



Microwave Radar Technology-A Review

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Abstract: For the identification of living or non-living object at a short range will be possible using UWB(Ultra wide band) radar system those other senses like optical sensors ,IR(Infra Red Sensors) , are available for short range they may be found good for range but may not be good for resolution and also waves will not be able to penetrate through different obstacles like wall of any material e.g.-Brick ,Plastic ,Wooden etc.As human being always desires to know what's happening behind the wall. Radar Technology configured with UWB is quiet useful or compressed to the other terms for measuring the range and resolution of an object behind the wall and for the buried objects in the ground .SFCW(Step frequency continuous wave radar) always takes an edge over frequency modulate continuous wave radar and pulse radar.

Keywords: Frequency modulated continuous wave radar, Infra red sensors, Optical sensors, Pulse radar, Step frequency continuous wave radar, Ultra wide band.

I. Introduction

In this paper we will discuss about the UWB radar in detection in hidden objects. As Radar technology has been used as cost effective and accurate technique for measuring distances, detection of hidden and buried objects applicable in military, surveillance and scientific applications. The microwave signals when incident on a medium gets penetrated into that medium hitting, the target and reflected back to the receiver, after passing through the same medium. Radar transmission transmits the wave signals with the help of transmitting antenna's like horn antenna and after the echo signal is received an proceed using DSP(Digital signal processing) techniques in order to measure the range of the object. Different researchers using these techniques for the measurement of the range and identification of the object (living or non-living) in through wall imaging technology and ground penetrating GPR technology with the help of radar. There are several studies on TWRI to detect targets behind walls with the known wall parameters such as thickness and dielectric constant [1-4]. An electromagnetic wave, which can pass through a dielectric wall, is transmitted and received at several locations along a synthetic array and combined into a two-dimensional image. In order to achieve a high-resolution image, a wide band signal should be used. The frequency band is typically implemented with several contiguous narrowband signals (step-frequency signal) In turn, a very wide bandwidth of several Mega-Hertz ,as in the case of indoor imaging, requires a large number of narrowband signals. For example, when 50 antenna locations and 200 narrowband signals are used, the total number of data samples becomes 10000. [5-6].

II. Range and resolution measurement

If the radar waveform is a rectangular pulse, it is known that the resolution is

$$\Delta R = \frac{c}{2B} \quad (1)$$

The bandwidth of a rectangular pulse is $B = 1/ T_p$. Hence, the range resolution ΔR is related to the signal bandwidth and the propagation velocity c by

$$\Delta R = \frac{c}{2B} \quad (2)$$

Where the $\frac{c}{2}$ factor converts the two-way travel time to range in meters.

A. Continuous Wave (CW)

A radar system that transmits continuously is termed as continuous-wave (CW) radar. The unmodulated, single-frequency waveform has been used for Doppler radars for a long time due to its capability of sensing target motion relative to the radar. The receiver of CW radar mixes (homodynes) the received signal with a replica of the transmitted signal. After low pass filtering, the only remaining component is the Doppler shift which can be used for velocity measurements. Since $B = 0$ for a CW signal, the range resolution according to equation (2) is infinity. Therefore, no target range information is available in CW radar, and a combination of pulse and CW radar is often used for practical purposes. This is termed Pulsed-Doppler Radar.

B. Short Pulse (Impulse)

The most obvious and straightforward HRR waveform is the impulse or short pulse. The time duration of these impulses is usually 0.25 - 1 ns. If the pulses are transmitted without carrier, they are often termed carrier less impulses or baseband video pulses. In many cases, it is advantageous to remove the DC content of the pulses by differentiation or high pass filtering. The resulting pulses are often called mono-cycle pulses. A popular short duration waveform is the Ricker wavelet that can be described mathematically as the negative of a second derivative of a Gaussian pulse

$$P(t) = -\frac{d^2(e^{-at^2})}{dt^2} = -2ae^{-at^2}(2at^2 - 1) \quad (3)$$

Where a is a constant that determines the time duration and amplitude of the wavelet.

C. Chirp (Linear Fm)

A common way of increasing the pulse energy while still maintaining the high resolution of radar is to apply a chirp waveform which is a sine wave with a linearly increasing/decreasing frequency. Hence, the frequency, $f(t)$ of a chirp is given by

$$F(t) = f_0 + at, \quad (4)$$

Where f_0 is the start frequency and a is the chirp rate [Hz/s]. Since the frequency is related to the phase ϕ by

$$F(t) = \frac{1}{2\pi} \frac{d\phi}{dt}, \quad (5)$$

The phase of the chirp waveform can be written as

$$\phi t = 2\pi \int_0^t f(\tau) d\tau = 2\pi \left(f_0 t + \frac{at^2}{2} \right) \quad (6)$$

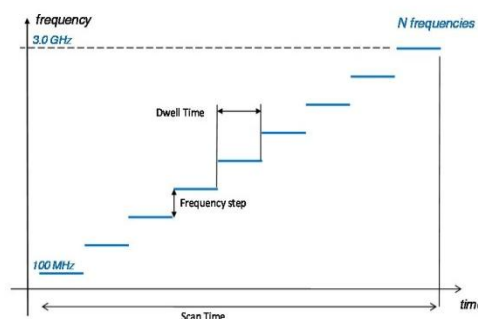
III. Radar Technologies

There are three types of radar techniques, which are as follows:

A. Stepped-Frequency Continuous Wave System

A stepped-frequency system generates a sweep that covers frequencies over a defined range, which is a comparable procedure to the Vibroseis method used in exploration seismology. The recorded response is then convolved with the original sweep to obtain the ground response. The width of the frequency step defines the resolution of the trace and determines, together with the specified frequency range, the scan time of an antenna. The dwell time is the time span or duration that a specific frequency is emitted. Comparable to stacking in a pulsed system, the dwell time can be increased to give a better signal-to-noise (S/N) ratio. Using a bandwidth of 200–1500MHz, a frequency step of 2MHz and a dwell time of 2ms, the scan time for 31 antennae is 1.5ms which results in about 3.5km h⁻¹ as the actual recording speed for an in-line spacing of 5cm. Unfortunately this is slower than a modern antenna array using time domain technology with 40 antennae and frequencies of 200 and 400MHz, which can record at 15km h⁻¹ with similar sampling intervals. The bandwidth of a single air-coupled bow-tie antenna is not large enough alone to cover the complete frequency range defined by the manufacturer. Hence the system uses three different antenna elements, called large, medium, and small according to its physical size and central frequency. The stepped-frequency continuous wave (SFCW) system uses a specially designed ultra-wideband antenna with monopoles tilted towards each other at about 45°. The height of the feeding points for all surveys presented here was at a height of 0.3m above ground. In theory stepped-frequency systems have a better S/N ratio and hence should perform better than a pulsed system, which is comparable to the advantage of a Vibroseis system in seismic. 3D Radar operation fig 1.

Figure 1 3D Radar Principle of operation [7]



B. Frequency Modulated Continuous Wave Radar System

CW radar sensors can be implemented either as frequency-modulated continuous wave (FMCW) radar sensors or stepped-frequency continuous wave (SFCW) radar sensors. These sensors can achieve an average power much higher than that of a pulsed radar sensor. FMCW radar sensors, also known as frequency domain radar sensors, have also been widely used as subsurface radar sensors, for instance, in measuring the thickness of a

coal layer and detecting buried objects under the ground shows the FMCW radar sensor using a beat frequency to seek the range information of a target. An important characteristic of FMCW radar sensors is that the rate of sweeping frequency should be carefully observed to obtain a satisfactorily accurate range of the target. However, it is quite difficult to achieve this specification over a wide band, due to the non-linearity of the voltage-controlled oscillator (VCO). Moreover, its wide bandwidth degrades the receiver's sensitivity, which results in reducing penetration depth. Hence, these drawbacks limit the FMCW radar sensor in some applications that need a greater degree of accuracy. Continuous Wave Radar fig 2

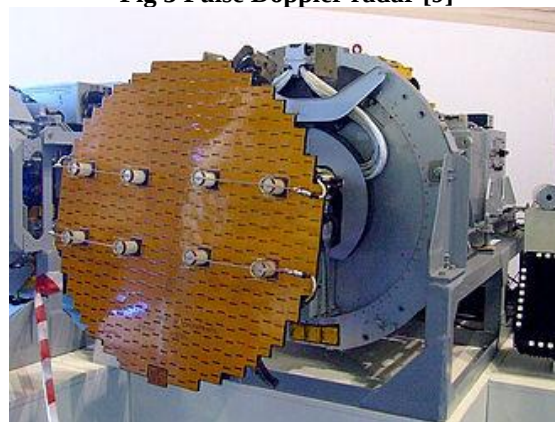
Figure 2 Continuous Wave Radar [8]



C. Pulsed Radar System

The pulsed radar sensor, also known as the time-domain radar sensor, typically employs a train of impulses, mono-pulses or modulated pulses, as the transmitting waveform the first subsurface radar sensor was the impulse radar that measured the properties of coal. The impulse radar transmits a short pulse train with a pulse repetition interval (PRI). Such an impulse can be generated by using avalanche transistors, step recovery diodes (SRD), or tunnel diodes to produce a high peak power or a pulse of short duration. The pulsed radar sensor has been widely used in many applications owing to its effective cost and simple structure. However, it has been found that this sensor is inappropriate and has severe constraints while operating as a High-Resolution Radar (HRR) sensor. To be a HRR sensor, the bandwidth (B) of the pulse needs to be increased as seen by equation. As the bandwidth of the pulse is increased by shortening the pulse width (t), which in turn is restricted by available technologies, this type of sensor finds its usage effectively constricted by technological limitations and hence finds itself limited in high resolution based radar applications. It is worthwhile to note that the increased bandwidth degrades the receiver sensitivity, which results in decreasing the penetration depth. Pulsed radars with a few hundred picot-seconds of pulse width can be designed, but only at very low power levels, up to a fraction of a watt of the average power. This means that the pulsed radars cannot achieve both high range resolution and deep penetration simultaneously, unless pulse compression technique is used. Pulse Doppler radar fig 3

Fig 3 Pulse Doppler radar [9]



IV. Hidden Objects for Detection

A. Through Wall Imaging (TWI)

The ability to locate moving targets inside a building with a sensor situated at a standoff range outside the building would greatly improve situational awareness on the urban battlefield. A radar imaging system was

developed to image through walls, providing a down-range versus cross-range image of all moving targets at a video frame rate. This system uses an S-band, frequency-modulated, continuous-wave radar with a spatial frequency range gate coupled to a time-division multiplexed, multiple-input, multiple-output antenna array to rapidly acquire, process, and display radar imagery at a frame rate of 10.8 Hz.

B. Ground Penetrating Radar (GPR)

The GPR operates either in time domain or in frequency domain. The time domain systems could work either with a single very short pulse. The shorter the pulse is the higher the range resolution is, or with a pulse train frequency modulated waveform or so-called “chirp radar”. The frequency domain GPRs are continuous wave systems in which the carrier frequency is changed either continuously or with a fixed step.

V. Conclusion

From theory it is known that SFCW systems have advantages over pulsed systems. Comparison of data recorded with both systems reveals a quite different situation: the bandwidth is not larger in the stepped- frequency system, but comparable to a single frequency antenna. The condition of the surface has a large impact on the detectability of any underlying interface and produces some spurious high energy areas in the depth-slices. Additionally there is electronic interference and an unequal balancing of antenna signals that makes the data processing very difficult. In the antenna array only 29 out of 31 antennae could be used and the overall recording speed is lower than recent pulsed systems. Instead of using a large bandwidth, a limited frequency range, comparable to a conventional pulsed antenna, will give better results and at the same time enhance the recording speed.

V1. References

- [1] F. Ahmad, M. G. Amin, P. Setlur, “Through-the-wall target localization using dual-frequency CW radars,” *Proc. SPIE*, Vol.6201, pp. 6-10, 2006.
- [2] D. D. Ferris, Jr., and N. C. Currie, “A survey of current technologies for through-the-wall surveillance (TWS),” in *Proc. SPIE*, Boston, MA, vol. 3577, pp. 62–72, Nov. 1998.
- [3] A. R. Hunt, “Stepped-frequency CW radar for concealed weapon detection and through-the-wall surveillance,” in *Proc. SPIE*, Orlando, FL, vol. 4708, pp. 99–105, April. 2002.
- [4] F. Ahmad and M. G. Amin, “A noncoherent radar system approach for through-the-wall imaging,” in *Proc. SPIE*, Bellingham, WA, vol. 5778, pp. 1405-1419, Mar –April 2005.
- [5] D. Donoho, “Compressed sensing,” *IEEE Trans. Inf. Theory*, vol. 52, no. 4, pp. 1289–1306, Apr. 2006.
- [6] E. J. Candes, J. Romberg, and T. Tao, “Stable signal recovery from incomplete and inaccurate measurements,” *Comm. Pure Appl. Math.*, vol. 59, pp. 1207–1223, Aug. 2006.
- [7] B.A. Cipra, “The Ubiquitous Reed-Solomon Codes,” *SIAM News* 26 (1), 1993.
- [8] W.W. Schrader, “MTI Radar,” in *Radar Handbook*, pp. 17.1– 17.60.
- [9] E.C. Freeman, ed., *MIT Lincoln Laboratory: Technology in the National Interest* (Lexington, Mass., 1995), pp. 15–33.