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Client: Vivato, Inc.
Report number: 2003034
Standards: FCC 15.247 & IC RSS-210
FCC ID: QLNVLJ24WFSW
Model Name: 2.4 GHz Wi-Fi Switch

APPENDIX A: RF EXPOSURE CALCULATIONS FOR HIGH GAIN ANTENNAS

Please see the following pages.

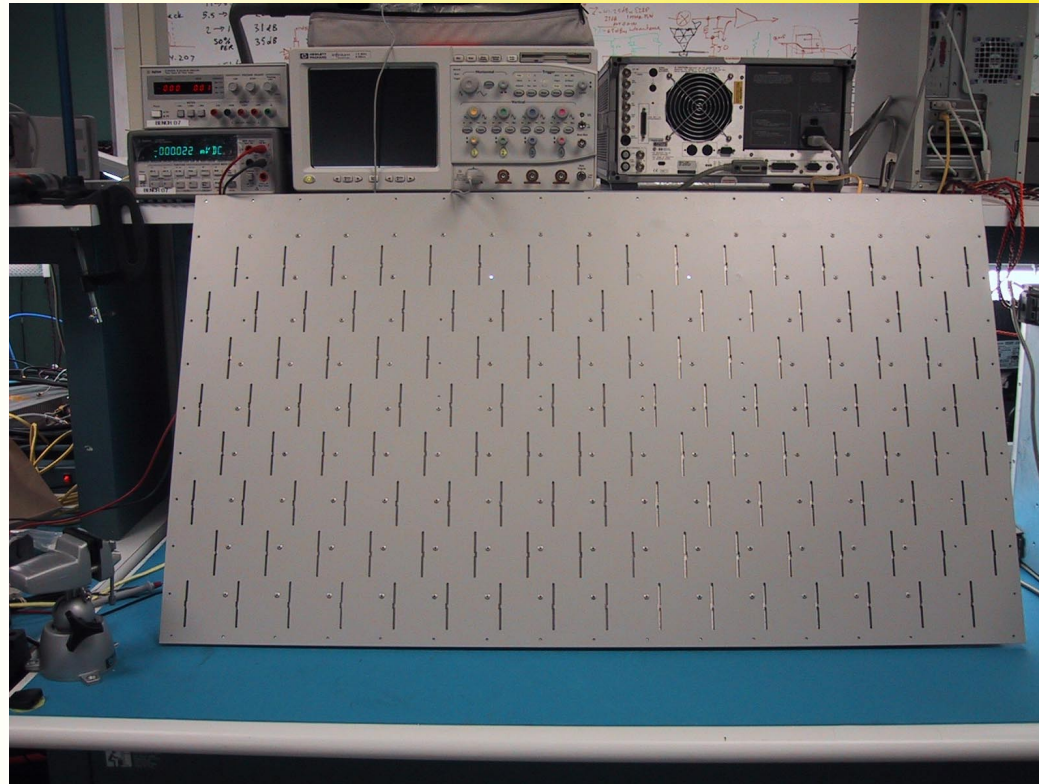
W i - F i E V E R Y W H E R E

Vivato ***RF Exposure***

Marcus da Silva

VP Engineering

Vivato Phased Array Antenna



Vivato 2.4 GHz Wi-Fi Switches: Antenna Design

Thin design

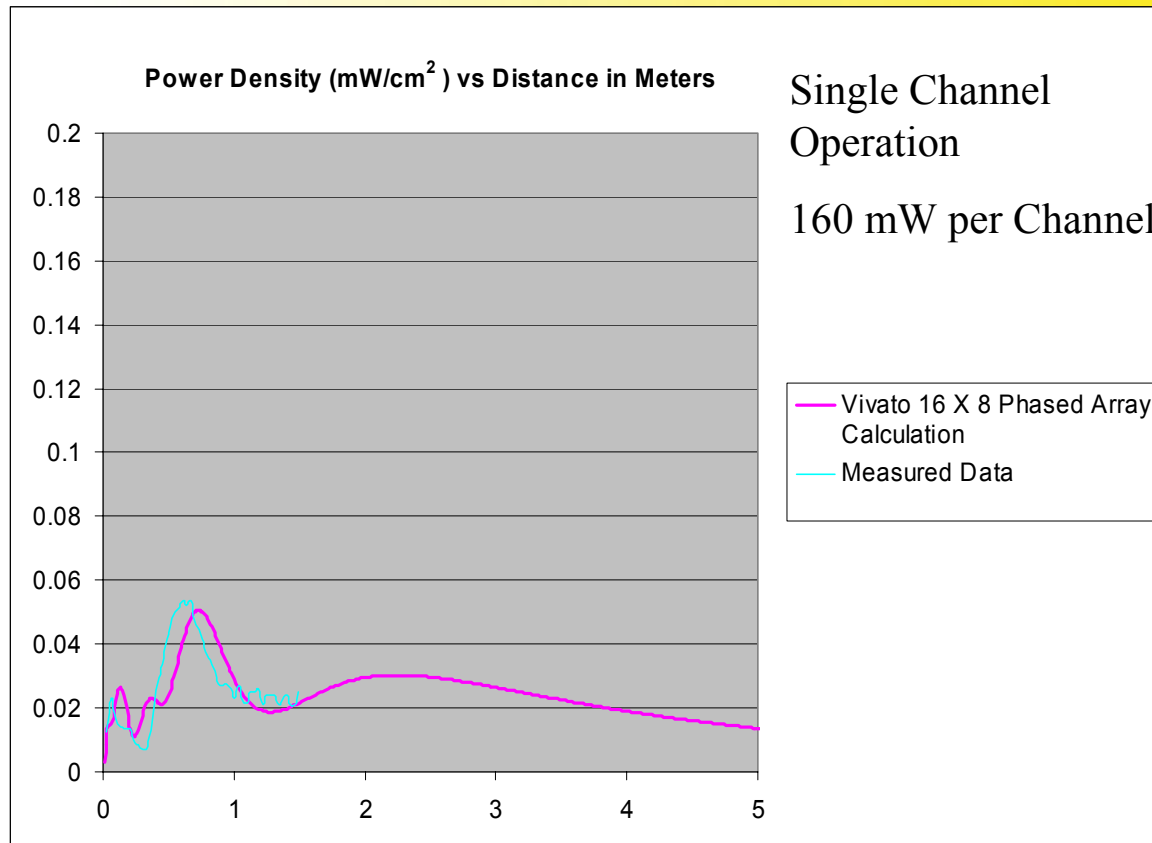
Vivato Wi-Fi Switches use low power

- Maximum total RF power to the antenna for a Vivato Wi-Fi Switch
 - Factory settings of 100 mW Maximum power per channel for the duration of a packet.
 - 300 mW maximum total conducted power during 3 channel operation
 - Vivato beam steering technology does not allow more than one channel to transmit at a given time in a given direction (6 degree width).
 - Power density decreases with distance.
 - Power is distributed over the entire antenna face area
- Maximum RF power for a typical *Access Point* (AP)
 - 100 mW/ channel “Omni-directionally”
- Maximum RF power for a Cell Phone
 - 200 mW “Omni-directionally”

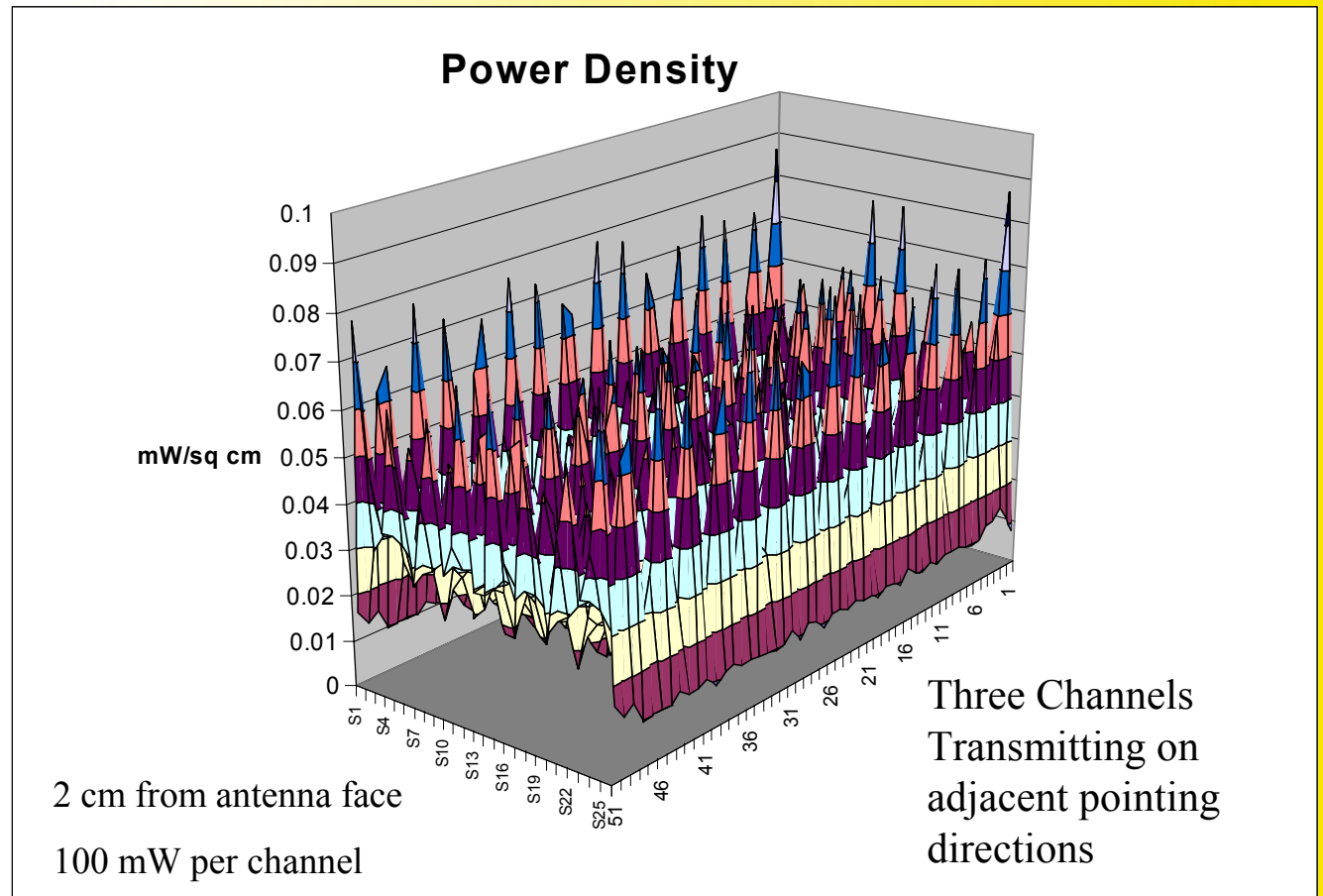
Safety Specifications

- FCC Indoor exposure limits for 2.4 GHz ISM Part 15 devices
 - 1 mW/cm² at 20 cm distance from antenna face
- Vivato worst case exposure:
 - **OET 65 upper bound method**
 - **0.247 mW/cm² at 20 cm distance from antenna face with all three channels transmitting simultaneously**
 - **OET 65 is a FCC publication detailing RF exposure calculation methods**
 - Worst case exposure at 20 cm from antenna face
 - <0.13 mW/cm²
 - 3 channels in adjacent pointing directions at the extreme left or right.

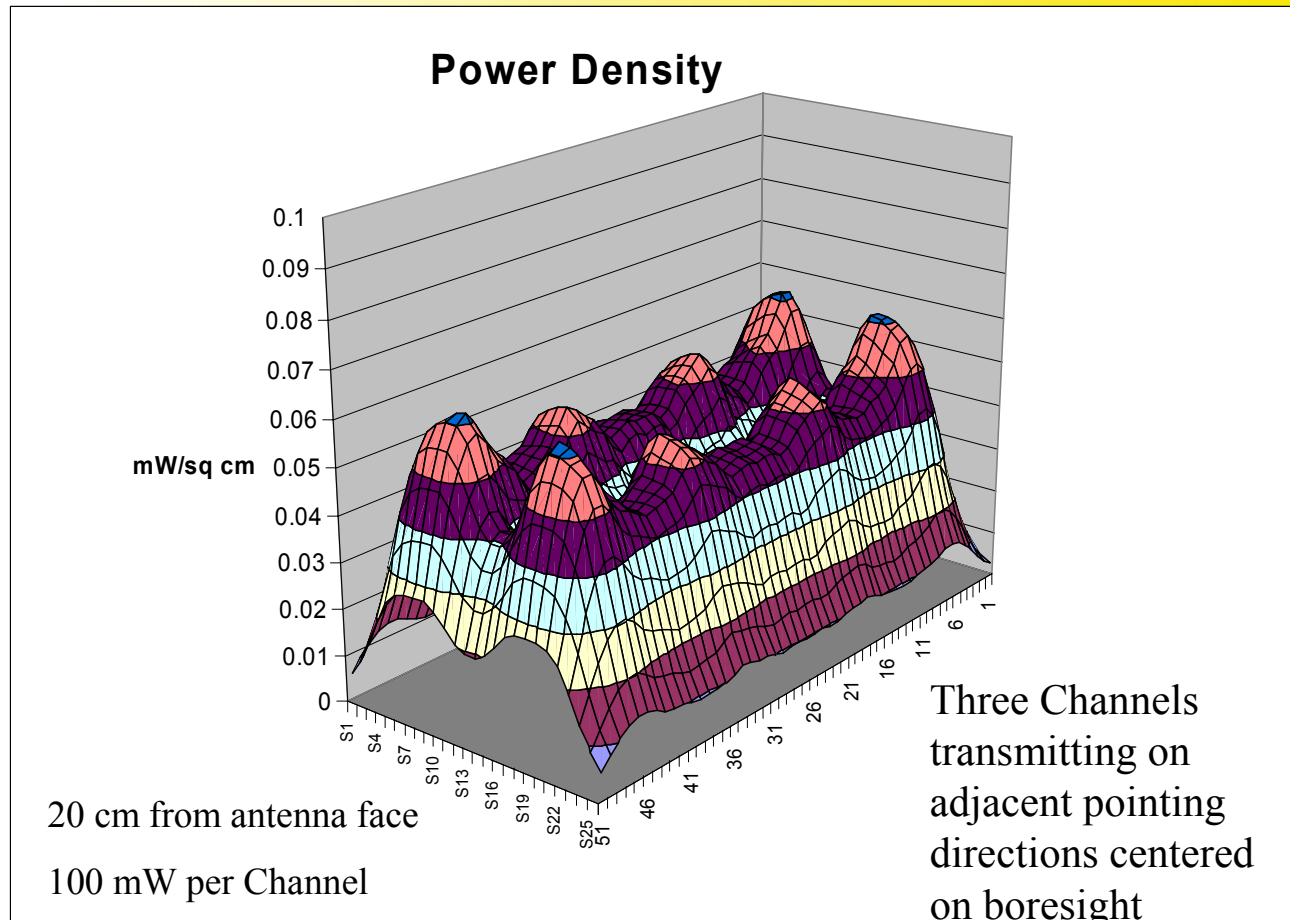
Power Density as a Function of Distance: Vivato 2.4 GHz Wi-Fi Switches Measured Along Bore-sight



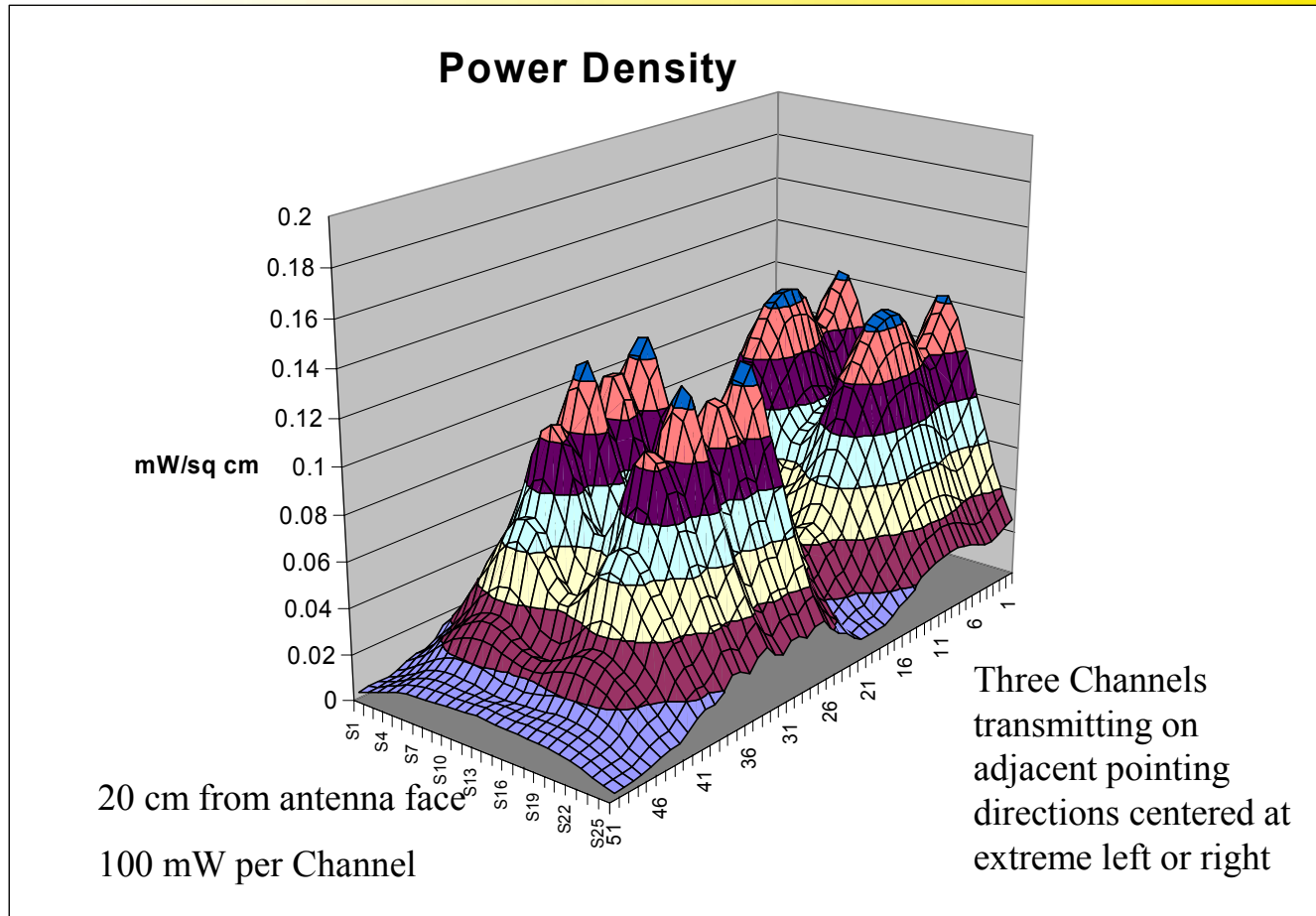
Power Density as a Function of Distance: Vivato 2.4 GHz Wi-Fi Switches



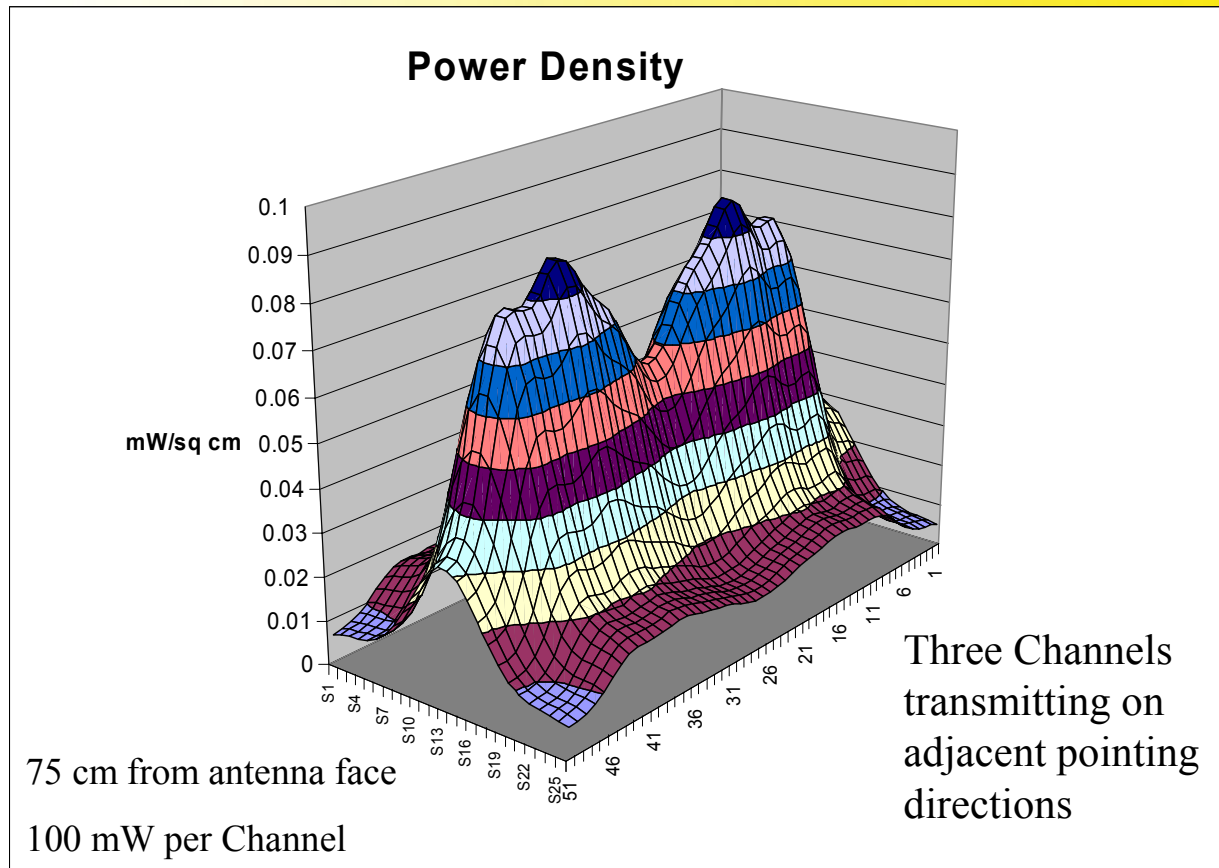
Power Density as a Function of Distance: Vivato 2.4 GHz Wi-Fi Switches



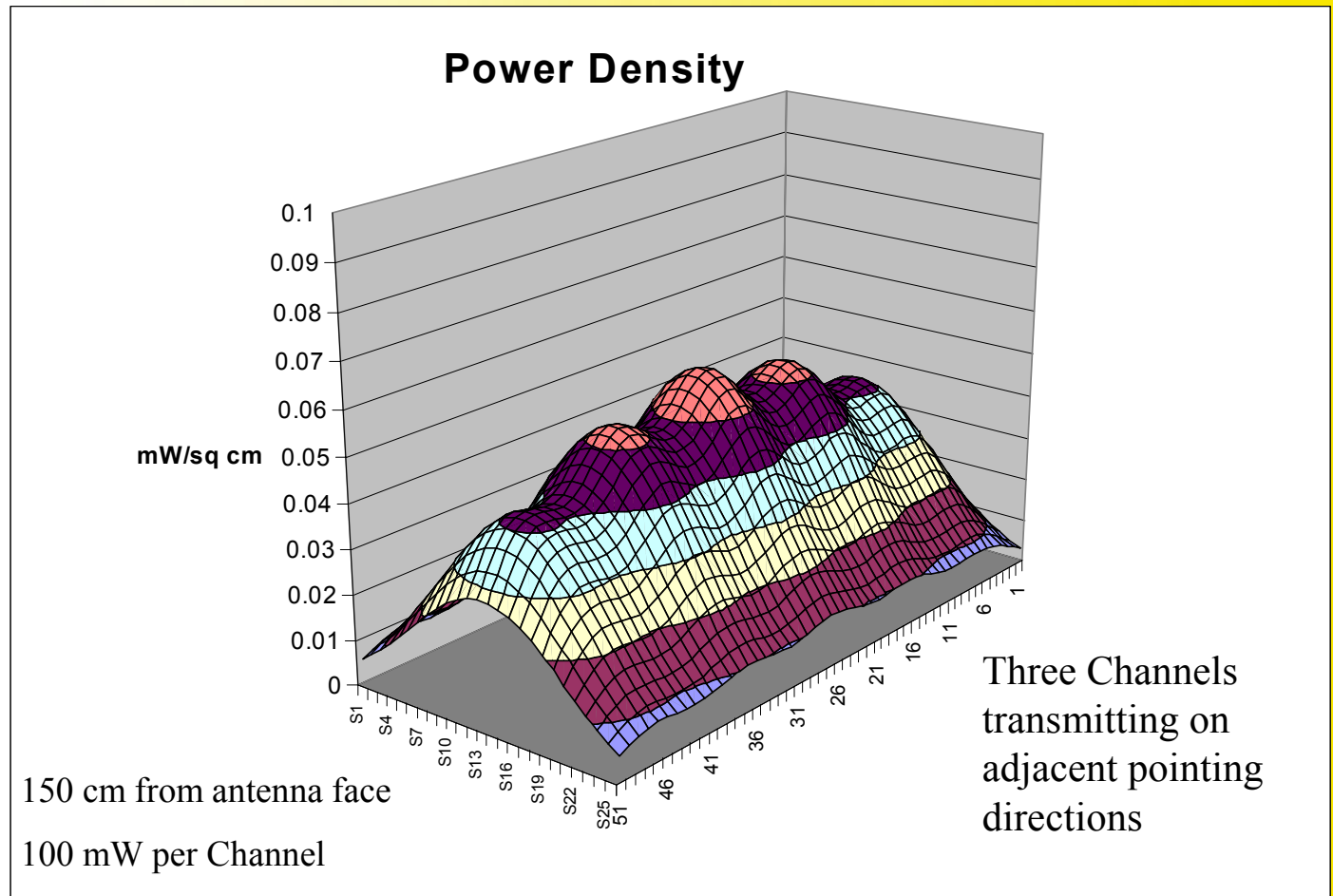
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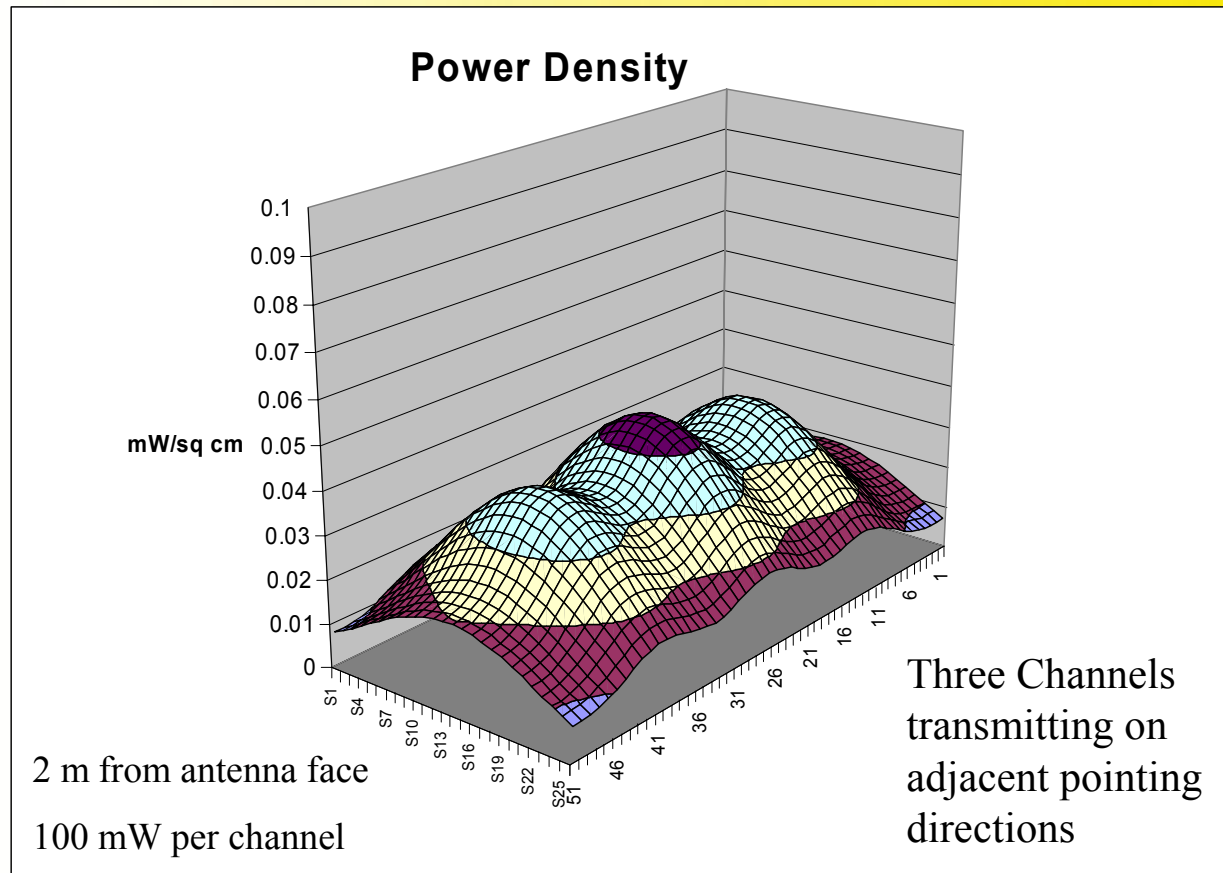
Power Density as a Function of Distance: Vivato 2.4 GHz Wi-Fi Switches



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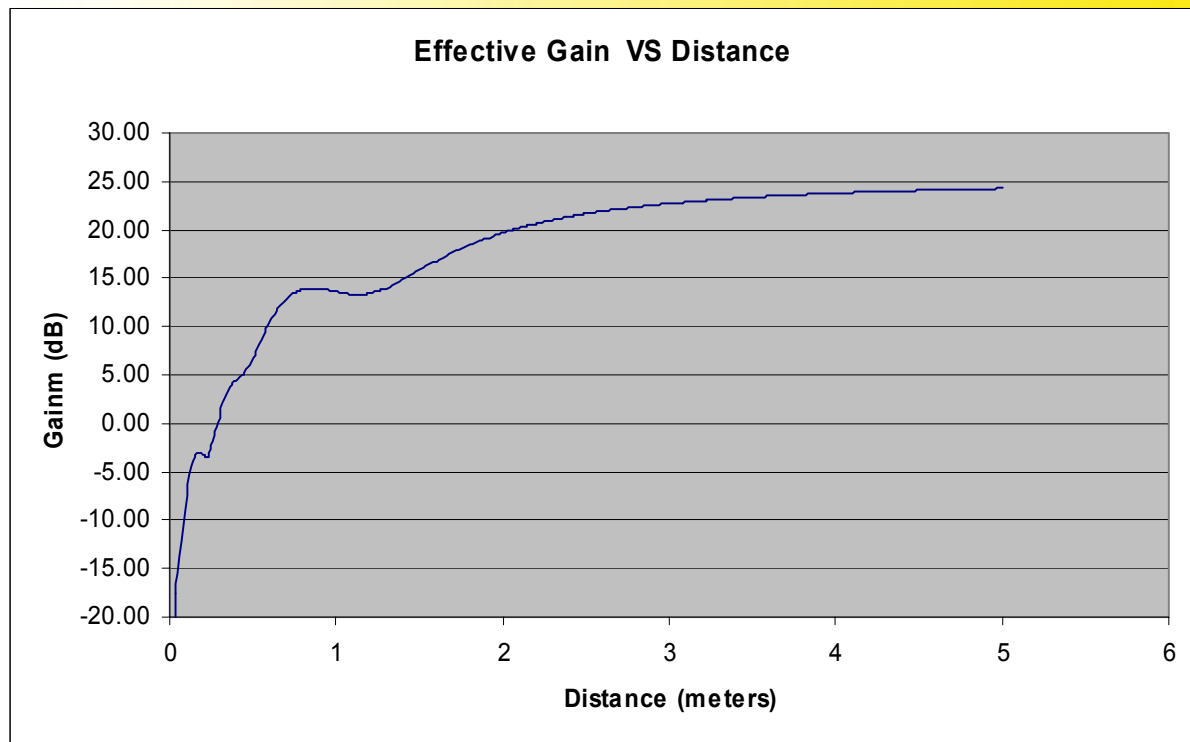
RF Exposure Comparisons

- Vivato Wi-Fi switch with 3 channels operating
 - $< 0.13 \text{ mW/cm}^2$ at 20 cm
- Microwave Oven Specification
 - 5 mW/cm^2 at 20 cm distance from Oven
 - It is typically worse at door seams, etc.
- Typical Cell Phone Radiation
 - 0.04 mW/cm^2 at 20 cm distance from antenna
 - 0.64 mW/cm^2 at 5 cm distance from antenna
 - Realistic distance from user's skull.
- Direct Sunlight
 - In the order of 100 mW/cm^2

Effective Antenna Gain is small close to the antenna

- The array produces a pattern that is not completely focused until about 5 meters from the antenna face.
- This leads us to the concept of an effective array gain.
- The effective array gain varies with direction and with distance. For a uniformly distributed array driven with equal phase to all elements, the maximum gain is along the perpendicular center line (bore sight).

Effective Bore-sight Gain of a Vivato 2.4 GHz Wi-Fi Switch Antenna Array VS Distance



OET 65 Approximation

- OET 65 ED 97-01, Page 27-28
 - Approximation for near field of antenna arrays
 - Max power density in the near field is 4 times the power divided by the antenna area

$$P_D = \frac{4P_T}{A}$$

- **OET 65 Applied to the Vivato Wi-Fi Switch**
 - 3 channels at 100 mW per channel
 - Antenna area = 4840 cm²
 - **$P_{DMax} = 0.248 \text{ mW/ cm}^2$**

Validity of equations used for contour plots

$$E_{\phi} = E_0 \left[\frac{j}{\beta r} + \frac{1}{(\beta r^2)} \right] \sin \Theta e^{-j\beta r}$$

Electric field of a single slot antenna

$$\frac{1}{\beta r} > \frac{1}{(\beta r^2)}$$

$$r > \frac{\lambda}{2\pi}$$

Near field is where the $1/r^2$ term dominates. Far field is where the $1/r$ term dominates

The far approximation is valid for **$r > 1.96 \text{ cm}$**

The Vivato logo is a vertical, stylized graphic on the left side of the slide. It consists of a yellow circle at the top, followed by a grey 'V' shape, and then a series of grey, downward-pointing chevrons that resemble the letters 'i', 'v', 'a', 't', 'o' stacked vertically.

Vivato Wi-Fi Switches are safe at all distances

- Measurements and calculations for Vivato Wi-Fi Switches show RF exposure levels well below existing requirements
- The OET 65 calculation method provides very significant margin compared to real-world measured power levels.
- The Vivato Wi-Fi Switch does not introduce new safety concerns.