ISART Workshop on Best Practices: Field Measurement Best Practices

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Outline

- Motivation
- Important Practices

Practice Makes Permanent

Motivation

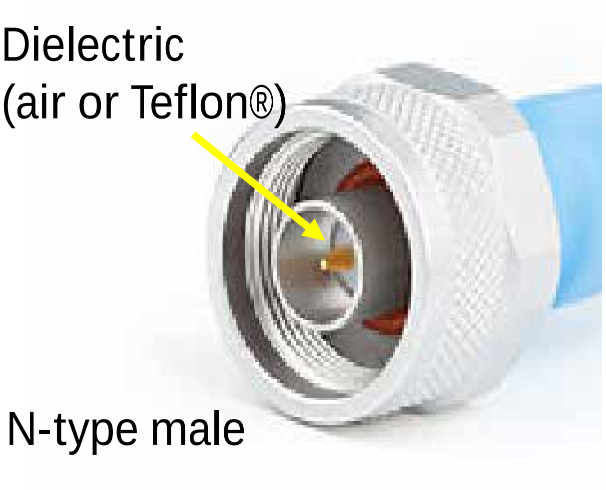
- Inform national policy
- To verify the ITS channel sounder prior to making measurements and disseminating results
- Deliver a system having reliability and repeatability
- To understand the uncertainties associated with propagation measurement systems and channel losses
- To provide measurements that our sponsors and the modelling community can trust

Important Practices

- Connector Repeatability
- Signal Generator Output Power Variability
- Transmit Power Amplifier Characteristics
- Component Measurements
- System Noise Floor and Dynamic Range
- Antennas – Directional vs. Omnidirectional
- Repeatability
- Terrain Database Variability
- Uncertainties

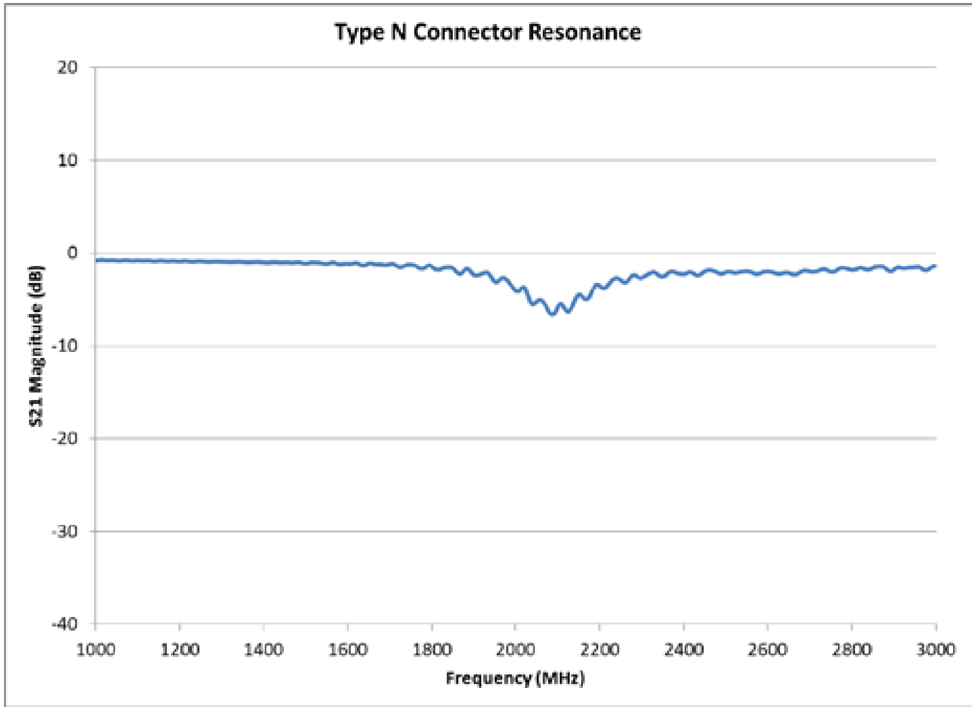
Connector Repeatability

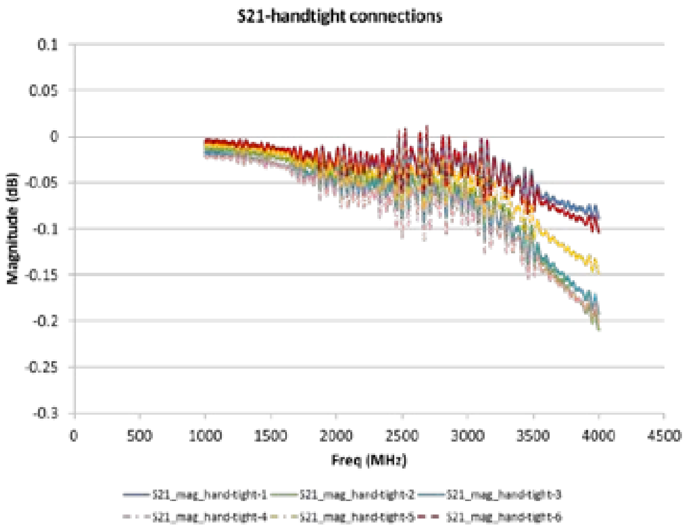
- Type N resonance – mismatch
- Is a torque wrench really necessary?
  - § Loose connections
  - § Overtightened connections

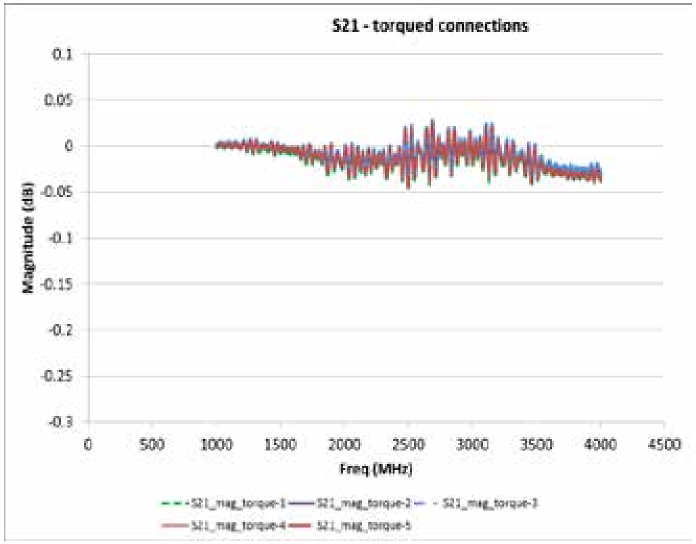


Also make sure depth of center pins and slots is correctly set, use gauge

N Connector S21 Measurements



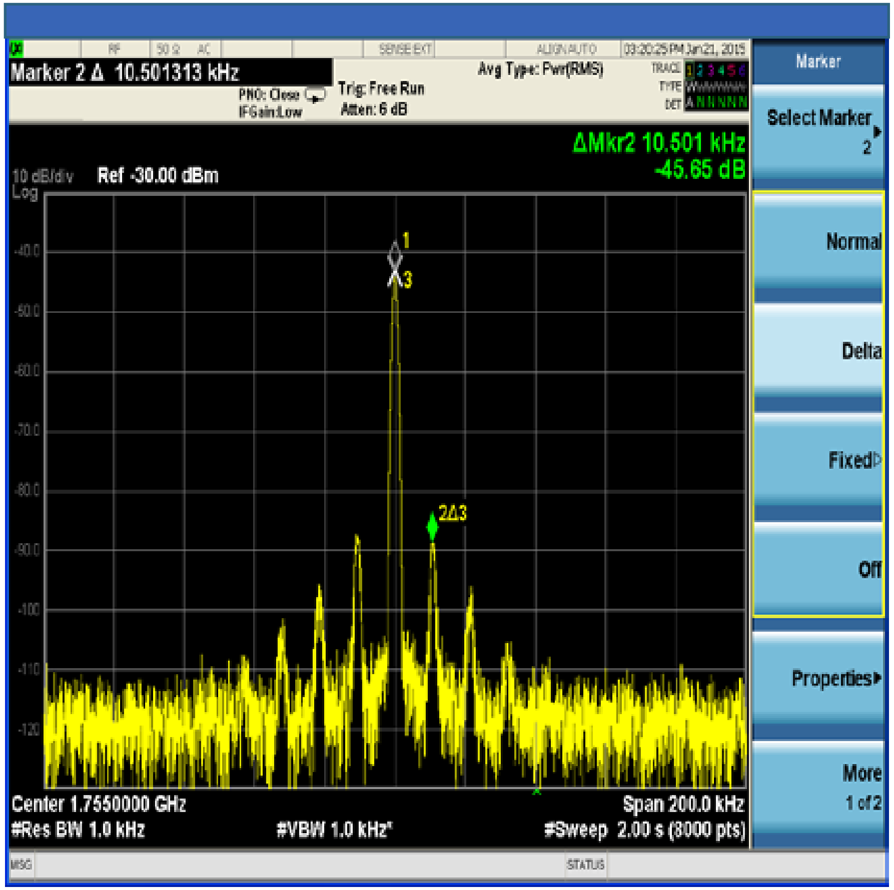




Signal Generator Output Power Stability Testing

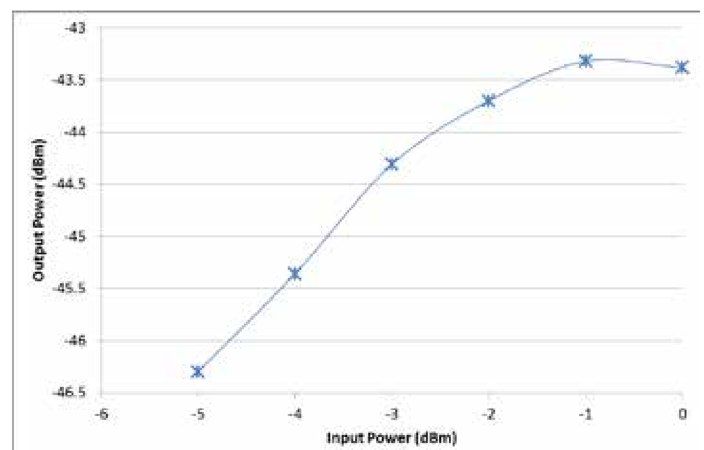
Date	Time	Power-Output (dBm)	Power_Coupled(dBm)	Temp (deg F)
4/11/2016	12:54 p.m.	-20.4	-40.55	--
4/11/2016	3:24 p.m.	-23.29	-40.54	--
4/12/2016	7:54 a.m.	-20.4	-40.55	--
4/12/2016	8:20 a.m.	-20.41	-40.54	--
4/12/2016	1:09 p.m.	-20.4	-40.56	--
4/12/2016	3:40 p.m.	-20.41	-40.55	--
4/13/2016	7:16 a.m.	-20.39	-40.57	--
4/13/2016	10:44 a.m.	-20.41	-40.57	--
4/13/2016	12:42 p.m.	-20.4	-40.56	--
4/13/2016	3:45 p.m.	-20.42	-40.56	--
4/14/2016	7:30 a.m.	-20.4	-40.56	83
4/14/2016	8:19 a.m.	-20.4	-40.54	83
4/14/2016	8:48 a.m.	-20.4	-40.56	83
4/14/2016	10:36 a.m.	-20.41	-40.57	79
4/14/2016	3:15 p.m.	-20.42	-40.57	--
4/15/2016	7:20 a.m.	-20.41	-40.56	77
4/15/2016	9:08 a.m.	-20.41	-40.55	79
4/15/2016	12:23 p.m.	-20.42	-40.57	83
4/15/2016	2:55 p.m.	-20.4	-40.56	78
mean		**-20.56**	**-40.56**	
stdev		**0.66**	**0.01**	

Power Amplifier Testing

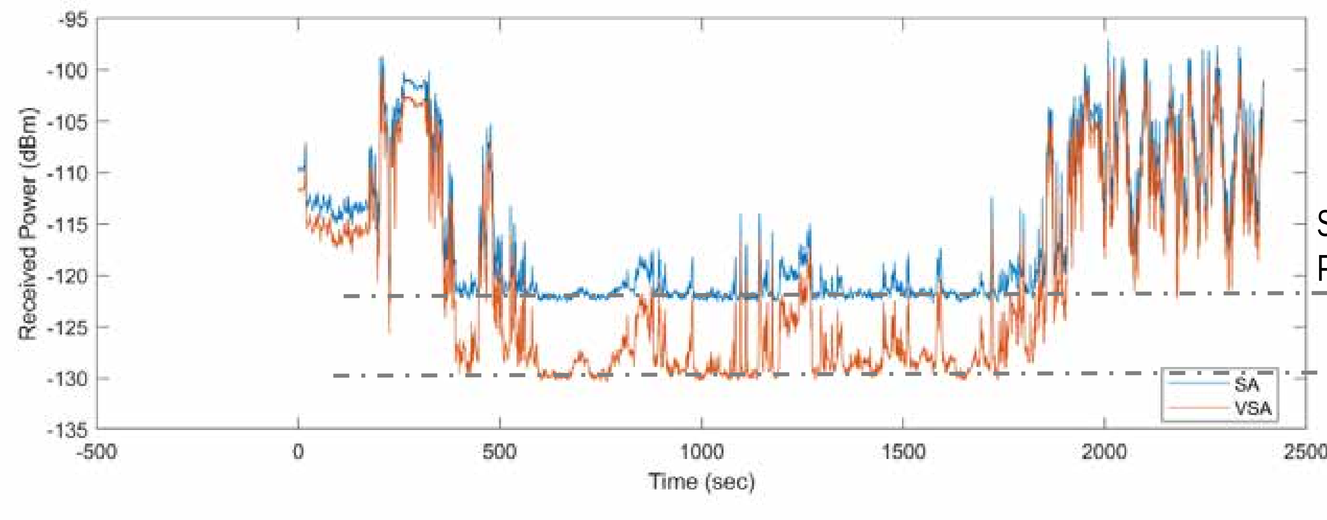


Sig Gen Output Power (dBm)	Spec An Measured Power (dBm)	Power (Watts)
-5	-46.3	27
-4	-45.36	33
-3	-44.31	38
-2	-43.7	47.8
-1	-43.32	52.2
0	-43.38	51.5

2nd harmonic @ 3510 MHz: -88.9 dBm at -1 dBm Sig Gen Power
3rd harmonic @ 5265 MHz: -103 dBm at -1 dBm Sign Gen Power

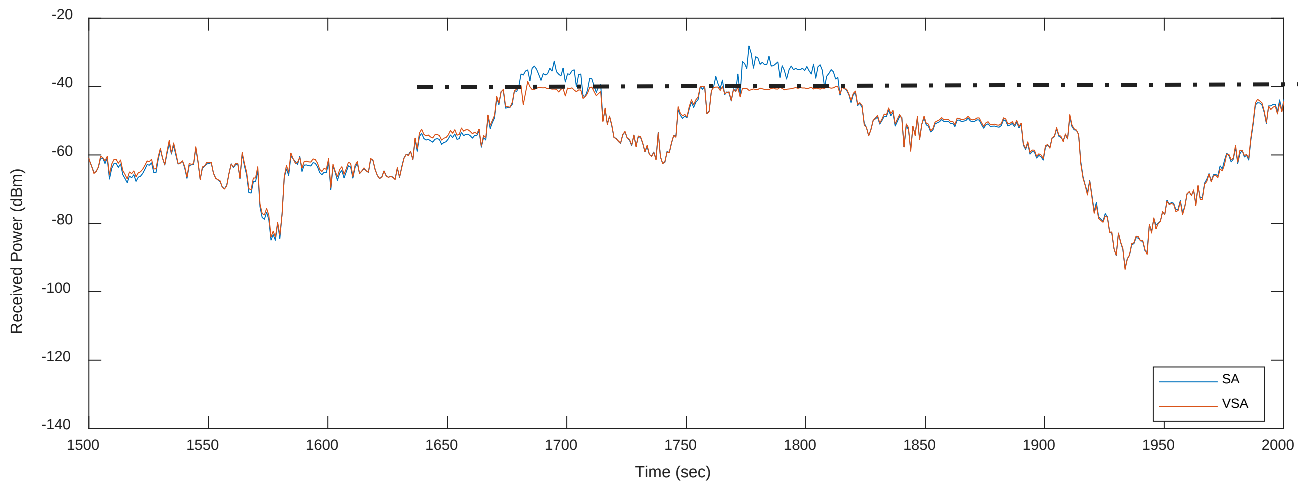


System Noise Floor and Dynamic Range



System Noise Floor – Portable SA

System Noise Floor – Lab-grade VSA



Maximum Dynamic Range- VSA

Antenna – Directional vs. Omnidirectional

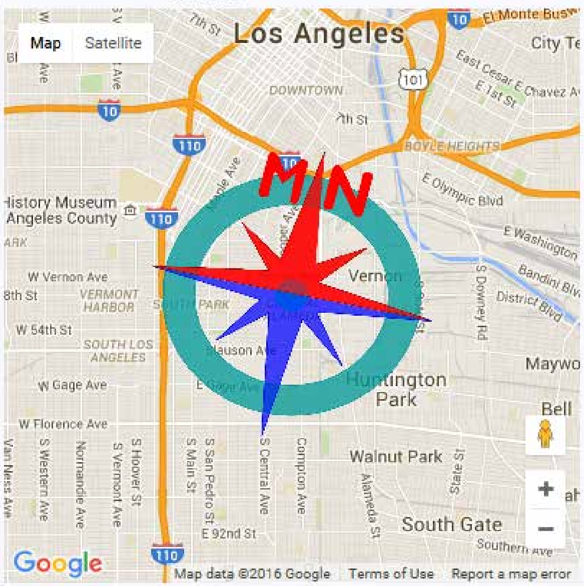
- Directional
  - Compass-Magnetic Declination
  - Antenna Positioning
- Omnidirectional
  - Azimuthal Pattern Accuracy
  - Elevation Accuracy

Directional Antennas

- § Directional
  - Magnetic Declination

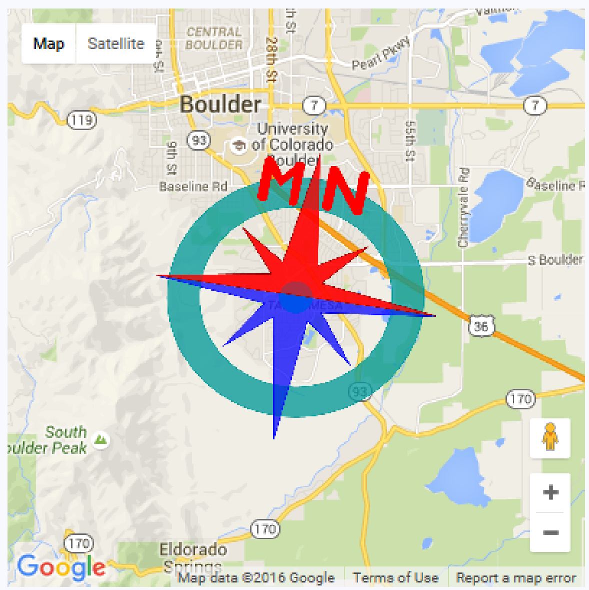
Declination

Model Used:	WMM2015
Latitude:	34° 0' 0" N
Longitude:	118° 15' 0" W
Date	**Declination**
2016-07-19	12° 7' E ± 0° 20' changing by 0° 5' W per year



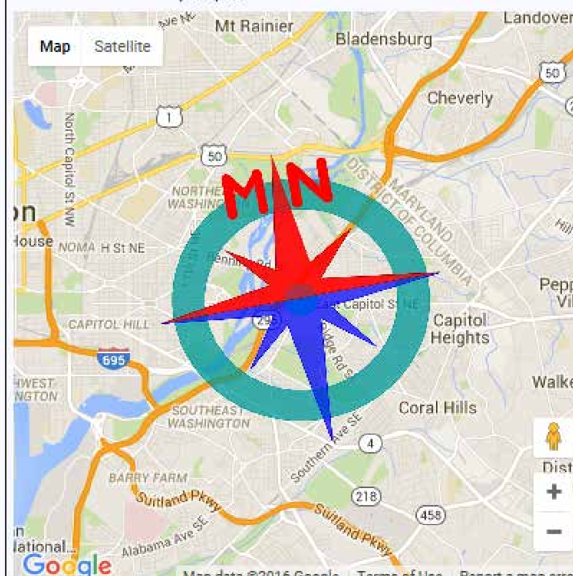
Declination

Model Used:	WMM2015
Latitude:	39° 58' 47" N
Longitude:	105° 15' 9" W
Date	**Declination**
2016-07-19	8° 31' E ± 0° 21' changing by 0° 6' W per year

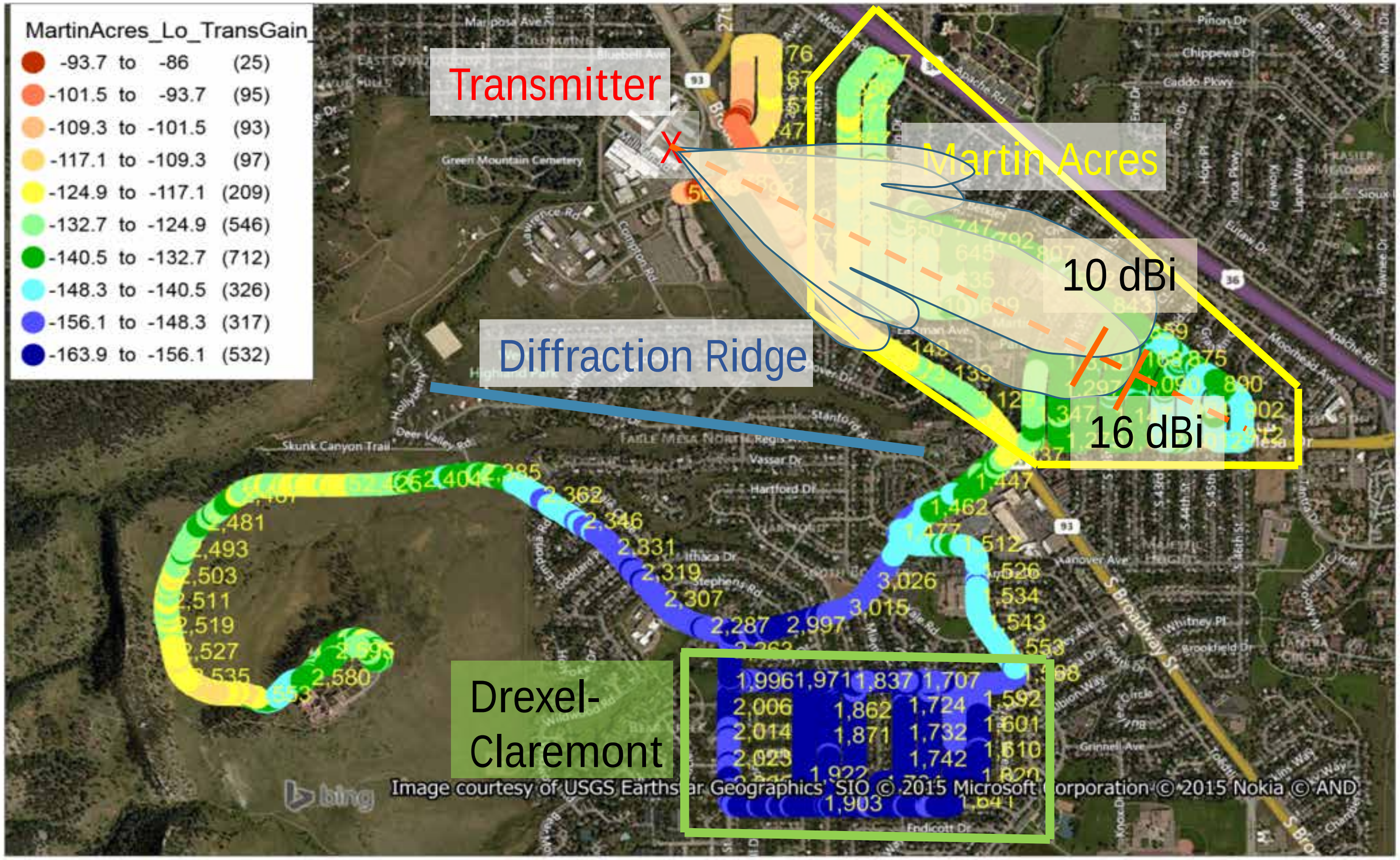


Declination

Model Used:	WMM2015
Latitude:	38° 53' 27" N
Longitude:	76° 57' 14" W
Date	**Declination**
2016-07-19	10° 52' W ± 0° 21' changing by 0° 0' W per year

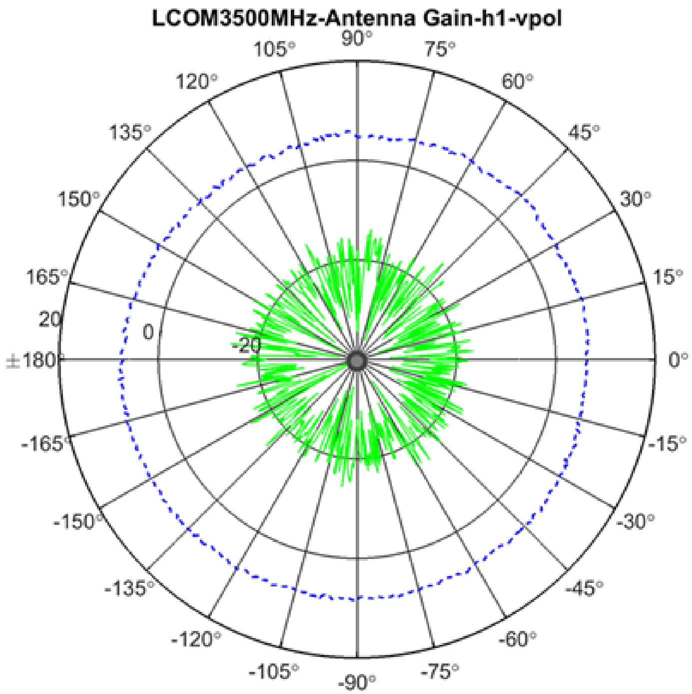


Directional Antennas

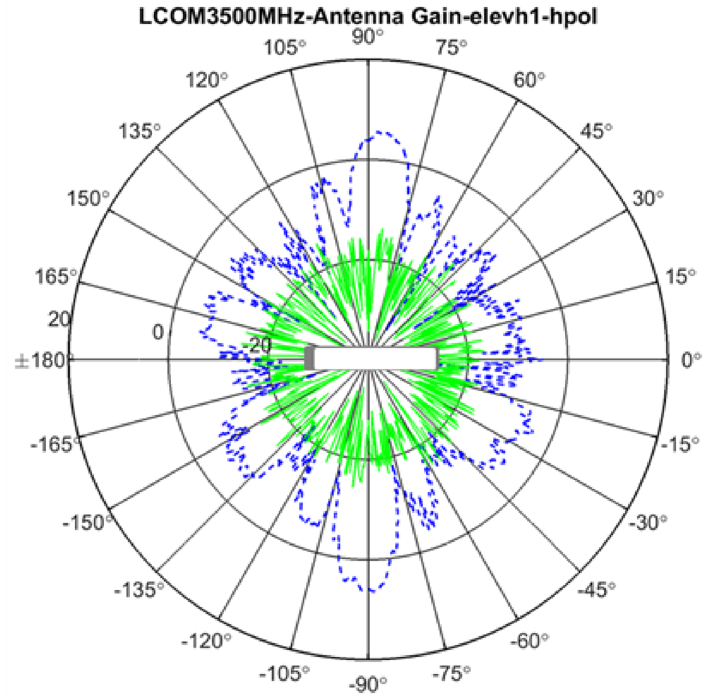


Omni-directional Antennas

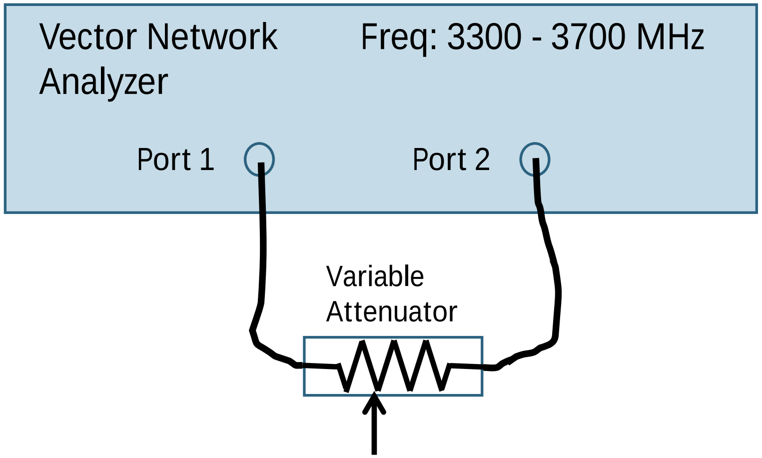
Azimuth

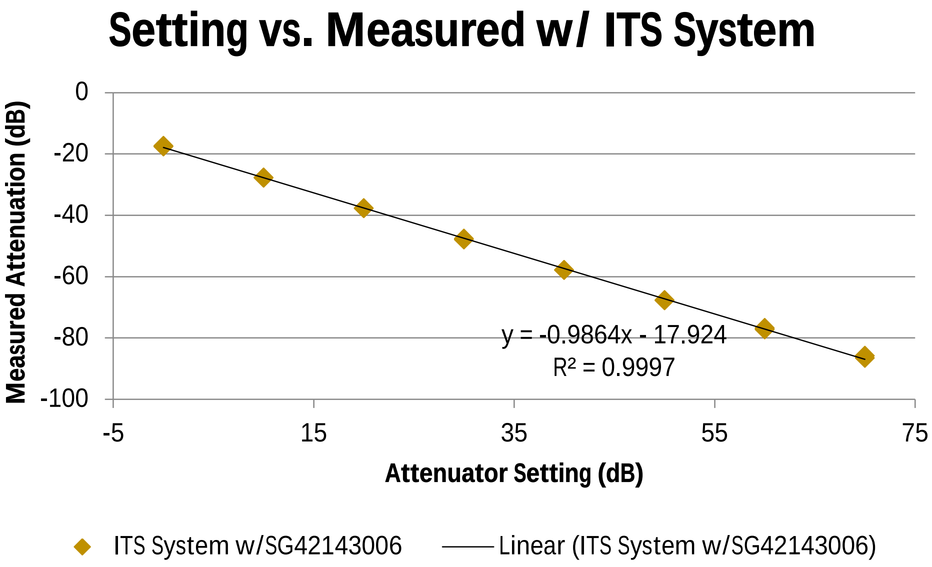


Elevation



Characterize System Components and Variable Attenuator for Bench System Testing

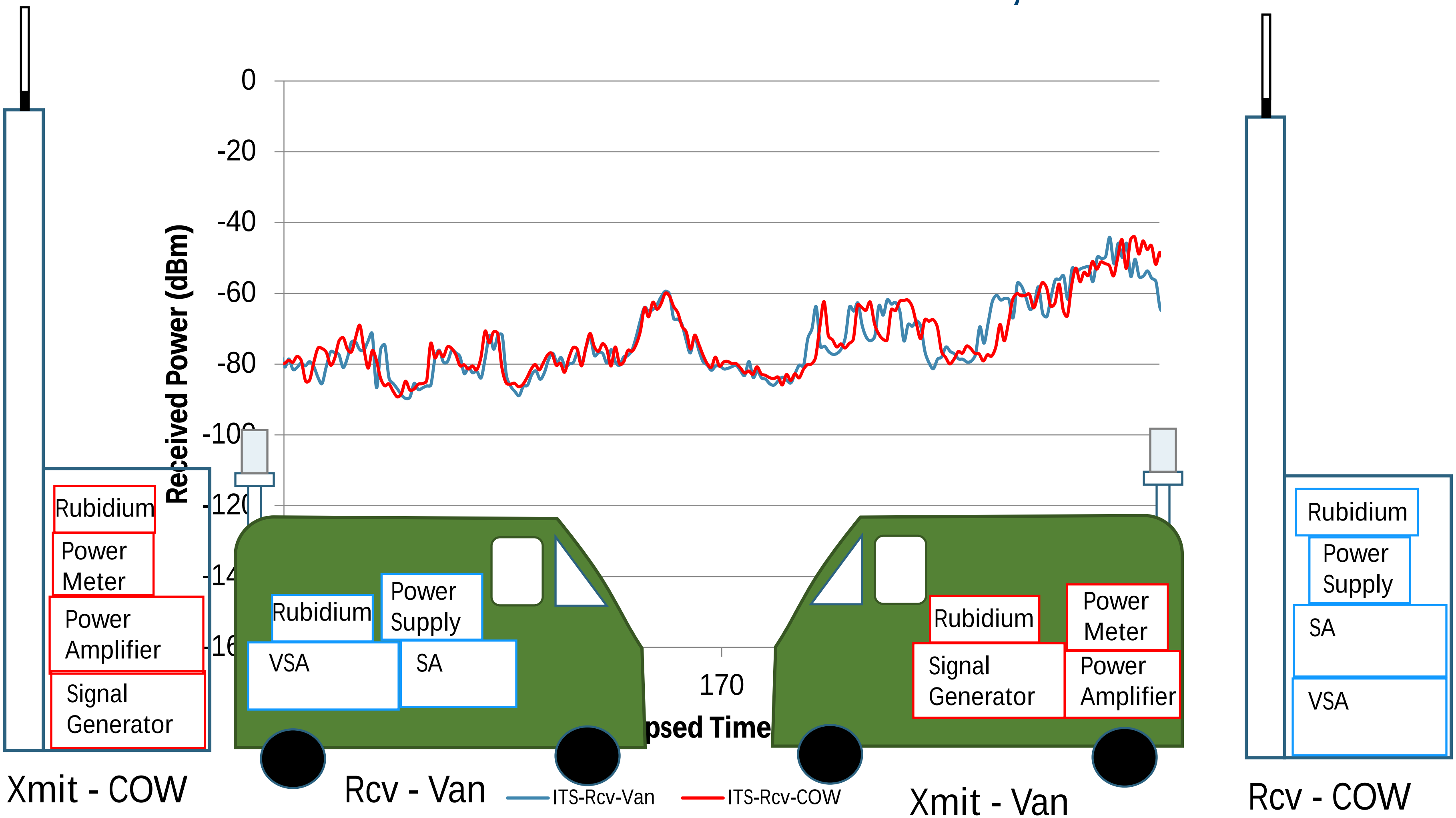




Repeatability

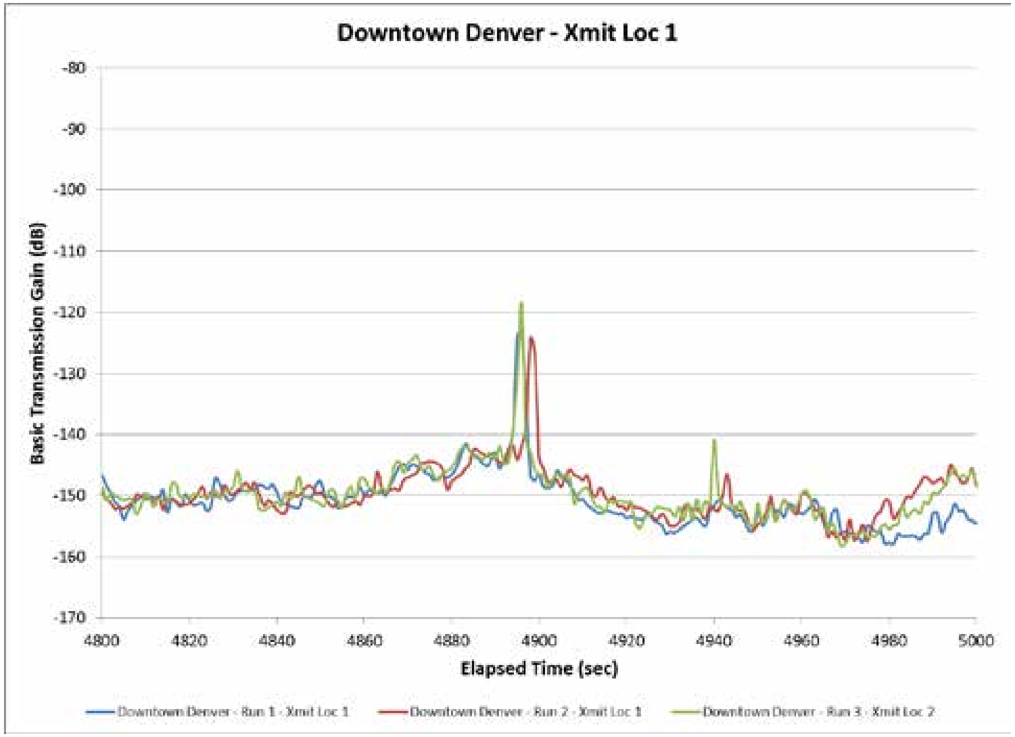
- Reciprocity
- Measurement Repeatability
- System to System Repeatability

Transmitter/Receiver Reciprocity Measurements in Boulder, CO

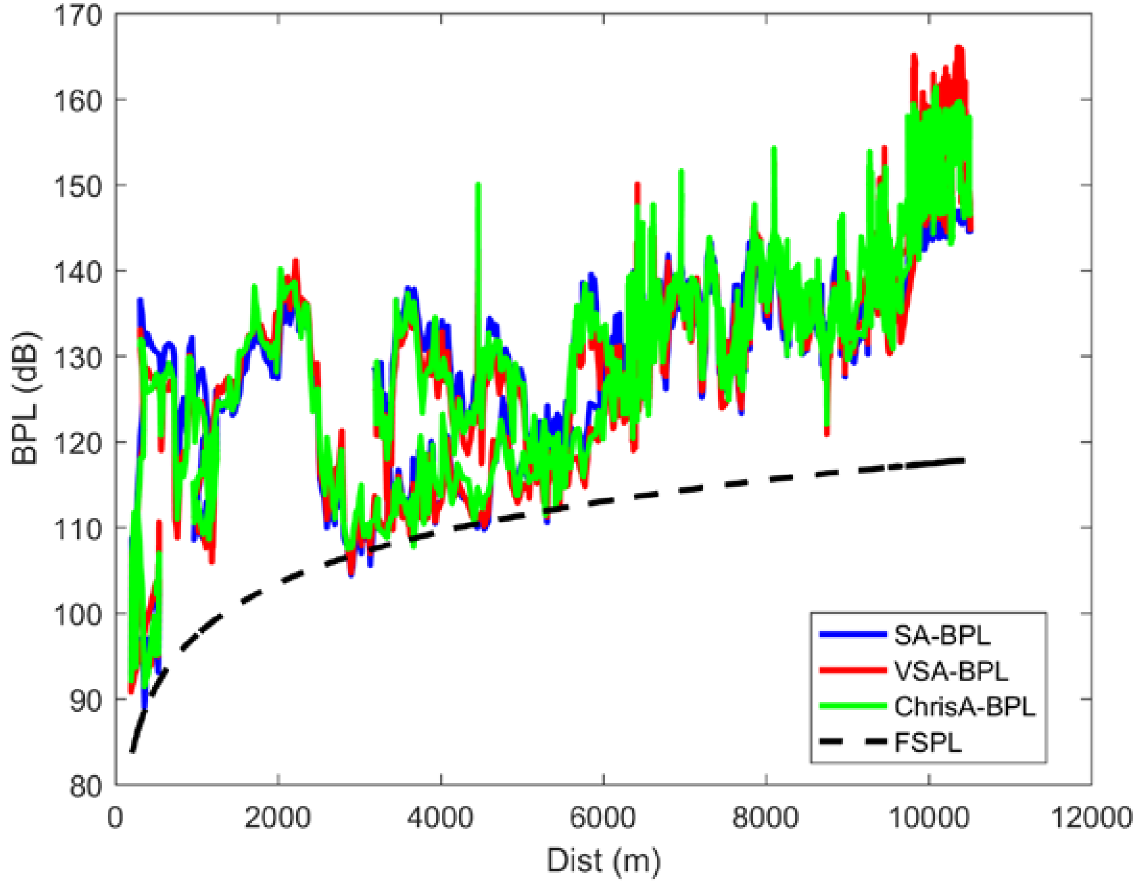


Measurement Repeatability

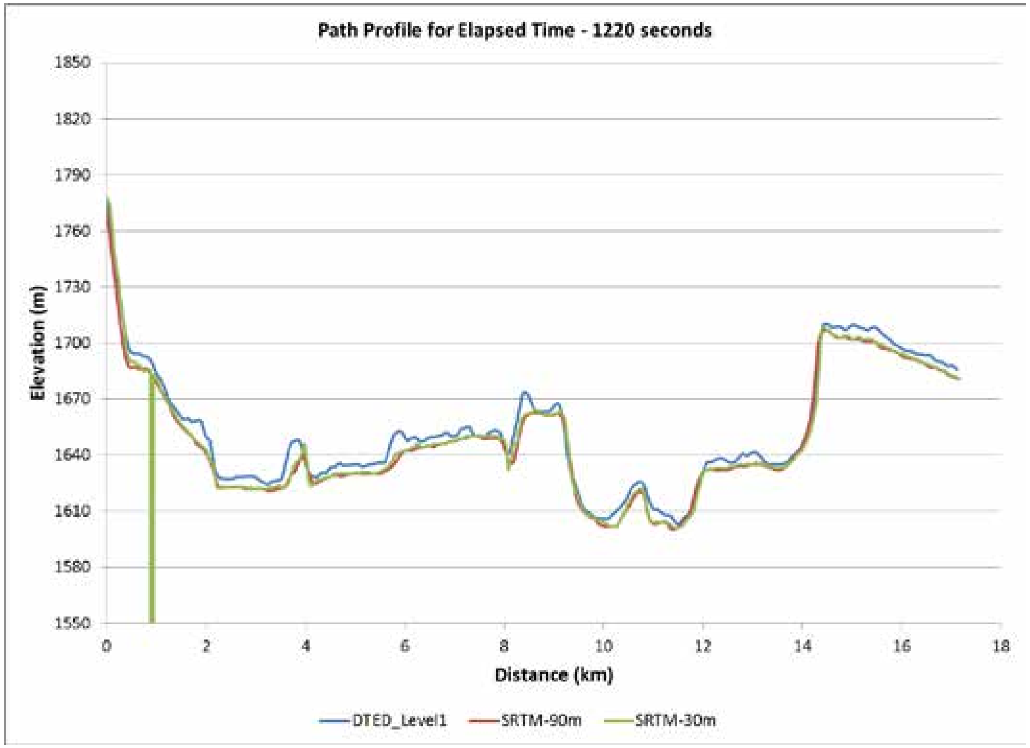
Park Ave. & 17th

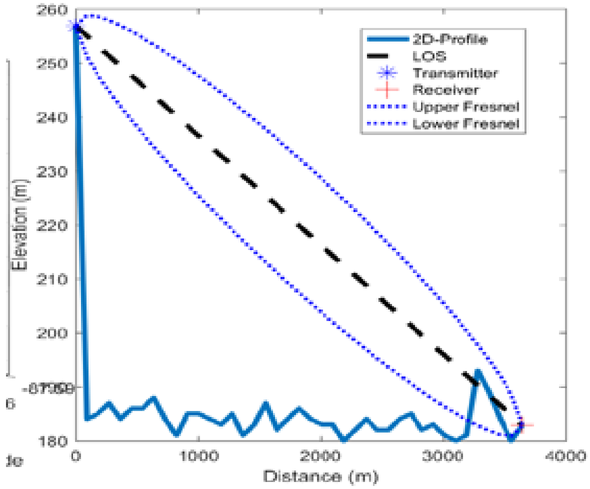


Los Angeles, CA:
ITS CW Channel Sounders vs. Chris Anderson CW Channel Sounder

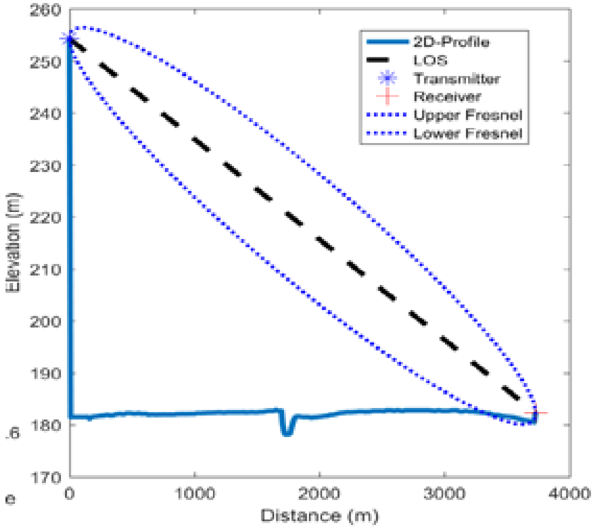


Terrain Database Comparison



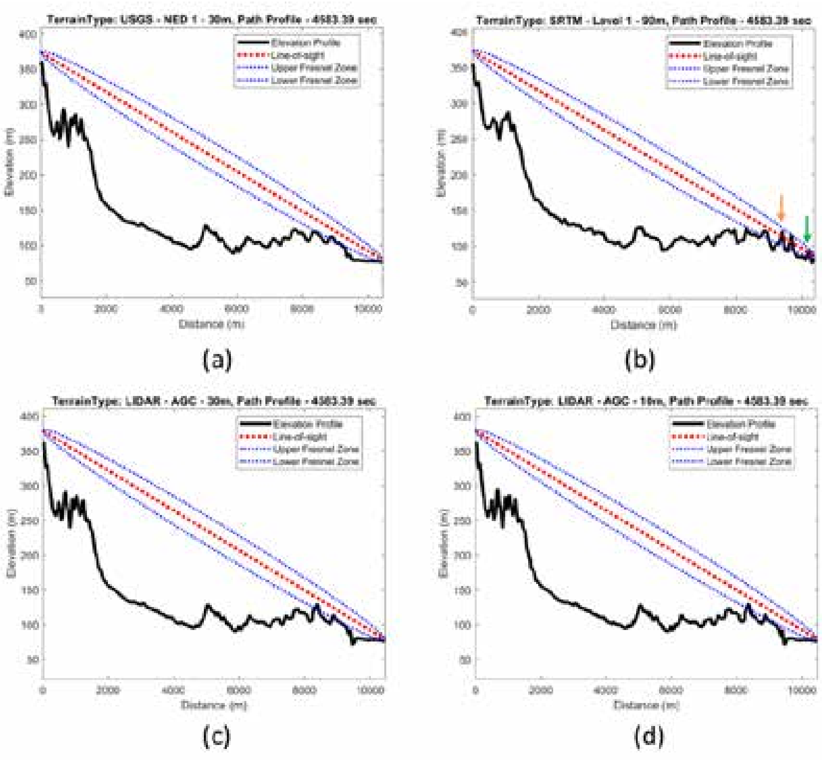


SRTM (DTED-Level1) – 90 m resolution



USGS DEM – 10 m resolution

ITM Predictions vs Terrain Database



Source	Measured and Predicted Basic Transmission Gain (dB)
	4583.38 sec
Measurement data	−149.96
Free-space	−117.79
USGS–NED-1–30 m **(a)**	−117.78
SRTM–Level-1–90 m **(b)**	−159.95
LIDAR–AGC–30 m **(c)**	−117.80
LIDAR–AGC–10 m **(d)**	−117.80

Uncertainty Analysis

Uncertainty Term	**Uncertainty (dB)**
Power Meter, manufacturer	0.04
Coupling Coefficient	0.50
Power Amplifier stability, measured	0.08
VSA, manufacturer	0.35
Γ_{PA}, manufacturer	0.17
Γ_{PM}, manufacturer	0.03
Γ_{VSA}, manufacturer	0.02
$\Gamma_{coupler}$, measured	0.02
Γ_{ch}, measured	0.02
Rb frequency stability	neg.
Antenna Gain, measured	3.00
Antenna Mismatch, manufacturer	0.35
Measurement System (Type A)	0.06
Measurement Repeatability (Type B)	5.25
Component Losses	0.50
Combined Uncertainty	6.11

Conclusions

- Connector repeatability is important and can be achieved with proper torque
- Signal generator variability must be characterized
- Power amplifier must be allowed to warm-up for an hour and we must know the sideband position and levels and the linear region of the amplifier
- Know the measurement range of the instrument by characterizing the noise floor and maximum detectable signal
- Understand the impact of misaligning directional antennas
- Make repeated measurements using the system and it would be good to test against another system to check both the data quality and post-processing algorithms
- Understand the uncertainties associated with inputs to a model
- Fill out an uncertainty table on your system to get an idea of the greatest contributor’s to a system’s uncertainty