Chapter 2
Case Studies on Detection Using mmWave FMCW RADAR System

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ABSTRACT

The content of this chapter provides a thoughtful analysis of case studies that highlight the detection capabilities of FMCW radar systems operating in mmWave configurations. The case studies demonstrate how mmWave FMCW radar technology may be used to detect objects, motions, and changes in both line of sight and non-line of sight settings with accuracy, and efficiency. Each case study explores the unique difficulties presented by the application environment, which can include anything from identifying impediments in automotive safety systems to detecting minute movements for vital sign monitoring in healthcare. The steps for detecting different gesture recognition using IWR 1843 BOOST FMCW radar system and its processing are focussed upon. The document highlights the technology's excellent resolution, motion sensitivity, and adaptability to a variety of challenging environments in LoS and NLoS scenarios and with the technical details of operating mmWave radars, including signal processing methods, machine learning algorithms, and mitigating interference from surrounding objects.

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1. INTRODUCTION

Millimeter wave (mmWave) radar is a type of radar technology that employs electromagnetic waves. Radar systems send out electromagnetic wave, which are subsequently reflected off nearby objects. A radar system can facilitate the measurement of range, velocity, and angle by processing the received signal (Jankiraman, 2018).

Radars operating at millimeter wavelengths [30 gigahertz (GHz) to 300 GHz] are known as mmWave radars (Jankiraman, 2018). The benefits of using these short wavelengths in the electromagnetic spectrum include high resolution, penetration through materials, high data rates etc. High precision of short wavelengths is also another benefit that can be achieved through several key factors like short wavelengths, high bandwidth, advanced signal processing, MIMO [*Multi-Input-Multi-Output*] antenna configurations, adaptive beamforming, high-speed data processing making it a valuable technology for a wide range of applications. For example, a wavelength of around 4 mm mmWave system operating at 76–81 GHz will be able to detect movements as small as a fraction of a millimeter as detailed in (Instruments, T., 2020).

A mmWave signal processing requires a compact system architecture design. mmWave radar system consists of radio frequency (RF) components for transmit and receive (TX and RX), analog components for clocking, and digital components like digital signal processors (DSPs), microcontrollers (MCUs), analog-to-digital converters (ADCs) and antenna design. The design of each component is complex and distinct in design. The use of discrete components in the implementation of these systems in the past raised power consumption and system costs (Jankiraman, 2018). Additionally, system design is challenging due to its complexity and high frequency. Texas Instruments (TI)- *XWR 1843 BOOST (Amar et al., 2021, pp.1-11), XWR 1642 BOOST (Gao et al., 2019, pp.1-6),* Infineon Technologies- *BGT23MTR12 (Ahmed et al., 2021)*, Novelda- *NVA6100, X4*(Borzov et al., 2017) and few other companies have addressed these issues by developing mmWave radar devices based on complementary metal-oxide semiconductor (CMOS) technology. TI Instruments (TI) devices incorporate TX-RF (transmit chain) and RX-RF (receiver chain) analog components such as clocks, as well as digital components such as the ADC, MCU, and hardware accelerator. To enhance their signal-processing capabilities, certain mmWave sensor models from TI incorporate a DSP (Instruments, T., 2020).

While mmWave technology has a wide range of applications, including telecommunications and imaging, one such application that utilizes its characteristics is radar that is frequency-modulated continuous-wave (FMCW), which uses mmWave frequencies for precise and efficient sensing as discussed by (Tang et al., 2023).