NuPhotonics

RF Design & Optimization With Genetic algorithms and FEM simulation

Vincens Gjokaj - PhD

Outline

- Company Background
- Genetic Algorithm Background
- Why we developed it
- Examples
  - Simple Antenna
  - More Complex Antenna
  - Device top metal optimization
  - Device placement optimization
- Further areas of interest
- Genetic Algorithm in an active antenna
  - RF- Switch Based Antenna -2023 TechConnect – Poster

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Who we are?

- Founded Feb. 2023
- RF & Opto-Electronic device manufacturer
  - DC - 67 GHz
  - Design/Simulation/Manufacturing
- Advanced prototyping
  - PCB, 3D Printing, Laser cutting, and CNC
  - Embedded software
- Who we supply
  - Aerospace
  - Data Centers\Telecom
  - Test and Measurement
- Distributed through DigiKey/DTC

25G InP DFB Laser

35G InGaAs Photodiode

9KHz – 67 GHz Amplifier

DC – 45 GHz Power Divider

9KHz – 67 GHz SPDT

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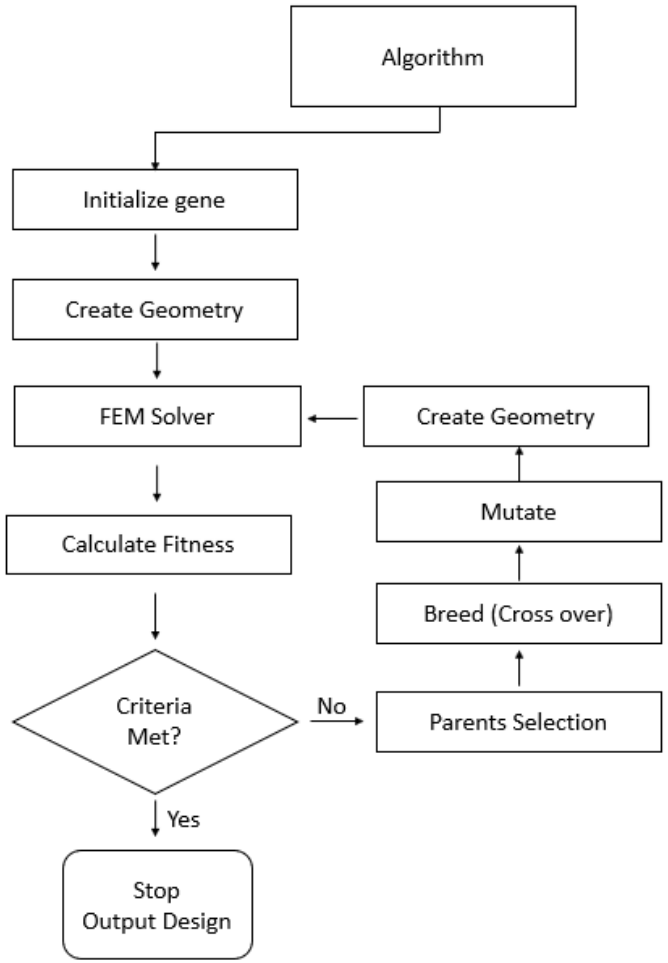
Genetic Algorithm Background

- Fallows Darwin's Theory of evolution
  - Desirable traits are passed onto next generation
- Solves both constrained and unconstrained optimization problems
  - Based on natural selection process that mimics biological evolution
  - Selects individuals from current population and uses them as parents to product next generation
  - Mutation function helps solve entire solve space



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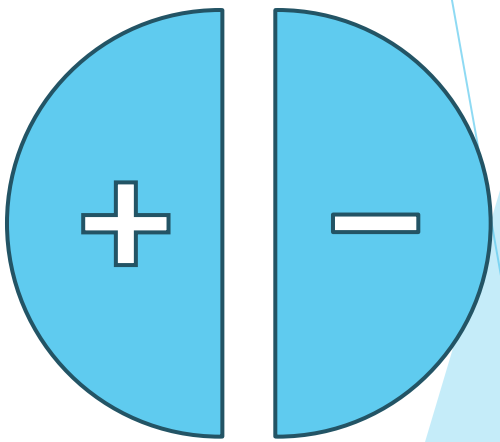
Why we developed it

- Design optimization is expensive
  - Less time wasted waiting for simulations to complete
  - RF engineers take about 5 minutes to fully process data
    - Understand the results
    - Make the necessary changes
  - GA takes about 3 seconds to process data
    - Understand RF performance
    - Adjust changes
    - Start simulations
    - Runs 24/7 for no compensation
- Unlike traditional AI solving it does not need any data sets
- Help clients bridge gap between custom design and off-the-shelf



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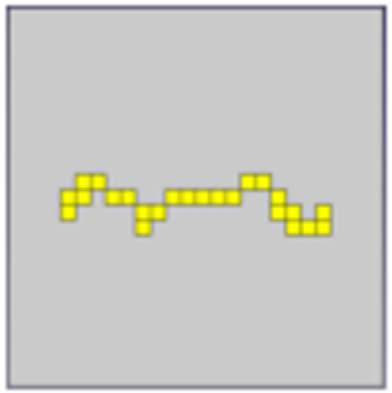
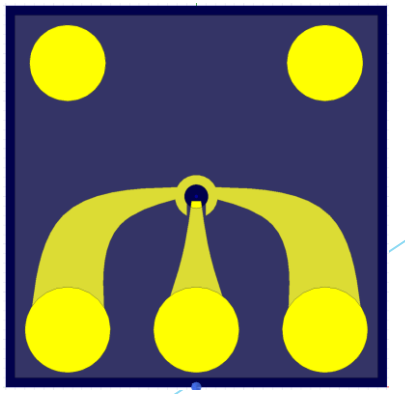
Examples



- Pixelated Microstrip Patch Antenna
  - 5.8 GHz
- Dielectrically Loaded UWB Horn Antenna
  - 12-27 GHz Operating range
  - Electrically small
- 50 GHz InGaAs Photodiode top metal Design
  - Balance capacitance and inductance of top metal design
- 50 GHz InGaAs Photodiode placement
  - Optimize wire bond configuration for optimal performance



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Pixelated Microstrip Antenna

- Microstrip Antenna
  - Rogers 4350B
  - Center fed pixelated antenna
- Grows outward.
  - 5mmx5mm square pixels
  - Next generation must be connected to previous generation
- Optimization
  - Largest Return Loss at 5.8 GHz
  - No other design criteria
- Constraints
  - X & Y Placement of pixels

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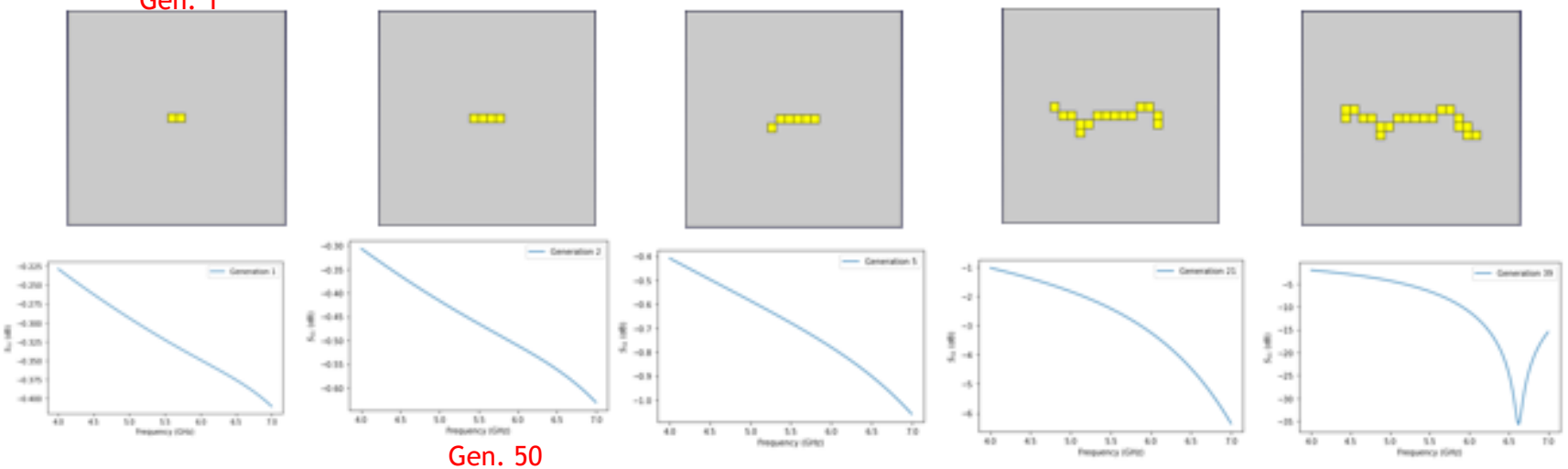
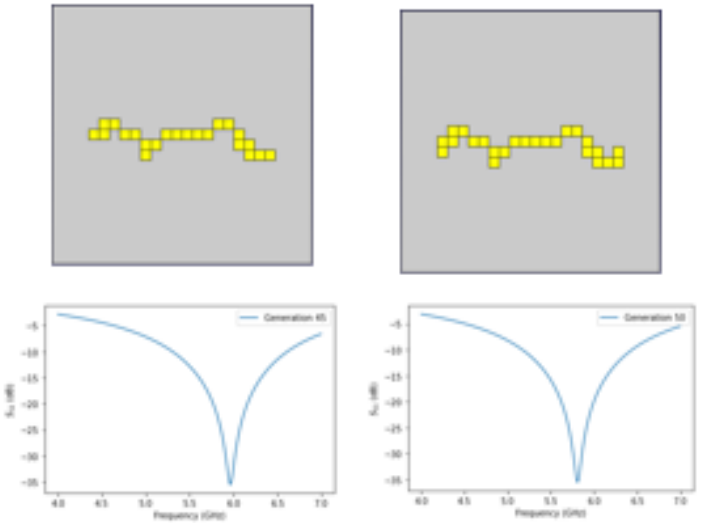
Pixelated Microstrip Antenna

Gen. 1



Gen. 50



- The antenna was limited to 50 Generations
- S11 ~ - 35 dB at 5.8 GHz
- Solve time was approximately 10 minutes
  - Simple design
  - Narrow band
  - No geometric curves

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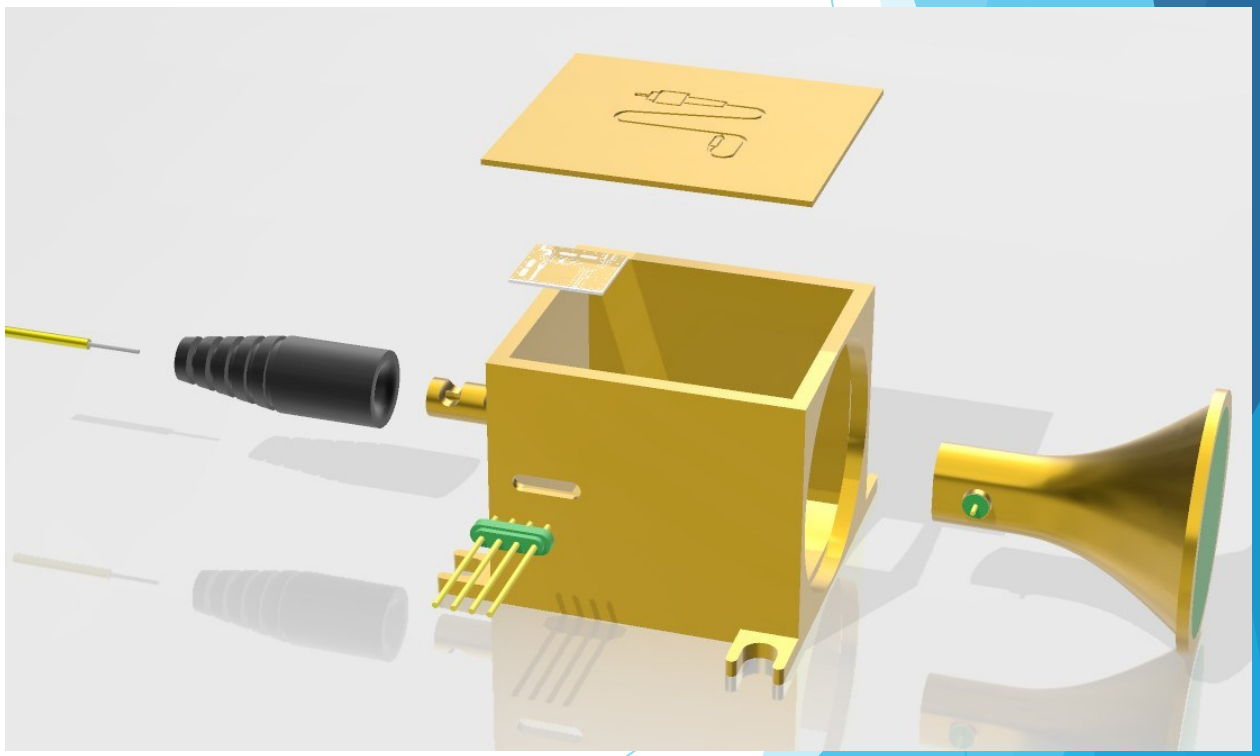
Dielectric Loaded Small Antenna

- Co-packaged TX & RX front end
  - UWB Antenna
  - DFB Laser/Photodiode
- Horn selected as antenna
  - High Gain/Directivity
  - Broadband
- More easily relocate front end system
- Geared towards Aerospace/Space



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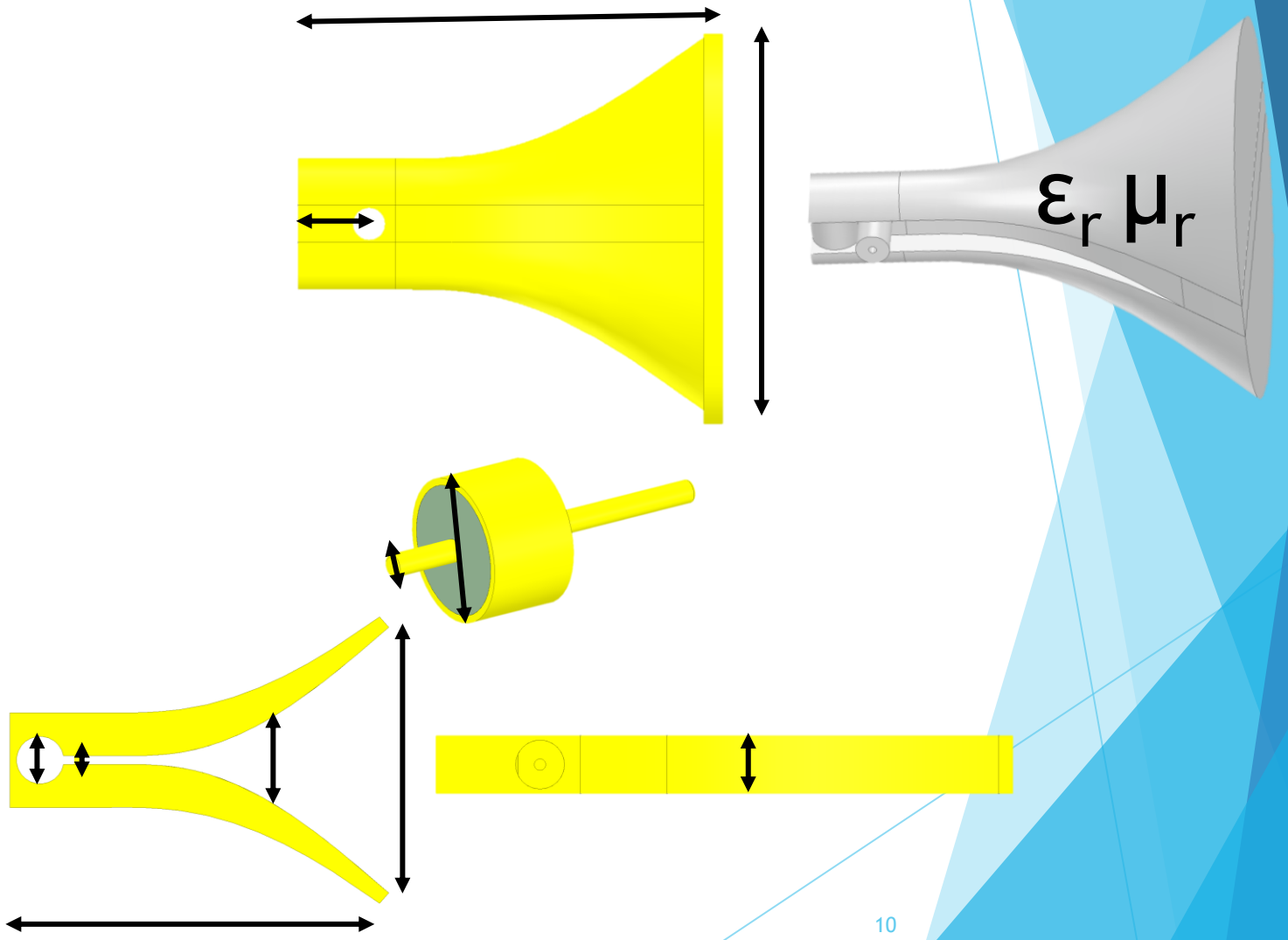
Small Antenna constraints

- Antenna dimensional size limits
  - No more then 23mm width/length
    - Working towards 1” package size
- Optimization Points
  - RF Feed
    - Insulator radius & Pin radius
    - Pin location
  - Vivaldi
    - Leg separation
    - Leg thickness
    - Resonator size
    - Length
  - Horn Flare
  - Loading dielectric properties
  - Optimize for S11 and Gain



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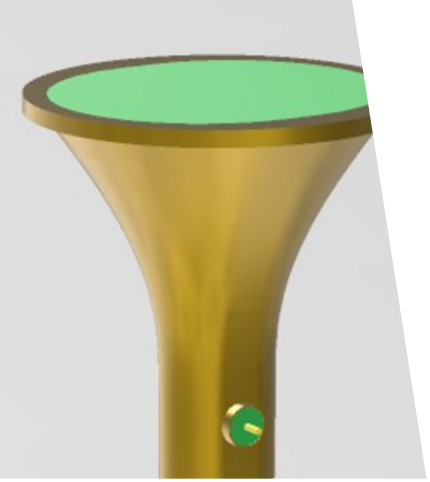

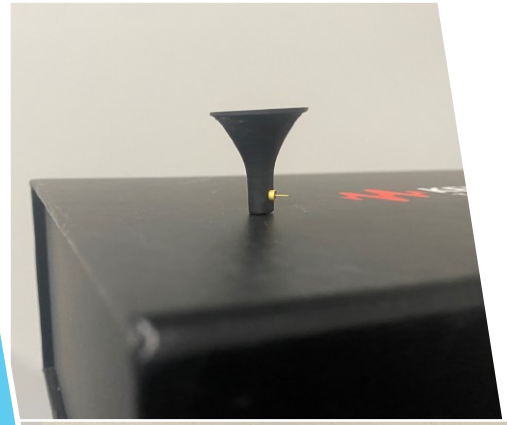

Small Antenna Solve Time

- Within 5 Generations it maxed out horn length and width
- Solve time 136 hours
  - 10 – 30 GHz
    - 401 Discrete points
    - Includes far field wave data
  - Ran on Desktop Computer
    - 28 logical core
    - 128 Gb Ram
    - Total memory generated 8 Tb

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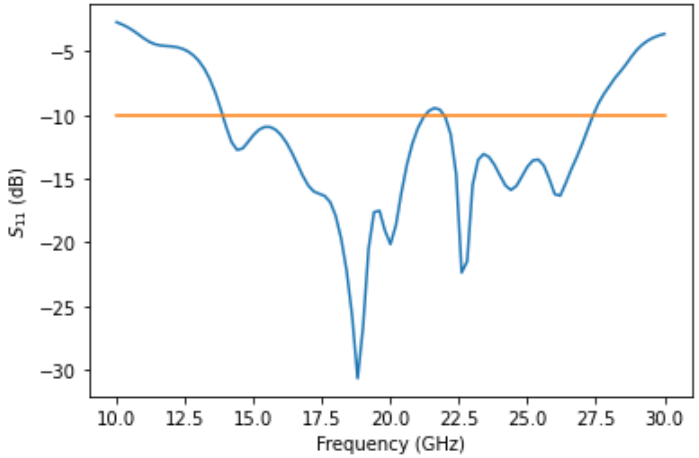
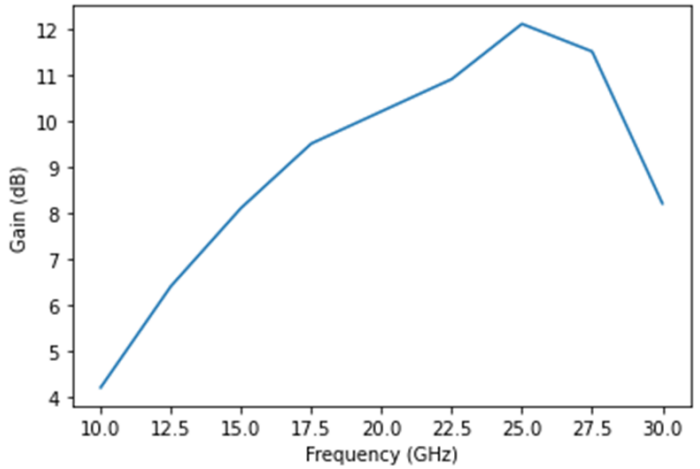
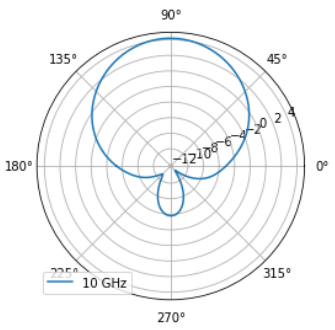
Small Antenna Results

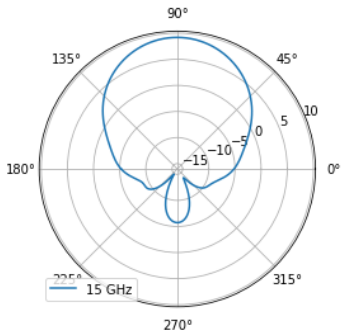
- Prototype Antenna – 3D Printed on $500 SLA Printer with Carbon/Ag loaded ABS-like plastic. Dielectric loading material was BaTiO3 loaded ABS-Like plastic



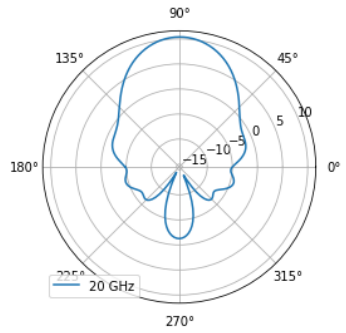




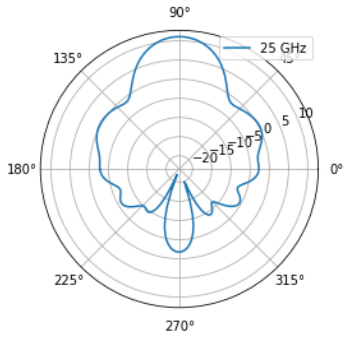
10 GHz



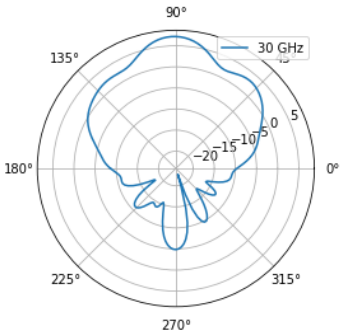
15 GHz



20 GHz



25 GHz



30 GHz

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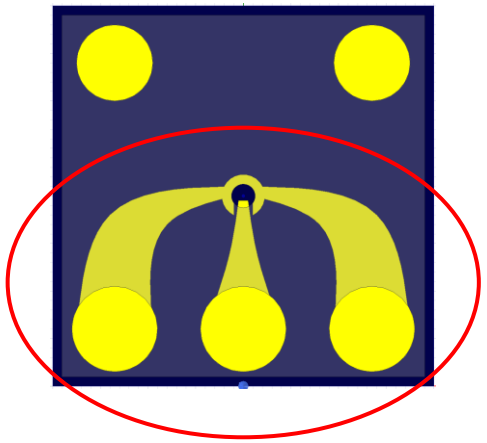
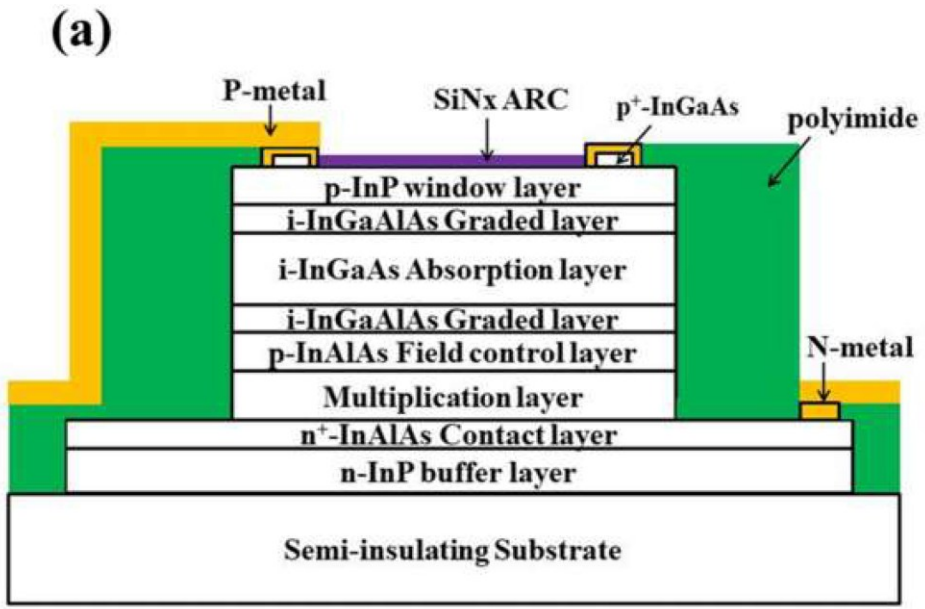
Device Top Metal Design

- We develop physical structure
  - Mesa stack up is defined and optimized
- Top metal needs to be optimized
  - Balance Capacitance & Inductance





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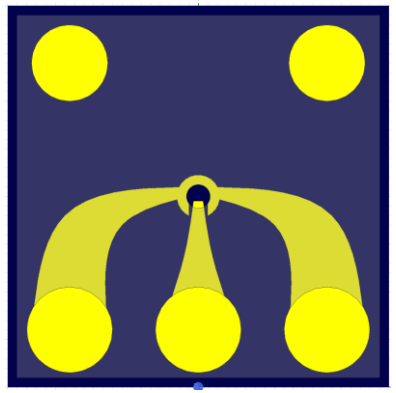
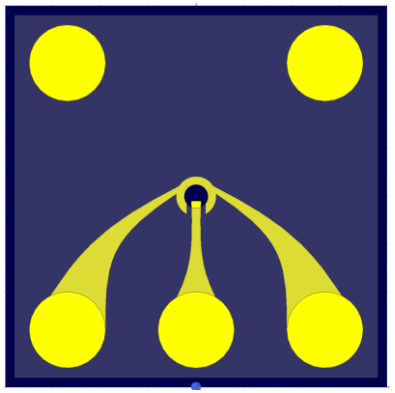
Photodiode Simulation

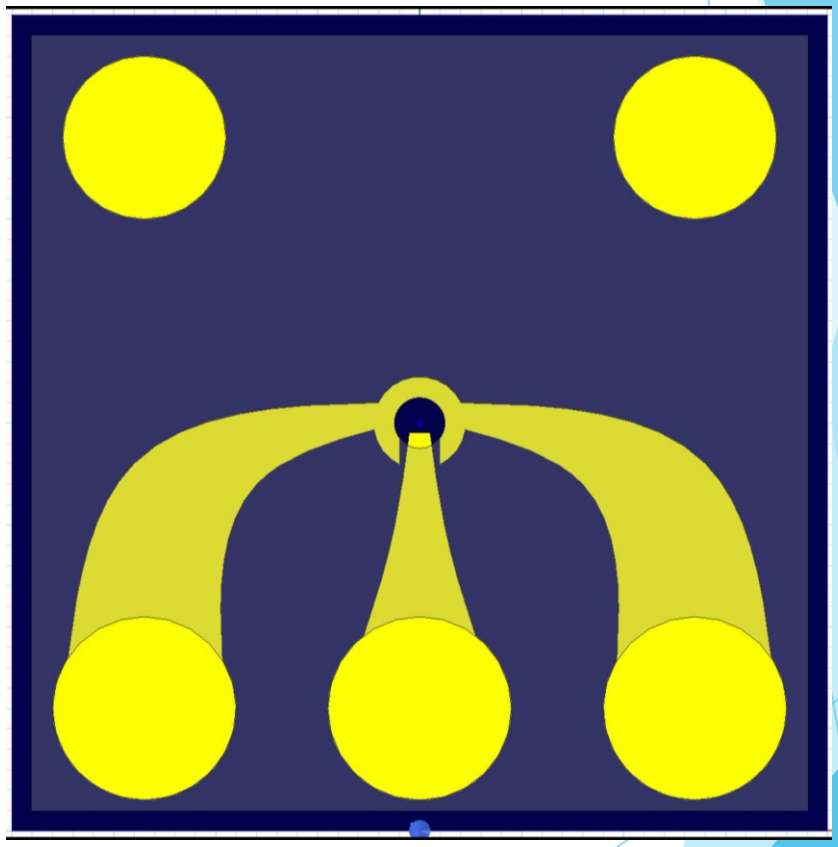
- Solved in 43 Generations
- Solve Time 18 Hours
- Solved for 10KHz-67 GHz
  - Solving for largest 3 dB bandwidth



Initial



Final



Some features hidden

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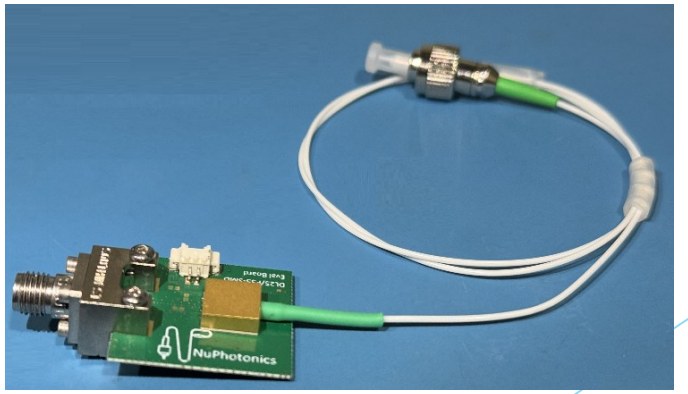
Device Placement

- Wirebonds act as RLC components
  - Wire bond placement needs to be optimized.
  - Balance L & C
- Utilized 8x8mm SMD package for this test
  - Solve for largest 3 dB Bandwidth



Device shown on an Evaluation Board

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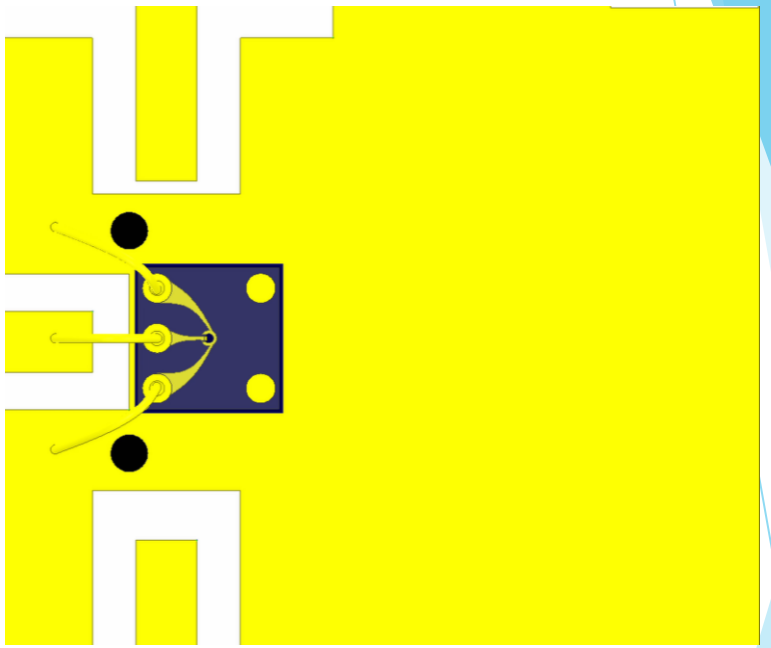
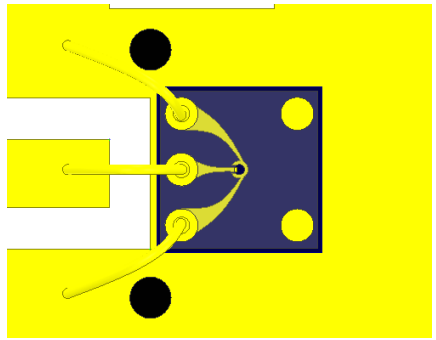
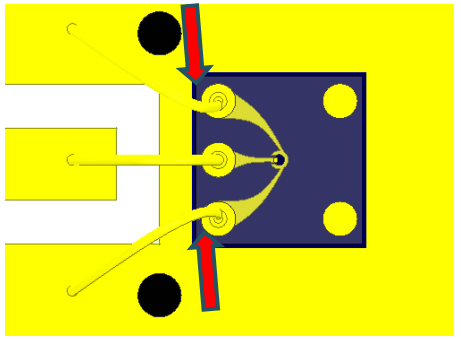
Device Placement

- 23 Generations
- 22-hour Simulation time
- Moved device 100 µm away
  - Increase inductive peaking
- Moved wire bonds inward
  - Increase Capacitance between bond wires
  - LC Impedance matching

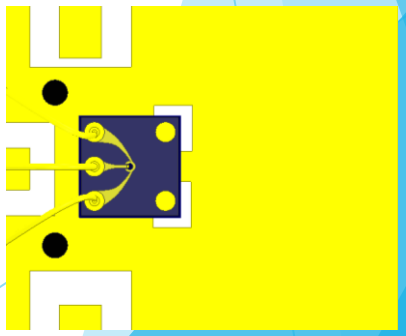




Initial



Final



Fiducial for Alignment

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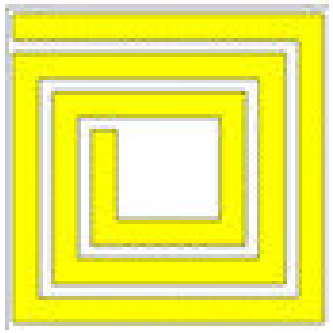
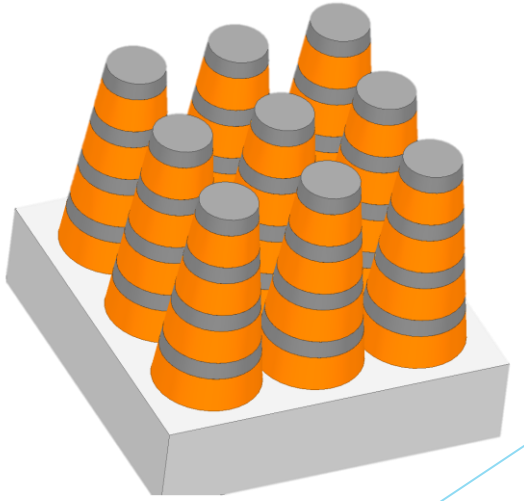
Other areas of interest

- Meta surface absorber
  - Planner surface absorbers
    - Low weight electromagnetic absorbers
  - 3D THz Absorbers
    - 3D geometries to absorb THz electromagnetic waves
- 3D Geometry for Low RCS
  - Optimize body geometries for stealth operations
  - Taken in a body and optimize outer geometry for RCS





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Bonus Topics

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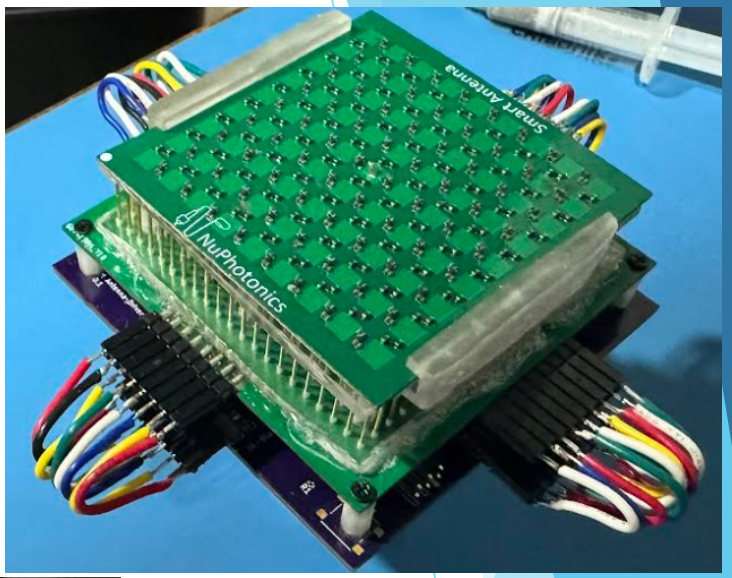
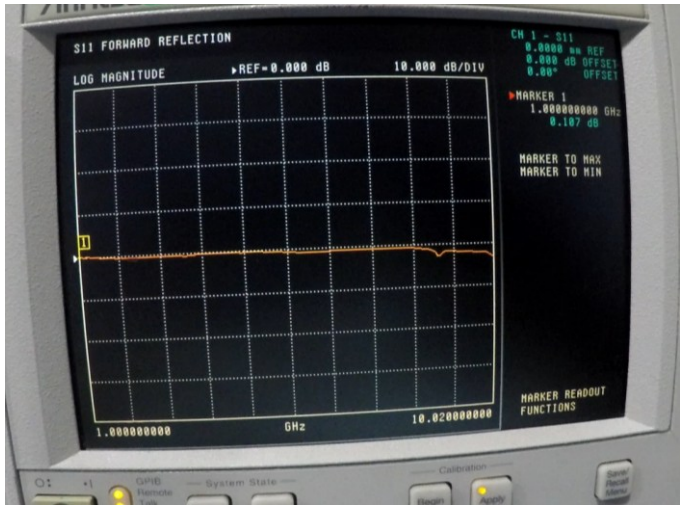
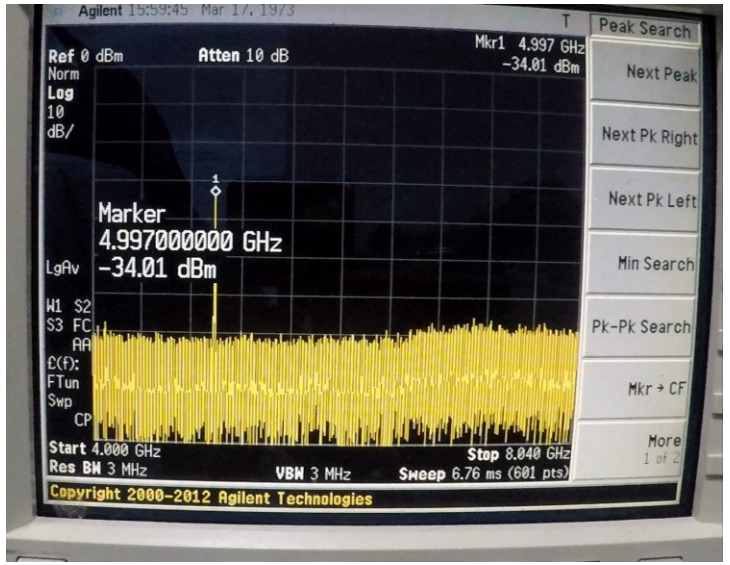
GA on Antenna

- Same GA has been demonstrated on an antenna
  - 128 RF switches distribute RF current
  - GA uses VNA for criteria fitness



Solving for 5-8 GHz





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Questions?