, even in lower dielectric medium. Nonconductive materials have reflectivity based on the dielectric constant exclusively. Materials with low dielectric constants absorb microwaves and provide much lower reflected signal back to the antenna, resulting in lower signal strength than do materials with high dielectric constants. It is important to understand that using time of flight measurements, the velocity of wave travel in the ambient tank atmosphere must be known or measured. The velocity of radar wave transmission is equal to the speed of light divided by the square root of the medium's dielectric constant. Radar waves are very similar to laser signals but are very different than ultrasonic waves in this regard. Radar waves are only slightly affected by the differing air velocities while ultrasonic waves are greatly affected.



Frequency-Modulated Continuous-Wave (FMCW)

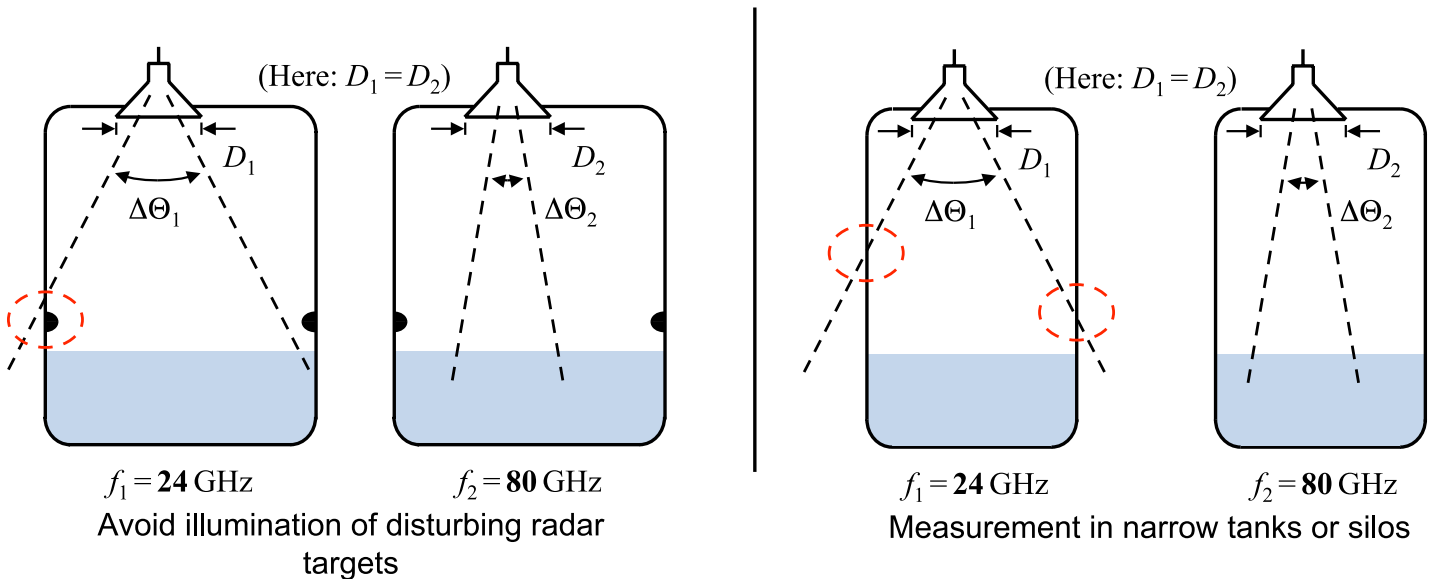
Frequency-Modulated Continuous-Wave (FMCW) uses electromagnetic wave forms or microwave energy to emit what is considered a continuous wave of signal which makes FMCW different than Pulsed Wave. The concept of FMCW radar systems is completely different in order to achieve a much better SNR. A continuous-wave signal is generated and emitted, i. e. a signal with a very large temporal duration and, accordingly, with a much larger energy as compared to the emitted signal of a pulse radar system (even in the case of the same peak amplitude). The frequency of the continuous-wave signal is linearly modulated over time (linear 'frequency sweep'), starting from the desired lower corner frequency up to the higher corner frequency (or vice versa) covering the required frequency band. Advantageously with this approach, the 'sweep-duration' can be chosen independently from the bandwidth, the signal can simply be generated by means of a voltage-controlled oscillator (VCO), and the spectral purity of the signal is very high. The latter enables easily to avoid non-intended emissions in adjacent frequency bands and to fulfill the given radio regulations. The approach for processing the echo (which is also a continuous-wave signal) in an FMCW radar system is to mix (multiply) the received signal with the transmit signal. After a subsequent low-pass filtering, a low-frequency signal (the so-called intermediate-frequency signal) is directly obtained. As another advantage of the FMCW concept, this signal can directly be digitised using a low-cost analogue-to-digital converter (ADC) (with a low sampling frequency) and no sequential sampling has to be performed. With the more recent advances in the technological field of mono-lithic microwave integrated circuits (MMIC) and with the much better availability of MMICs, the majority of industrial manufacturers and suppliers of radar level measurement systems now also move from pulse radar systems to the FMCW radar technology (at least in their latest systems). Besides this trend, which is motivated by the largely improved performance of the FMCW concept, a large variety of pulse radars are still available in the market.



Things To Consider

Beam Width, or Angular Beam Width

The antenna radiation field is inversely proportional to the aperture diameter of the antenna and to the center frequency. Beam width decreases with increasing center frequency in the case that the diameter of the antenna is kept constant. Furthermore, in the case of keeping the frequency constant, the beam width also decreases with increasing diameter of the antenna. In conclusion, the beam width does not simply depend on one single parameter, but both parameters center frequency and antenna diameter are degrees of freedom for determining the angular beam width. The choice of one specific antenna from a set of available antennas with different beam widths has to be made dependent on the given application conditions.



Transmission Loss

The transmission loss is the ratio between the transmitted power and the received power, and this parameter is largely dependent on the properties of the antenna (gain and efficiency), the utilized frequency, and also of course, on the reflection or backscattering properties of the liquid or bulk solid respectively. While the reflection coefficient of the liquid surface does not change with frequency, the backscattering at fine granulated bulk solids largely increases with increasing frequency. Accordingly, the penetration of microwaves into the bulk solid heap decreases. As a general rule of thumb, the received power generally increases with increasing frequency and with increasing diameter of the antenna. For this reason, the echo signal level can generally be increased by using a high frequency and an antenna with a large diameter.

Range Resolution

There is another interesting parameter of the modern day radar system, Range Resolution, which describes its ability to separate different radar targets from each other over distance. This parameter is inversely proportional to the bandwidth. For this reason, a large band-width is required to allow a good separation between echoes from the filling medium and from other 'disturbing' objects like the antenna outlet reflection (being the root cause for the so-called 'upper dead zone') or, for example, weld seams in the tank or silo wall. Typically, the bandwidth of a radar system is proportionally increasing with its center frequency.

Conclusion

The two types of non-contact level radar, Pulse Level Radar and Frequency Module Continuous Wave (FMCW) Level Radar have been widely used throughout the process industry. Both non-contact “free space” techniques are low maintenance, easy to use, and effective, but FMCW is considered more accurate than pulse and is the preferred choice in challenging applications. With FMCW technology, the transmitter emits a continuous signal and determines the distance to the target by measuring the frequency difference between the emitted and the reflected signals. With pulse radar, the transmitter sends a pulse and then stops and waits for a reflection. Which technology is chosen typically depends on the accuracy required, temperature limitations and cost, amongst other considerations.

Hawk Measurement System

For more information on [HAWK's FMCW non-contacting radar level solution](#), please visit hawkmeasure.com

About Hawk Measurement Systems

Established in Melbourne in 1988, HAWK is the global market leader in innovative level measurement, positioning and flow solutions. HAWK has won several prestigious awards for its breakthrough technologies. HAWK develops and manufactures level measurement equipment based on different technologies such as, Acoustic Wave, Ultrasonic, Microwave, Radar, Flotation Cell Level Monitoring, and Fiber Optic Sensing. The company has a distinguished record of success in the application of level, positioning and flow measurement technology, and a plethora of expert services which range from the provision of instrumentation and technical assistance, through to implementation and ongoing asset management. HAWK systematically monitors and evaluates its projects and employs the best practice and quality assurance procedures. Experts of the highest caliber who are selected for their experience and are trained in our factory to assure proper application of the instruments and ultimate customer satisfaction address application examples.

