MEASUREMENTS OF POWER HANDLING OF RF ABSORBER MATERIALS: CREATION OF A MEDIUM POWER ABSORBER BY MECHANICAL MEANS

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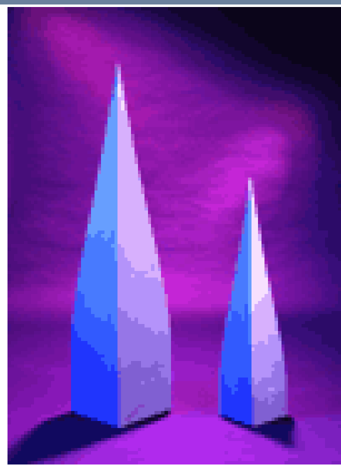
Outline

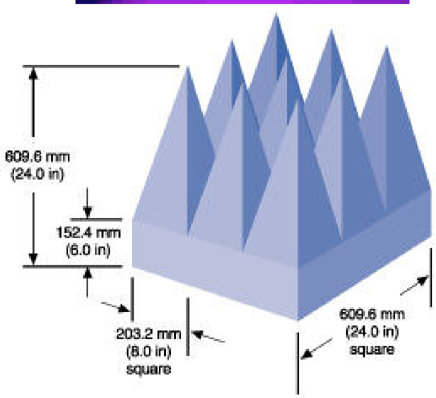
- RF Absorber
- How does it work
- Measurements of power density limits
- Conclusions

Flammability and Fire Retardancy

- Absorbers convert EM energy into Thermal Energy
- If too much EM energy is applied a lot of thermal energy is generated
- Material will burn

The Absorber Family 1





Microwave
Pyramidal absorber.

Electric Losses

Preferred technology for High frequencies It can be used for low frequencies if size (length) is increased

The Absorber Family 2

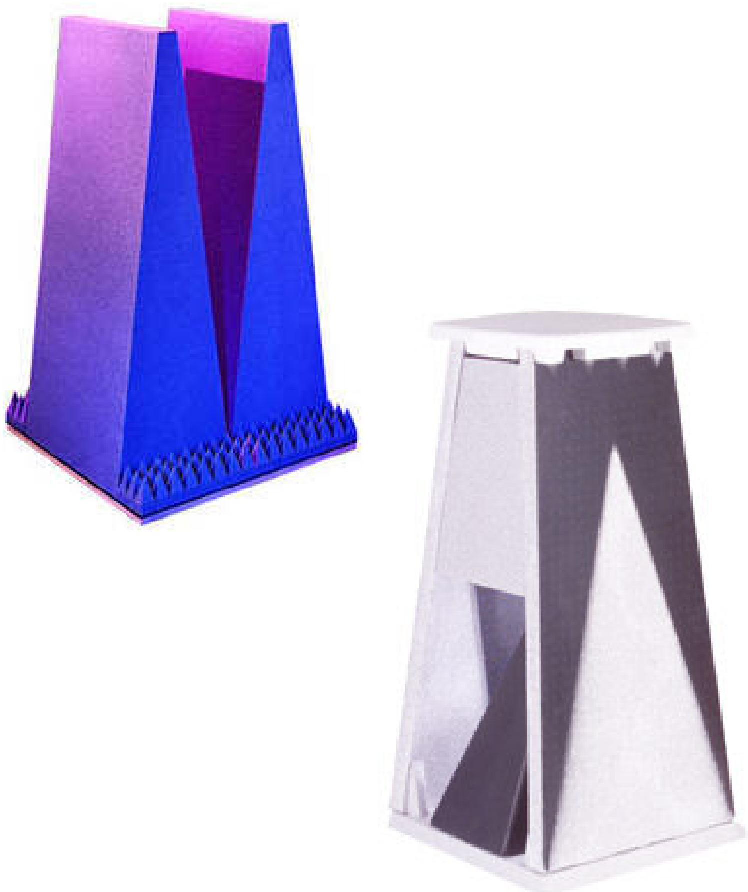
Ferrite Tile .

Magnetic Losses

Preferred technology for Low frequencies (up to 2GHz), it has low profile (7mm max).

It cannot be used for high frequencies

The Absorber Family 3

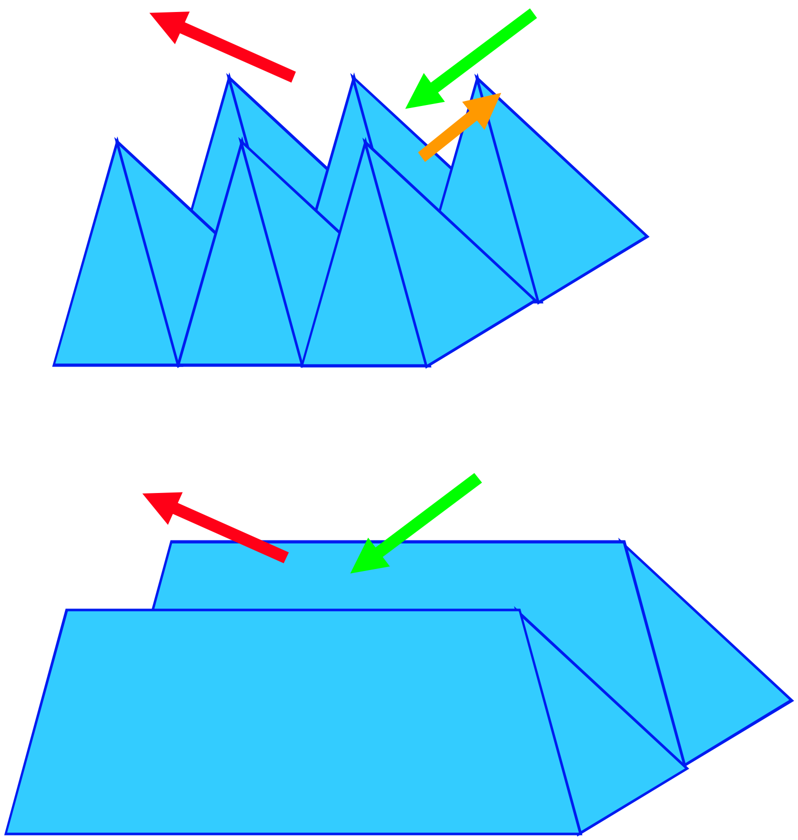


Hybrid Absorber .

Electric and Magnetic Losses

Preferred technology for EMC Applications. foam has to have special low carbon content for good matching with ferrite tile at the bottom. At High frequencies its performance is not as good as MW pyramid of equal size.

The Absorber Family 5

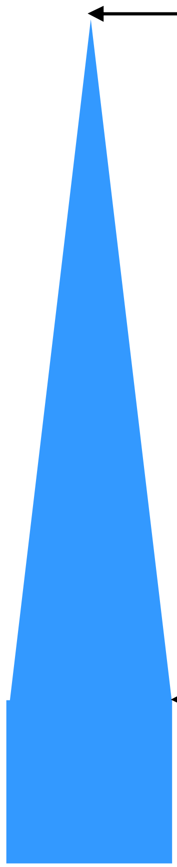


Wedge and pyramid

Electric Losses

A variant of pyramidal absorber wedge does not show backscattering. Preferred technology for QZ treatment and for RCS chambers.

Pyramidal Absorber Theory (Example)



At the tip of the absorber
The wave impedance is that of air

$$Z = 377\angle 0^{o}$$

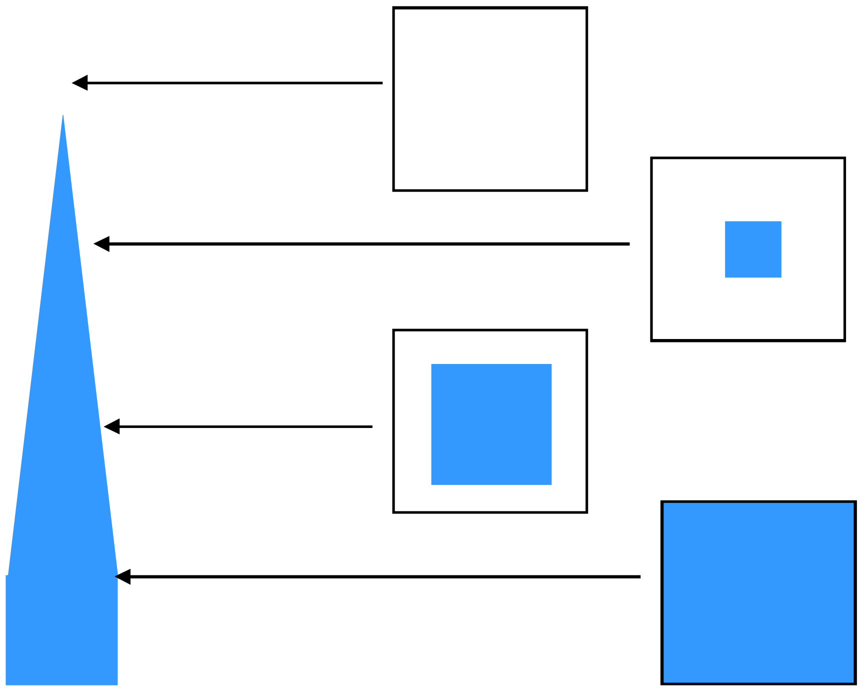
NO SUDDEN CHANGE IN WAVE IMPEDANCE = LOW REFLECTIVITY

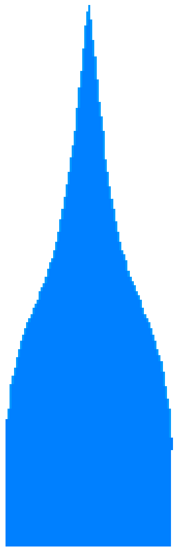
Along the length of the pyramid the wave impedance falls between those two values.

At the base of the pyramid
The wave impedance becomes

$$Z = \frac{377}{\sqrt{2 - j1}} = 252\angle 13.3^{o}$$

Pyramidal Absorber Theory





Curvilinear absorbers have a special shape to ensure better penetration and absorption of the wave

Flammability and Fire Retardancy

- Some materials can take more EM energy (power). Non flammable substrates are used and/or forced air cooling is used
- If enough power is used even “high-power” absorber will ignite.
- Flammability test standards are used to rate the absorber materials. NRL(Naval Research Laboratory) tests are the true anechoic chamber RF material standards. Other Standards such as UL-94 or DIN standards deal with flammability of foams or of construction materials

Power levels

- For traditional polyurethane absorber most manufacturers have between 775 and 1000w/sq. m CW hence:

$$\left(\frac{P}{A}\right)\left(\frac{w}{m^2}\right) = \frac{(E)^2\left(\frac{v}{m}\right)^2}{377\Omega} \Rightarrow E = \sqrt{377 \cdot \frac{P}{A}} \Rightarrow$$

$$for \quad 775\frac{w}{m^2} \Rightarrow E = 540\frac{v}{m}$$

$$for \quad 1000\frac{w}{m^2} \Rightarrow E = 614\frac{v}{m}$$

Heat transfer

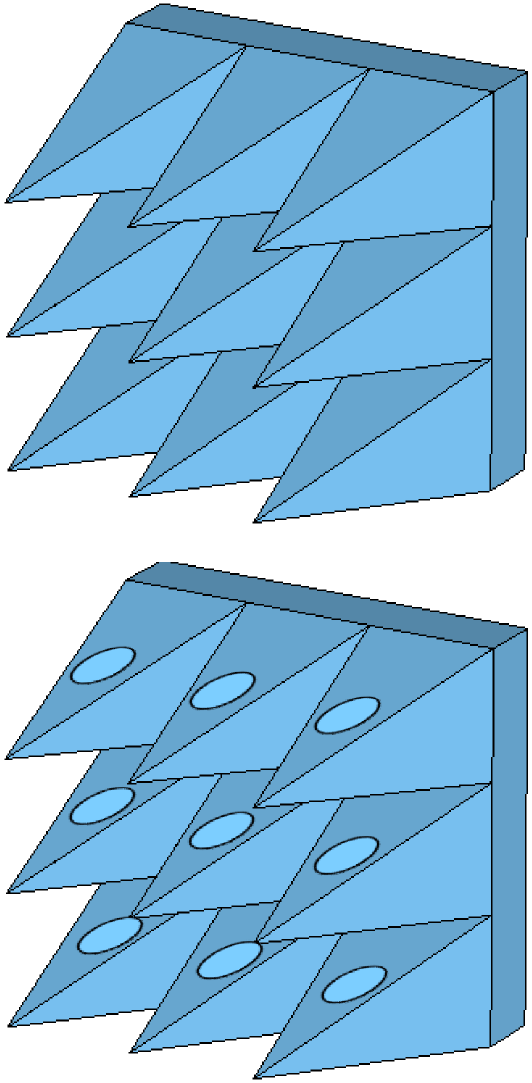
- Absorber: changes EM energy into Thermal energy
- Thermal energy then dissipates by radiation into the surrounding air
- Foam is an insulator so does not have a good heat transfer

Help the transfer of Heat

- One way of helping the transfer of heat is to cool the surrounding air.
- High power honeycomb absorber works on this principle.
- Substrate can withstand more heat and the honeycomb structure can be use to flow cooling air through it. But it is a high cost material about 10 to 20 times the cost

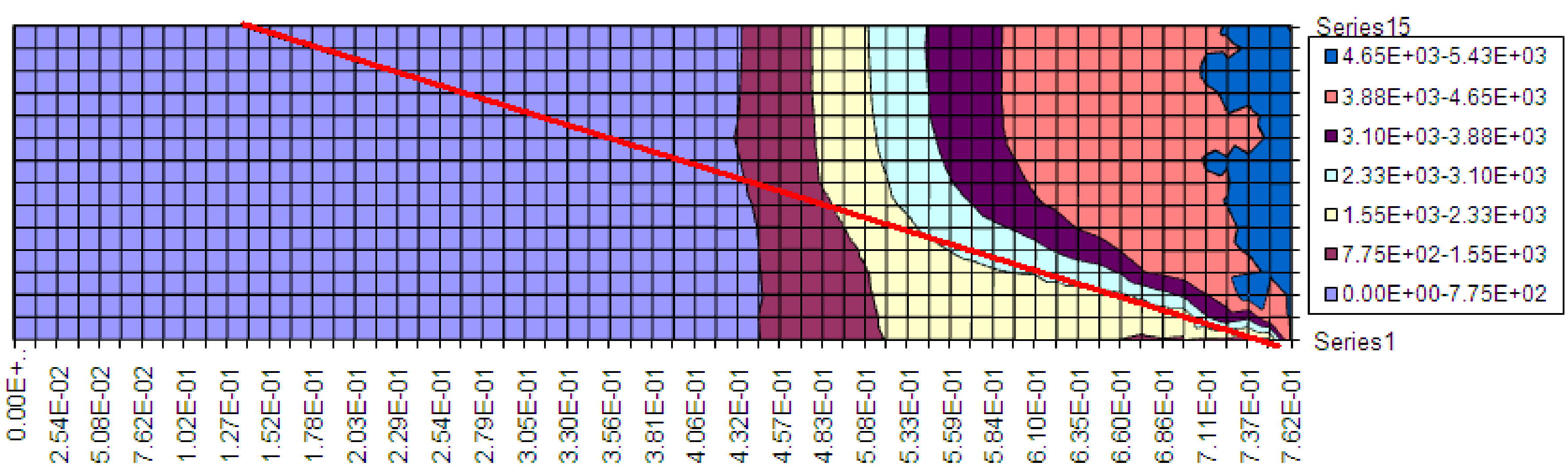
Approach for medium power

- Increase the surface area for a given piece of absorber to increase the heat transfer and therefore cool the material faster
- Holes



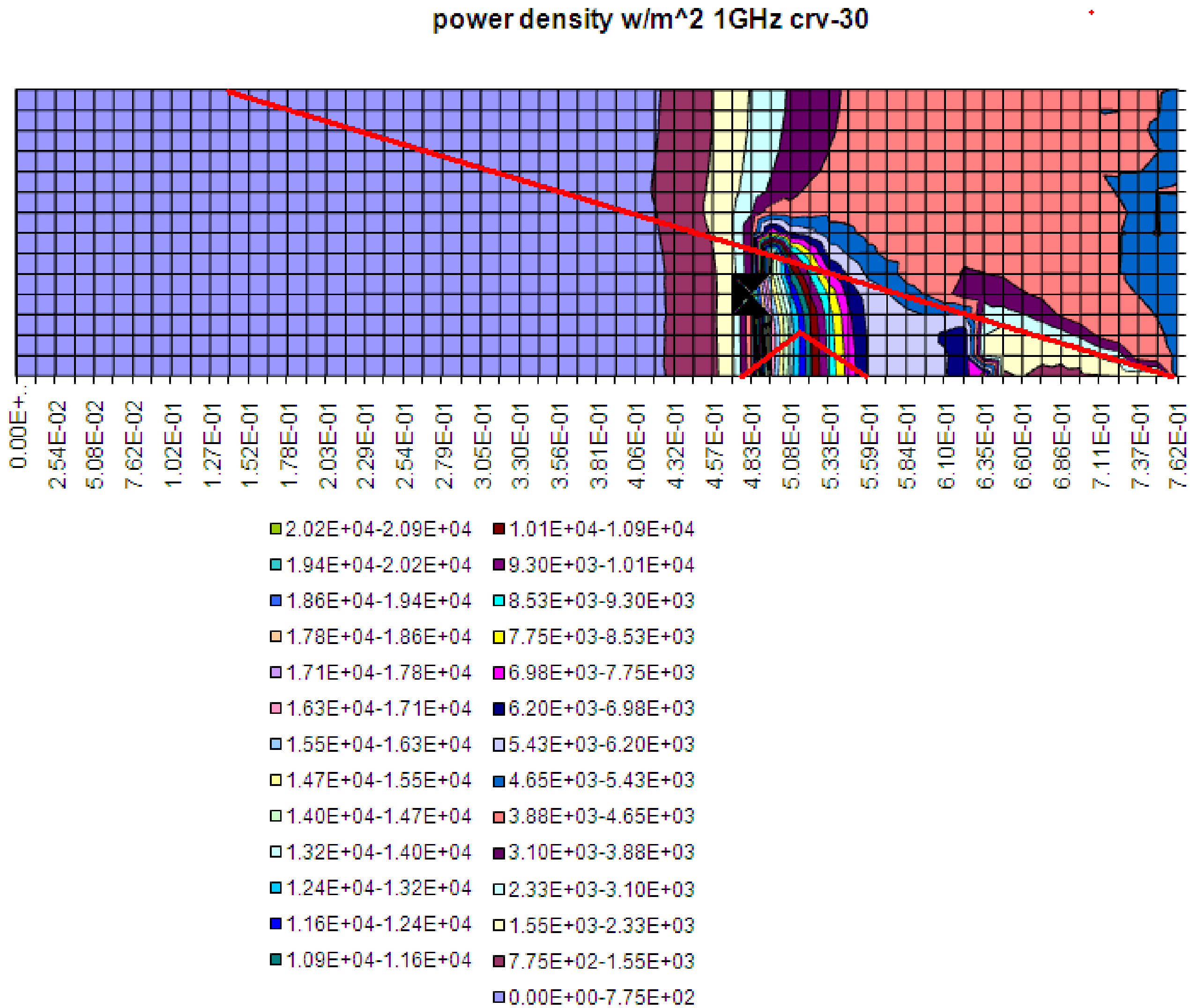
Numerical analysis

- HFSS, using the measured complex permittivity of the absorber
- Export the power density from the total field on the absorber.
- To reduce the size of the problem symmetry is used. 3kW/m^2



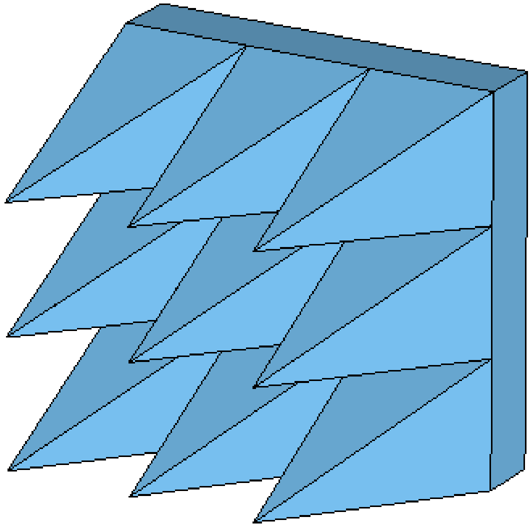
Numerical analysis

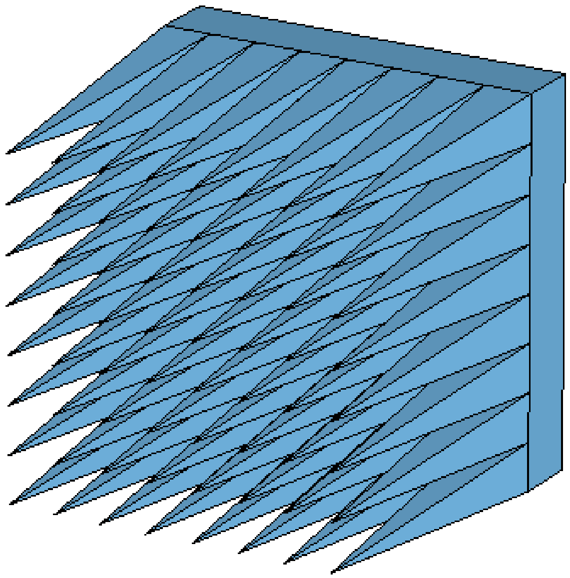
- Holes on the tip to increase the surface area and the heat transfer have problems as they distort the wave impedance transition that the pyramid tries to create



Approach for medium power

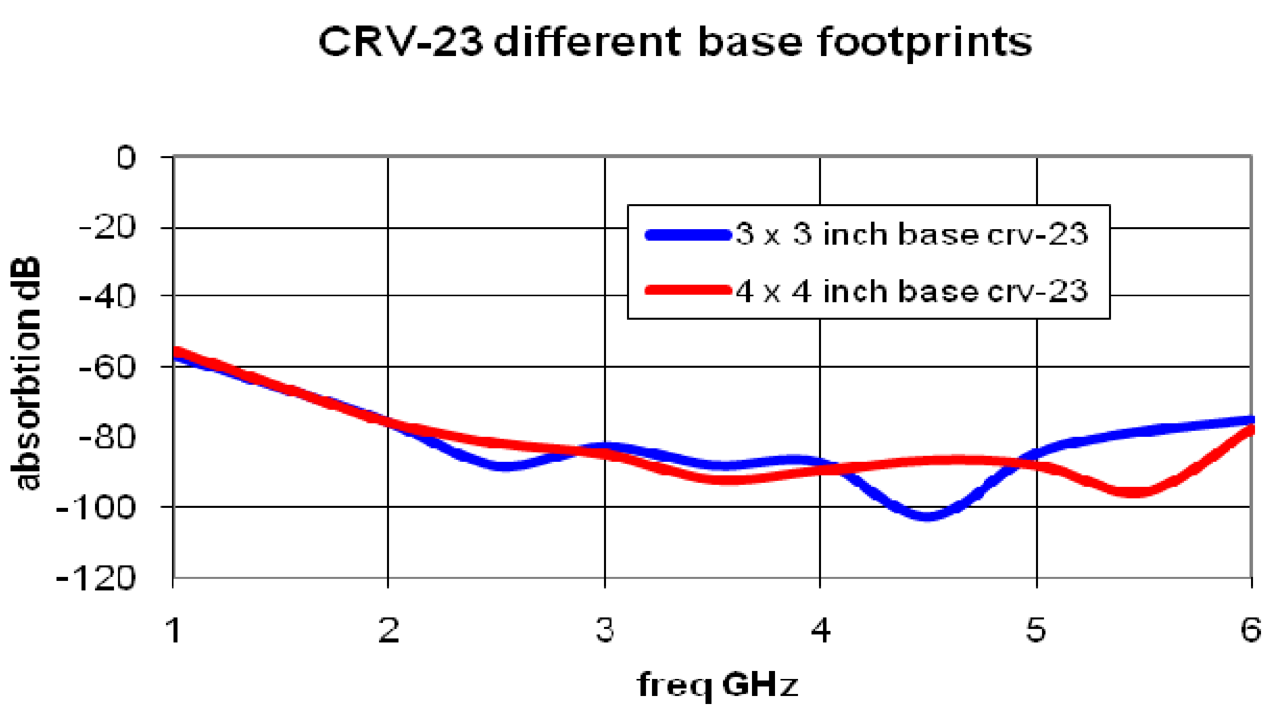
- Increase the surface area for a given piece of absorber to increase the heat transfer and therefore cool the material faster
- More surface area





Approach for medium power

- No detrimental effects on the reflectivity



Medium Power absorber

- Regular foam substrate
- Smaller foot print from 8 inch by 8 inch per pyramid to 3inch by 3inch (more surface more heat transfer)
- Cooling flow
- A test cell was set to measure the absorber

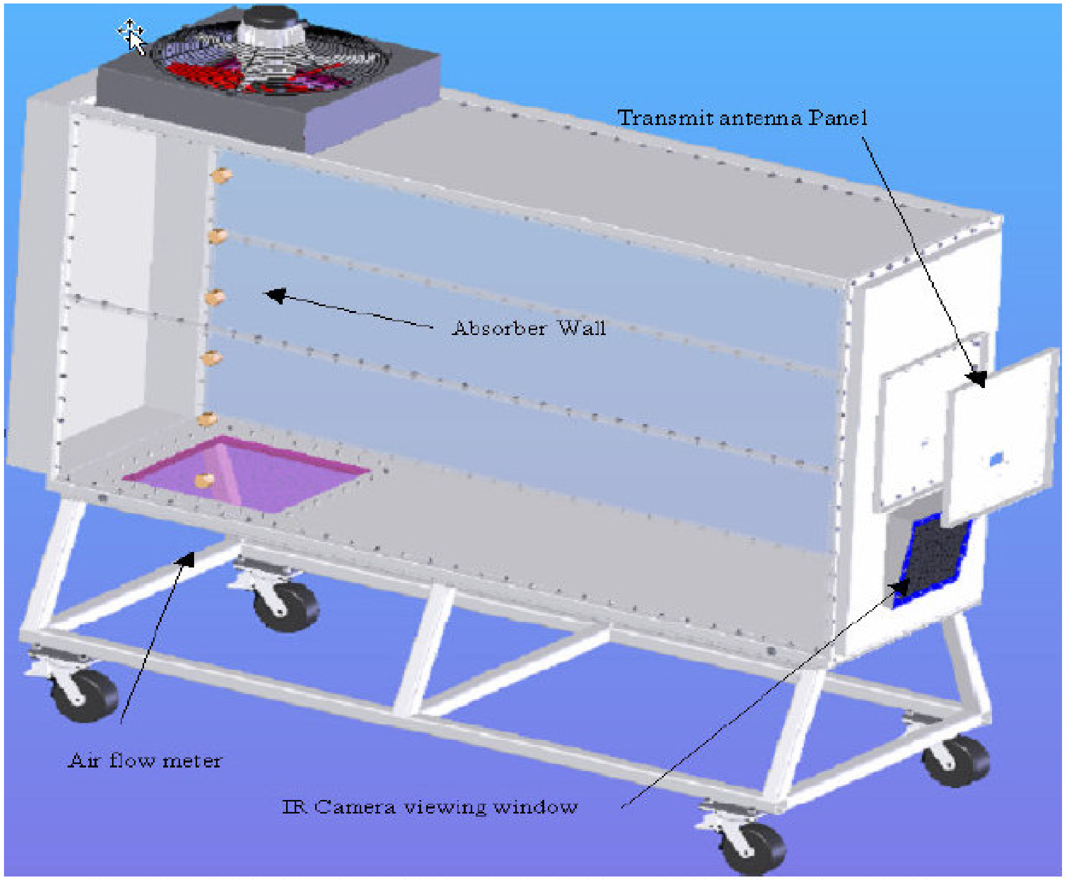


Figure 1. The mobile test fixture for power handling capability test

Measurement of the absorber

- A field mapping is perform at lower power. So that a better idea of the power density at the absorber location can be developed.
- The field is measured to create a series of field maps on a grid right before the absorber
- Also a table describing the power to field level is developed

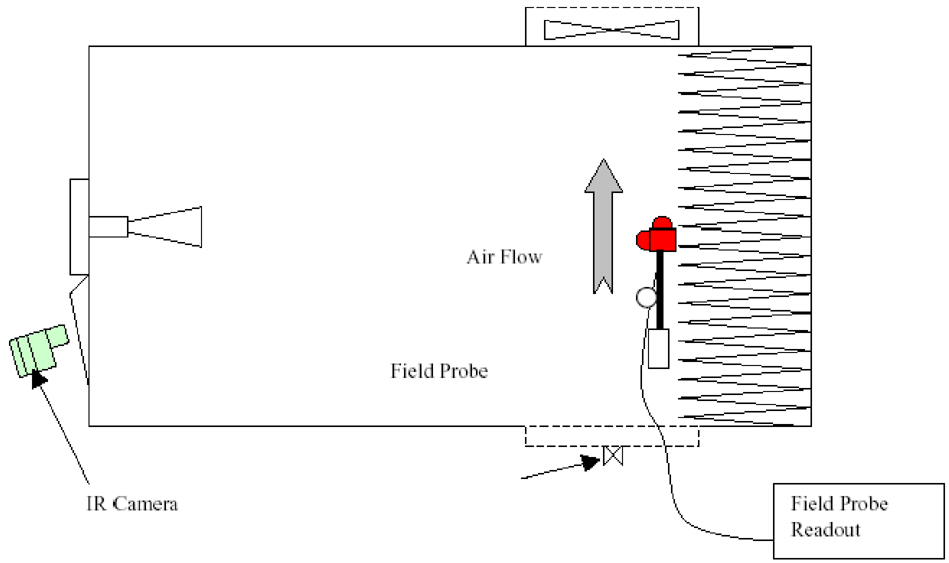


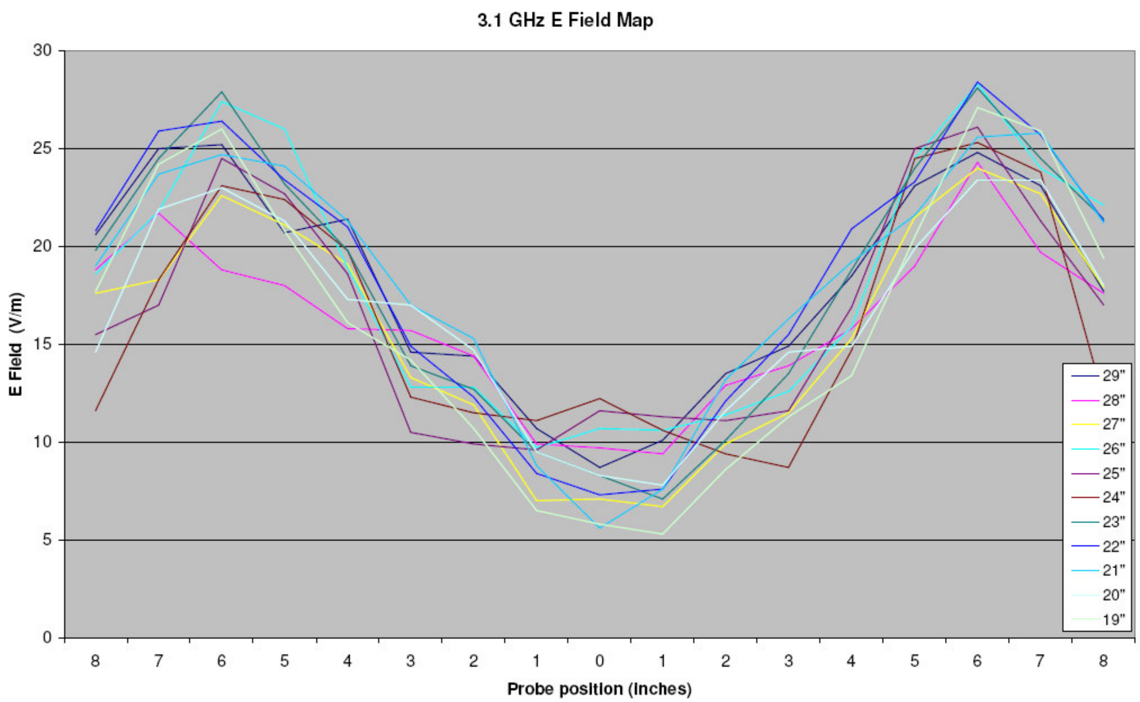
Figure 2: Medium Power Absorber Development test schematic

Field levels at 3.1GHz

3.1 GHz

Drive Power	Power Density	Drive Power	Power Density	Drive Power	Power Density
0.3 watt	0.0013 w/in^2	400 watt	1.677 w/in^2	700 watt	2.934 w/in^2
100 watt	0.419 w/in^2	500 watt	2.096 w/in^2	800 watt	3.354 w/in^2
200 watt	0.838 w/in^2	550 watt	2.305 w/in^2	850 watt	3.563 w/in^2
300 watt	1.257 w/in^2	600 watt	2.515 w/in^2		

Table 1: Input power scaled and converted to power density at the absorber surface at 3.1 GHz.

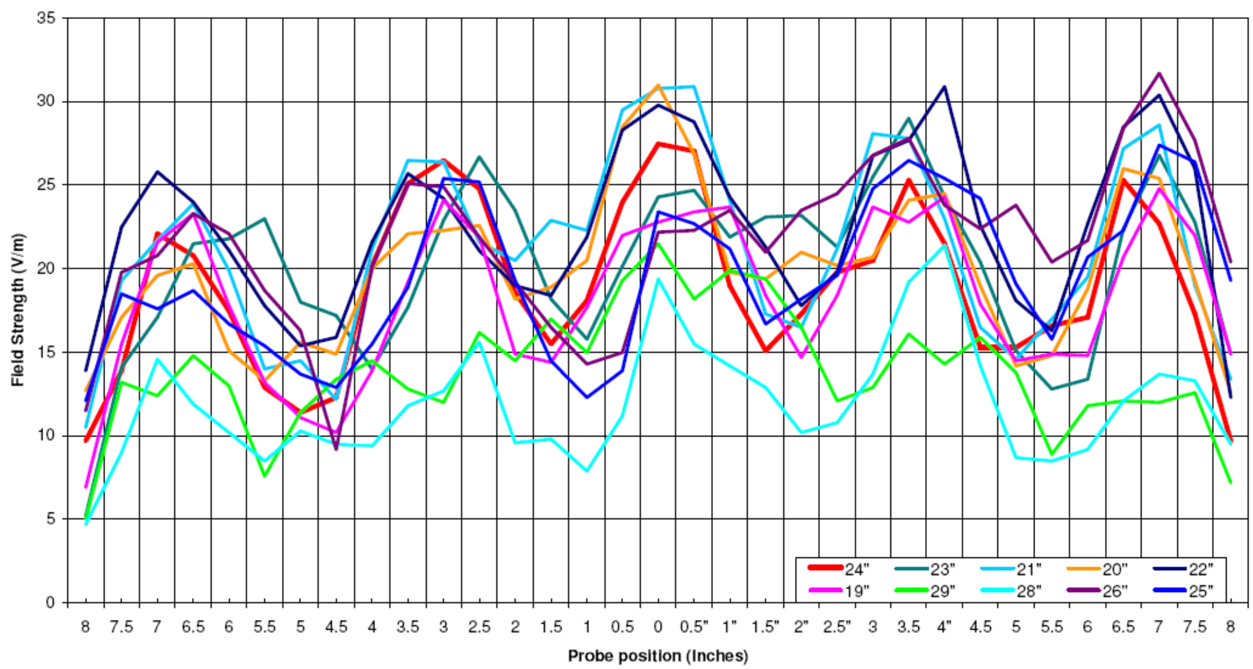


Field levels at 10.35GHz

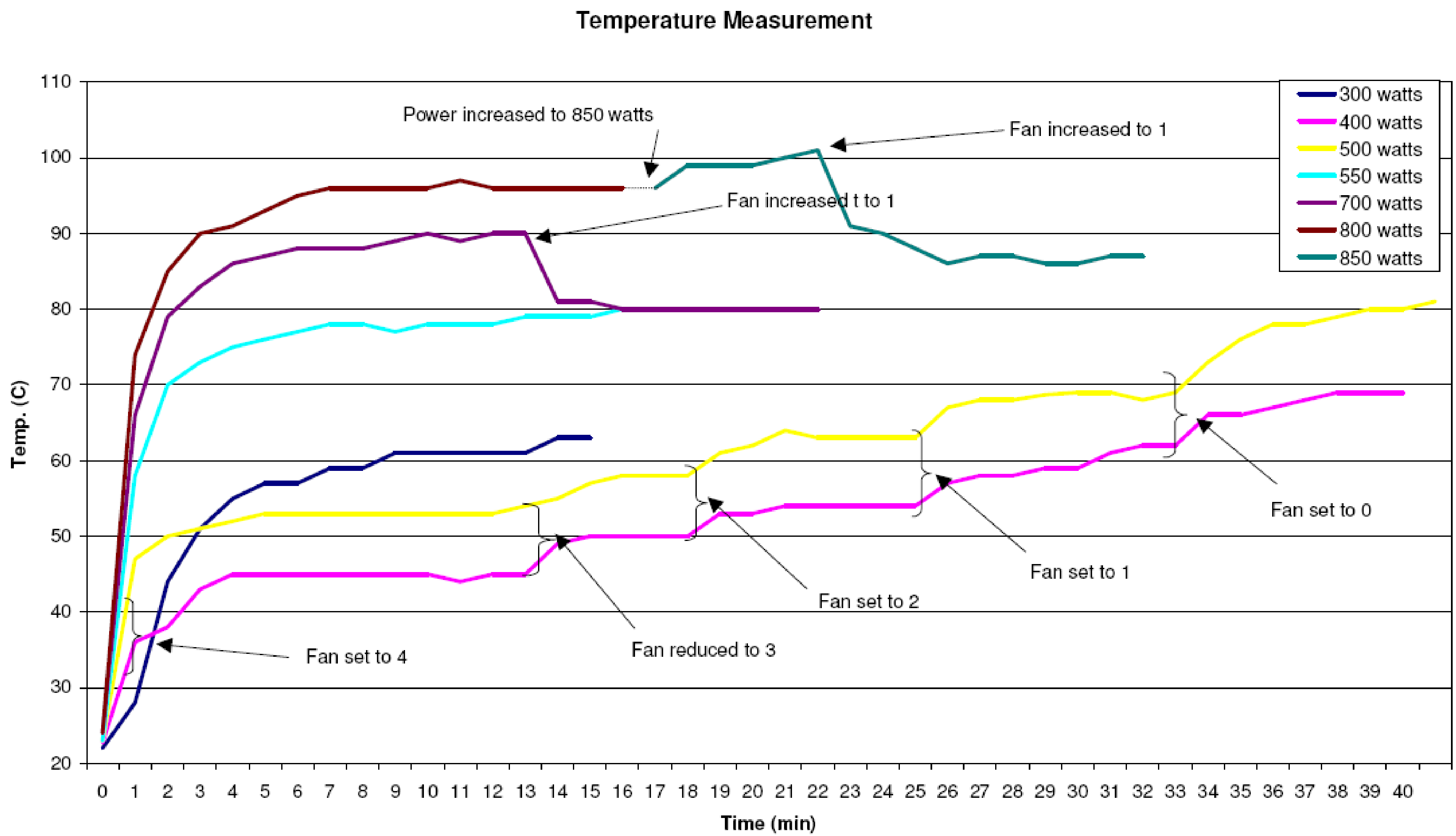
10.35 GHz

Drive Power	Power Density	Drive Power	Power Density
0.3 watt	0.0017 w/in^2	400 watt	2.149 w/in^2
100 watt	0.537 w/in^2	500 watt	2.686 w/in^2
200 watt	1.074 w/in^2	550 watt	2.955 w/in^2
300 watt	1.612 w/in^2	600 watt	3.224 w/in^2

Table 2: Input power scaled and converted to power density at the absorber surface at 10.32 GHz.



Temperature vs. time and air flow



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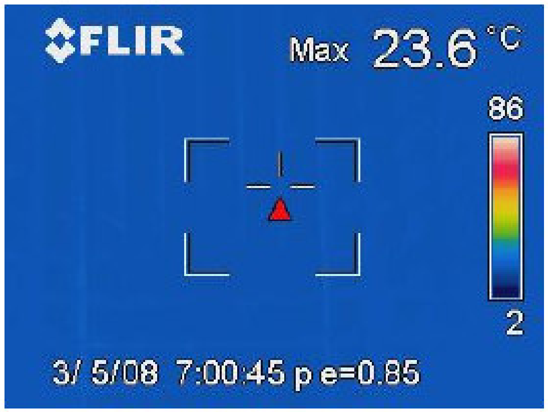

Figure 7: Ambient Temperature on the absorber surface

1.664kW/sq. m
792v/m

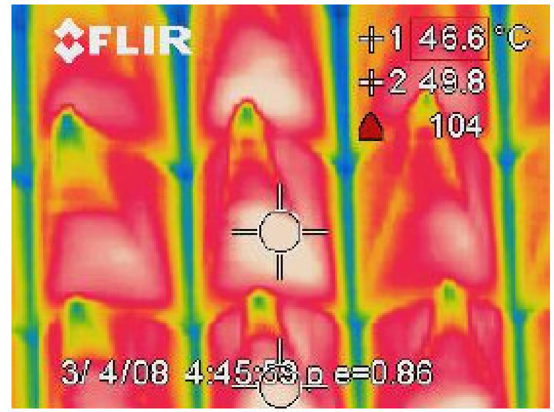

Figure 8: 10.35GHz, **1.074 w/in²** *after 10 mins. with no airflow.*

2.498kW/sq. m
970v/m

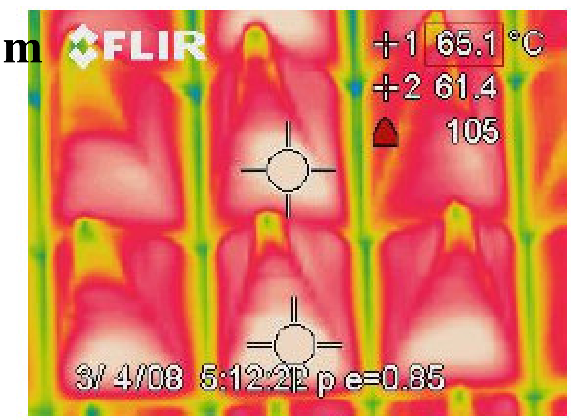

Figure 9: 10.35GHz, **1.612 w/in²** *after 10 mins. with no airflow.*

3.331kW/sq. m
1121v/m

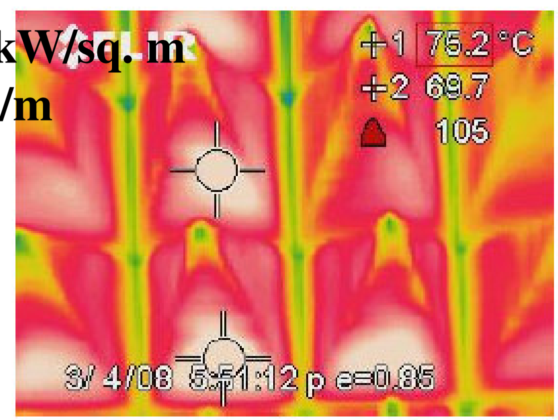

Figure 10: 10.35GHz **2.149 w/in²** *after 10 mins. with no airflow.*

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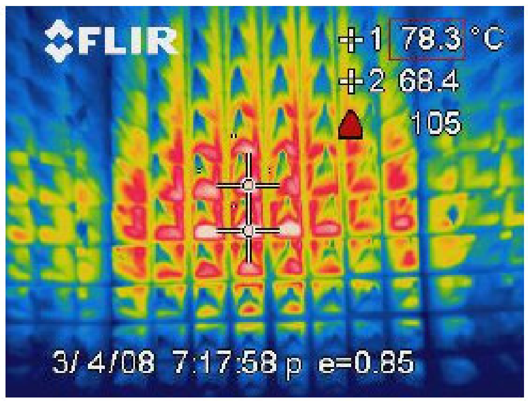


Figure 11: 10.35GHz Maximum temperature on absorber surface at **3.224 w/in^2** *with the fan speed set to speed 2.*

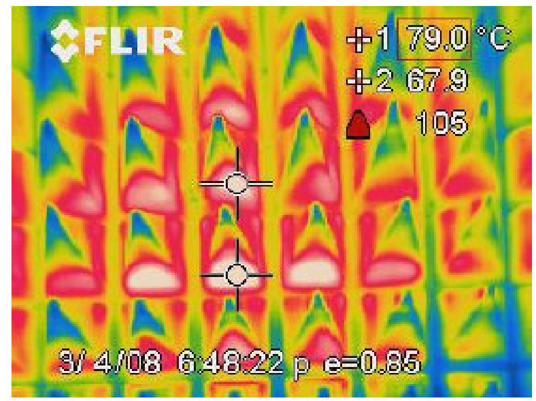
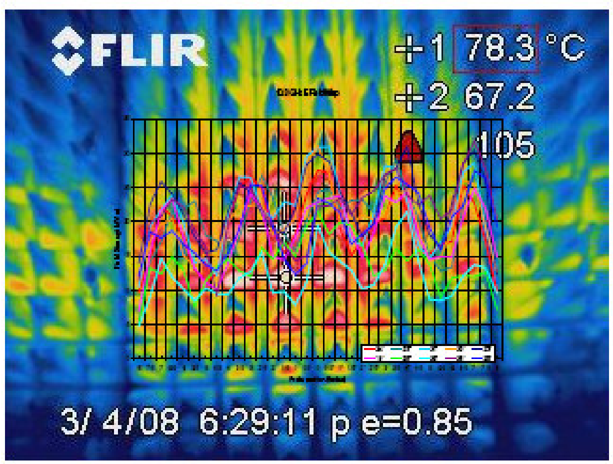


Figure 12: 10.35GHz maximum temperature at **3.224 w/in^2** *Close up*



5kW/sq m. power density.
1373v/m

Figure 13: The 10.35GHz field map superimposed onto thermal map to show general agreement with expected locations of hot spots. The possible limited field of view through the waveguide vent may be limiting the camera's accuracy at the edges of the image.

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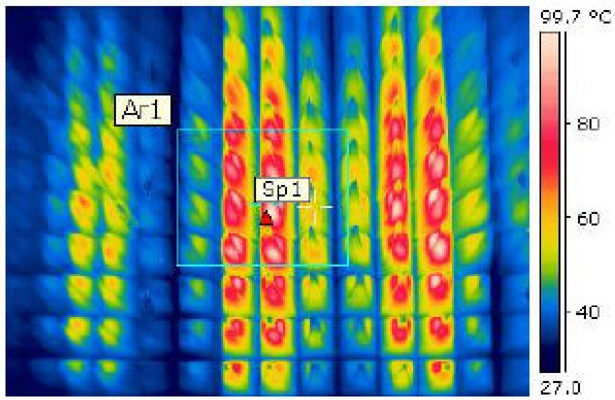


Figure 14: 3.1GHz maximum temperature on absorber surface at **3.563 w/in^2**

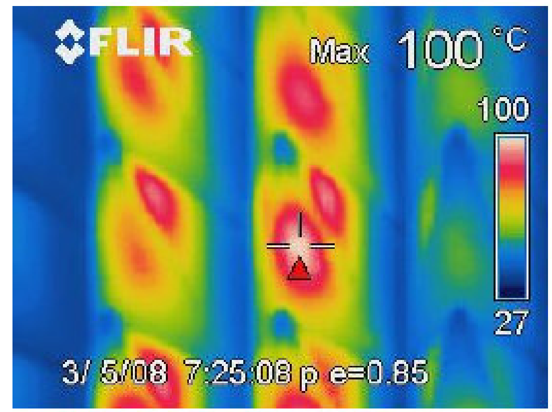
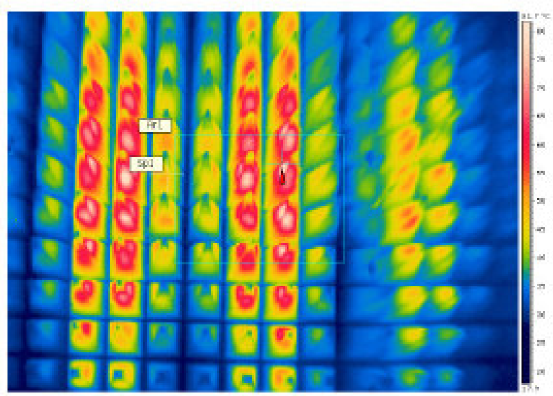


Figure 15: Close up of 3.1GHz maximum temperature of 100º C at **3.563 w/in^2**

5.522kW/sq m. or 1443v/m



Ar1 Min 27.8 °C Max 79.6 °C Average 44.2 °C
Sp1 46.3 °C

Figure 16: Verification of Thermocouple reading. The thermocouple was positioned 10" from the back of the absorber in the cone labeled SP1. The measurement in this location coincided with the IR camera reading of 79 degrees at the rer arrow marker.

Conclusion

- Reported power handling capability tests demonstrate that the specially designed absorber is capable of handling greater than 3W/in2 or 4.65kW/m2 (1324v/m) incident power density without raising the surface or internal temperature above 100℃.
- The 100℃ threshold is defined as the absorber durable and safe handling temperature since it is used in the manufacturing process (drying of the soaked raw foam).
- tests also concluded that the power handling capability was achieved without forced airflow to help with the removal the heat generated in the absorber. Additional air cooling increases the power capability.