MIT LL Group 105 MQP Final Presentation

Design of a Ku-Band Instrumentation Synthetic Aperture Radar System

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LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

WPI

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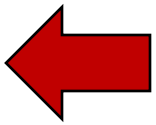
Outline

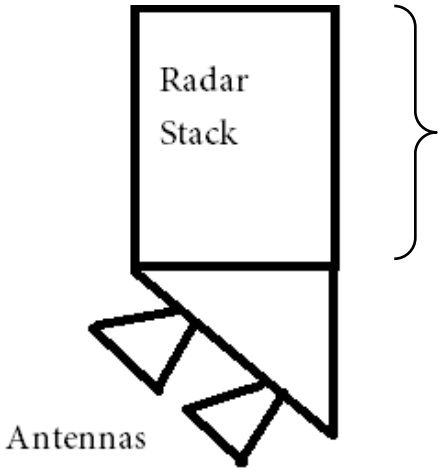
- Project Description 
- Design
- Lab Test Results
- Field Test Results
- Conclusion

Project Motivation

MIT Lincoln Laboratory has developed a small form factor Ku-band Synthetic Aperture Radar (SAR) intended for deployment on a Tier-1 UAV

Example SAR Image

https://engineering.purdue.edu/~ace/sar/libcong.jpg



Pro: Small form factor great for field use on UAVs

Con: Performance sacrificed for a small form factor, not good as an instrumentation radar

Goal: Design a chassis based radar system that is not limited by size, weight, or power

Radar Requirements

	LL LiTE SAR	MQP radar
Operating Frequency	16 to 17 GHz	16 to 17 GHz
Usable Instantaneous Bandwidth	500 MHz	1 GHz
SAR Resolution	12”	6”
point-scatter side lobes	-20 dB	-30 dB
Recording Mechanism	Compact Flash	1 GbE Streaming
Real-time Display	No	Yes
Nominal Range	700 feet	700 feet
Range Swath	200 feet	200 feet
NEσ0 (SAR Sensitivity)	-40 dB	-40 dB

***The relationship of basic radar parameters to performance can be obtained in open literature and textbooks such as: Introduction to Radar Systems (Skolnik 1981)**

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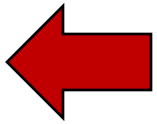
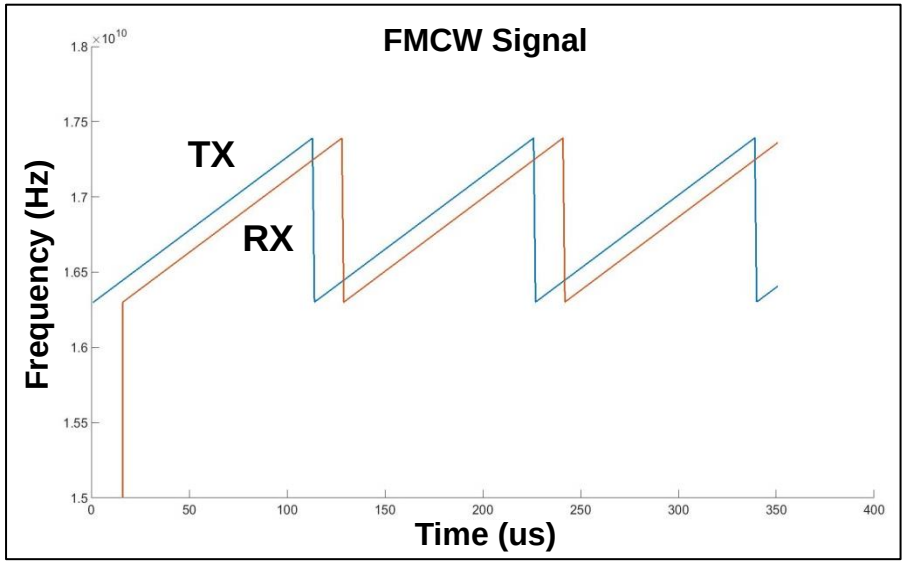
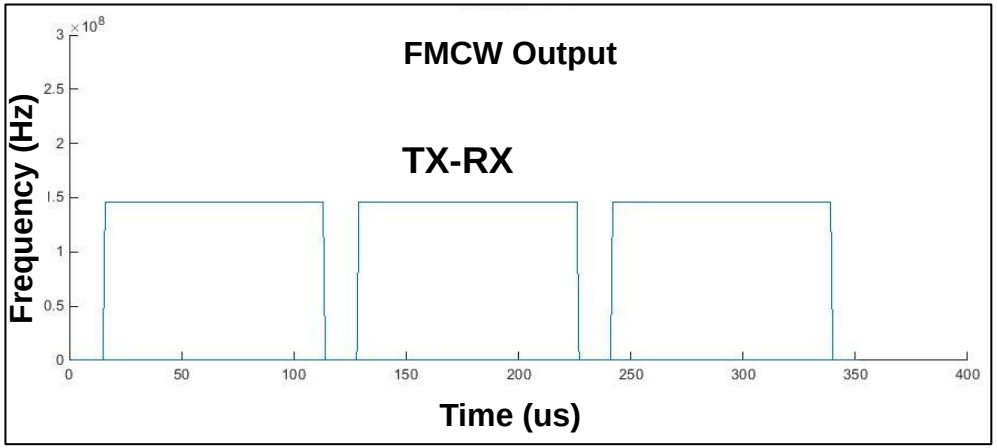
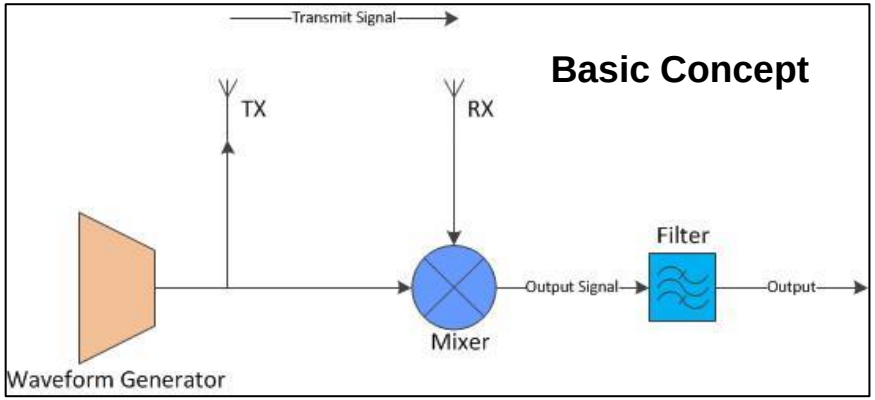


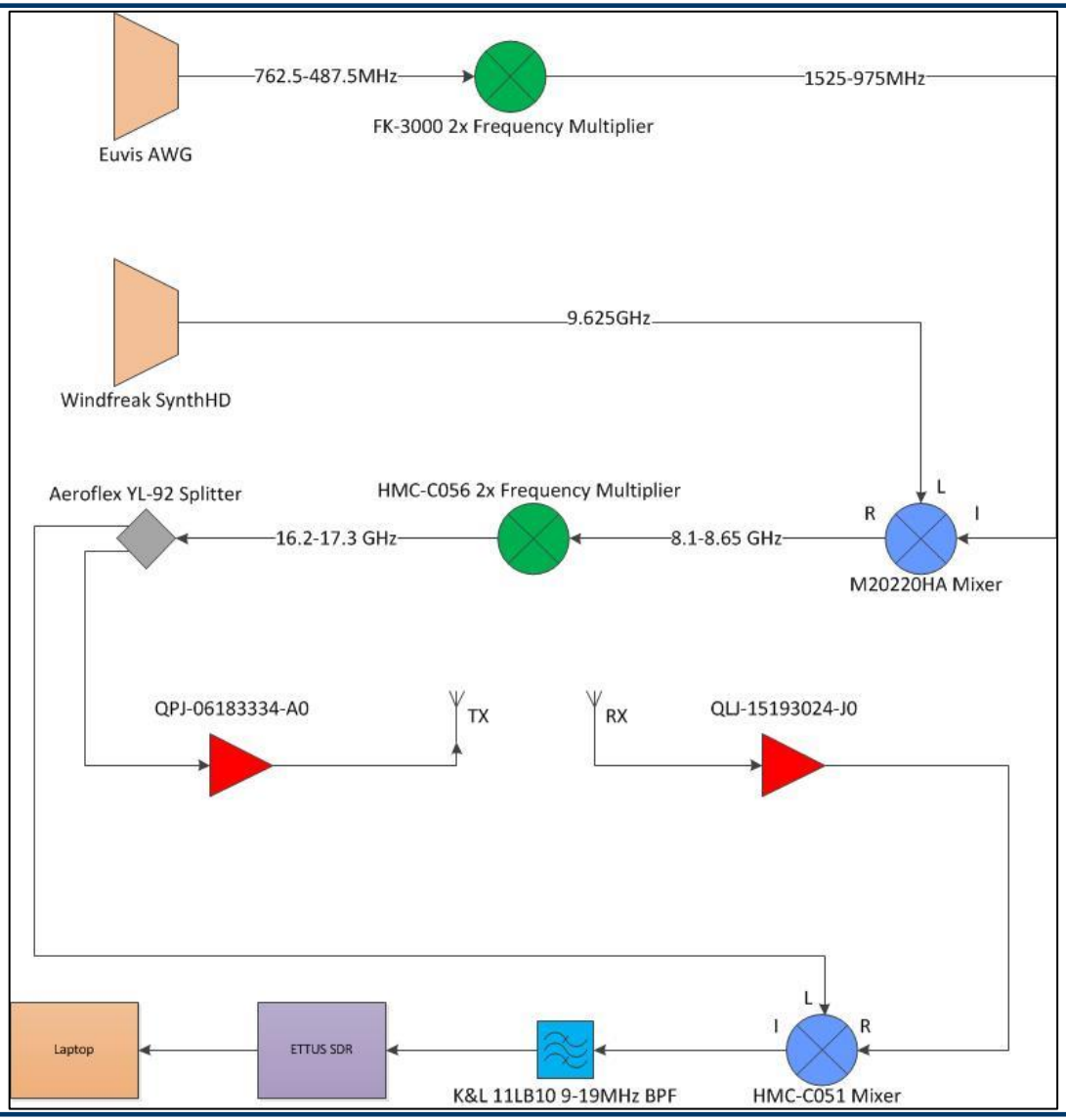
Frequency Modulated Continuous Wave (FMCW) Radar



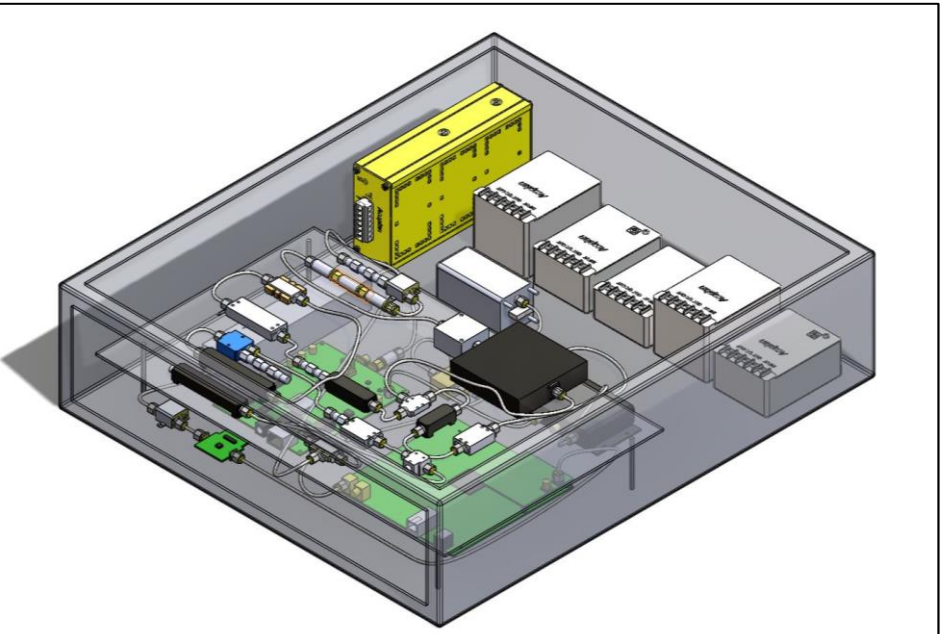




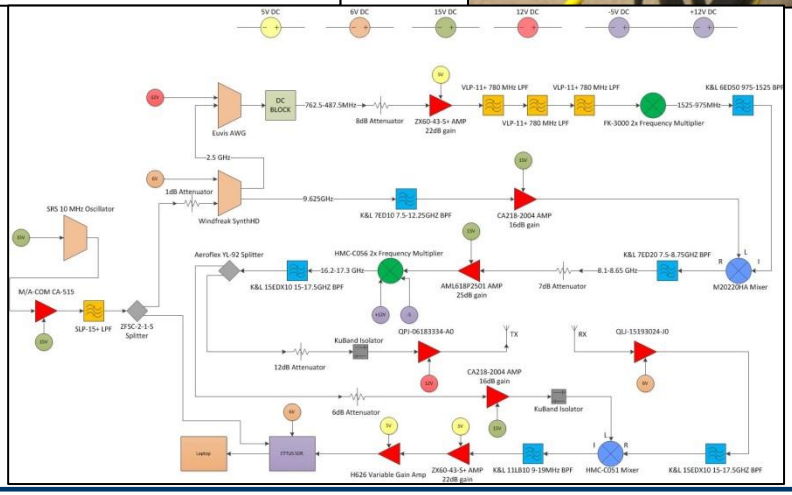
Basic System Model



Final Product



20in by 17.5in by 5in,
1750 cubic inches



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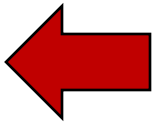
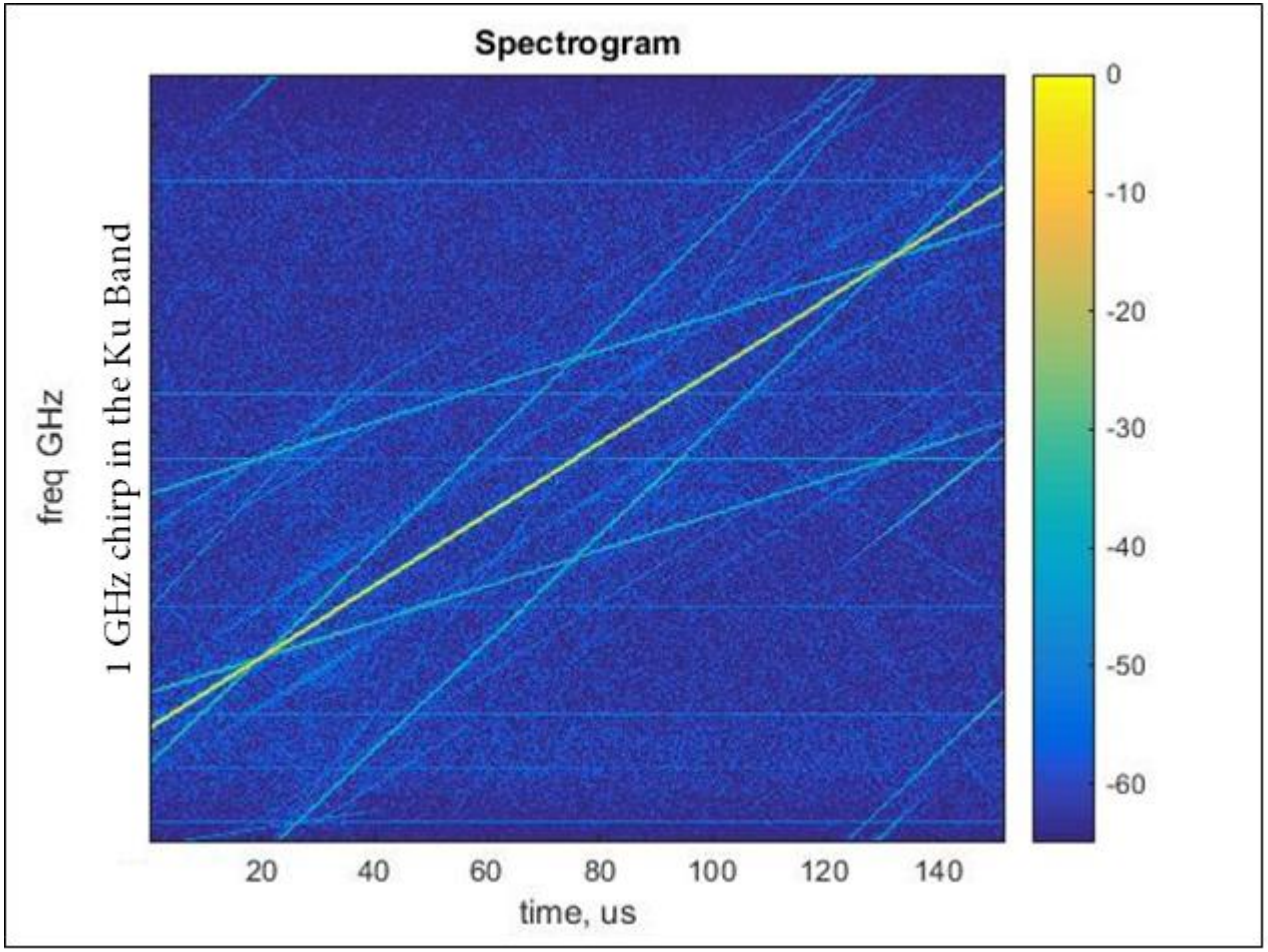


Setup

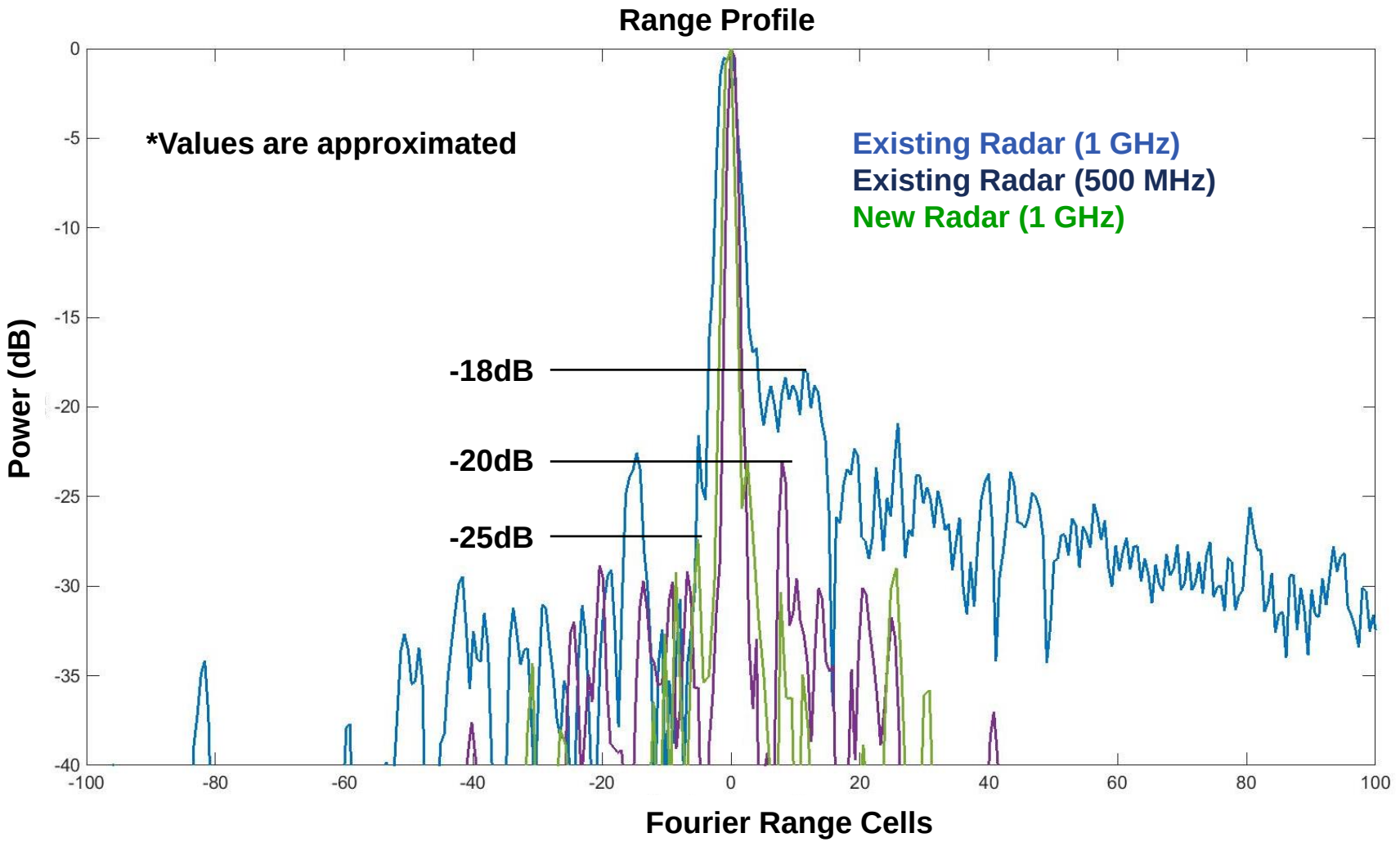
- **Measured the signal out of the Power Amplifier with a 60 Gsps Oscilloscope**
- **Frequency range of the signal was 16-17 GHz**
- **Signal was attenuated with a high power attenuator**
- **Waveform was saved with the Oscilloscope and analyzed in Matlab**

Spectrogram



- **Useable Bandwidth of the Signal Measured to be 1.0923 GHz**
- **Noise cause by DAC spurs that can be removed with future work**

Range Profile and Spectrogram



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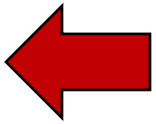
- Field Test Results 
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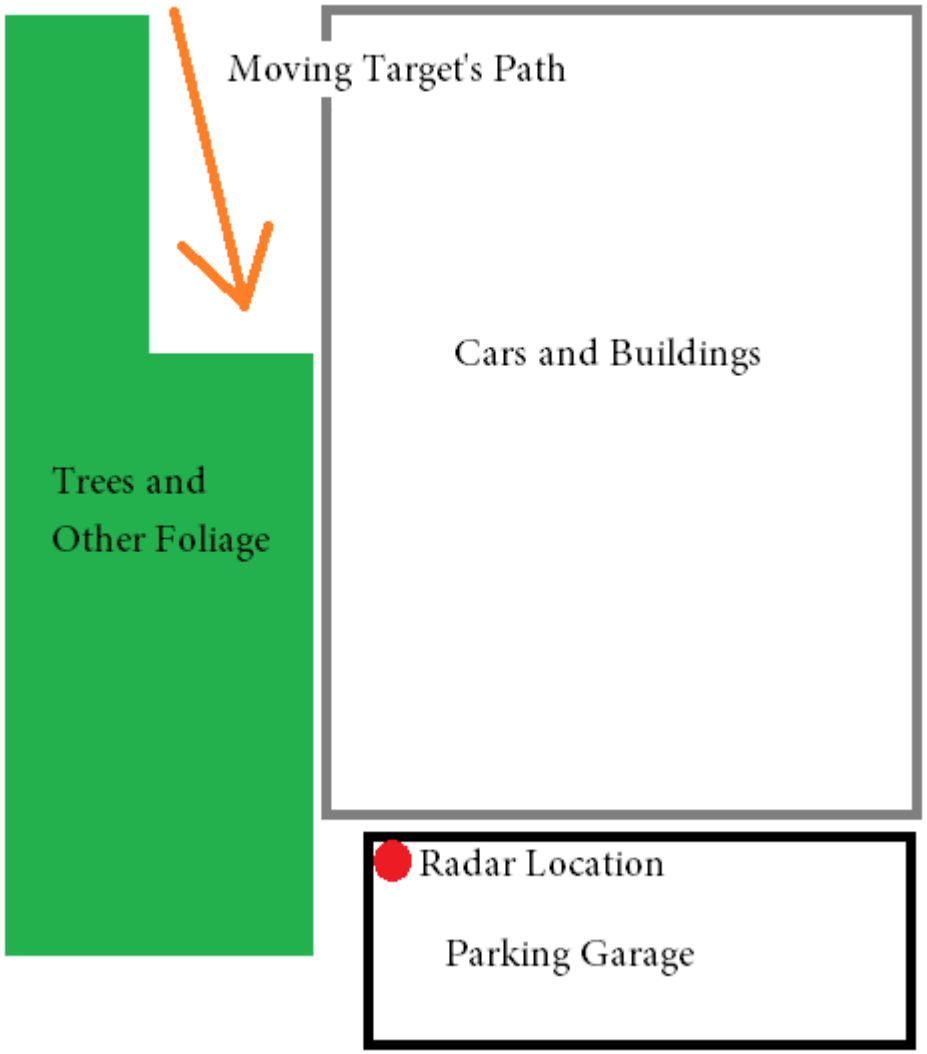
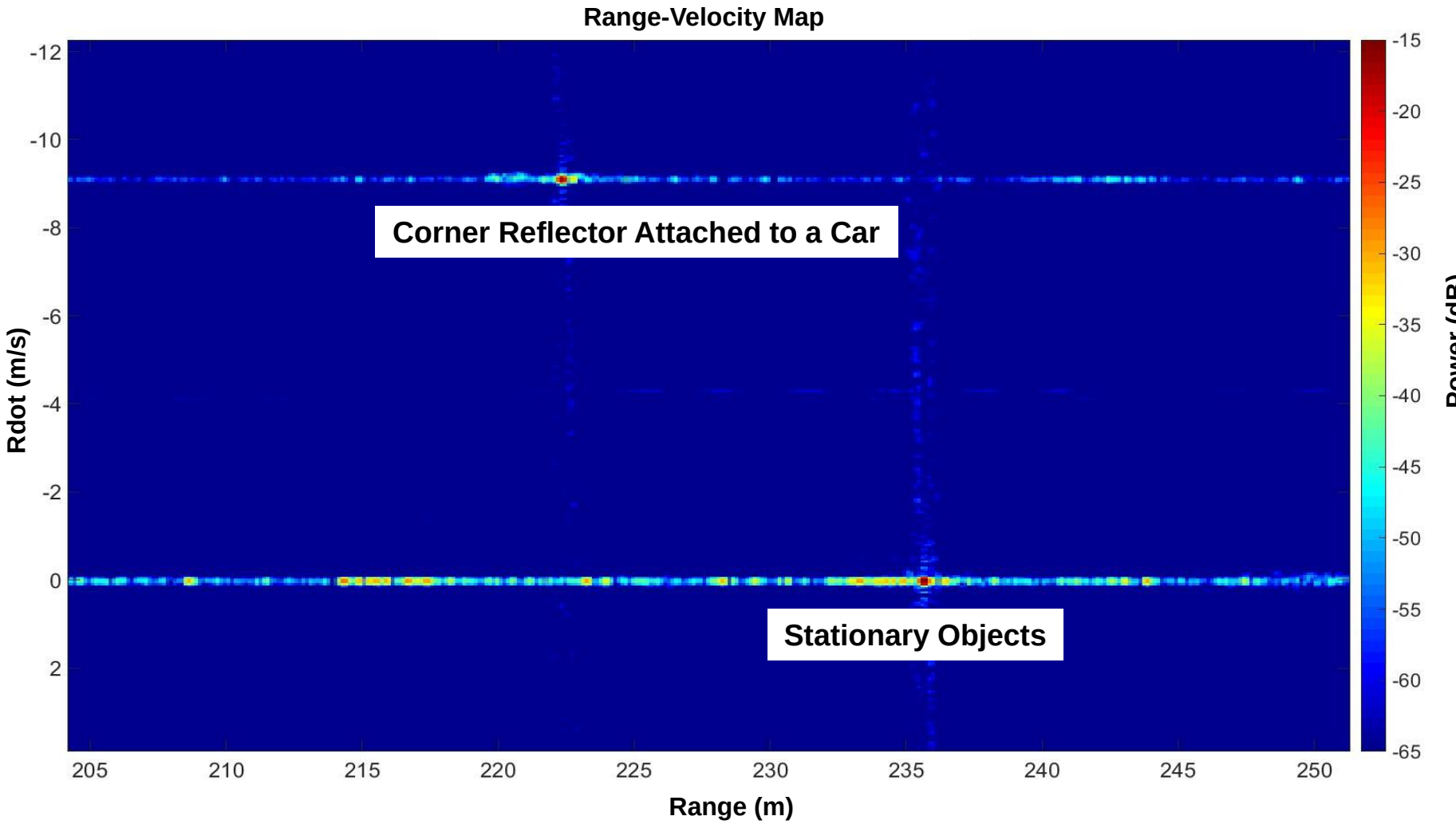
Test Setup

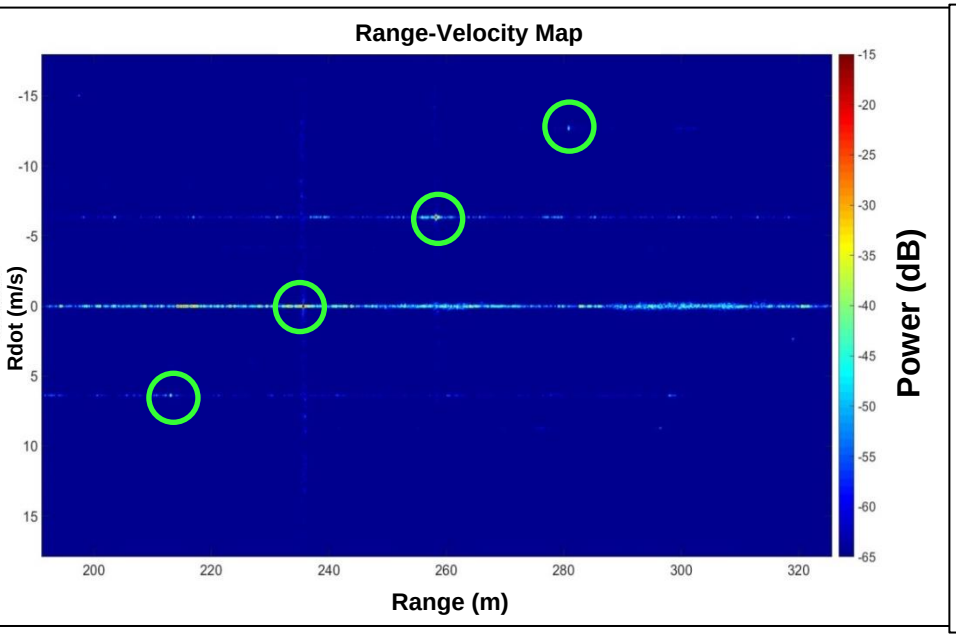


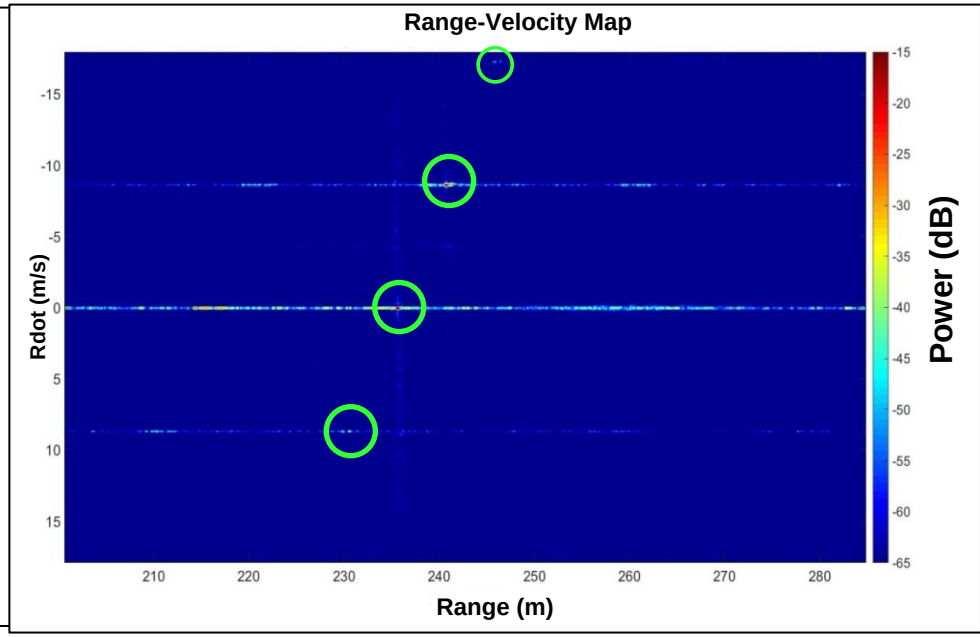
- **Radar placed on top of parking garage**
- **Targeted Bestic Dr between Hartwell Ave and Schilling Cir**
- **Radar system used 15 dBi antennas**
- **Target was a corner reflector with an RCS = 34dBsm**

Moving Car


Range-Velocity Map
Corner Reflector Attached to a Car
Stationary Objects
Rdot (m/s)
-12
-10
-8
-6
-4
-2
0
2
Range (m)
205
210
215
220
225
230
235
240
245
250
Power (dB)
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65

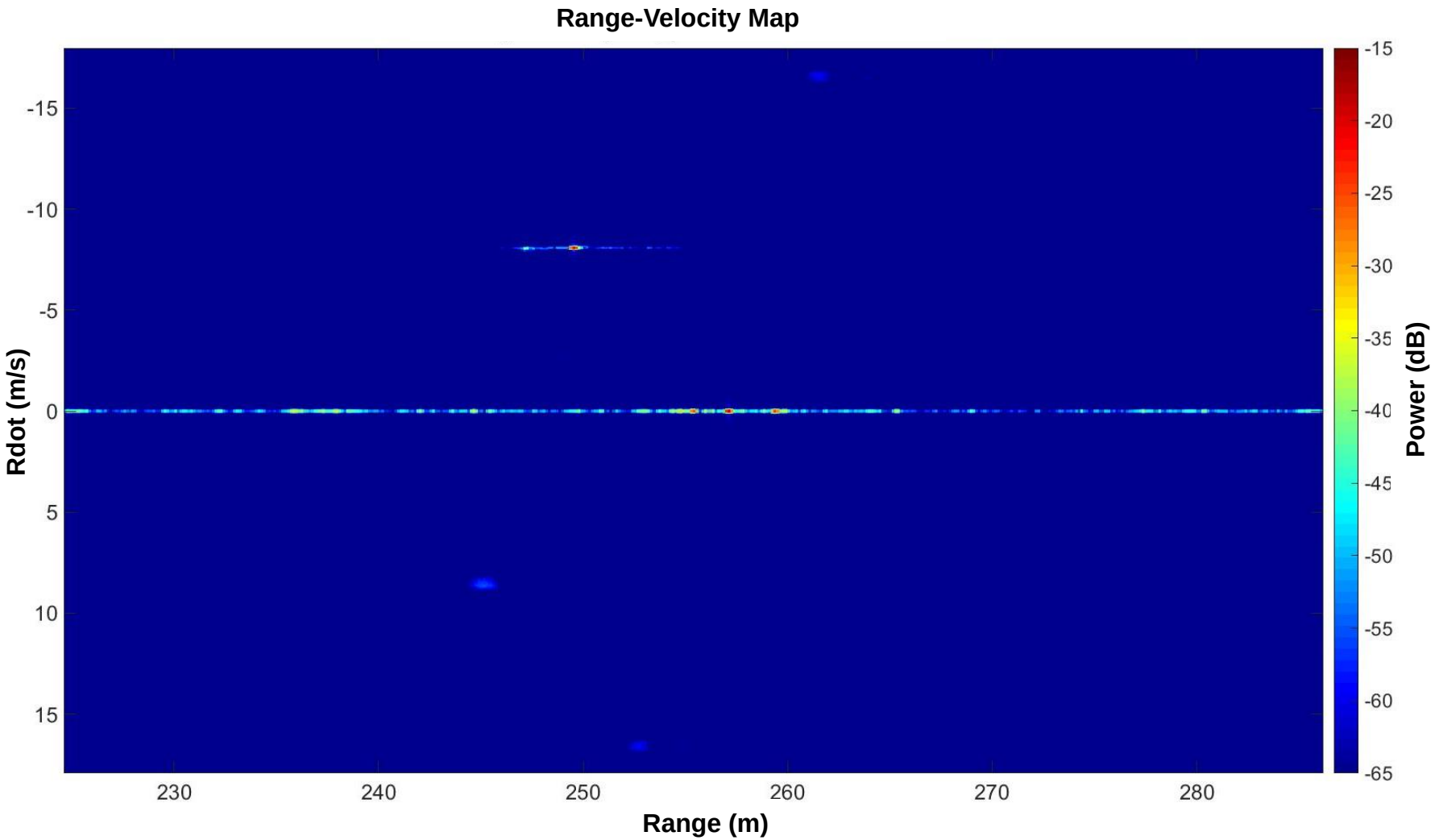
Intermod Anomaly



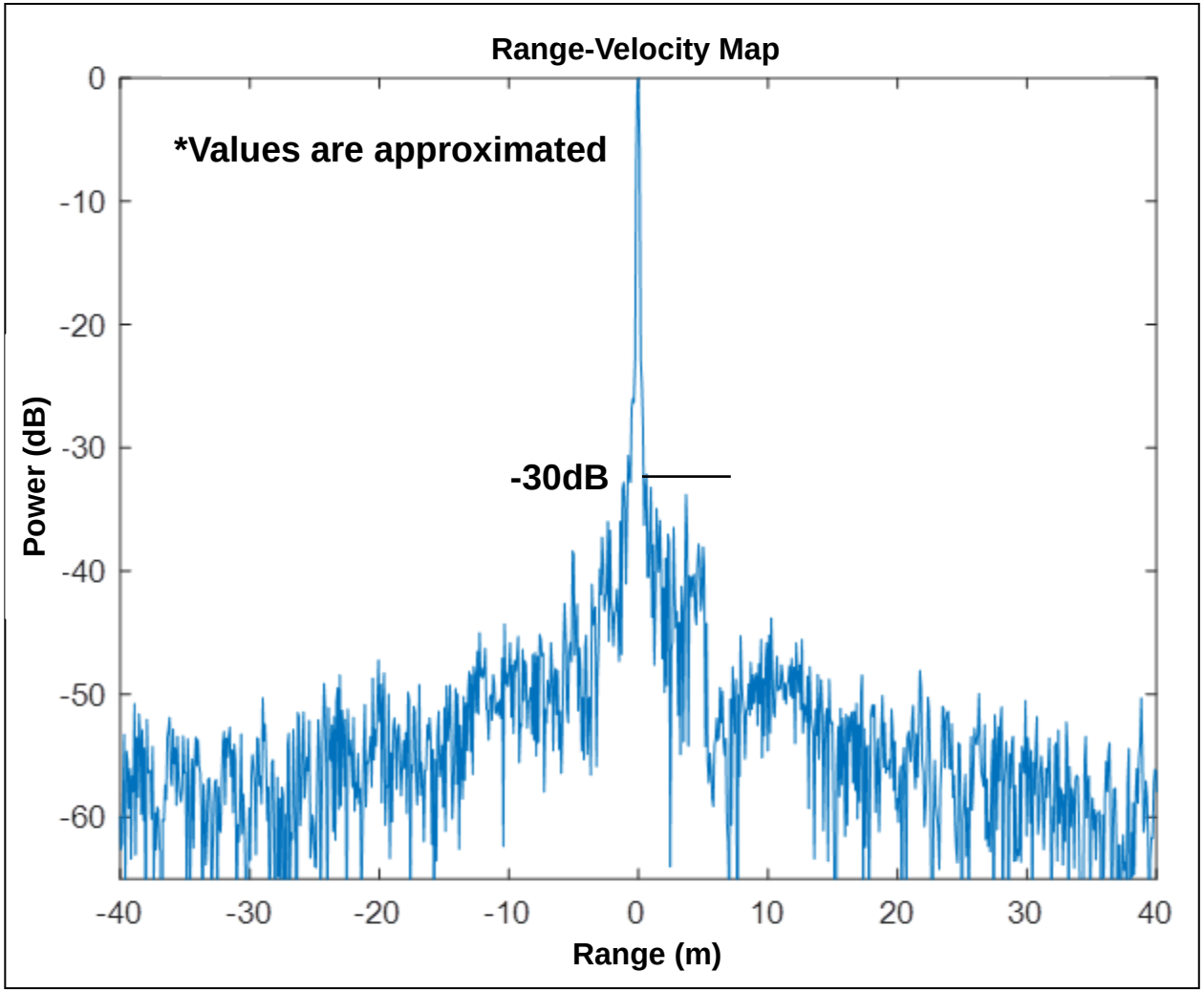


Intermodulation signals caused by frayed cables and a bad variable gain amplifier.

Retest with New Amplifier and Cables



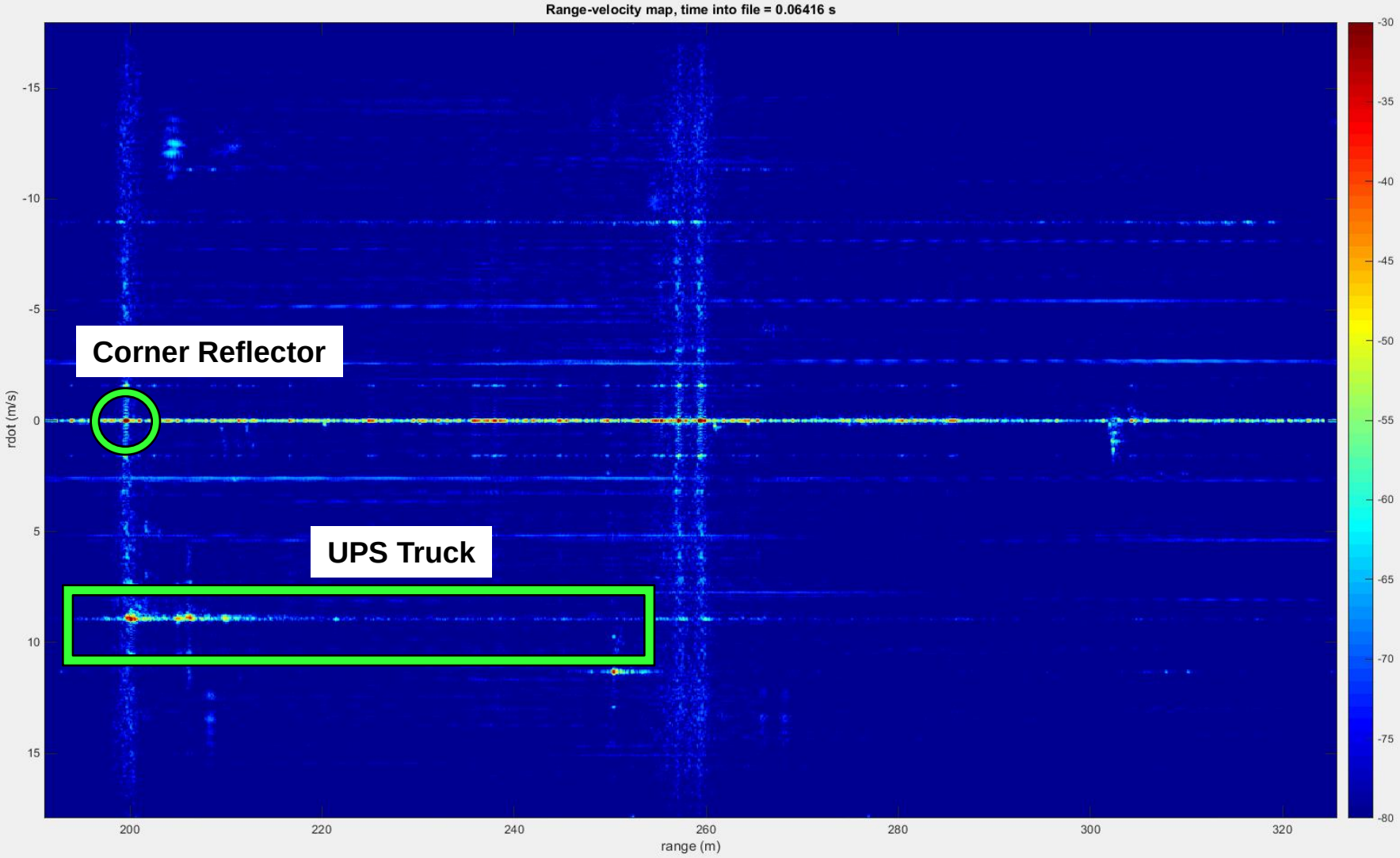
Field Measured Range Sidelobes



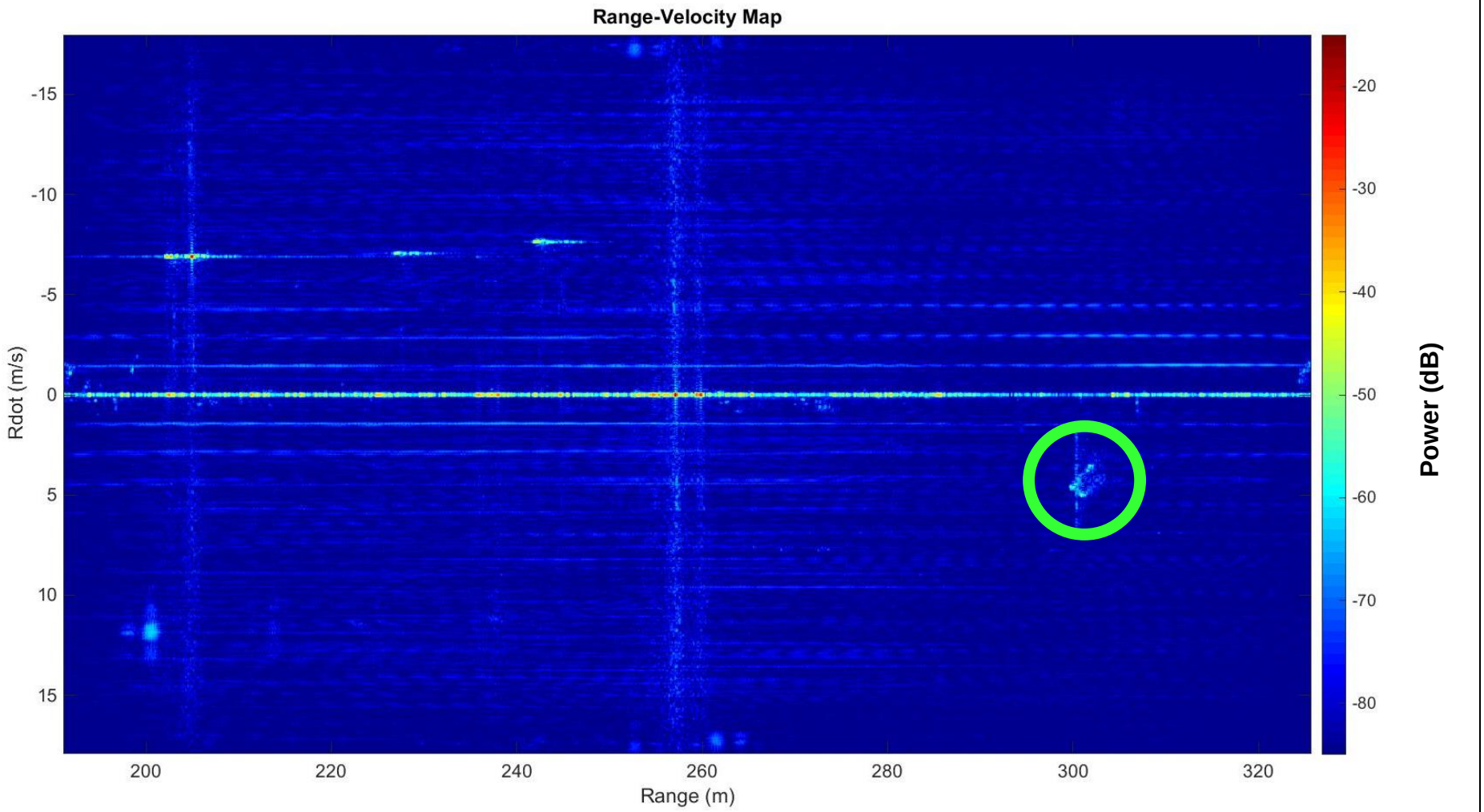
1 GHz bandwidth and 40 dB Taylor sidelobe control used

Range Sidelobe values of about -35*dB* , 10*dB* lower than measured in the lab

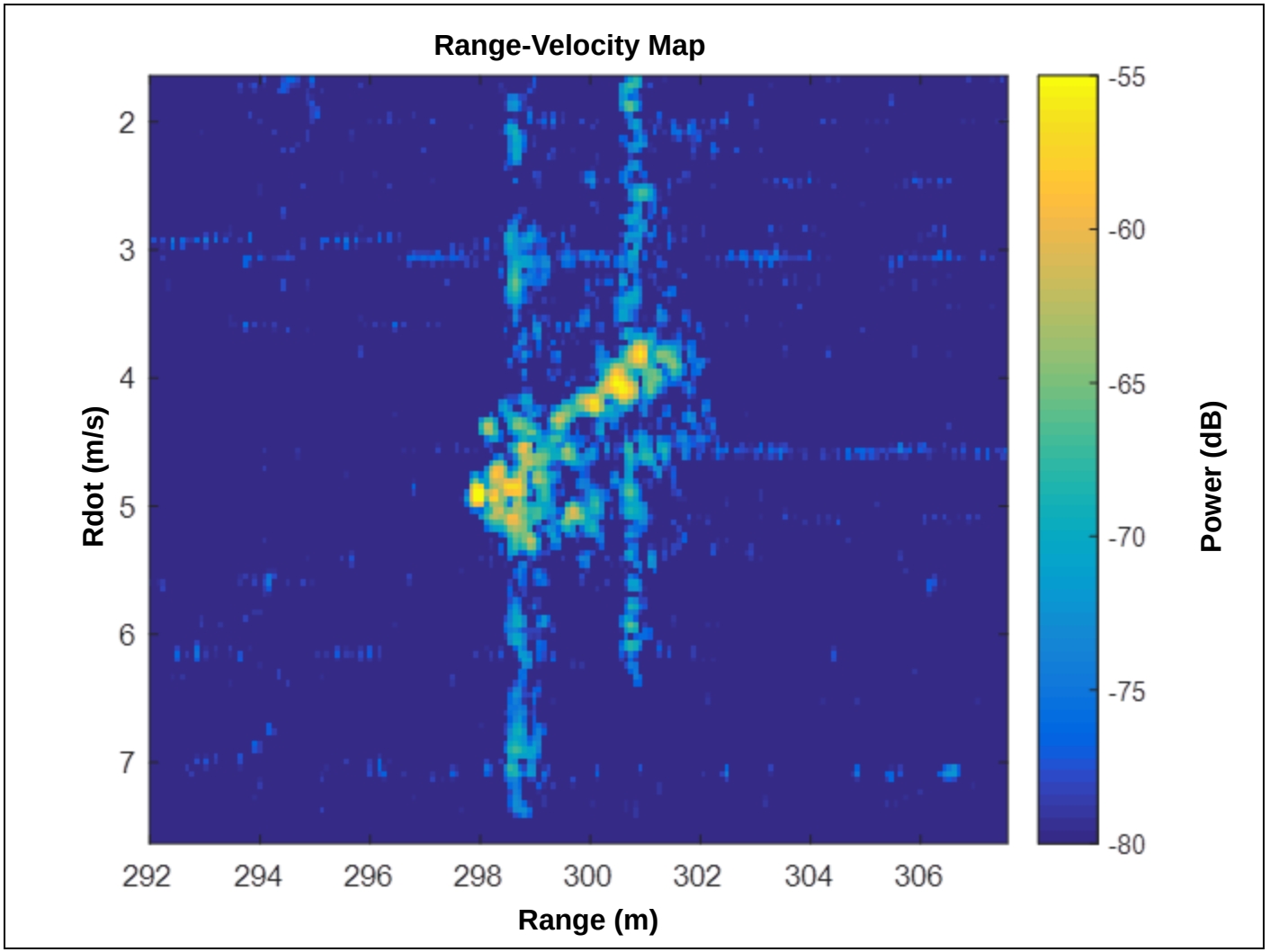
Semi Truck Car



ISAR Image


Range-Velocity Map
Rdot (m/s)
-15
-10
-5
0
5
10
15
200
220
240
260
280
300
320
Range (m)
Power (dB)
-20
-30
-40
-50
-60
-70
-80

Keystone Transform on an ISAR Image



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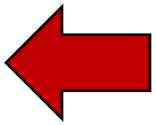


Comparing the Radar Systems

	LL LiTE SAR	MQP radar	How the Parameter was Measured
Operating Frequency	16 to 17 GHz	16 to 17 GHz	Lab Oscilloscope
Usable Instantaneous Bandwidth	500 MHz	1 GHz	Lab Oscilloscope
SAR Resolution	12”	5”	Calculated
point-scatter side lobes	-20 dB	-35 dB	Field Data
Recording Mechanism	Compact Flash	1 GbE Streaming	n/a
Real-time Display	No	Possible	n/a
Nominal Range	700 feet	700 feet	Field Data
Range Swath	200 feet	200 feet	Field Data
NEσ0 (SAR Sensitivity)	-40 dB	-40 dB	Calculated

***Values are approximated**

Future Work

- **Remove DAC spurs with post processing or equalization**
- **Add isolators and check mixer power levels to remove unwanted signals**
- **Test with a more powerful laptop for more real time data**
- **Adapt the design for a Ka-band instrumentation radar system**
- **Test SAR capabilities of radar**

Acknowledgements

Project Supervisor

- Andy Messier – Group 105

Initial Learning and Setup

- Jeffery Blanco – Group 105
- Tasadduq Hussain – Group 105

Hardware Debugging

- Ricky Hardy – Group 105

Field Testing

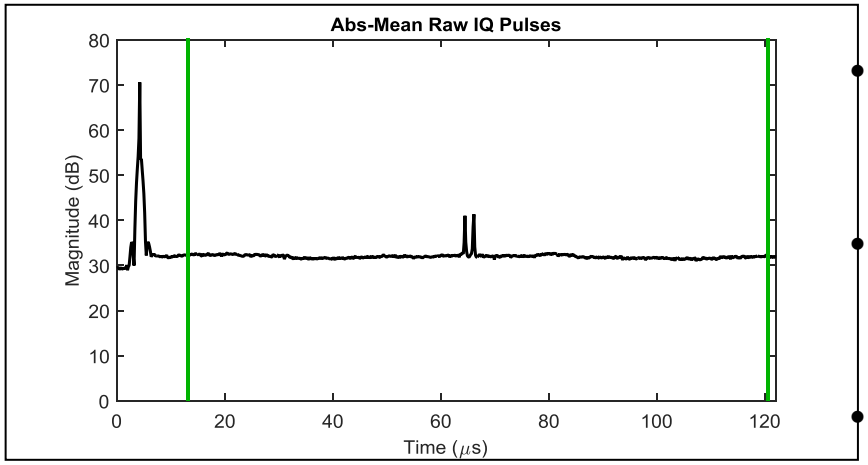
- Will Bartlett – Group 107
- Dennis Blejer – Group 105

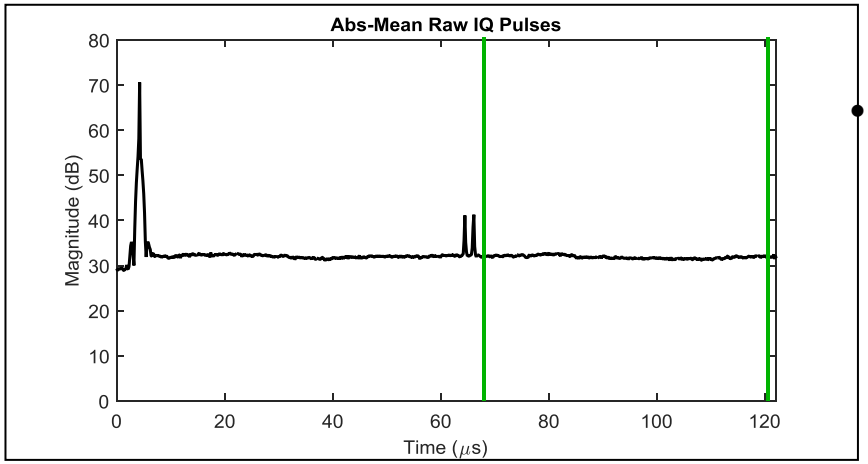
Matlab Analysis

- Gerald Benitz – Group 105

Supplemental Slides

Bandwidth Issues of the Old Radar System





- Old radar used two analog waveform generators
- One would start an LMF chirp when the other finished it's chirp
- When the two signals overlapped, the filters in the radar could not remove the resulting peaks
- Only about half of the bandwidth could be used

Pulse Width and SAR Resolution

Time Delay: $2 * \frac{d}{c} = 2 * \frac{(707) * .3048\ m}{3 * 10^8 m/s} = 1.437us$

Pulse Slope: $\frac{f}{t_{delay}} = \frac{0.014GHz}{1.437us} = 9.74MHz\ per\ us$

Pulse Width: $\frac{\Delta f}{m_{pulse}} = \frac{17.3GHz - 16.2GHz}{9.74MHz\ per\ us} = 112.82us$

SAR Resolution: $\frac{c}{2B} = \frac{3e8}{2(1.0923e9)} = 0.137m = 0.450ft$