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Interference Testing on Radio Frequency Polarization Fingerprinting

Page Heller
Endpoint Security Inc.
email: heller@endpointsecurityinc.com

ENDPOINT
Security Inc

Author Bio

Seven times founder Page Heller is an experienced manager of technology companies. He is the CEO of Endpoint Security Inc, a cybersecurity startup for industrial control systems. Working for Texas A&M and Notre Dame, he has evaluated more than 600 innovations for commercial potential and personally negotiated more than 200 license agreements. As an entrepreneur he has self-funded, angel-funded, venture-funded and formed strategic alliances with major corporations. His companies have designed industrial control products for 3M, General Electric, Schlumberger, Pirelli and NASA.

Introduction

Polarization Mode Dispersion is being vetted for use in providing a secure, physical-layer method for fingerprinting wireless devices. Lab tests show the method to be stable and repeatable. But, for use in an industrial setting, it must perform under harsh and undesirable conditions. The following is a study of tests performed with devices transmitting low signal-to-noise ratio waveforms. Also included are tests where electrical interference was located near the sensors and where a microwave oven was operated near the sensors. The results are shown in the following slides.
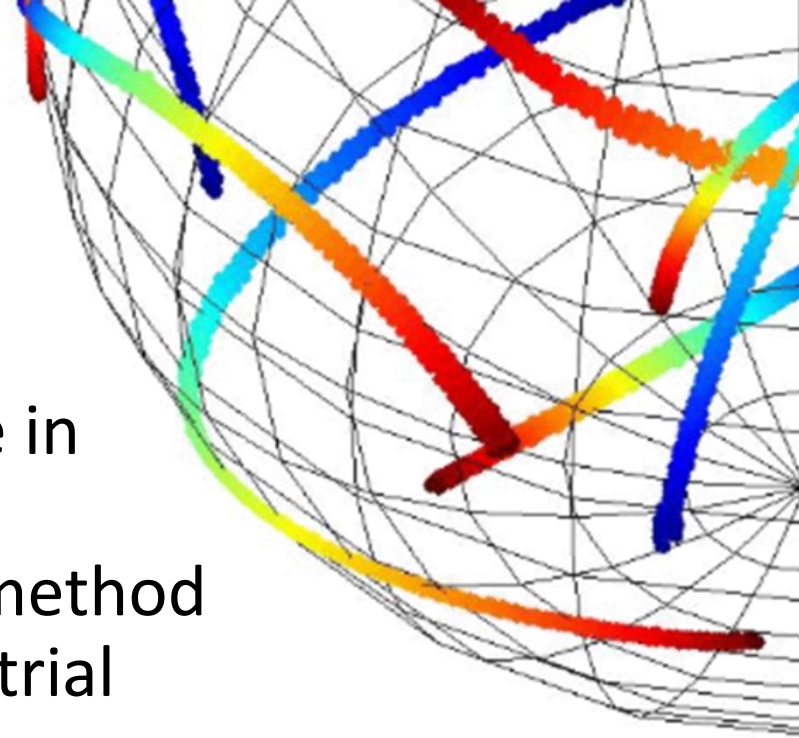
Test Setup

A prototype (above) was set up in a factory-like space (right) with 4 transmitting sensors, shown here in a close-proximity test

Test Setup

- SDR with 22 MHz bandwidth centered on 2462 MHz
- 4dBi vertically polarized antennas
- Sample rate 20 MSPS
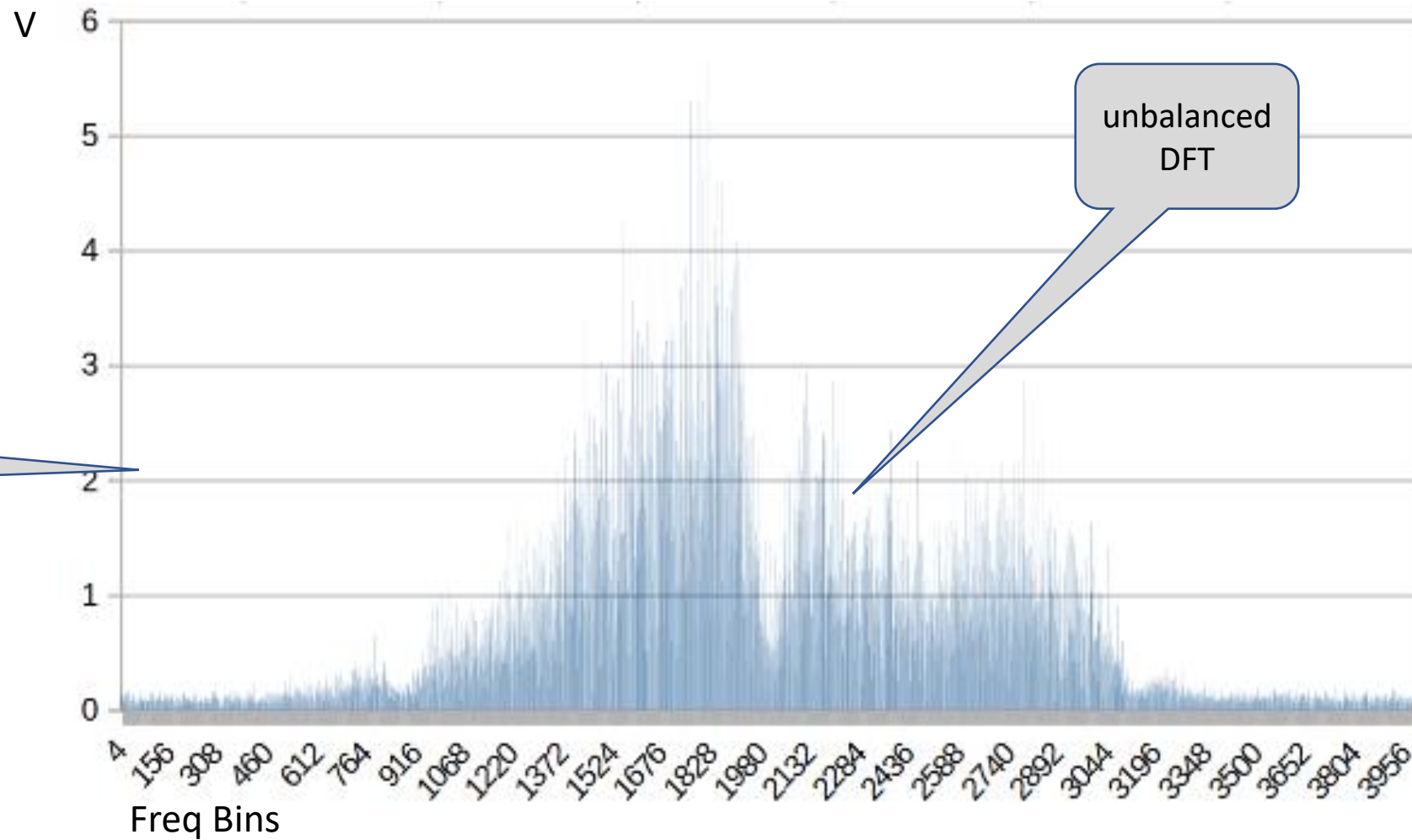- No demodulation
- No packet capture

Test Set I: Low SNR

- 4 sensors with low signal-to-noise ratio waveforms received
- 2 prototype receivers
- 16 tests performed x 4 sensors = 64 cases

Low Relative Signal Strength

Correlation of Each Signal in Low SNR Test

strong correlation

weak correlation; column C added

|	loop no.	sensor 1	sensor 2	sensor 3	sensor 4												
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	1413	0.381423	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1421	0.985606	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1429	0.576645	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1437	0.569673	0.970146	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	2138	0.388929	0.549711	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	2146	0.392907	0.548636	0.980437	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2469	0.514161	0.487836	0.633292	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2478	0.5154	0.488585	0.633106	0.953287	0	0	0	0	0	0	0	0	0	0	0	0
9	4536	0.982116	0.582043	0.387855	0.550378	0	0	0	0	0	0	0	0	0	0	0	0
10	4544	0.984775	0.583317	0.387692	0.550525	0	0	0	0	0	0	0	0	0	0	0	0
11	4554	0.558086	0.961378	0.500233	0.525264	0	0	0	0	0	0	0	0	0	0	0	0
12	4563	0.559648	0.975531	0.500785	0.527218	0	0	0	0	0	0	0	0	0	0	0	0
13	5262	0.392161	0.547333	0.980971	0.665639	0	0	0	0	0	0	0	0	0	0	0	0
14	5270	0.388699	0.547698	0.978809	0.663464	0	0	0	0	0	0	0	0	0	0	0	0
15	5593	0.519952	0.492553	0.632407	0.953818	0	0	0	0	0	0	0	0	0	0	0	0
16	5602	0.52003	0.491187	0.629693	0.954135	0	0	0	0	0	0	0	0	0	0	0	0

average correlation: 0.974

no false positives
no false negatives

Background

Poincaré Sphere

We plot polarization mode dispersion on the surface of a sphere. The plane made by the vertical and horizontal polarization make up the equator. The poles are right-hand and left-hand circular polarization. Thus, the red dot at the top pole of this sphere indicates a signal with a purely right-hand circular polarization.
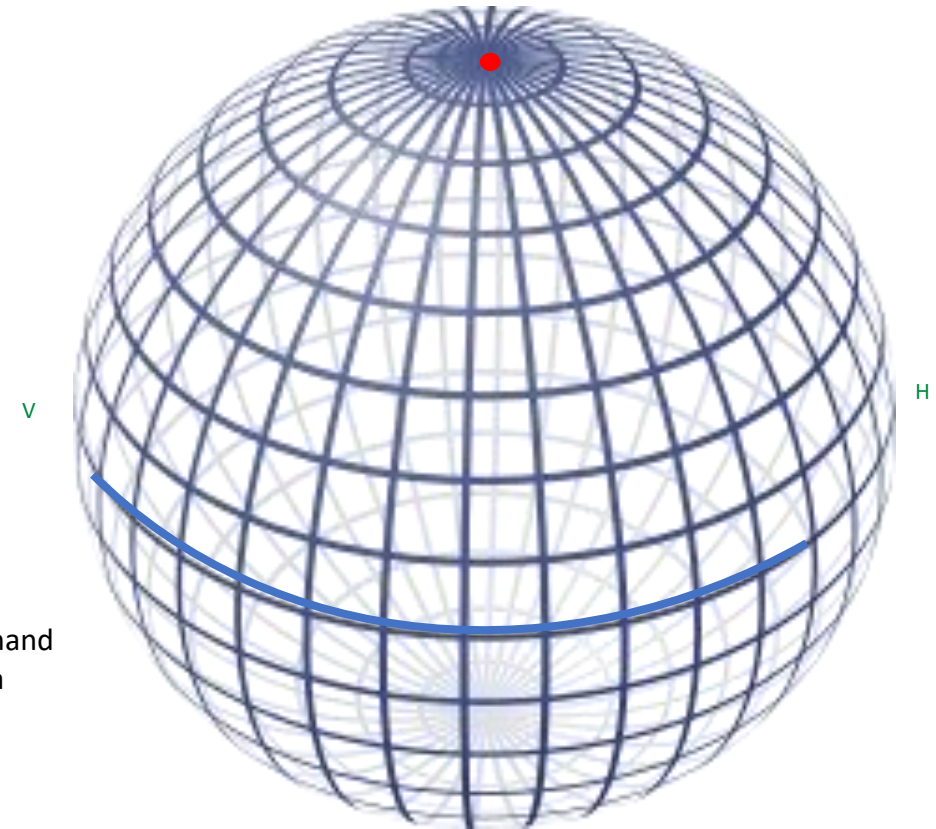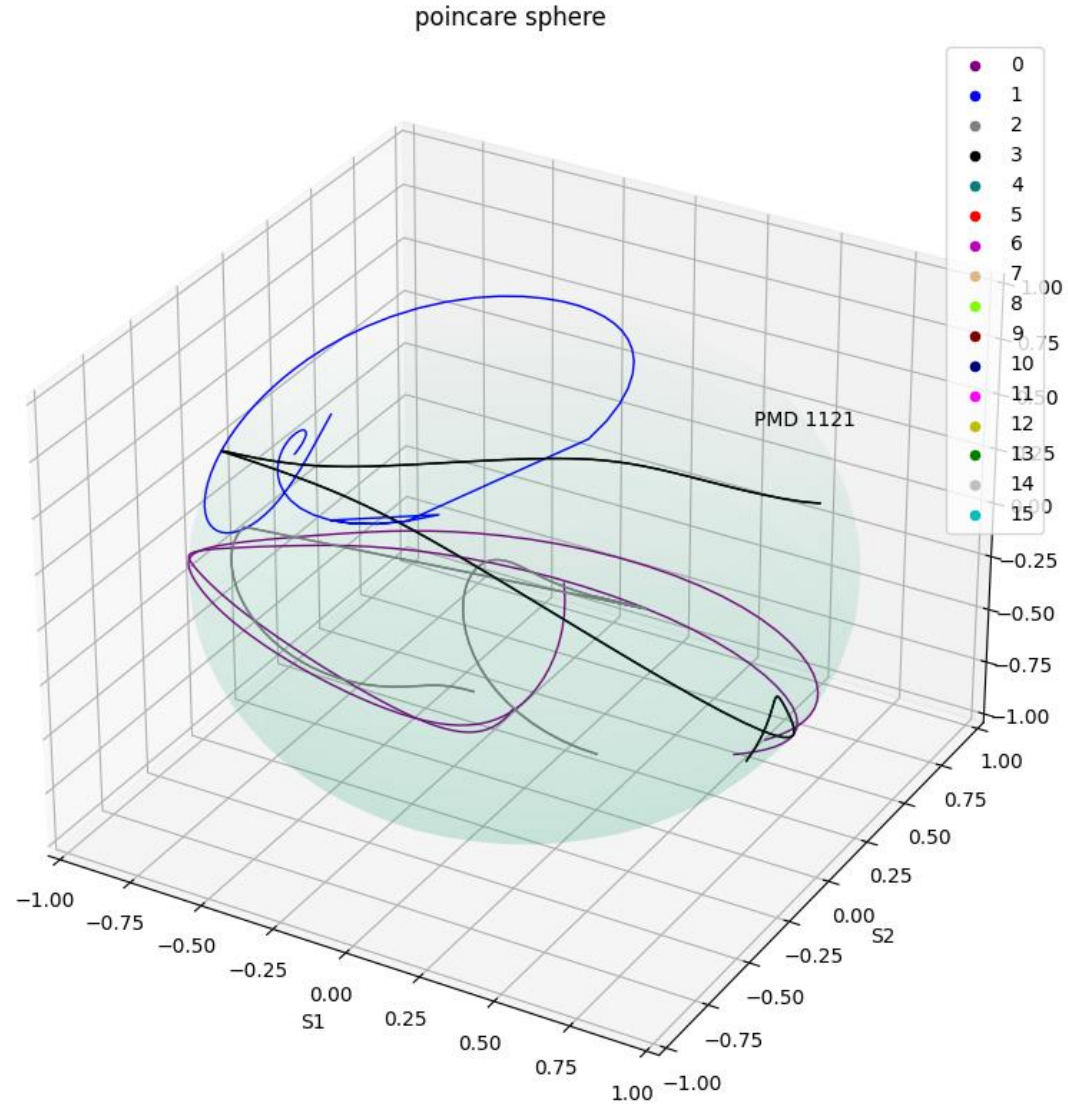
Fingerprints for Low SNR Test

For ease, we show only 2 of the 4 fingerprints for discussion. Each sensor is color-coded.

2 sensors

poincare sphere

PMD 220

●	0
●	1
●	2
●	3
●	4
●	5
●	6
●	7
●	8
●	9
●	10
●	11
●	12
●	13
●	14
●	15
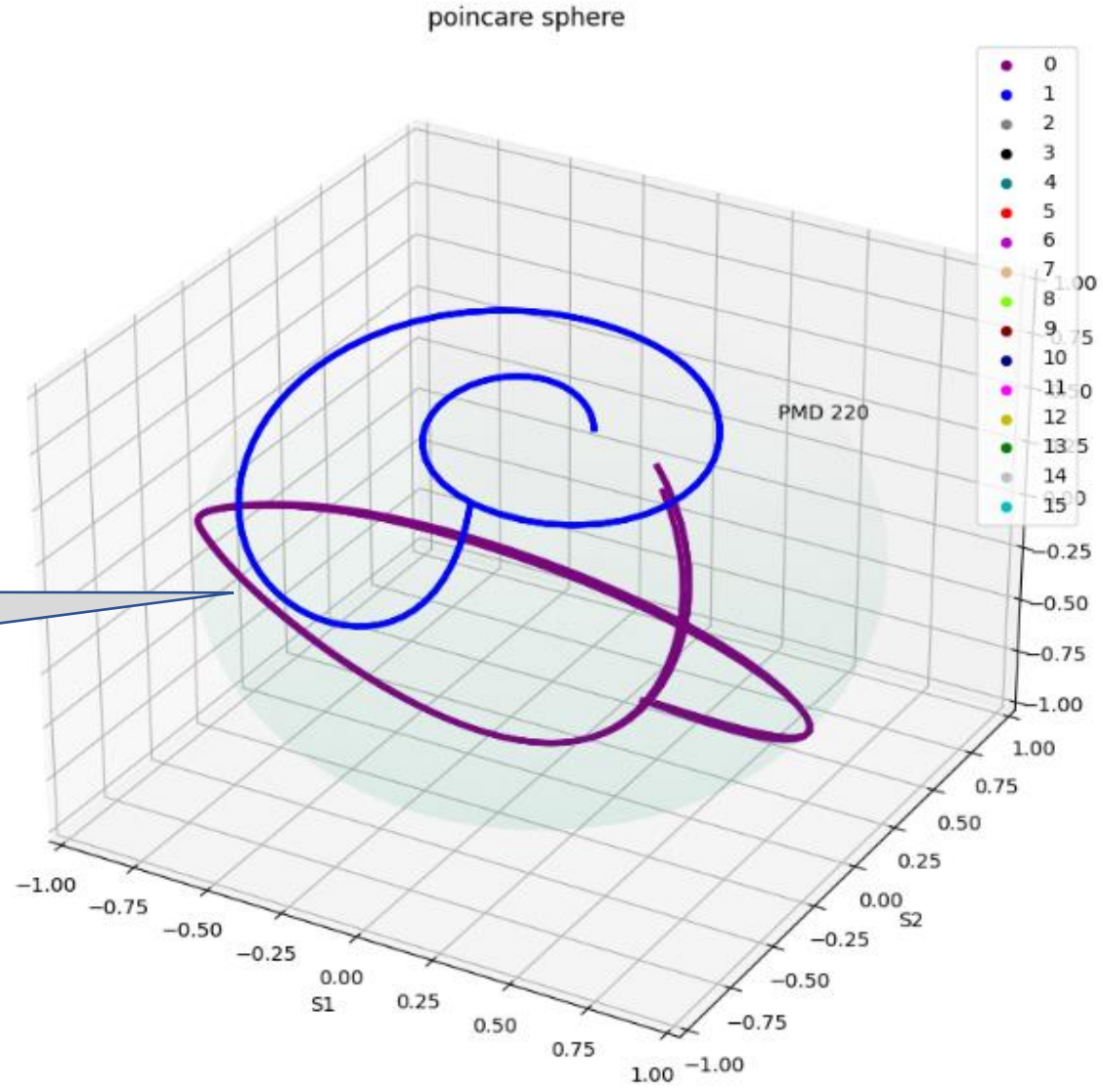
Fingerprints for Low SNR Test

When we plot all 4 devices, it is harder to visually see the various fingerprints. But, the algorithm maintains them mathematically.

Fingerprints for Low SNR Test

Each device is assigned a color and its fingerprint is plotted on the surface of a sphere.

Note the red fingerprint has two instances overlayed.
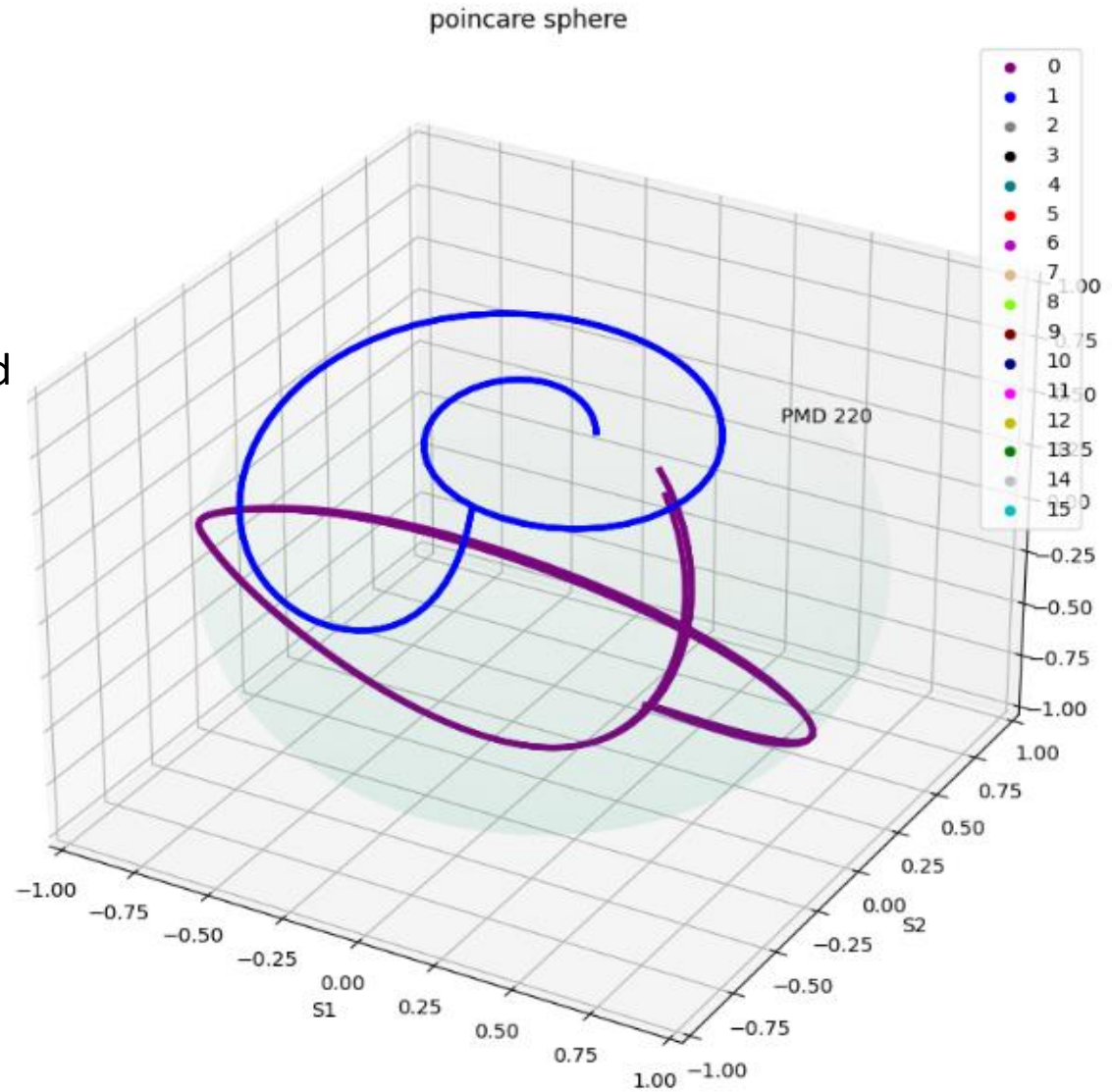
Fingerprints for Low SNR Test

Forced error by setting threshold to average such that some correlations will fall below. Note that the black and blue fingerprints appear to be from the same device and should be the same color.

This is verification that the algorithm is working properly.

poincare sphere

Theshold = 0.97
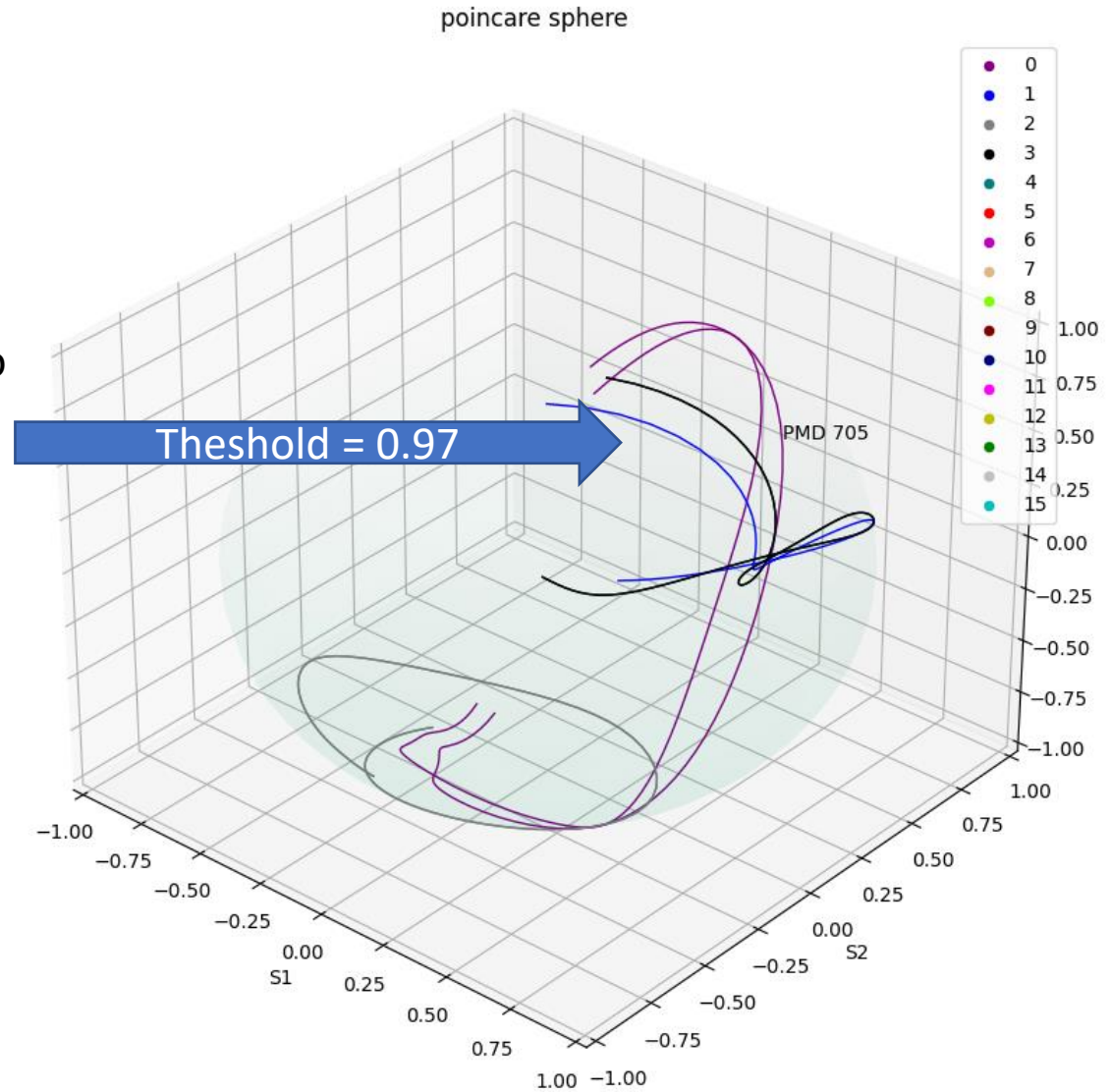
Test Set II: Electrical Interference

- 4 sensors with table-top fan in near field

- 4 sensors with box fan in near field

- 2 prototype receivers

- 16 tests performed x 4 sensors = 64 cases
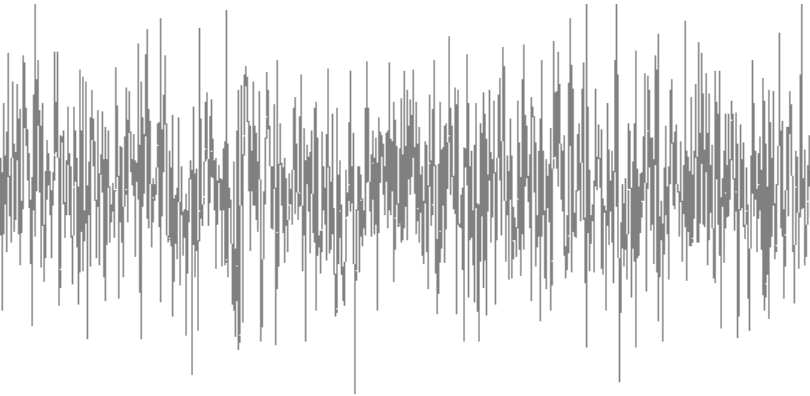
Electrical Interference
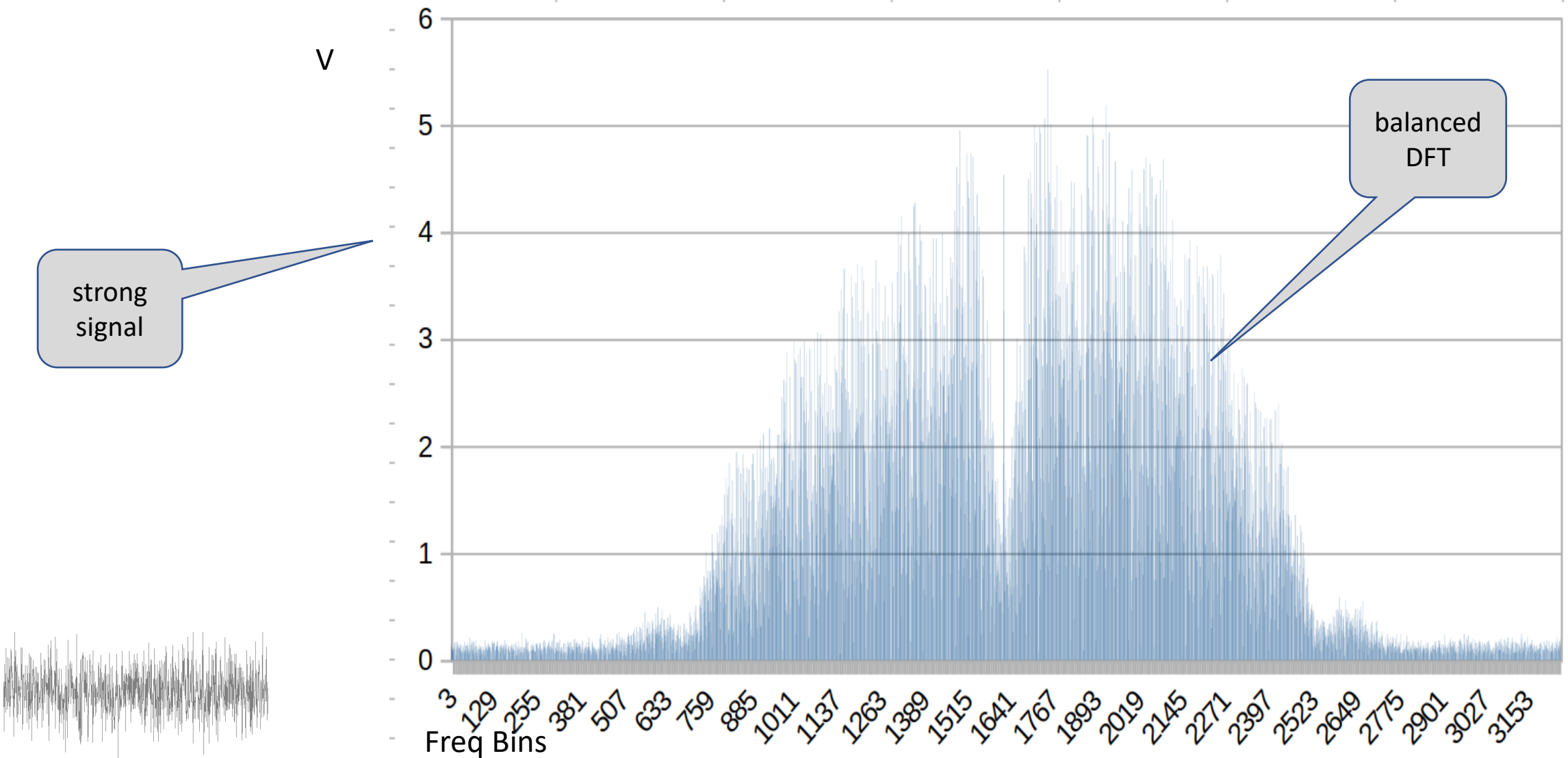
Correlation with Electrical Interference

loop no. sensor 1   sensor 2

A	B	C	D	E	F	G	H	I
1343	0.332854	0.989012	0	0	0	0	0	0
1395	0.337972	0.988296	0	0	0	0	0	0
1447	0.337852	0.98963	0	0	0	0	0	0
1499	0.348528	0.98086	0	0	0	0	0	0
1551	0.338046	0.983611	0	0	0	0	0	0
1603	0.340209	0.98555	0	0	0	0	0	0
1655	0.338646	0.991615	0	0	0	0	0	0
1710	0.994813	0.338962	0	0	0	0	0	0
1762	0.958974	0.314693	0	0	0	0	0	0
1814	0.992098	0.311701	0	0	0	0	0	0
1866	0.994895	0.339035	0	0	0	0	0	0
1919	0.983355	0.315388	0	0	0	0	0	0
1964	0.992452	0.326877	0	0	0	0	0	0
1966	0.988685	0.340708	0	0	0	0	0	0
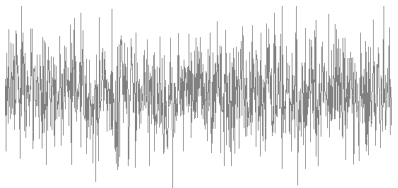
average correlation: 0.976

no false positives
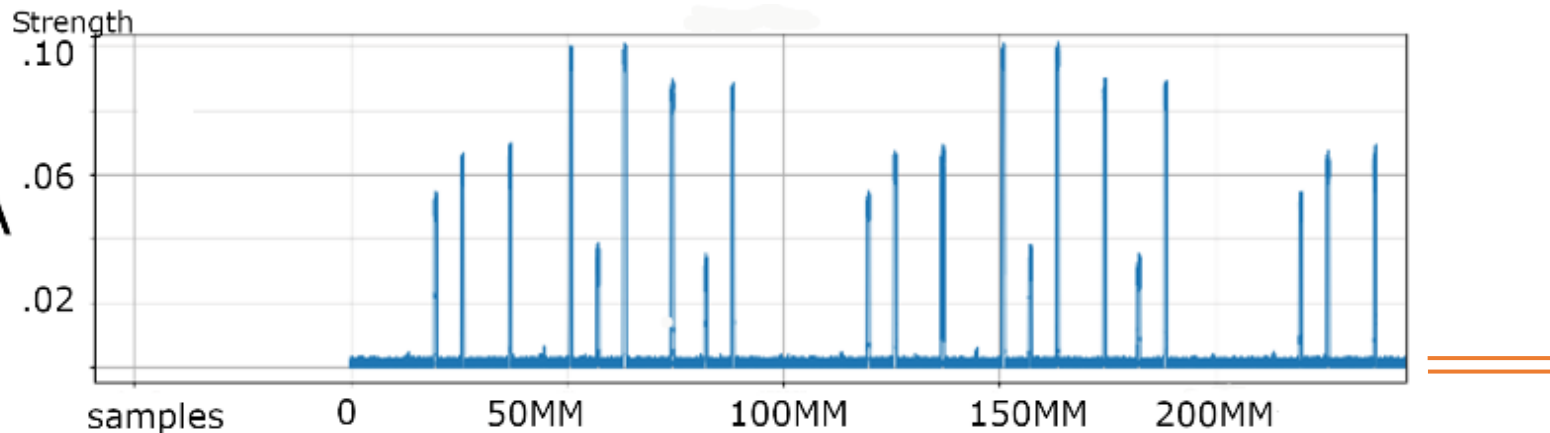no false negatives

Test Set III: Microwave Interference

- 4 sensors with microwave oven running nearby

- 2 prototype receivers

- 8 tests performed x 4 sensors = 32 cases
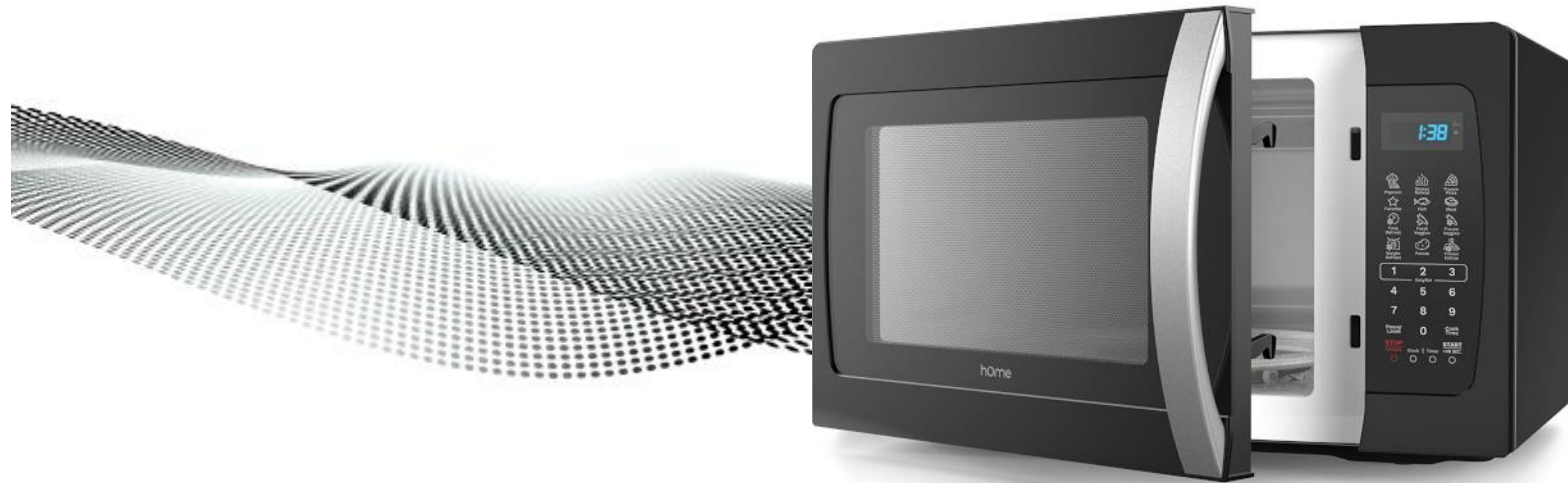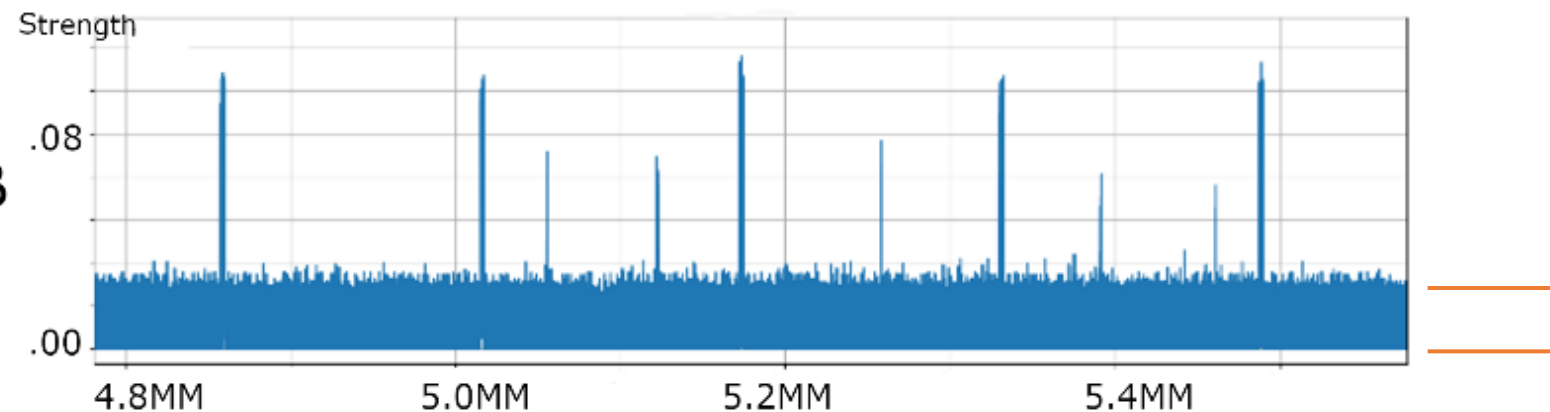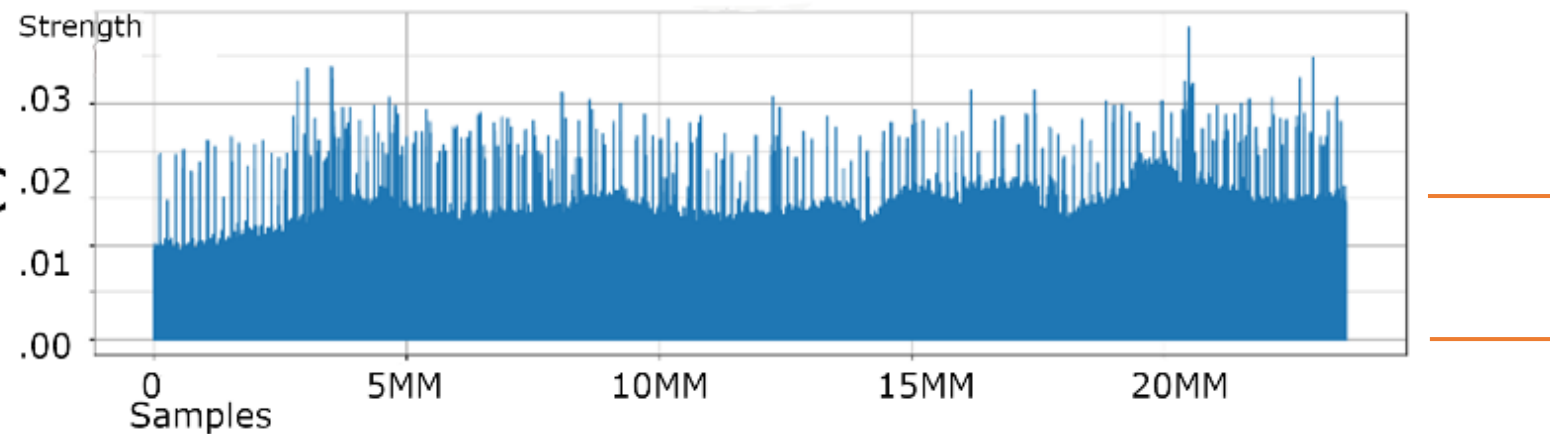
Time Domain Signals

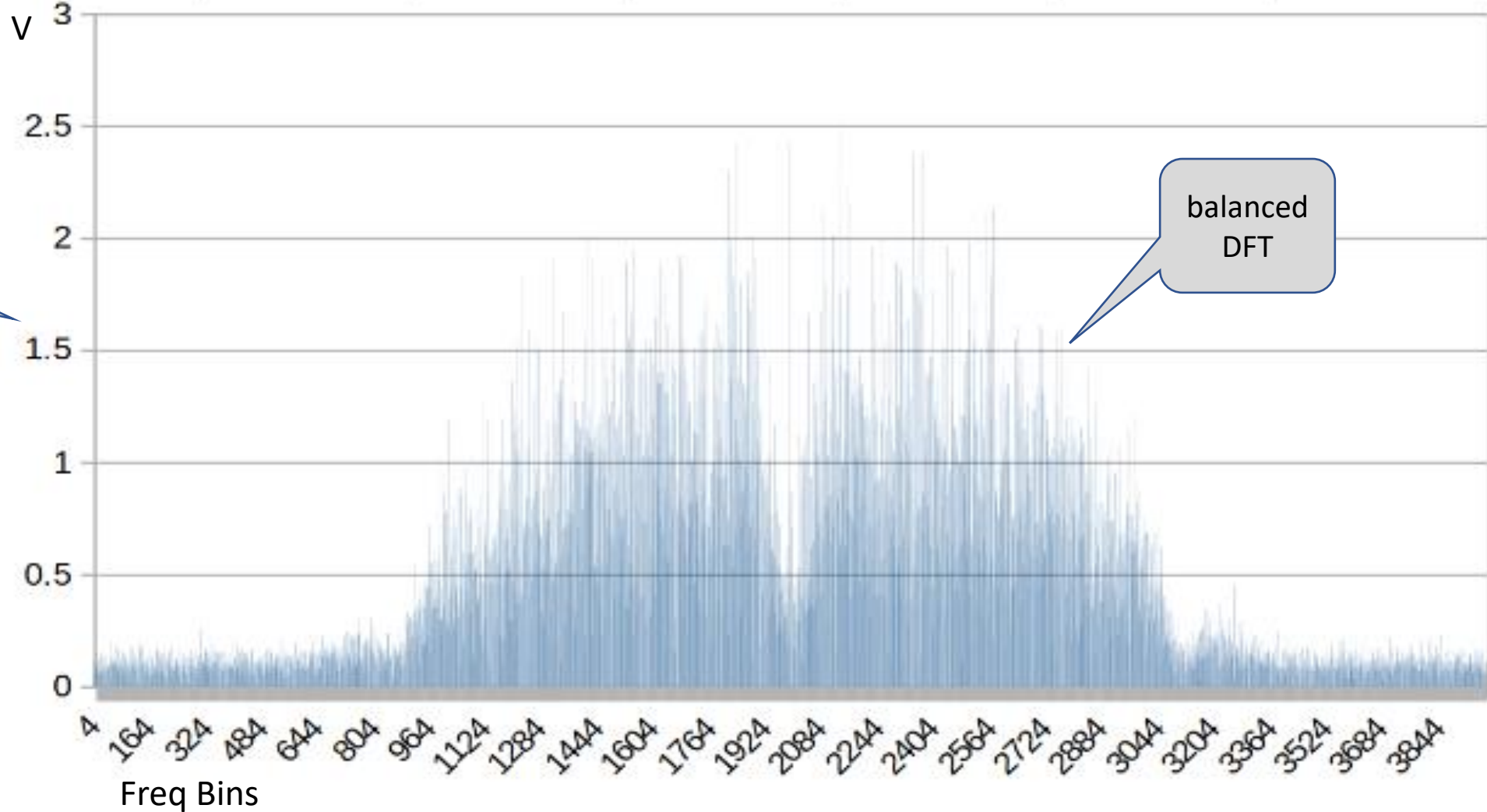# Microwave Interference Test – Sensor Signal
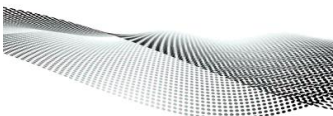
Signals in Time Domain in Microwave Test
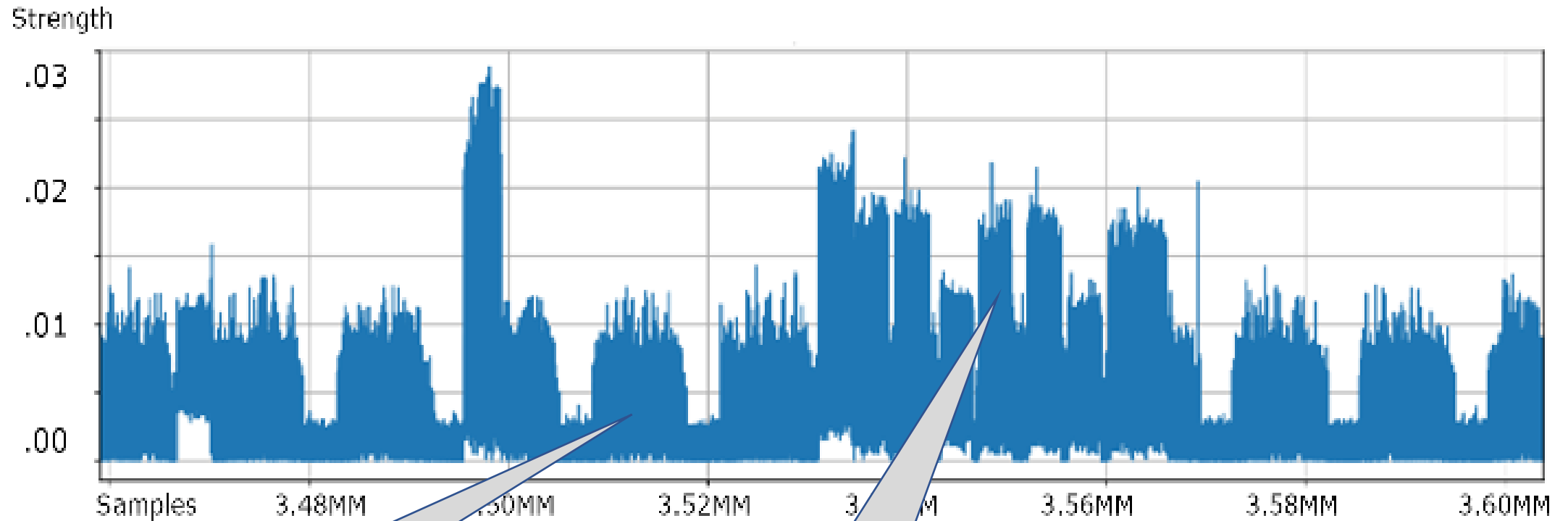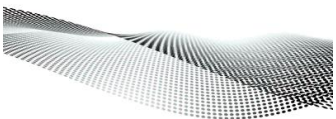
Correlation with Microwave Oven Operating

loop no.   sensor 1   sensor 2   sensor 3

| A	B	C	D	E
2925	0.997363	0.280506	0.479806	0
2933	0.991603	0.288831	0.445451	0
2940	0.998467	0.278772	0.471116	0
2948	0.995722	0.263678	0.477303	0
2949	0.993933	0.28638	0.451883	0
2950	0.997216	0.281345	0.45965	0
2951	0.995665	0.262752	0.473222	0
2972	0.345614	0.276045	0.904639	0
3001	0.994992	0.300204	0.209843	0
3007	0.996566	0.2818	0.225786	0
3008	0.998804	0.291693	0.224715	0
3037	0.22814	0.930224	0.277406	0
3058	0.995564	0.608924	0.216747	0
3061	0.245521	0.909515	0.311155	0
3078	0.996653	0.198457	0.226637	0

:
:
:

average correlation: 0.984

no false positives
no false negatives
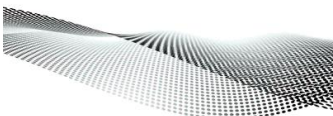
Fingerprints for Microwave Interference Test
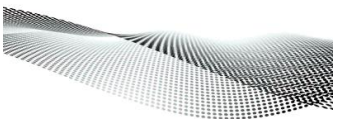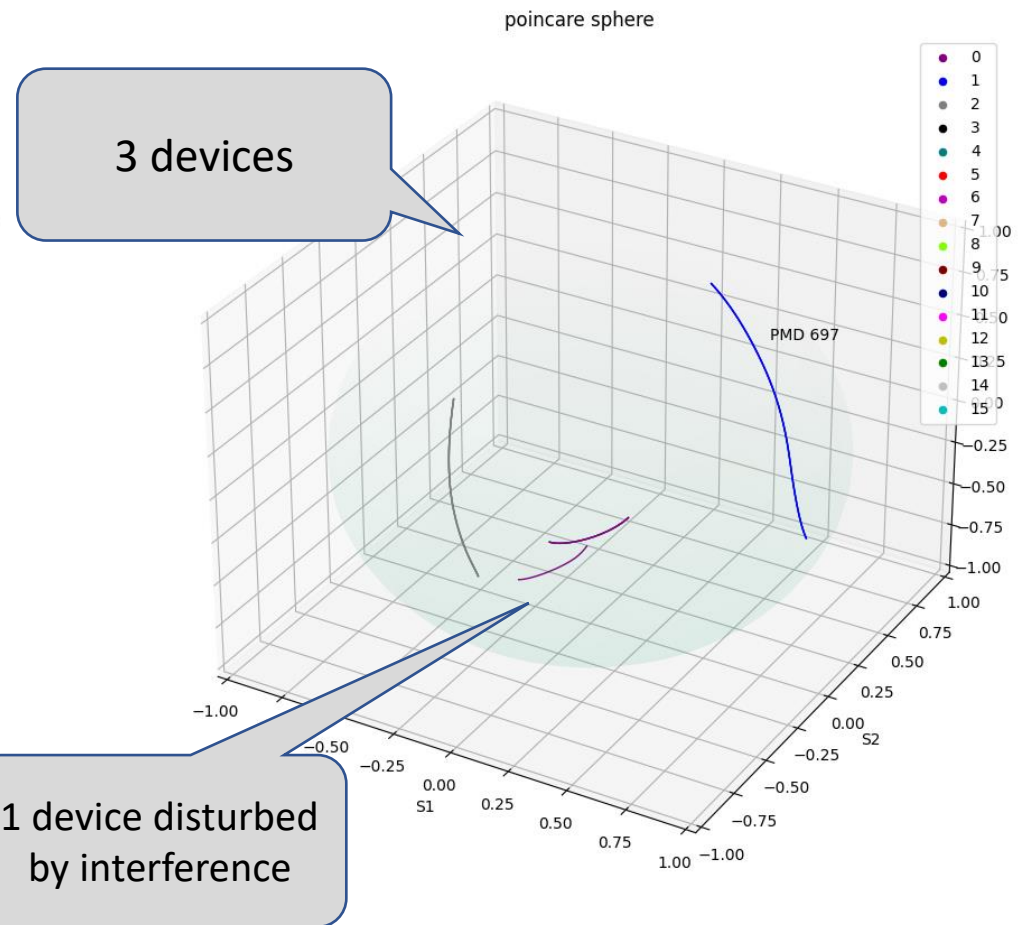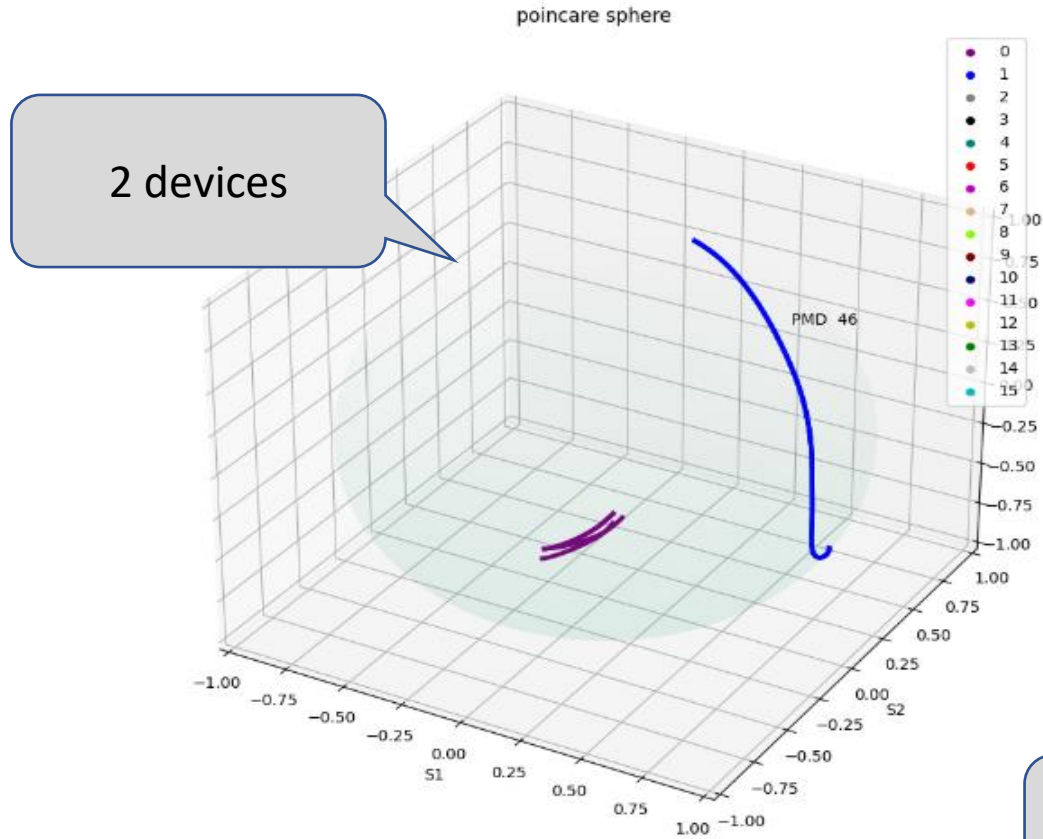
Conclusion

- Low Signal-to-Noise Ratio: 100% correlation with no false positives, no false negatives with an average 97.4% confidence. (64 cases)

- Electrical Interference: 100% correlation with no false positives, no false negatives with an average 98.6% confidence. (64 cases)

- Microwave Interference: 100% correlation with no false positives, no false negatives with an average 98.4% confidence. (32 cases)

- Use of Polarization-Based Fingerprints is Promising.

- Future Work: Testing Motion in the Multipath.

Page Heller
Endpoint Security Inc.
email: heller@endpointsecurityinc.com

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Security Inc