参考資料

デザイン・ガイド：TIDEP-01010
アンテナ・オン・パッケージ採用ミリ波センサを使用したエリア・スキャナのリファレンス・デザイン

概要

TIDEP-01010は、TIのシングルチップ・ミリ波（mmWave）テクノロジーを使用して、3D空間内で検出と位置識別を実行できるエリア・スキャナを実装しています。ミリ波センシング・テクノロジは本質的に熱、水分、塵、照明の不十分などの条件に強く、産業用施設に導入するアプリケーションには不可欠なものです。

このリファレンス・デザインは、IWR6843 ミリ波センサを使用し、包括的なレーダー処理チェーンをデバイスに実装します。この処理チェーンには、アナログ・レーダー構成、アナログ/デジタル・コンバータ(ADC)キャプチャ、低レベルFFT、信号処理が含まれます。このリファレンス・デザインは、TIのミリ波SDK上に構築され、評価、開発、データの視覚化を行うためのAPI、ライブラリ、ツールを含む、総合的なソフトウェア環境を作成することを目的としています 。このリファレンス・デザインは、IWR6843ISK または IWR6843AOPEVM 評価モジュールを使用して評価できます。IWR6843 アンテナ・オン・パッケージ採用ミリ波センサを使用すると、設計および製造コストの低減、システム設計の簡素化、センサ占有面積の縮小、ひいては開発期間の短縮が可能です。

リソース

TIDEP-01010	デザイン・フォルダ
IWR6843AOPEVM	ツール・フォルダ
IWR6843ISK	ツール・フォルダ
MMWAVEICBOOST	ツール・フォルダ
IWR6843	プロダクト・フォルダ
mmWave SDK	ツール・フォルダ

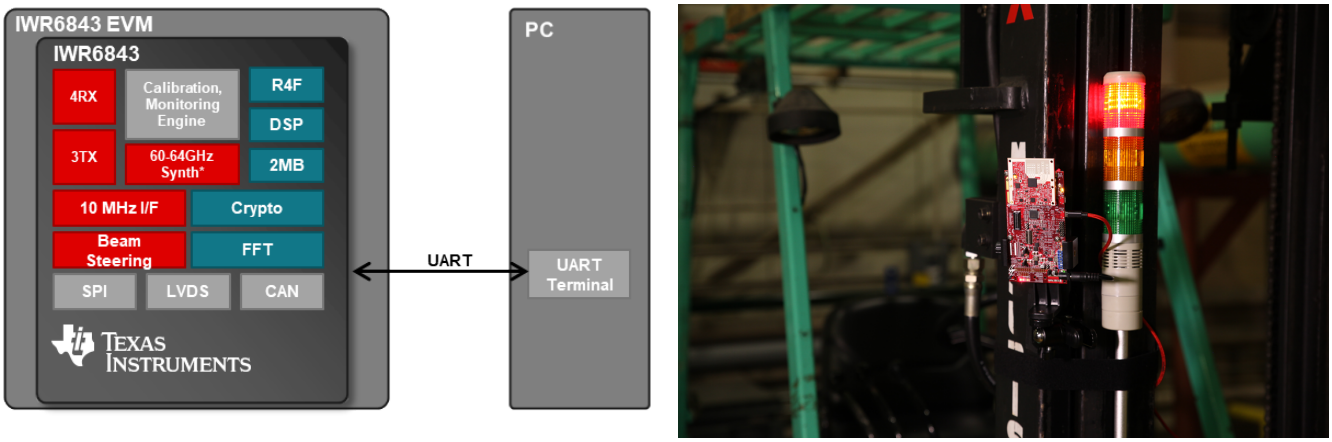
TI E2E™ Community　E2E™エキスパートに質問

特長

- TIのシングルチップ・ミリ波センサを使用した、環境に対して堅牢なエリア・スキャナのデモンストレーション
- 3D空間内での人物や物体の検出と位置識別
- 1 つのデバイスを使用して、以下の検出に対応
  - 0m～10m の距離
  - IWR6843ISK を使用した場合に最大 120° の水平視野角 (FOV)
  - IWR6843AOP を使用した場合に水平・垂直 130° の FOV
- ミリ波ソフトウェア開発キット(SDK)をベースとして提供される処理チェーンのソースコードを参照
- 実績のあるEVMハードウェア設計を基礎とし、短期間での市場投入と、即時のデモンストレーションを実現

アプリケーション

- エリア・スキャナの安全保護
- 近接センサ
- ライト・カーテンの安全保護



1 System Description

The TIDEP-01010 provides a reference for creating a area scanner or safety guard application using TI's IWR6843, based on 60-GHz mmWave radio-frequency complementary metal-oxide semiconductor (RF-CMOS) technology. Frequency-modulated continuous-wave (FMCW) radars enable accurate measurement of distances and relative velocities. Thus, radars are useful for detection of occupancy and whether an object or person has entered a space of interest.

In area scanner or light curtain safety-guard applications, where it is important to have precisely defined "keep-out" zones, the ability of radar to accurately localize detected objects can be used to implement multiple detection zones and trigger corresponding responses. A single radar deployed to equipment with a critical "keep-out" perimeter could implement a multi-stage response, so that when an object or person first approaches the perimeter, a moderate warning flag is raised. Then, if the perimeter is breached, a critical response is triggered.

With the widespread growth of factory automation, there is a greater need for smarter incident management solutions that can detect the movement of people and objects around heavy machinery while maintaining productivity. Using TI's 60-GHz mmWave sensors, both presence detection and the ability to gauge the object's trajectory and speed are enabled. Thus, a system can be created that can dynamically adjust the safety zone's size depending on the object's speed of approach, alert before a safety zone is breached while also ignoring objects whose trajectory is not towards the zone.

An important advantage of radars over camera and light-detection-and-ranging (LIDAR)-based systems is that radars are relatively immune to challenging environmental conditions common in industrial facilities such as dustsmoke. Because FMCW radars transmit a specific signal (called a chirp) and process the reflections, they can work in both complete darkness and bright daylight (radars are not affected by glare). When compared with ultrasound, radars typically have a much longer range and faster transit time for their signals.

The IWR6843AOP variant features a short-range, wide field of view antenna-on-package (AOP), achieving unprecedented levels of integration in an extremely small form factor.

The AoP sensor design addresses three main challenges for robotics or factory automation:

- Wide 3D coverage with a single sensor: The AoP antenna's wide FoV configuration provides a 130-degree view in the azimuth and elevation, which provides true 3D sensing enabling detection of the object height and filtering out ground clutter. This maximizes a sensor's accuracy and measurement performance. The wide azimuth area coverage reduces the number of sensors used for area scanning and hence reduces overall system cost.
- Small form factor: The smaller form factor of AoP sensors means that they can fit into smaller enclosures, which is important for sleek, small autonomous robot designs such as autonomous guided vehicles, delivery robots, and smaller robotic arms in factories for sense-and-avoid applications.
- Fast time to market: By eliminating expensive PCB substrates and RF expertise, AoP sensors simplify the design and manufacturing process, enabling in-house designs and reducing time to market.

1.1 Key System Specifications

表 1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
Field of view (FOV)	IWR6843 ISK: 120° azimuth, 40° elevation	The field of view of the sensor is determined by the antenna design of the EVM. Both EVMs enable a 3D point cloud with elevation information with the IWR6843ISK featuring greater azimuth resolution while the IWR6843AOP features wider, symmetrical FOV in azimuth and elevation.
	IWR6843 AOP: 130° azimuth, 130° elevation	
Frame rate	10 Hz	This parameter defines the data output and visualizer update rate.
Maximum range	12.79 m	The maximum range is defined by the radar chirp characteristics, and can be configured to suit application requirements. The maximum range defined for this reference design is with respect to the dimensions of the testing site.
Range resolution	0.125 m	Range resolution is the ability of a radar system to distinguish between two or more targets on the same bearing but at different ranges.
Maximum velocity (m/s)	1.6 m/s	This is the native maximum velocity obtained using a two-dimensional FFT on the frame data. Additional processing that can extend the maximum trackable velocity by 3x the chirp maximum velocity
Velocity resolution	0.05 m/s	This parameter represents the capability of the radar sensor to distinguish between two or more objects at the same range that are moving with different velocities.

2 System Overview

2.1 Block Diagram

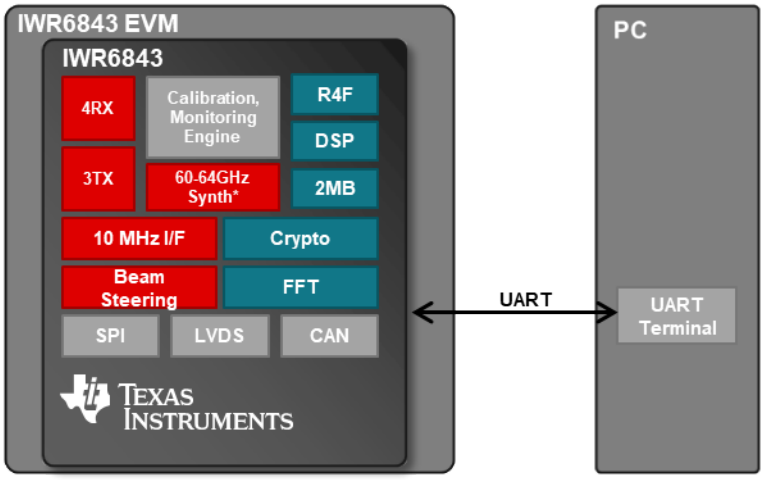


図 1. Area Scanner Using mmWave System Block Diagram

2.2 Highlighted Products

This reference design can be implemented using either the IWR6843ISK or IWR6843AOP EVM. Using either EVM, objects within the sensor's field of view are detected and represented as 3D point clouds. Each point within the point cloud has an X, Y, and Z location coordinate as well as associated doppler and SNR information.

2.2.1 IWR6843ISK or IWR6843AoP EVM

The IWR6843ISK andIWR6843AOPEVM are both easy-to-use evaluation module for the IWR6843 mmWave sensing device. The IWR6843 family of single-chip device features a 60-GHz mmWave Radar transceiver, on-chip C67x DSP core and low-power ARM R4F controllers. For the IWR6843ISK variant, antennas are etched on the PCB while the IWR6843AOP variant integrates the 4 receiver and 3 transmitter antennas on the device package.

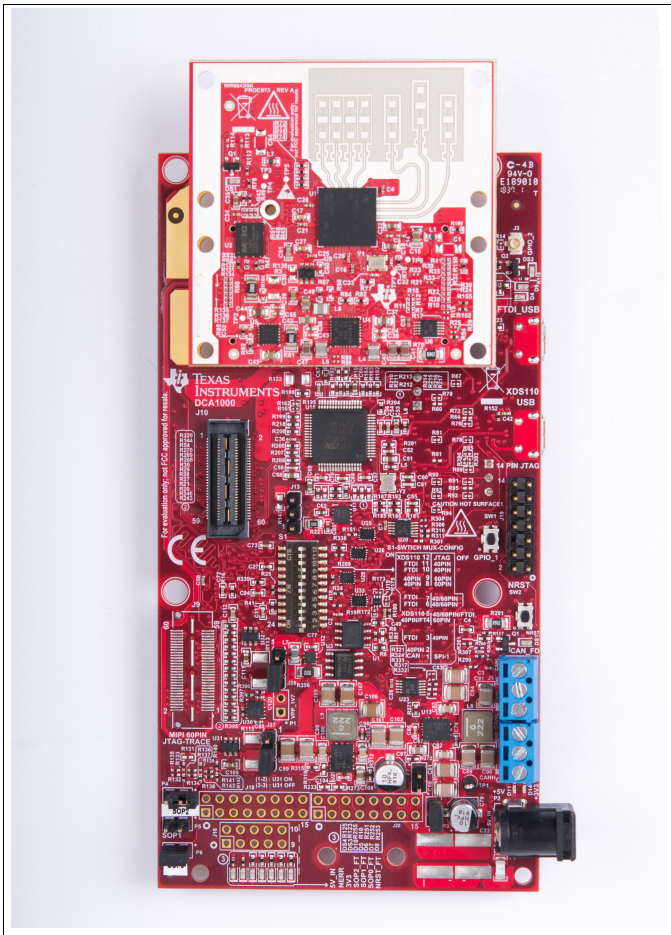


図 2. IWR6843ISK + MMWAVEICVBOOST

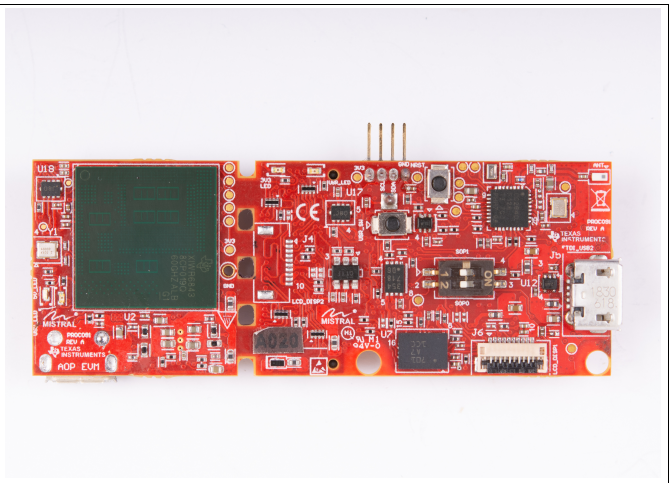


図 3. IWR6843AOPEVM

2.2.1.1 Key Features of IWR6843

- FMCW transceiver:
  - Integrated PLL, transmitter, receiver, baseband, and A2D
  - 60- to 64-GHz coverage with 4-GHz continuous bandwidth
  - Four receive channels
  - Three transmit channels
  - Option for integration of 4 receiver and 3 transmitter antenna-on-package (AOP)
  - Ultra-accurate chirp engine based on Fractional-N PLL
  - TX power: 10 dBm
  - RX noise figure: 14 dB
  - Phase noise at 1 MHz: -92 dBc/Hz
- Built-in calibration and self-test:
  - Arm® Cortex®-R4F-Based Radio Control System (RCS)
  - Built-in firmware (ROM)
  - Self-calibrating system across frequency and temperature
- On-Chip programmable core for embedded-user application:

  - Integrated Arm® Cortex®-R4F Microcontroller clocked at 200 MHz
  - On-Chip Bootloader supports Autonomous mode (Loading User application from QSPI Flash memory)
- Integrated peripherals:
  - Internal Memories With ECC
  - ARM-R4F microcontroller for object detection, and interface control
    - Supports autonomous mode (loading user application from QSPI flash memory)
  - Radar Hardware Accelerator (FFT, Filtering, and CFAR processing)
  - C674x DSP for advanced signal processing (IWR6843 or IWR6843 AOP only)
  - I2C
  - Two SPI ports
  - CAN-FD interface
  - Up to six general-purpose ADC ports

2.2.2 MMWAVEICBOOST

The MMWAVEICBOOST is an add-on board used with TI's mmWave sensor in all Starter Kits, to provide more interfaces and PC connectivity to the mmWave sensors. The MMWAVEICBOOST board provides an interface for the mmWave Studio tool to configure the radar device and capture the raw analog-to-digital converter (ADC) data using a capture board, such as the DCA1000 evaluation module (EVM). It also provides an interface to the MSP43xx boards through 40-pin LaunchPad™ / BoosterPack™ connectors.

2.3 System Design Theory

2.3.1 Operation

The IWR6843 is loaded with a flashed image that, when booted and initialized, receives a chirp configuration specified using the area scanner visualizer. In the area scanner visualizer, the location and dimension of the zones to monitor are set as well as other visualization properties. Then, using the visualizer, the chirp configuration is loaded and sent to the sensor to start monitoring the area of interest for zone occupancy.

The strongest reflections reported by the radar device are reported as detected objects to the host PC through the UART. The detected objects collectively form a point cloud representation of the scene as seen by the sensor. If an object generates a point cloud of at least 15 points within an area, the area is considered breached and the visualizer updates to highlight the occupied area.

2.3.2 Use Case Considerations

This reference design is intended to demonstrate the detection of people or objects moving into a zone for an indoor environment. Given this use case, the system implements static clutter removal so that other permanent fixtures in the scene, such as walls, do not trigger a zone occupancy detection. The use case drove the design of the chirp configuration in with primary considerations being achieving high doppler resolution with sufficient range resolution and maximum velocity for localizing and tracking human movement, including walking.

表 2. Chirp Configuration

KEY INPUT PARAMETERS	
Antenna pattern	Three Tx, Four Rx
Maximum range	12.79 m
Range resolution	12.5 cm
Maximum velocity	1.6 m/s
Velocity resolution	0.05 m/s
Frame duration	100 ms

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Required Hardware and Software

3.1.1 Hardware

- One of the following mmWave EVM options:
  - IWR6843ISK and MMWAVEICBOOST Boards
  - IWR6843AOP EVM and optionally, MMWAVEICBOOST for debugging
- If using MMWAVEICBOOST, a 5-V, 3.0-A power supply
- A PC for Code Composer Studio™ (CCS) and the demonstration UART terminal

3.1.2 Software

For this reference design, software is provided for the IWR6843 device and the host PC.

The software required for the target IWR6843:

- Latest mmWave SDK. The SDK automatically installs the required component versions. These components are listed in the SDK's release notes in the /docs folder of the software package. Install the SDK and all required components before installing and building the demonstration source.
- Code Composer Studio (CCS). See the SDK release notes for the required version.
- Latest mmWave Industrial Toolbox. Using CCS, access and install the mmWave Industrial Toolbox through the Resource Explorer. The Industrial Toolbox contains a quick start guide with precompiled binaries for the device, the source code, and a detailed user's guide to run the demo as presented in this reference design. When installed, the material specific to the reference design is located at under the labs directory in Area Scanner.

The software required for the host PC:

- Latest mmWave Industrial Toolbox. The Area Scanner visualizer is packaged in the Industrial Toolbox. The /gui folder includes the compiled executable and source code for the visualizer.

The application software used in this reference design is from the mmWave SDK version 3.0.0.8 and mmWave Industrial Toolbox version 3.0.0. TI recommends getting the latest version of the demo software from the mmWave Industrial Toolbox.

3.2 Testing and Results

The following results are using the IWR6843ISK with a MMWAVEICBOOST board. Similar results can also be achieved for the IWR6843AOP EVM using the configuration provided in the software download.

3.2.1 Test Setup

Use case testing for implementing an area scanner and safety guard around equipment was carried out using a IWR6843 EVM. The EVM was mounted to a forklift located in a warehouse dock as depicted in 図 4. The EVM was oriented towards the area of concern where people could walk into the scene and approach the equipment.

A tower stack light was controlled by the output of the IWR6843 EVM. The top red light was used to indicate the critical zone had been breached, the middle yellow light was used to indicate that an object was in a cautionary zone, and the bottom green light was used to indicate that an object was detected in the area but outside either the critical or cautionary zones. The tower stack light was configured to be off entirely if the mmWave sensor had no detections in the field of view.

図 4. IWR6843 EVM Mounting and Test Scene

3.2.2 Test Results

To test the area scanner implementation, a person walked towards the IWR6843EVM while the output of the visualizer as well as the tower stack light was recorded. The ability of the mmWave based area scanner system to detect the person within the areas specified are summarized in 表 3

表 3. Area Configurations and Summary of Testing Results

Area	Configured to be Triggered by Detections Located Within:	Indicator Triggered by Person Walking Into Area:
Critical Area Indicator (Red)	1-m radius from EVM	Yes
Cautionary Area Indicator (Yellow)	1-m to 3-m radius from EVM	Yes
Acceptable Area Indicator (Green)	>3-m radius from EVM	Yes

The images below depict the system as implemented, as well as the output of the mmWave sensor to the visualizer. The visualizer plots the detected points and highlights the 1-m radius block area in which a person or object is detected. The point cloud illustrates the 3D data provided from the mmWave sensor, enabling X and Y localization as well as points in the elevation plane, to enable estimating the vertical extent of the object.

図 5. Acceptable Area

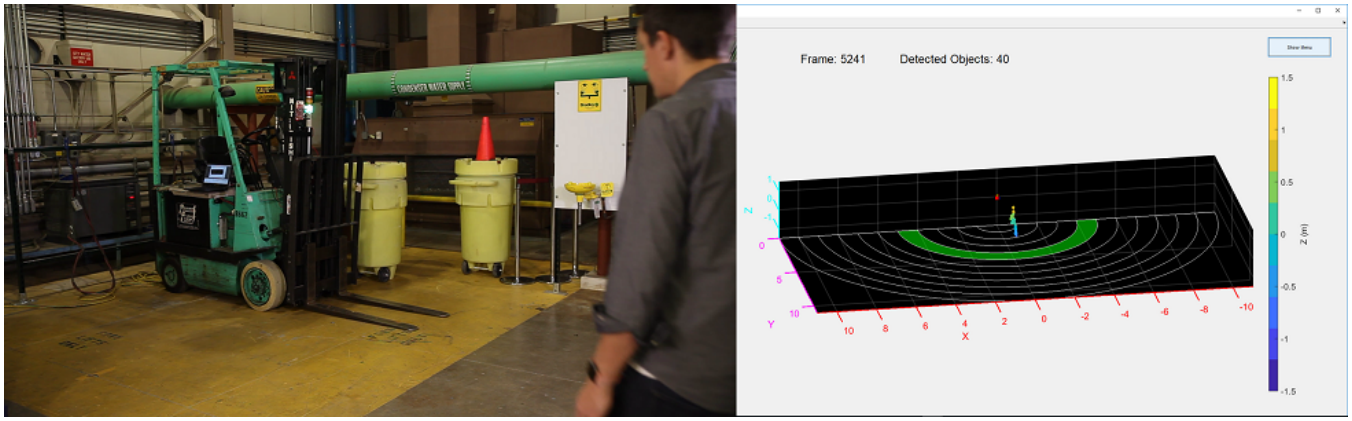


図 6. Cautionary Area

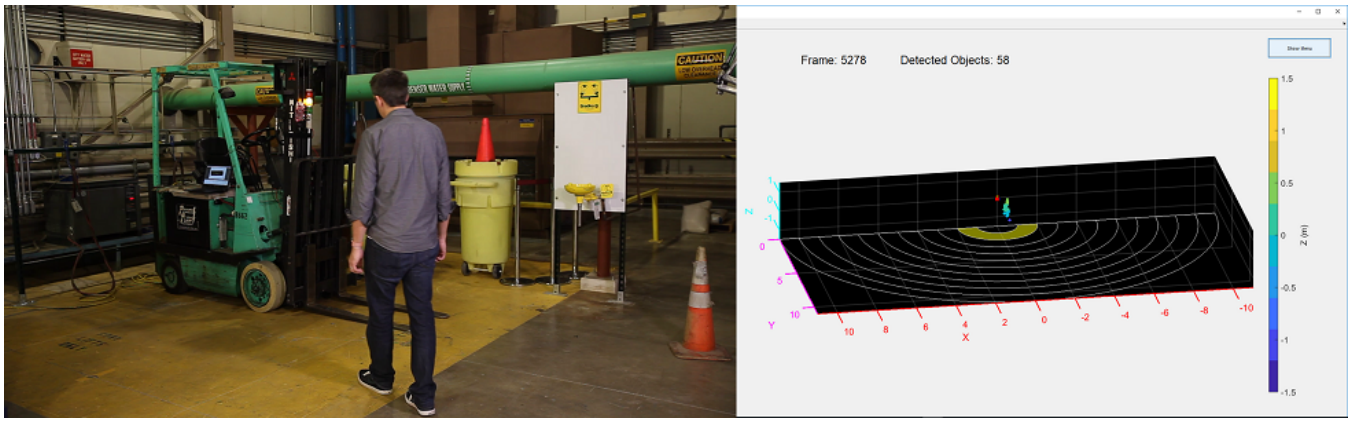
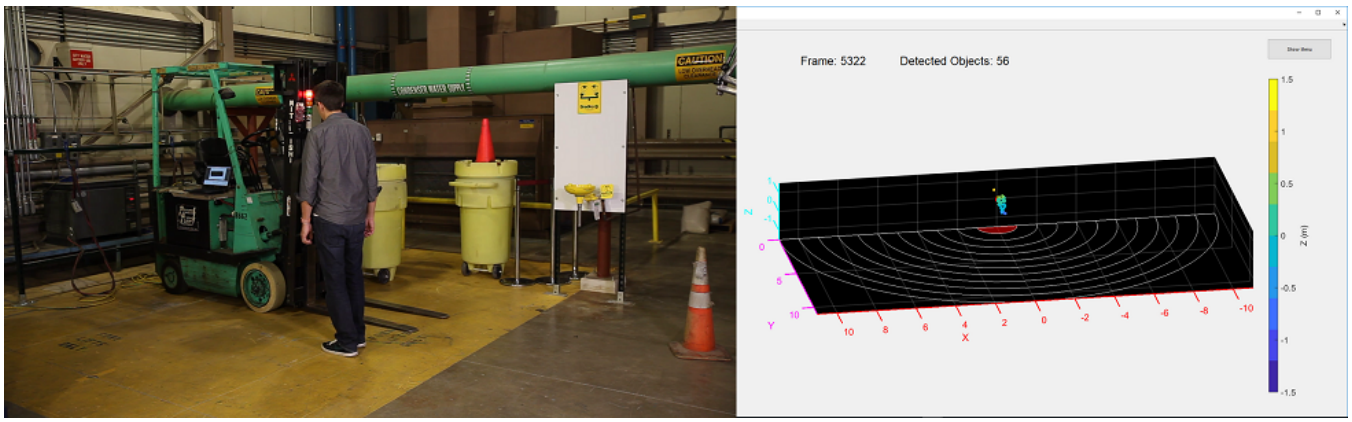


図 7. Critical Area



3.2.3 Observations and Conclusions

Using the IWR6843 EVM, the system demonstrated the ability to define and detect whether a human had entered into three distinct areas. A tower stack light was also integrated with the sensor as a visual warning indicator. With three transmitters on the IWR6843, elevation information is enabled and 3D point clouds are generated. When the person is closer to the sensor, a rich and dense point cloud with elevation information representative of the sensed object's height is generated. The area scanner system supports configuration and customization for specific use cases. The size of the areas are fully configurable by configuring the radial limits of each area. The detection range can be extended or reduced by designing and loading a different chirp configuration. The mmWave Sensing Estimator tool can be used to design a chirp configuration based on an application's sensing requirements.

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDEP-01010.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDEP-01010.

4.3 Altium Project

To download the Altium Designer® project files, see the design files at TIDEP-01010.

4.4 Gerber Files

To download the Gerber files, see the design files at TIDEP-01010.

4.5 Assembly Drawings

To download the assembly drawings, see the design files at TIDEP-01010.

5 Software Files

To download the software files, see the Area Scanner lab in the latest mmWave Industrial Toolbox.

6 Related Documentation

1. Texas Instruments, *IWR6843 Data Sheet*
2. Texas Instruments, *IWR6843 Evaluation Module (IWR6843ISK + mmWaveICBoost) Singe-Chip mmWave Sensing Solution*, user's guide
3. Texas Instruments, *IWR68xx/16xx/14xx Industrial Radar Family,* technical reference manual
4. Texas Instruments, *mmWave SDK*, tools folder

6.1 商標

6.2 デベロッパー・ネットワークの製品に関する免責事項

改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Revision A (June 2019) から **Revision B** に変更 **Page**

- タイトルを「ミリ波を使用するエリア・スキャナのリファレンス・デザイン」から「アンテナ・オン・パッケージ採用ミリ波センサを使用したエリア・スキャナのリファレンス・デザイン」に 変更 1
- 「IWR6843AOP」を「IWR6843AOPEVM」に 変更 1
- 「IWR6843 アンテナ・オン・パッケージ採用ミリ波センサを使用すると、設計および製造コストの低減、システム設計の簡素化、センサ占有面積の縮小、ひいては開発期間の短縮が可能です。」を 追加 1
- 「0m～10m の距離」を 追加 1
- 「最大 120°の視野角」を「IWR6843ISK を使用した場合に最大 120° の水平視野角 (FOV)」に 変更 1
- 「と 0m～10m の距離」を「IWR6843AOP を使用した場合に水平・垂直 130° の FOV」に 変更 1

2018年11月発行のものから更新 **Page**

- SK 評価モジュール (EVM) をミリ波センサに 変更 1
- IWR6843AOPEVM ツール・フォルダを 追加 1
- IWR-6843ISK を IWR6843ISK に 変更 1
- IWR6843AOP description 追加 2
- IWR6843 ISK: 追加 3
- Field of view detail information 変更 3
- specifications 追加 3
- highlighted products introduction 追加 4
- IWR6843ISK +MMWAVEICBOOST to IWR6843ISK or IWR6843AoP EVM 変更 4
- MMWAVEICBOOST are part of mmWave EVMs hardware. The boards combine to form the IWR6843 Industrial starter kit from Texas Instruments, an easy-to-use evaluation module for the IWR6843 mmWave sensing device. This board contains a 60-GHz mmWave Radar transceiver, in which antennas are etched and act as a radar front-end board. 削除 4
- paragraph 削除 6
- MMWAVEICBOOST subsection 追加 6
- System Design Theory description 削除 6
- Operation description 変更 6
- Industrial mmWave Starter Kit (IWR6843 EVM) 削除 8
- "5-V, 3.0-A power supply for the IWR6843 EVM" to "If using MMWAVEICBOOST, a 5-V, 3.0-A power supply" 変更 8
- Testing and Results description 追加 9
- Software Files text 変更 12

重要なお知らせと免責事項

TI は、技術データと信頼性データ (データシートを含みます)、設計リソース (リファレンス· デザインを含みます)、アプリケーションや設計に関する各種アドバイス、Web ツール、安全性情報、その他のリソースを、欠陥が存在する可能性のある「現状のまま」提供しており、商品性および特定目的に対する適合性の黙示保証、第三者の知的財産権の非侵害保証を含むいかなる保証も、明示的または黙示的にかかわらず拒否します。

これらのリソースは、TI 製品を使用する設計の経験を積んだ開発者への提供を意図したものです。(1) お客様のアプリケーションに適した TI 製品の選定、(2) お客様のアプリケーションの設計、検証、試験、(3) お客様のアプリケーションに該当する各種規格や、その他のあらゆる安全性、セキュリティ、規制、または他の要件への確実な適合に関する責任を、お客様のみが単独で負うものとします。

上記の各種リソースは、予告なく変更される可能性があります。これらのリソースは、リソースで説明されている TI 製品を使用するアプリケーションの開発の目的でのみ、TI はその使用をお客様に許諾します。これらのリソースに関して、他の目的で複製することや掲載することは禁止されています。TI や第三者の知的財産権のライセンスが付与されている訳ではありません。お客様は、これらのリソースを自身で使用した結果発生するあらゆる申し立て、損害、費用、損失、責任について、TI およびその代理人を完全に補償するものとし、TI は一切の責任を拒否します。

TI の製品は、TI の販売条件、または ti.com やかかる TI 製品の関連資料などのいずれかを通じて提供する適用可能な条項の下で提供されています。TI がこれらのリソースを提供することは、適用される TI の保証または他の保証の放棄の拡大や変更を意味するものではありません。

お客様がいかなる追加条項または代替条項を提案した場合でも、TI はそれらに異議を唱え、拒否します。

郵送先住所：Texas Instruments, Post Office Box 655303, Dallas, Texas 75265