

Y-band Phenomenology of Indoor Environment

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Introduction

Nowadays radars are commonly used in many civilian and military applications where standoff sensing and detection is needed. With the advent of technology and shortage of available spectrum at lower bands the operating frequency of the radars are being pushed higher. There are of course certain advantages associated with higher frequencies; most importantly is the reduction in size and mass of the radar for certain angular resolution as the frequency goes higher. In recent years, millimeter-wave radars have been widely used in applications ranging from automotive collision avoidance [1] to guidance systems for aircraft landing [2] and target detection and tracking [3]. Ability to penetrate poor weather, dust, smoke, cloth and other low loss but optically opaque material makes millimeter-wave radars suitable for navigation and surveillance [4]. To examine the utilization of radars for any application a thorough understanding of interaction of electromagnetic wave with the intended target and its environment is needed. In the past 20 years significant effort has been directed towards development of models based on theory and experiments at Ka-band and W-band [5]. However, such studies are rare at higher MMW frequencies. Our research group is engaged in developing an ultra lightweight short range MMW radar system operating at Y-band frequencies for collision avoidance and navigation of micro autonomous robotic platforms. Enclosed spaces and indoor environments are intended domain of operations for such system. In this paper, phenomenology of indoor environment at 215 GHz is investigated. A stepped frequency 215 GHz instrumentation radar system capable of vertical and horizontal polarization transmission and reception is utilized to collect backscatter data in indoor environment as the radar is moved within the building. As will be shown, horizontal polarization measurements give a much more accurate mapping of the environment compared to the vertical polarization. Measurement results are then processed to eliminate noise and shadow images, in order to create a clear mapping of the building.

Radar Front-End

A 215 GHz FMCW radar system has been used for performance assessment of such systems in indoor environment. This is a quasi-polarimetric radar which allows co-polarized and cross-polarized measurements for both vertical and horizontal polarizations. Two Gaussian Optics Lens Antennas (GOLAs) are used to transmit and receive radar signal. As can be seen in Table 1, the radar has narrow transmit and receive beams of 2.5° and 1.5° respectively. RF signal has bandwidth of up to 2 GHz, which results in a theoretical range resolution of 7.5 cm. LO signal is generated at 106 GHz by a Gunn oscillator, which is mixed with the IF signal (2 to 4 GHz) and up-converted to the Y-band RF signal using a harmonic mixer. A simplified block diagram of the radar RF-subsystem is shown in Fig 1.

Measurement Setup

A full scan of the environment is needed to map the hallways and obstacles in the indoor environment. For that, the radar is placed on a turntable with 360° rotation ability. The turntable is controlled with Aerotech Soloist SC motion controller. For data accusation, radar is connected to a HP 8735 30kHz-6GHz vector network analyzer. A Personal Computer (PC) governs the turntable position and data accusation by VNA. A LabView interface has been developed for data collection. Fig 2 shows the schematic of the measurement setup.

In order to create a complete map of the indoor environment, the hallways are scanned in 1 meter steps (Fig. 3). At each step, radar scans from -90° to 90° in steps of 1° . At each step, 401 frequency points are swept from 2.2 GHz to 3.2 GHz. The transmitted output power of the radar is about 0 dBm.

Measurement Results and Data processing

The raw data for HH measurement of a hallway with tile walls in the time domain is shown in Fig. 4. As can be seen, background noise and the side lobes of strong targets make the figure difficult to interpret. A MATLAB code has been developed to eliminate the background noise and other distortions in the image. The corrected image shows a clear map of the hallway (Fig. 5). Sharp edges in tile walls result in large reflections for both VV and HH polarization. However, for the drywall hallways, there is significant difference in the images created by horizontal and vertical polarization measurements. Fig. 6 and Fig. 7 compare the images VV and HH measurements in a drywall hallway. One of the main problems in the indoor imaging is the presence of “ghost” images which are the reflection of strong targets (corners, door frames, etc.) from other walls (Fig. 3). This problem is exaggerated in VV measurements compared to HH measurements. For oblique incidence, a large portion of horizontally polarized signal penetrates into the wall, and hence, larger backscatter results from volume scattering, whereas vertically polarized signal are reflected on the smooth surface of drywall, and contribute to the ghost image problem.

Conclusion

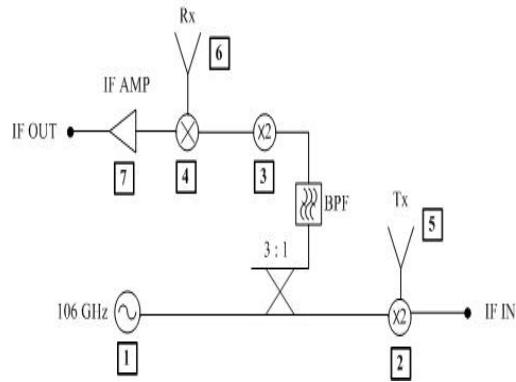
Characteristics of indoor environment at Y-band frequencies have been investigated. Radar measurements of hallways were carried for both vertical and horizontal polarizations. Measurement results show that horizontal polarization gives a more accurate mapping of the indoor obstacles.

References

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Table 1 215 GHz FMCW Radar Characteristics

Items	Specifications
RF Frequency	214 GHz to 216 GHz
IF Frequency	2 GHz to 4 GHz
Transmit Power	10 mW
Downconvertor Conv. Loss	10 dB
Transmit Beam	2.5°
Receive Beam	1.5°
Transmit Polarization	V and H
Receive Polarization	V and H



1. Gunn Oscillator (106 GHz, 31 mW)
2. Harmonic Up-convertor
3. Doubler
4. Down Coverter
5. Gaussian Optics Lens Antenna (3 inches)
6. Gaussian Optics Lens Antenna (1.5 inches)
7. Medium Power IF Amplifier (13 dBm)

Fig. 1 Block diagram of the RF-Subsystem

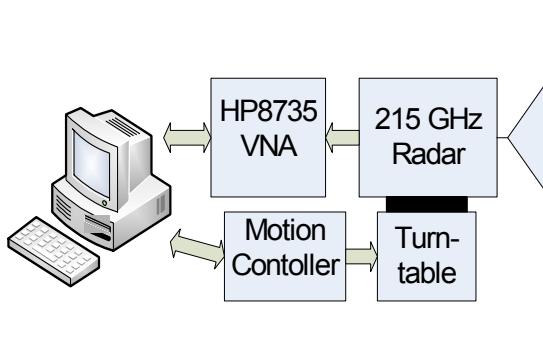


Fig. 2 Block diagram of the measurement setup

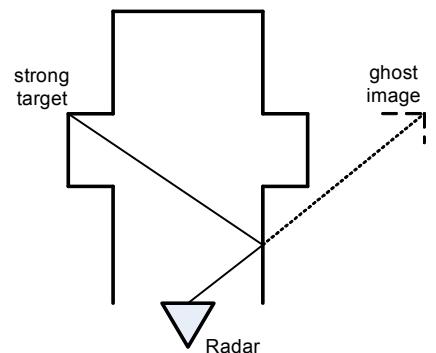


Fig. 3 ghost image in indoor imaging

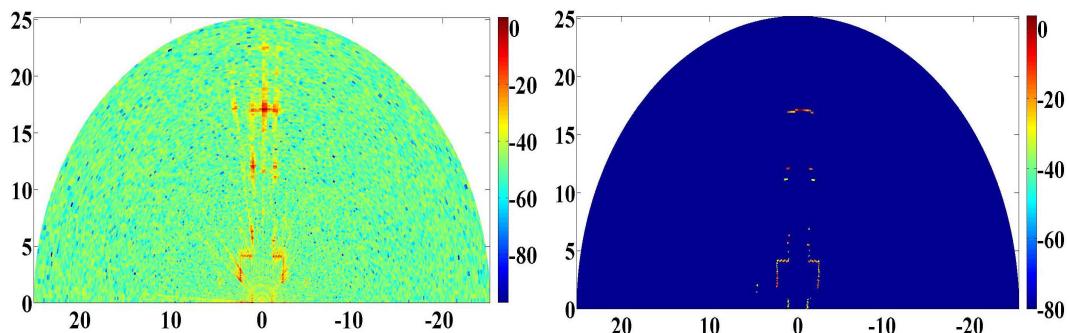


Fig. 4 Raw image of tile wall hallway (HH measurements)

Fig. 5 Corrected image of tile wall hallway (Fig. 4)

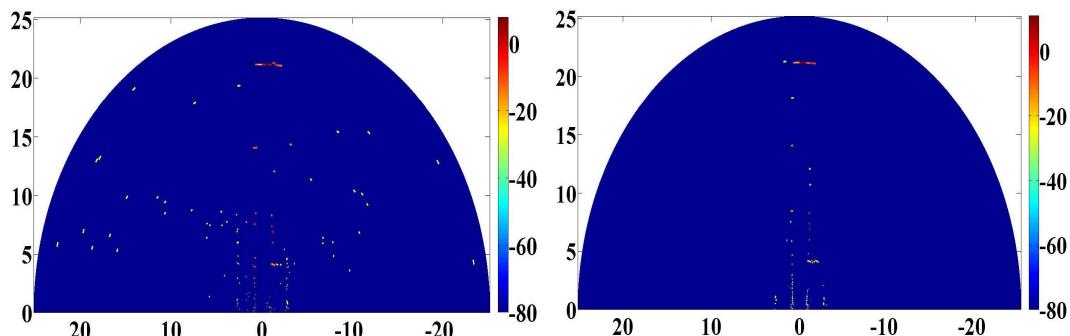


Fig. 6 Image of drywall hallway for VV measurements

Fig. 7 Image of drywall hallway for HH measurements