FMCW Radar Simulation for Range Estimation

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FMCW Radar Simulation Overview

– Evaluation Case
  • According to the given specifications of FMCW radar system, to evaluate the desired radar detection performance

– Objectives
  • Range estimation under different ranges of target
  • Radar ranging accuracy
  • Radar range resolution
FMCW Radar System Specifications

- Waveform
  - LFMCW,
  - PRI: 2.5ms,
  - Frequency Sweep Time: 2ms,
  - Off Time: 0.5ms,
  - Bandwidth: 300MHz

- Antenna Gain: 27dB

- Carrier Frequency: 34GHz

- Tx: Transmitting Power: 1W

- Rx: Gain = 75dB, NF = 5dB

- Target RCS: 0.5m²

The theoretical calculating value of range is about 3000 m under these specifications.
Simulation Platform

– Win7 x64 on HP EliteBook 840G1 with 8GB RAM

– SystemVue2015.01 x64
Simulation Flow

Create Schematic
- Create FMCW radar system schematic with Radar library and basic algorithm models
- Connect models into a complete system

Parameters Setting
- Select models to set up variables
- Set variables as parameters

Simulation
- Set simulation parameters
- Perform simulation

Data View
- Check CFAR and threshold
- Check range estimation
Initial Estimation

By using Radar Equation

Assume:

- System Loss = 2 dB,
- Propagation Path Loss = 2 dB,
- Minimum SNR = 13 dB,
- Single Detection

The maximum range might be detected is about 3500 m.
LFMCW Radar Solution in SystemVue

Estimated Range = 3001.0986 m
Distance = 3000 m
Radial Velocity = 0 m/s

Input parameters:
- Velocity = 0
- Distance = 3000 m
- Estimated Velocity = 0 m/s
- Estimated Range = 3001.0986 m
LFMCW Radar Waveform Generation

Source

FreqUpTime=2e-3 s
FreqDownTime=0 s
FreqFixTime=0 s
OffTime=0.5e-3 s
DeltaFreq=300e+6 Hz [Bandwidth]
SampleRate=600e+6 Hz [fs]

StartStopOption=Auto

StartStopOption=Time
Transmitter RF chain & Antenna

CCDF_Env model is used as power meter

Tx Transmitting Power

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<th>Index</th>
<th>C4_MeanPower_dBm_Index</th>
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Antenna Radiating Power

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<th>C6_MeanPower_dBm_Index</th>
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Two targets are used for estimating the range resolution.
Receiver Antenna & RF chain

CCDF_ENV model is used as power meter

IQ receiver is used for calculating the beat frequency
Anti-aliasing filter and digital decimation

F1 (FIR_Cx@Data Flow Models)
Taps=(1x462) [3.574e-3, 3.358e-6, 3.754e-9, ...]

D2 (DownSample@Data Flow Models)
Factor=50
Phase=0

Anti-aliasing filter
DSP - estimating the beat frequency

FFT based digital beat frequency estimation

F2 {FFT_Cx@Data Flow Models}
FFTSize=32768 [FFTSize]
Size=30000 [PRI*fs/downsample_rate]
Direction=Forward
FreqSequence=0-pos-neg
Target CFAR detection

CFAR and target detection probability measurement

CFAR detection adaptive threshold (blue)
CFAR detection result (red)
Target range measurement

MatlabScript based user-defined model for range estimation

Matlab based range and velocity estimation algorithm
Target detection in different ranges
false alarm probability is 1e-6

Target range = 2000m
Target detection in different ranges
false alarm probability is $1e^{-6}$

Target range = 2700m
Target detection in different ranges
false alarm probability is $1\times 10^{-6}$

Target range = 3200m
Target detection in different ranges
false alarm probability is $1 \times 10^{-6}$

Target range = 3300m
Target detection in different ranges
false alarm probability is $1e^{-6}$

Target range = 3400m

The target cannot be detected by Radar when the target range is 3400m
The ranging accuracy is about 0.3m
The distance between the two targets is 1m

Both of the two targets located in 3000m range away are detected by radar
Range resolution

Sweep the distance between two targets, from 0.1m to 1m

Only one target located in 3000m range away is detected by radar when the distance between two targets is equal to or less than 0.6m
Range resolution

The distance between the two targets is 0.5m

Only one target located in 3000m range away is detected by radar
Conclusion

– SystemVue can implement the FMCW Radar system architecture and simulation for range estimation.

– SystemVue can get the desired results of range estimation, ranging accuracy and range resolution.

– It is easy and flexible to get the range estimation results by adjusting the specification parameters of custom FMCW Radar in SystemVue.