Evaluation of a High Accuracy Range Detection Algorithm for FMCW/Phase Radar Systems

Philipp Pahl #1, Thorsten Kayser #*2, Mario Pauli #*3, Thomas Zwick #4

#Karlsruhe Institute of Technology (KIT)
Kaiserstraße 12, D-76131 Karlsruhe, Germany
3mario.pauli@kit.edu

*PKTEC GmbH
Bahnhofstraße 30, D-77746 Schutterwald, Germany

***Abstract*— The FMCW radar is the most versatile radar principle used today. Depending on the system configuration, it is possible to use an FMCW radar to detect targets in the range from hundreds of kilometers down to a few centimeters. This paper describes an algorithm, which can be applied to improve the FMCW range accuracy down to a few mm. Numerical system simulations are used to evaluate the possibility of using a combination between an FMCW and a phase radar for a line based range detection at 24 GHz.**

I. Introduction

Depending on the application different kinds of radar techniques are used. If the radar has to have an unambiguous range of a few meters but also a range resolution of less than one centimeter most of the known radar techniques drop out. One radar technique, which meets the requirements is the FMCW radar. Combined with an accurate signal processing an accuracy of less than 5 mm can be achieved by using only a smart FMCW configuration. The FMCW radar separates targets at different distances by transmitting a frequency modulated signal. Depending on the bandwidth and sweep time of the used modulation signal, an acceptable range of unambiguity together with an acceptable accuracy can be achieved. If this radar technique is combined with a phase evaluation technique, the FMCW radar can be used to detect targets over a distance of a few meters with an accuracy of a few μm [1], [2], [3].

In this paper different parameters of an FMCW radar will be considered in terms of range resolution and unambiguous range. A FMCW radar system model is introduced to investigate the influence of the used elements (depicted in Fig. 1) on the range detection. Using the derived equations and the system model an improved range detection algorithm with high accuracy is described and evaluated.

II. Resolution of an FMCW Radar

The FMCW radar transmits a linear frequency chirp to determine the distance of targets. Within this paper only stationary or slow moving targets are considered. Therefore a saw tooth modulation scheme is applied during the system investigation instead of a triangular modulation.

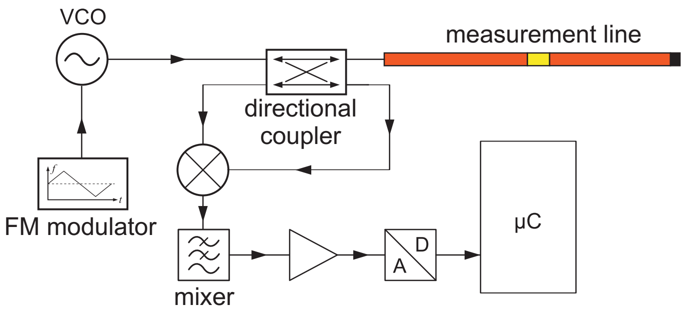

Fig. 1. Blockdiagram of an FMCW radar

Using a saw tooth modulation with a bandwidth B and a cycle duration T a target at a distance R generates the beat frequency

$$\begin{aligned} f_{\mathrm{IF}}(t,R) &= |f_{\mathrm{Tx}}(t) - f_{\mathrm{Rx}}(t,R)| \\ &= \frac{B}{T}\cdot\frac{2R}{c} \end{aligned} \quad (1)$$

at the output of the down-converting mixer, where c represents the propagation velocity on the measurement line. To obtain the frequency resolution Δf_{IF}, which is proportional to the range resolution ΔR, (1) can be rewritten using Δf_{IF} and ΔR to

$$\begin{aligned} \Delta f_{\mathrm{IF}} &= |f_{\mathrm{IF}}(R_2) - f_{\mathrm{IF}}(R_1)| \\ &= \frac{2\cdot B}{c\cdot T}|R_2 - R_1| \\ &= \frac{2\cdot B}{c\cdot T}\Delta R \quad . \end{aligned} \quad (2)$$

Considering the case that the roundtrip time $\Delta t \ll T$, the IF frequency stays constant during a single sweep. This means that a single target in front of the radar, induces a single beat frequency. In time domain the received beat signal is a sinusoidal signal, which transformed to the frequency domain is represented by a Dirac impulse. However, the maximum measurement period, equivalent to the cycle time of the radar signal, has to be taken into account. The limited measurement time distorts the beat signal in frequency domain by convoluting the Dirac impulse with a sin(x)/x function.