Near Field Measurements of a Vivato Planar Phase Array Antenna

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The Vivato Wi-Fi Switch uses a planar array antenna composed of 128 slot elements. The array is composed of 16 vertical sub-arrays with 8 slots each. Each sub-array is fed with an individual power amplifier. Each of the 16 power amplifiers is fed through a beam-forming network that provides the phase shifts required for the RF beams to form in the required direction.

The test methodology outlined in the following pages is intended to validate theoretical calculations for RF field strength within 2 meters of the antenna array. The measurements were made in the bore-sight direction, along a line orthogonal to the array plane at the center of the array. Power is applied to the beam-forming network such that a narrow beam of RF energy is formed in the far field with maximum field strength in the bore-sight direction.

It has been recognized that beams from a planar antenna array are only fully focused at distances that are large compared to the dimensions of the array. Extensive modeling has been done to predict field strengths at smaller distances. Measurements to validate the model require careful methodology and interpretation.

Measurement Difficulties

1. Antenna apertures are large compared to a wavelength. There are field strength variations relative to position in a plane parallel to the array near the array.
2. Any reflections from nearby objects can affect measurement results. This is exacerbated by the act that the array measured has a far-filed gain of 25 dB.
3. The cable leading to the test antenna can induce measurement errors and has to be carefully positioned to avoid variability.
4. The absence of a large anechoic chamber forced us to make measurement outdoors with the direction of radiation pointed vertically.

Measurement Set Up

1. The apparatus comprises a wooden frame 10ft high with a linear bearing on the top of the unit

2. Inside the bearing is a sliding shaft that contains the dipole antenna used for measurement as well as the cable leading to the antenna.

3. The panel to be measured is placed face up and the dipole is aligned at the bore-sight

4. Measurements are taken at 0.1 foot increments.

5. Height measurement is made using a plastic measuring tape parallel to the antenna

6. The dipole is repositioned each time before a reading is taken to ensure that it is looking down on the bore sight of the panel. Care is taken to assure polarization is correct

7. A continuous wave (CW) signal at 2437GHz is injected into the beam-forming network at the port corresponding to a bore-sight beam. The antenna, power amplifiers and beam-forming network are from a Vivato 2.4 GHz Wi-Fi switch.

8. The levels are measured with a spectrum analyzer.

9. Amplitude and distance data are taken. Those data are then corrected for cable losses, test antenna gain, power calibration, etc.

Set-UP details

SignalGenerator
Agilent E4438C
SN:MY42080517
Options:002,005,403,405,506,UN7,UNB,UNJ

Spectrum Analyzer
Agilent 8563EC
SN:???

Antenna Array
SN:9A2-01 (Vivato Wi-Fi Switch modified to allow a Sgnal Generator to be substituted for the modulated RF signal)

Frequency
2437MHz-802.11 Channel 6

Measurement Block Diagram

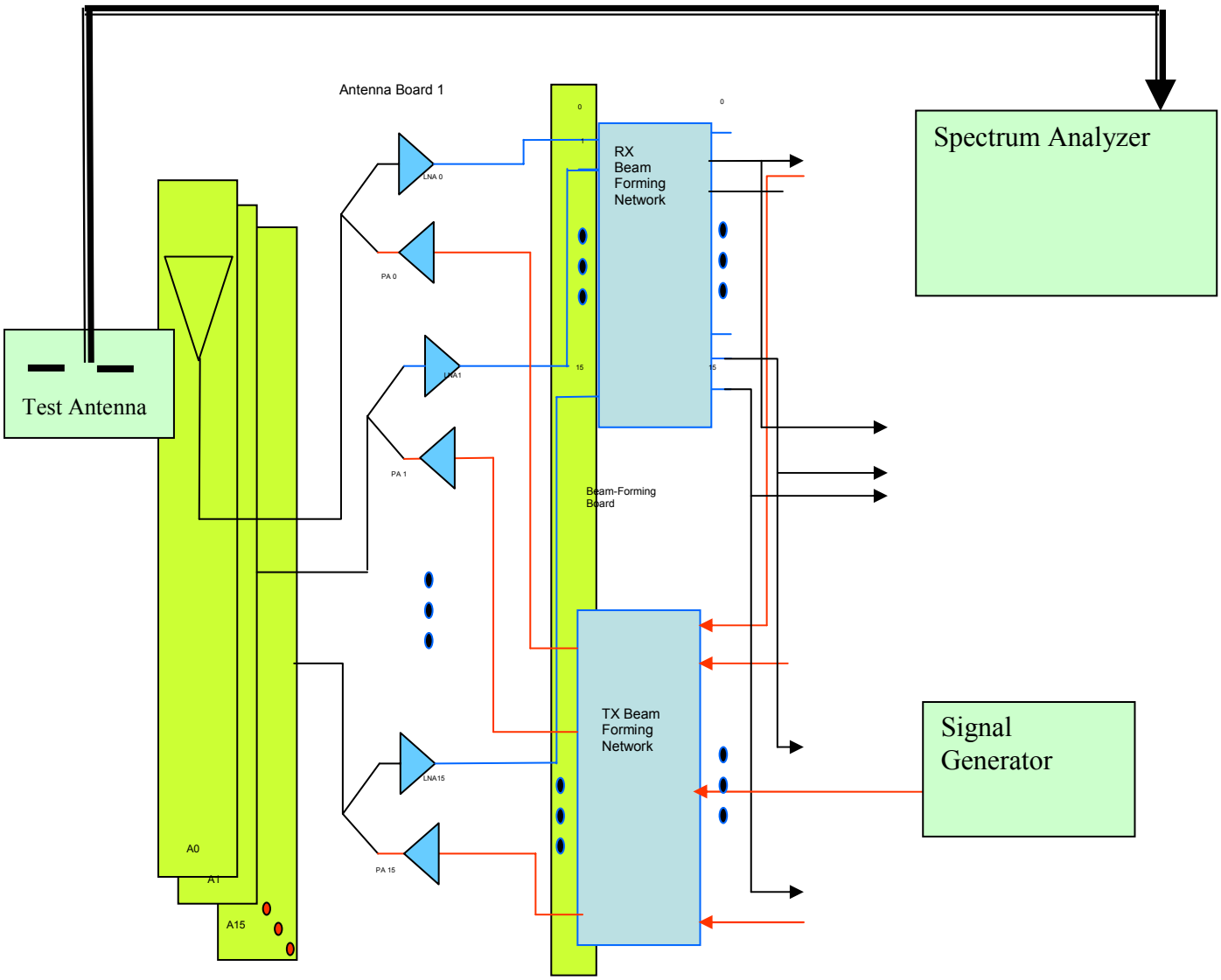


Figure 1: Front View of measurement apparatus

Figure2: Side view if the measurement apparatus. The linear bearing is the white piece of PVC piping at the top of the picture.

Figure 3: Rear view of measurement apparatus

Figure4:
Internal view of Vivato Wi-Fi Switch. The board in the black rectangle in the middle of the picture is the adapter board used to inject the signal for the measurement

Figure 5: Close-up of the adapter board

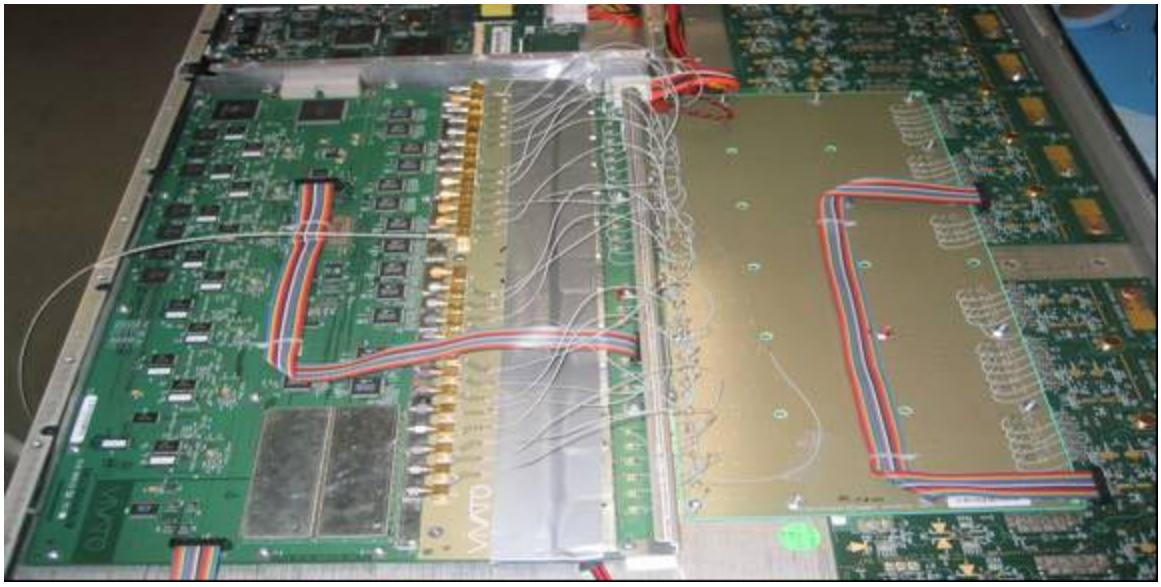


Figure 6: Close-up of panel with measurement dipole

Figure 7 : Closeup of measurement dipole

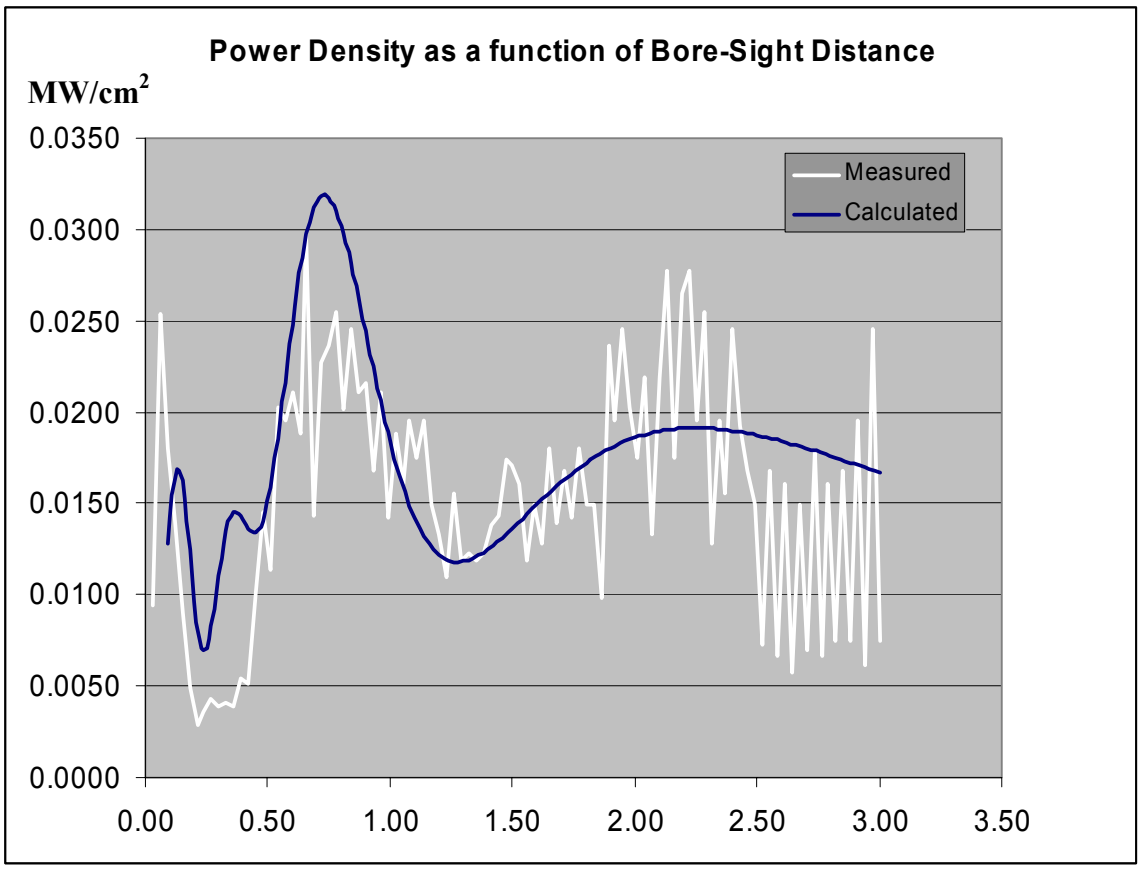
Figure 8: Sliding Linear bearing. Black strip is a made of Velcro and provides a friction fit holding the gray PVC pipe section in place

Figure 9: Spectrum analyzer used to make the measurement

Figure 10: ESG Signal generator used to generate 2437GHz CW signal

Measurement results

The following plot shows measurements of field strength along with a numerical prediction. The plots assume single channel operation and 100 mW of total power fed to the Vivato planar array.



Raw Measurements

Distance (ft)	Amplitude (dbm)
0.1	-38
0.2	-33.7
0.3	-35.17
0.4	-36.3
0.5	-38.17
0.6	-40.8
0.7	-43.2
0.8	-42.2
0.9	-41.4
1	-41.8
1.1	-41.67

1.2	-41.83
1.3	-40.4
1.4	-40.67
1.5	-37.67
1.6	-36.1
1.7	-37.17
1.8	-34.67
1.9	-34.83
2	-34.5
2.1	-35
2.2	-33
2.3	-36.17
2.4	-34.17
2.5	-34
2.6	-33.67
2.7	-34.7
2.8	-33.83
2.9	-34.5
3	-34.4
3.1	-35.5
3.2	-34.5
3.3	-36.2
3.4	-35
3.5	-35.67
3.6	-34.83
3.7	-35.3
3.8	-34.83
3.9	-36
4	-36.5
4.1	-37.33
4.2	-35.83
4.3	-37
4.4	-36.83
4.5	-37
4.6	-36.83
4.7	-36.33
4.8	-36.17
4.9	-35.33
5	-35.4
5.1	-35.67
5.2	-37
5.3	-36
5.4	-36.67
5.5	-35.17
5.6	-36.3
5.7	-35.5
5.8	-36.2
5.9	-35.17
6	-36

Corrections

Spectrum Analyzer Detector	2.5 dB
RX Cable Loss	21 dB
Test Antenna Gain	2 dB
Frequency	2.437 GHz
Test Antenna Aperture	12 cm^2
Correction for 100 mW power	3.2 dB

Corrected Field Strength

See Plot

Distance (m) (m)	Corrected dBm	Corrected Power (mW)	Power Density (mW/sq cm)
0.03	-14.5	0.035	0.0094
0.06	-10.2	0.095	0.0253
0.09	-11.67	0.068	0.0181
0.12	-12.8	0.052	0.0139
0.15	-14.67	0.034	0.0091
0.18	-17.3	0.019	0.0049
0.21	-19.7	0.011	0.0028
0.24	-18.7	0.013	0.0036
0.27	-17.9	0.016	0.0043
0.30	-18.3	0.015	0.0039
0.33	-18.17	0.015	0.0040
0.36	-18.33	0.015	0.0039
0.39	-16.9	0.020	0.0054
0.42	-17.17	0.019	0.0051
0.45	-14.17	0.038	0.0102
0.48	-12.6	0.055	0.0146
0.51	-13.67	0.043	0.0114
0.54	-11.17	0.076	0.0203
0.57	-11.33	0.074	0.0195
0.60	-11	0.079	0.0211
0.63	-11.5	0.071	0.0188
0.66	-9.5	0.112	0.0298
0.69	-12.67	0.054	0.0143
0.72	-10.67	0.086	0.0227
0.75	-10.5	0.089	0.0236
0.78	-10.17	0.096	0.0255
0.81	-11.2	0.076	0.0201
0.84	-10.33	0.093	0.0246
0.87	-11	0.079	0.0211
0.90	-10.9	0.081	0.0216
0.93	-12	0.063	0.0167

0.96	-11	0.079	0.0211
0.99	-12.7	0.054	0.0142
1.02	-11.5	0.071	0.0188
1.05	-12.17	0.061	0.0161
1.08	-11.33	0.074	0.0195
1.11	-11.8	0.066	0.0175
1.14	-11.33	0.074	0.0195
1.17	-12.5	0.056	0.0149
1.20	-13	0.050	0.0133
1.23	-13.83	0.041	0.0110
1.26	-12.33	0.058	0.0155
1.29	-13.5	0.045	0.0118
1.32	-13.33	0.046	0.0123
1.35	-13.5	0.045	0.0118
1.38	-13.33	0.046	0.0123
1.41	-12.83	0.052	0.0138
1.44	-12.67	0.054	0.0143
1.47	-11.83	0.066	0.0174
1.50	-11.9	0.065	0.0171
1.53	-12.17	0.061	0.0161
1.56	-13.5	0.045	0.0118
1.59	-12.5	0.056	0.0149
1.62	-13.17	0.048	0.0128
1.65	-11.67	0.068	0.0181
1.68	-12.8	0.052	0.0139
1.71	-12	0.063	0.0167
1.74	-12.7	0.054	0.0142
1.77	-11.67	0.068	0.0181
1.80	-12.5	0.056	0.0149