

Advances in Low Cost Active Array Panels

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ABSTRACT — Active array panels, made possible by the advent of highly efficient wide band-gap monolithic microwave integrated circuits (MMICs), allow large arrays to be cheap, modular, and flexible. These panels can be integrated into structural parts of vehicles, and allow digital radar arrays to have element level control and information.

Why Active Panels?

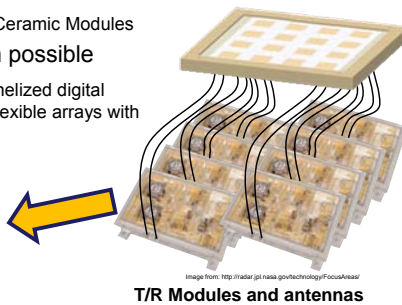
Better performance in low cost compact package

Low Cost, High Performance

- Integrated antennas minimize distance to amps
 - Shorter distance and no connectors means lower loss
 - Better HPA efficiency, lower received noise
 - No connectors to fail
- Organic FR-4 like construction
 - Much lower cost than Ceramic Modules
- Panel-level integration possible
 - When coupled with panelized digital backend, this enables flexible arrays with multiple receive beams



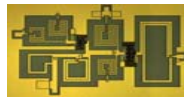
Integrated T/R panel



T/R Modules and antennas

Wide Band Gap Semiconductors

- Modern MMICs can amplify high powers at high efficiency
- We have demonstrated over 50W at 42% panel-level PAE at 3.3 GHz with CREE GaN



GaN class-F amp

Panels Can Be Structural

- Patch antennas allow active panel to be integrated with structural composite panels
 - Panels can theoretically be built into walls of vehicles
 - Hides and protects vehicle antennas



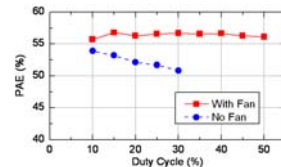
Composite panel

Challenges of Panelization:

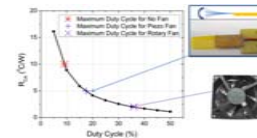
We want at least 25W radiated per element

Thermal Relief in GaN Packages

- Quality of thermal path directly maps to amplifier performance
 - Higher temperature in the channel leads to lower efficiency
 - Better thermal path allows higher power, higher duty cycle
- If GaN gets too hot, it might cause stress failures
 - Simplest package has GaN soldered to copper for heat sink
 - Thermal mismatch between GaN and copper



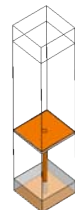
GaN PA efficiency vs. % duty cycle



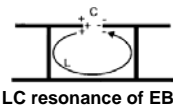
Maximum packaged thermal resistance at 25W vs. % duty cycle

Mutual Coupling of Antennas

- Mutual coupling limits scan range
 - When two adjacent elements transmit, mutual coupling causes additional effective reflection (called "active reflection")
 - Reflection causes loss of efficiency, and can destroy front end components
 - This "reflection" can be compensated for by designing the physical reflection of the antenna to cancel out the mutual coupling
 - However, this only works for one scan angle



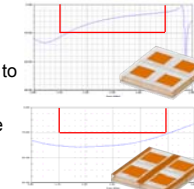
Unit cell EBG



LC resonance of EBG



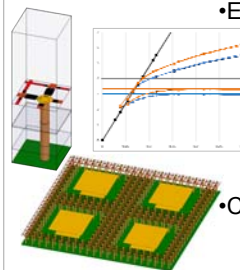
Active reflection



Active reflection at 55° scan angle without (top) and with (bottom) EBGs

Electromagnetic Band Gap structures

- Mutual coupling caused by surface waves
- EBGs break up surface waves
 - LC resonance makes ground-plane look like open circuit, stopping surface waves
- Allows greater scan angle
- Can be tunable
 - Edge capacitance can be replaced with varactors
 - Could potentially tune to optimize for different scan angles in E and H planes



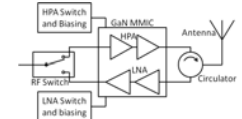
Tunable EBGs

Our Panel

Over 50W radiated from FR-4 like panel

What's On-Board

- Integrated patch antenna
- GaN amps
 - HPA is class-F, 25+ W and 60% PAE
 - LNA provides high linearity
- Biasing and local charge storage
- T/R switch on back end, circulator on front end

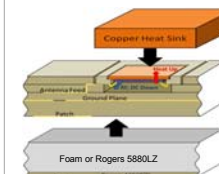


Element block schematic

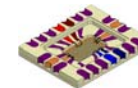
Stack-up: Heat and control up, RF down



16 element panel (4 elements populated)



Board Stack-up

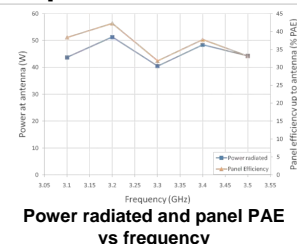


SMT package

- GaN package cross between QFN, CPU packages
 - Heat sink attaches to top like CPU heat sink
 - Can use conventional heat sinks
 - Pads similar to QFN layout
- Heat sink, bias lines, RF backend connections on top
- Antennas integrated on back of panel

50 Watts radiated at 42% panel level PAE

- Over 50W radiated
 - 40V on drain
- 10% duty cycle
 - Air cooling with small fan
- Panel efficiency from 32% to 42%



Power radiated and panel PAE vs frequency