PaveScan Antenna Verification

Rich Giessel, P.E.

Sweden & Norway: April 2-3, 2019

Why Verify Antennas?

1. How precise are readings between sensors?
2. Will DPS conform to proposed specifications?
3. What is important in equipment assembly?
4. Is verification data useful for troubleshooting equipment malfunctions?
5. Can antenna verification data be used to produce post-processing improvements to accuracy and precision?

Why Verify Antennas?

- How precise are readings between sensors?
- Will DPS conform to proposed specifications?
- What is important in equipment assembly?
- Is verification data useful for troubleshooting equipment malfunctions?
- Can antenna verification data be used to produce post-processing improvements to accuracy and precision?

Why Verify Antennas?

- How precise are readings between sensors?
- Will DPS conform to proposed specifications?
- What is important in equipment assembly?
- Is verification data useful for troubleshooting equipment malfunctions?
- Can antenna verification data be used to produce post-processing improvements to accuracy and precision?

Why Verify Antennas?

- How precise are readings between sensors?
- Will DPS conform to proposed specifications?
- What is important in equipment assembly?
- Is verification data useful for troubleshooting equipment malfunctions?
- Can antenna verification data be used to produce post-processing improvements to accuracy and precision?

Why Verify Antennas?

- How precise are readings between sensors?
- Will DPS conform to proposed specifications?
- What is important in equipment assembly?
- Is verification data useful for troubleshooting equipment malfunctions?
- Can antenna verification data be used to produce post-processing improvements to accuracy and precision?

AASHTO Specifications for DPS

Sensors on multi-sensor systems should agree with each other within a dielectric value of 0.08 on a known source material (Polyethylene).

We increased that tolerance by 50% (to 0.12) to account for the increased variability of an asphalt surface.

AASHTO Specifications for DPS

Sensors on multi-sensor systems should agree with each other within a dielectric value of 0.08 on a known source material (Polyethylene).

We increased that tolerance by 50% (to 0.12) to account for the increased variability of an asphalt surface.

Antenna Verification Setup & Safety

- Make certain that antenna check area is protected by traffic control.
- Setup Field Book

Antenna Verification Setup & Safety

- Make certain that antenna check area is protected by traffic control.
- Setup Field Book

DATE

ANTENNA CHECK (LEFT REFERANCE)

		3 ANTENNA OVERLAP			
LATERAL OFFSET (FT)	0'	2'	4'	6'	8'
LINE #	1	2	3	4	5
RUN 1					
RUN 2					
RUN 3					
RUN 4					
RUN 5					

RUN	LT (#60)	C (#61)	RT (#63)
1			
2			
3			
4			
5			
AVE			

Δ

PASS/FAIL

LOCATION:

Rite in the Rain

Verification Procedure - Step 1

- Set antennas at required spacing
- (Typically 2’ or 0.6 m)

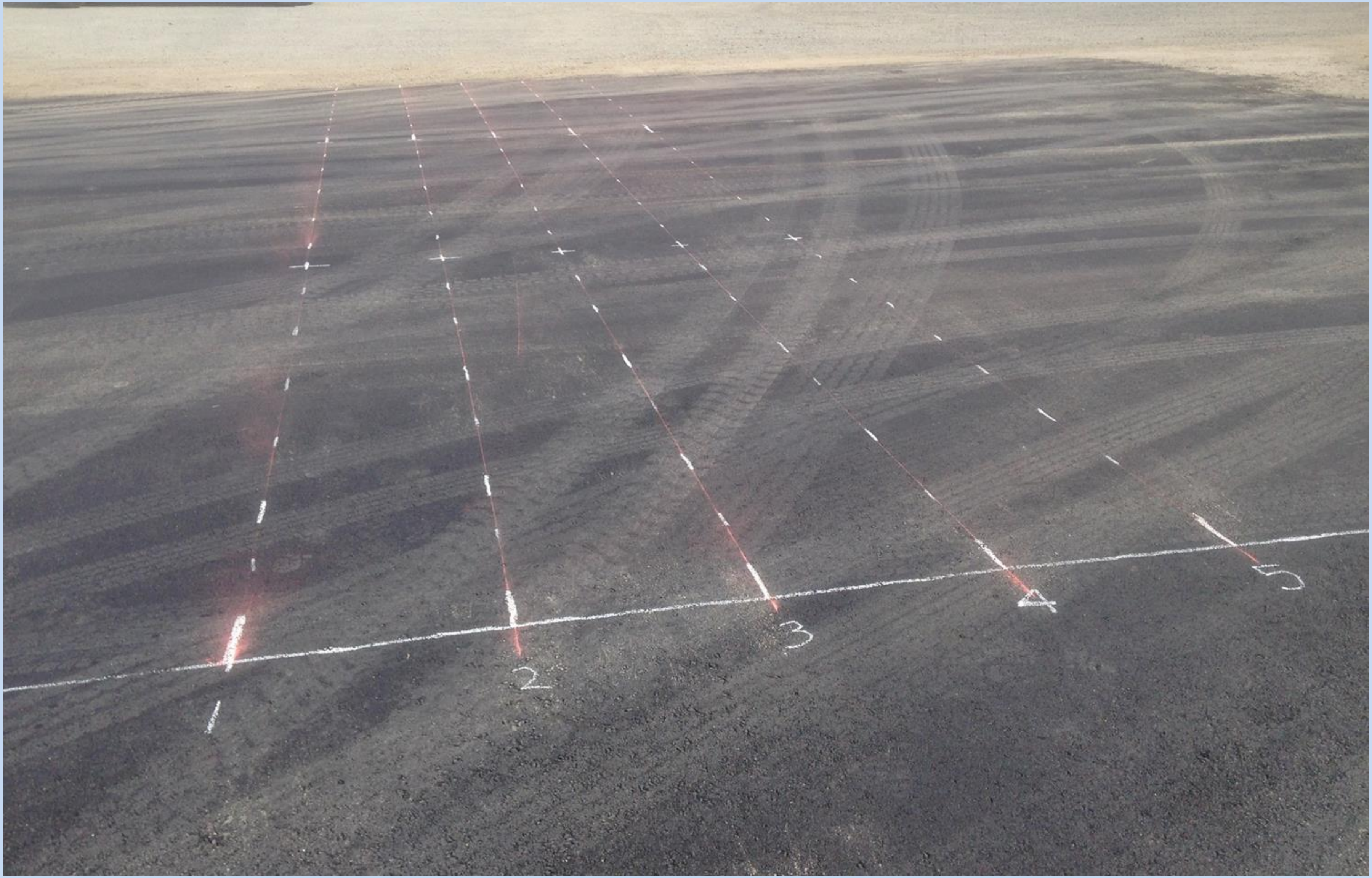
Verification Procedure - Step 2

- Mark a base line with 5 marks at the antenna spacing along one side of test area.

Verification Procedure - Step 3

- Layout 5 equal length (4-12 m) parallel lines transverse to the paving direction.

Layout of Antenna Check area



5 lines spaced 2’ apart, each line 35’ long.

Note that only lines 2, 3, and 4 will be measured by all three antennas.

Step 4 - Collecting Data

- Name a file "Antenna Check" and set offset equal to 0’.

Collecting Data

Position PaveScan with center antenna right at the marked starting point of Line 1.

Collecting Data

- Collect distance file along Line 1. Stop right at the marked end point and save data.

End Marks for Lines 1-5

Place end marks one foot from paving edge to avoid inclusion of highly irregular readings at pavement edge.

Collecting Data

- Increase file offset setting by 2 feet

(or the antenna spacing selected for that day).

Collecting Data

- Back up and index over to the right one Line such that the center antenna is now at the starting point of Line 2.

Collecting Data

- Collect distance file along Line 2.

Collecting Data

- Repeat this procedure until center antenna has travelled on Lines 1-5.
- At this point all three antennas will have collected dielectric readings every 0.1’ down the length of Lines 2, 3, 4.
- Average every 5 readings and look at 6” slices of data for ease of viewing.

Collecting Data

- Repeat this procedure until center antenna has travelled on Lines 1-5.
- At this point all three antennas will have collected dielectric readings every 0.1’ down the length of Lines 2, 3, 4.
- Average every 5 readings and look at 6” slices of data for ease of viewing.

Collecting Data

- Repeat this procedure until center antenna has travelled on Lines 1-5.
- At this point all three antennas will have collected dielectric readings every 0.1’ down the length of Lines 2, 3, 4.
- Average every 5 readings and look at 6” slices of data for ease of viewing.

DATE: 9-5-2018

ANTENNA CHECK (LEFT REFERENCE)

LATERAL OFFSET (FT)	0'	2'	4'	6'	8'
		3 ANTENNA OVERLAP			
LINE #	1	2	3	4	5
RUN 1		4.84			
RUN 2		4.77	4.86		
RUN 3		4.83	4.77	4.85	
RUN 4			4.81	4.76	
RUN 5				4.80	

} ORDER OF COLLECTION (DIELECTRIC VALUES)

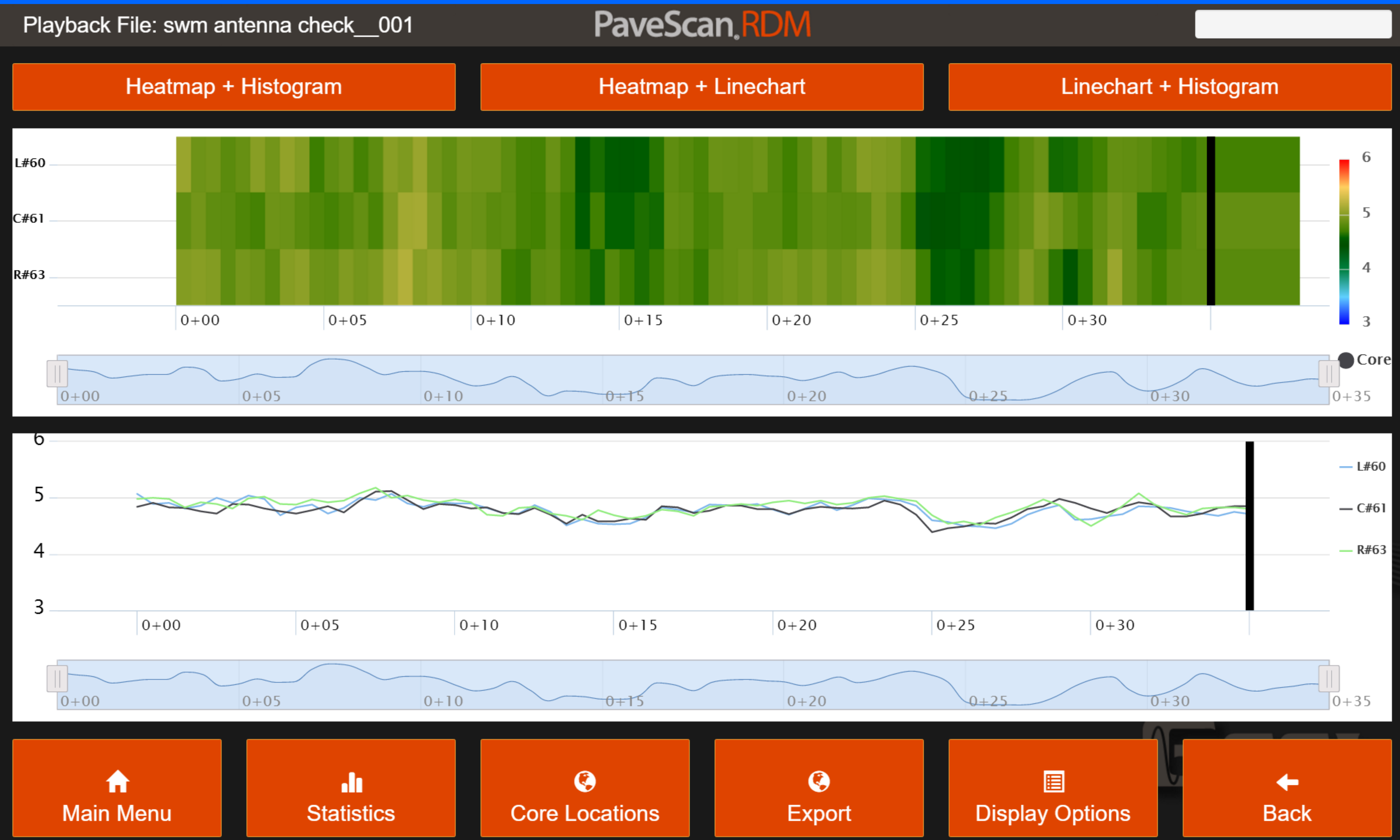
RUN	LT(#60)	C(#61)	RT(#63)
1			4.84
2		4.77	4.86
3	4.83	4.77	4.85
4	4.81	4.76	
5	4.80		
AVE.	4.81	4.77 (LOW)	4.85 (HIGH)

} REARRANGED BY ANTENNA (AVERAGE BY INSPECTION)

Δ: Δ = 0.08 (OK ≤ 0.12) ← CALCULATE Δ

PASS/FAIL: (PASS)

LOCATION: STATEWIDE MATERIALS ACCESS ROAD, 30' EAST OF NE CORNER OF DRILL SHOP ACROSS 36' OF NEW PAVING (AUG 2018)


Playback File: swm antenna check__001
PaveScan RDM
Heatmap + Histogram
Heatmap + Linechart
Linechart + Histogram
L#60
C#61
R#63
0+00
0+05
0+10
0+15
0+20
0+25
0+30
0+35
6
5
4
3
Core
L#60
C#61
R#63
Main Menu
Statistics
Core Locations
Export
Display Options
Back

Run 1: Only uses Right (#63) Antenna Average Dielectric

Lateral Offset	Sensor Position	Serial #	Start Dist	End Dist	# Measurements	Median	Average
-2	Left	60	0+00.00	0+35.40	71	4.81983	4.78838
0	Center	61	0+00.00	0+35.40	71	4.81031	4.78106
2	Right	63	0+00.00	0+35.40	71	4.86482	4.8434

Run 1 Data Entry

Antenna check:		Left - #60	Center - #61	Right - #63	Average Values		
September 5, 2018, 8:15 AM							
Left Reference			3 Antenna Overlap lines				
Offset (ft):	-2	0	2	4	6	8	10
	Line 0	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Run 1			4.84				
Run 2							
Run 3							
Run 4							
Run 5							
		Low					
		High					
		Delta					

Run 2: Uses Center (#61) and Right (#63) Antenna Average Dielectric

Lateral Offset	Sensor Position	Serial #	Start Dist	End Dist	# Measurements	Median	Average
0	Left	60	0+35.60	0+71.20	72	4.85482	4.83195
2	Center	61	0+35.60	0+71.20	72	4.7583	4.76554
4	Right	63	0+35.60	0+71.20	72	4.88336	4.86162

Run 2 Data Entry

Antenna check:		Left - #60	Center - #61	Right - #63	Average Values		
September 5, 2018, 8:15 AM							
Left Reference			3 Antenna Overlap lines				
Offset (ft):	-2	0	2	4	6	8	10
	Line 0	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Run 1			4.84				
Run 2			4.77	4.86			
Run 3							
Run 4							
Run 5							
		Low					
		High					
		Delta					

Run 3: Uses Average Dielectric of all three Antennas

Lateral Offset	Sensor Position	Serial #	Start Dist	End Dist	# Measurements	Median	Average
2	Left	60	0+71.40	1+06.80	71	4.86152	4.82886
4	Center	61	0+71.40	1+06.80	71	4.76964	4.77005
6	Right	63	0+71.40	1+06.80	71	4.86475	4.85069

Run 3 Data Entry

Antenna check:		Left - #60	Center - #61	Right - #63	Average Values		
September 5, 2018, 8:15 AM							
Left Reference			3 Antenna Overlap lines				
Offset (ft):	-2	0	2	4	6	8	10
	Line 0	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Run 1			4.84				
Run 2			4.77	4.86			
Run 3			4.83	4.77	4.85		
Run 4							
Run 5							
		Low					
		High					
		Delta					

Analyzing Data

- In walk mode dielectric reading variations among the three antennas should be within 0.12

Antenna check:

Left - #60	Center - #61	Right - #63

September 5, 2018, 8:15 AM

Antenna Reference			3 Antenna Overlap lines				
Offset (ft)-->	-2	0	2	4	6	8	10
	Line 0	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Run 1			4.84				
Run 2			4.77	4.86			
Run 3			4.83	4.77	4.85		
Run 4				4.81	4.76		
Run 5					4.80		
		Low	4.77	4.77	4.76		
		High	4.84	4.86	4.85		
		Delta	0.08	0.09	0.09		

Left - # 60 Lines 2, 3, 4, Average =	4.81
Ctr - # 61 Lines 2, 3, 4, Average =	4.77
Right - # 63 Lines 2, 3, 4, Average =	4.85
Low	4.77
High	4.85

Delta = 0.09 **PASS** < 0.12 is Passing

Trouble Shooting

- If variation is greater than 0.12 check that all antenna cables and mounting bolts are tight.
- If loose electrical connections or bolts are found, tighten them and recalibrate the PaveScan RDM with new Air and Metal plate readings.
- Rescan the five lines.

Trouble Shooting

- If variation is greater than 0.12 check that all antenna cables and mounting bolts are tight.
- If loose electrical connections or bolts are found, tighten them and recalibrate the PaveScan RDM with new Air and Metal plate readings.
- Rescan the five lines.

Trouble Shooting

- If variation is greater than 0.12 check that all antenna cables and mounting bolts are tight.
- If loose electrical connections or bolts are found, tighten them and recalibrate the PaveScan RDM with new Air and Metal plate readings.
- Rescan the five lines.


HLL
2.5MM
BONDHUS
HEX LONG
PROGUARD™ MADE IN USA
0 37231 15954 2


HLL
6MM
BONDHUS
LONG
MADE IN USA
battery in percent.

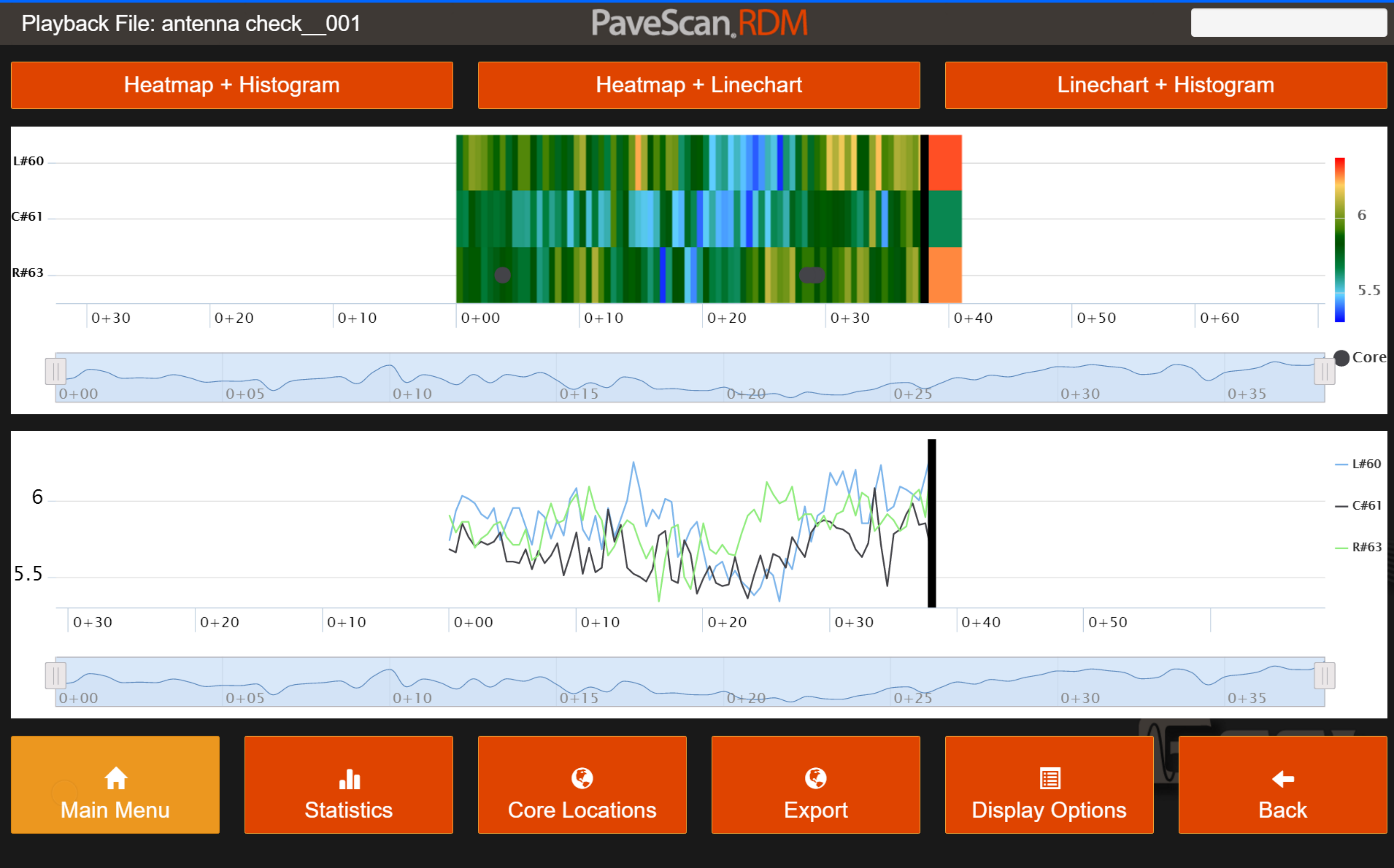
Trouble Shooting 2

- If the outward Mechanical and electrical connections are sound then there could be an internal problem with the Sensors.
- Here is what to look for in the antenna check runs…

Trouble Shooting 2

- If the outward Mechanical and electrical connections are sound then there could be an internal problem with the Sensors.
- Here is what to look for in the antenna check runs…

Center Antenna Reading Low



Antenna check:

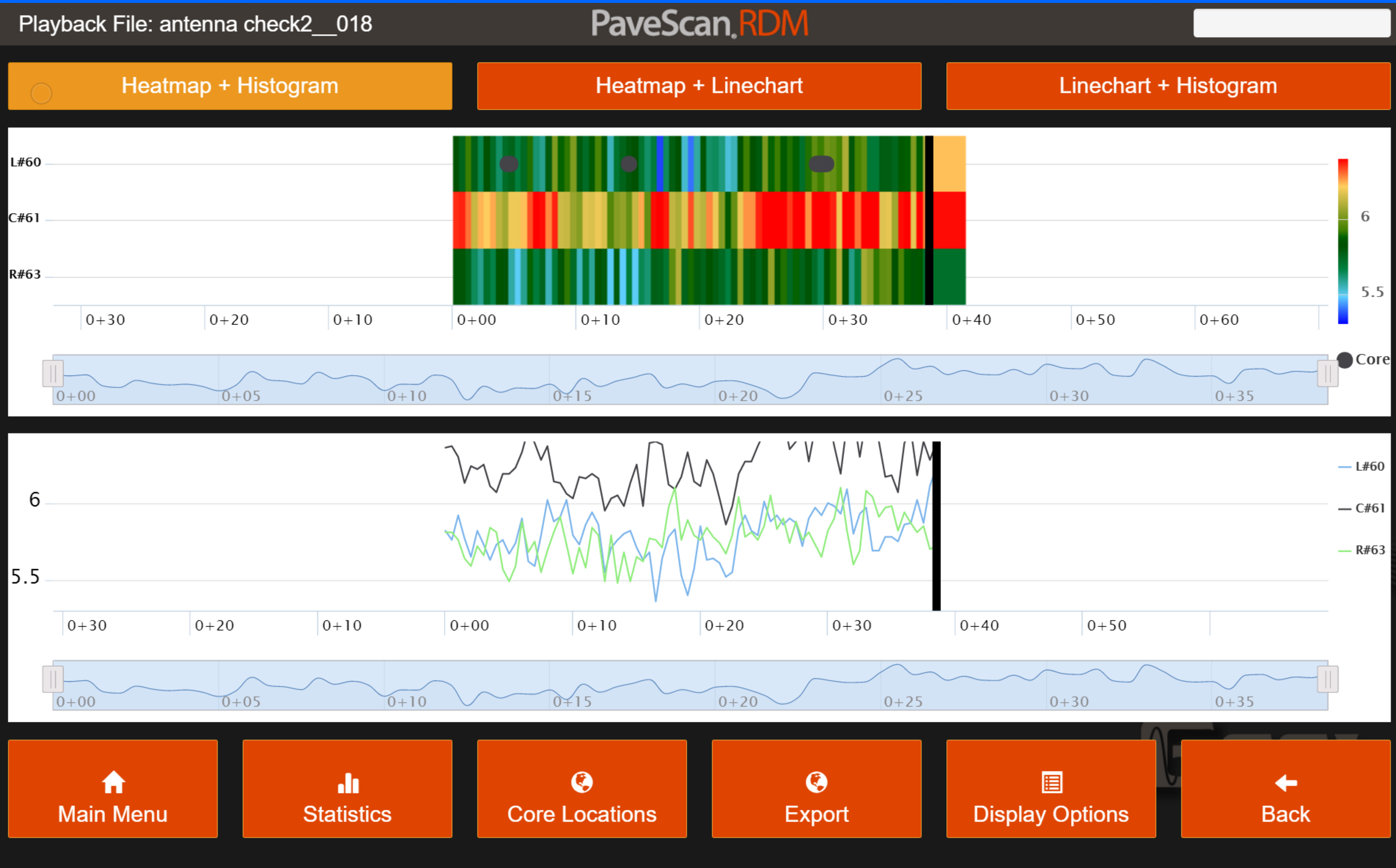
Left - #60 | Center - #61 | Right - #63 | Average Values

Left Reference		3 Antenna Overlap lines				
Offset (ft):	-2	0	2	4	6	8	10
	Line 0	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Run 1	5.85	5.67	5.84				
Run 2		5.85	5.69	5.92			
Run 3			5.86	5.73	5.88		
Run 4				5.90	5.75	5.92	
Run 5					5.88	5.75	5.89
		Low	5.69	5.73	5.75		
		High	5.86	5.92	5.88		
		Delta	0.17	0.19	0.14		

Left - # 60 Lines 2, 3, 4, Average =	5.88
Ctr - # 61 Lines 2, 3, 4, Average =	5.72
Right - # 63Lines 2, 3, 4, Average =	5.88
Low	5.72
High	5.88
Delta	**0.16**

FAIL < 0.12 is Passing

Center Antenna Reading High



Antenna check:

		Left - #60	Center - #61	Right - #63	Average Values		
Left Reference			3 Antenna Overlap lines				
Offset (ft):	-2	0	2	4	6	8	10
	Line 0	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Run 1	5.77342	5.81628	5.74772				
Run 2		5.75366	5.85743	5.77178			
Run 3			5.79668	6.26623	5.77558		
Run 4				5.81111	5.91457	5.74399	
Run 5					5.78530	5.87794	5.74490
		Low	5.75	5.77	5.78		
		High	5.86	6.27	5.91		
		Delta	0.11	0.49	0.14		
Left - # 60 Lines 2, 3, 4, Average =			5.80				
Ctr - # 61 Lines 2, 3, 4, Average =			6.01				
Right - # 63Lines 2, 3, 4, Average =			5.77				
		Low	5.77				
		High	6.01				
		Delta	0.25	**FAIL**	< 0.12 is Passing		

Possible Precision Improvements Using the 5 Line Method

Statistics for 10 Check Runs

Antenna check:	Left - #60	Center - #61	Right - #63	Average Values

(All runs)

	Average	Max	Min	Range
Left - # 60 Lines 2, 3, 4, Average =	4.79	4.84	4.74	**0.10**
Center - # 61 Lines 2, 3, 4, Average =	4.79	4.82	4.76	**0.06**
Right - # 63 Lines 2, 3, 4, Average =	4.84	4.87	4.83	**0.04**
Low	4.79			
High	4.84			
Delta	0.05	**PASS**	< 0.12 is Passing	

Possible Precision Improvements

- **Select antenna with least variation (#63) to read core locations for mix calibration**

	Average	Max	Min	Range
Left - # 60 Lines 2, 3, 4, Average =	4.79	4.84	4.74	0.10
Center - # 61 Lines 2, 3, 4, Average =	4.79	4.82	4.76	0.06
Right - # 63 Lines 2, 3, 4, Average =	4.84	4.87	4.83	**0.04**

Possible Precision Improvements

- Post process data with antenna correction factor to improve accuracy of density mapping
- Note that this correction would only apply for this particular asphalt mix design

Possible Precision Improvements

- Post process data with antenna correction factor to improve accuracy of density mapping
- Note that this correction would only apply for this particular asphalt mix design

Possible Precision Improvements

- In this example we used Antenna #63 as Master
- We could then correct readings from antennas #60 and #61 by adding a dielectric value of 0.05 to all dielectric values collected by these two antennas

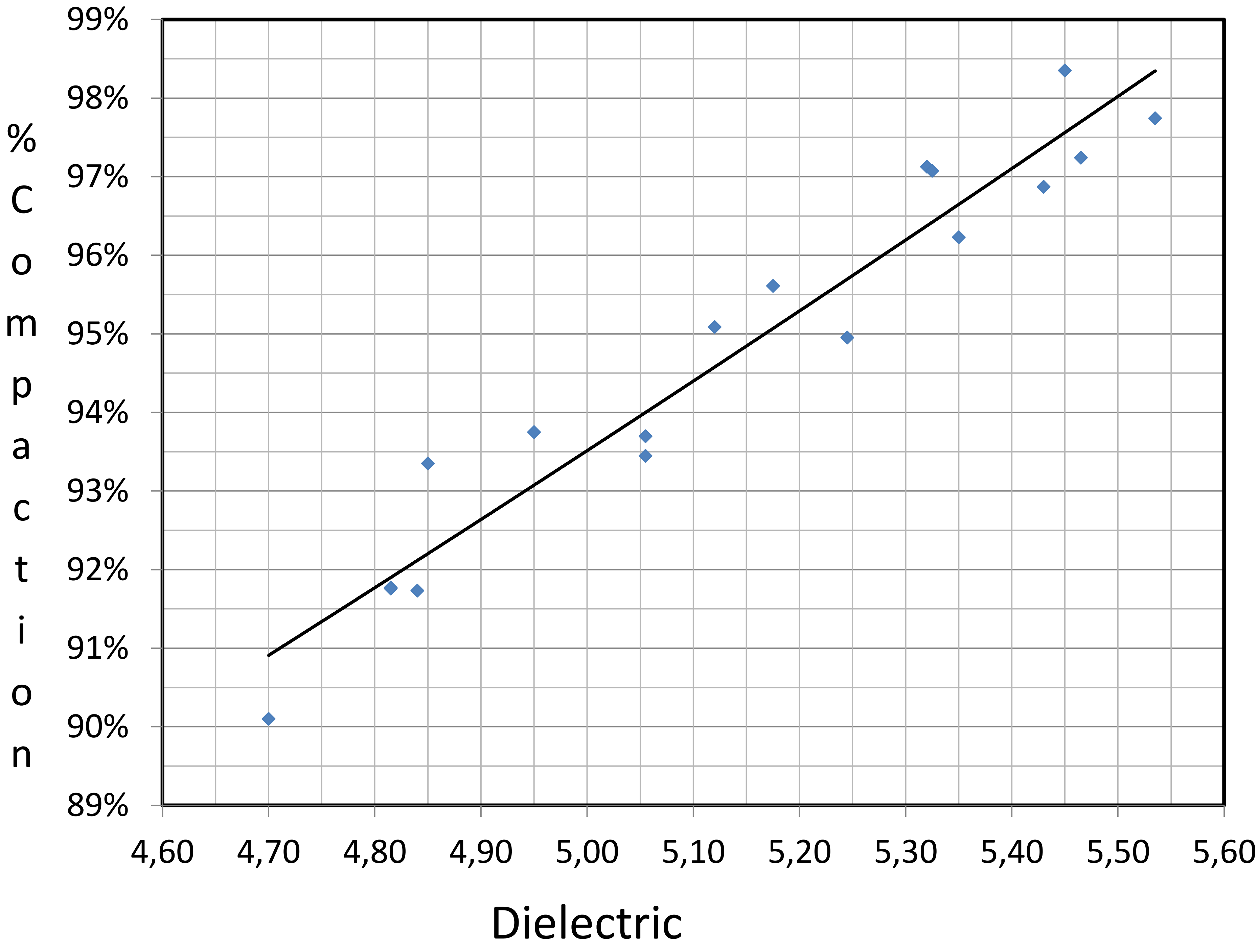
Possible Precision Improvements

- In this example we used Antenna #63 as Master
- We could then correct readings from antennas #60 and #61 by adding a dielectric value of 0.05 to all dielectric values collected by these two antennas

Possible Precision Improvements

- **Correct other two antennas to the calibration antenna**

	Average	Correction	**New**
Left - # 60 Lines 2, 3, 4, Average =	4.79	0.05	**4.84**
Ctr - # 61 Lines 2, 3, 4, Average =	4.79	0.05	**4.84**
Right - # 63 Lines 2, 3, 4, Average =	4.84	-	**4.84**


99%
98%
97%
96%
95%
94%
93%
92%
91%
90%
89%
% Compaction
4,60
4,70
4,80
4,90
5,00
5,10
5,20
5,30
5,40
5,50
5,60
Dielectric

Possible Precision Improvements

The calibration graph indicates that a Dielectric correction of 0.05 would improve Compaction correlation between antennas by 0.5% for this asphalt mix with this PaveScan machine.

QUESTIONS?

richard.giessel@alaska.gov

(907) 269-6244