

# Patch Antenna Miniaturization through the use of Genetic Algorithms

Presenter: Daniel N. de Araujo



*LeadingInsight*

Application Workshops for High-Performance Design

# Objective

## Miniaturization

- ▲ **Lowest Frequency**
- ▲ **High Efficiency**
- ▲ **Smallest Physical Volume**



# Test Case

## Patch Miniaturization

Goal - In a given Area, Minimize resonant frequency while:

- ▲ Achieve high efficiency (no lossy materials)
- ▲ Achieve well behaved patterns (symmetric patterns, good CX)
- ▲ Achieve good matching (for  $50\Omega$ )



# Patch Miniaturization

## Two approaches

- ▲ Traditional designs based on modal expansion (open loop)
- ▲ Synthesis based on statistical methods (optimization)



# Deterministic vs. Statistical Optimizers

<i>Parameter</i>	<i>Deterministic Optimizers</i>	<i>Statistical Optimizers</i>
Convergence	Guaranteed if solution exists in the searching space	Not guaranteed
Convergence to the best solution	Dependent on initial guess, sensitive to local minima,	Less sensitive to local minima
Computational efficiency	Better	Good
Good initial guess	Required	Not necessary



# Genetic Algorithms

- ▲ An evolutionary based optimization/search routine
  - ▲ Applications:
    - ▲ Engineering
    - ▲ Biomedical
    - ▲ Computer science
- ▲ Attempts replication of natural processes
  - ▲ Searches for optimal solutions
  - ▲ “Survival of the fittest”
- ▲ Optimization routine of choice
  - ▲ Among current research community

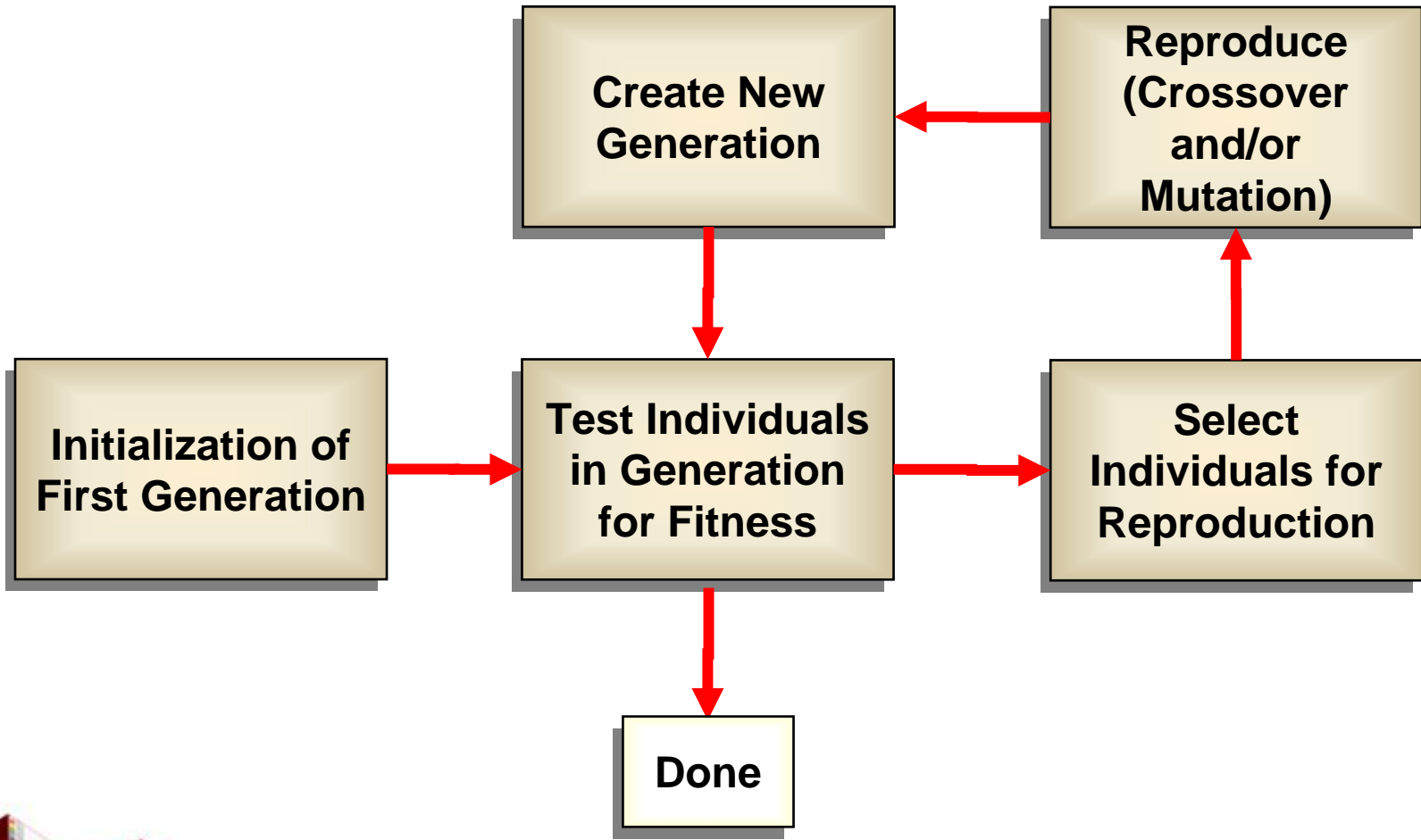


# Genetic Algorithm Terminology

- ▲ Individual
- ▲ Generation
- ▲ Fitness
- ▲ Generation



# Genetic Algorithm Flowchart



# GA VBS

- ▲ A Genetic Algorithm (GA) implementation
  - ▲ VBScript based
  - ▲ Based on FORTRAN program
- ▲ A generalized optimization routine
  - ▲ User determines implementation and usage



# GA - Initialization

## ▲ Individual

- ▲ A potential solution to the problem being optimized

## ▲ Generation

- ▲ A group of solutions “competing” to reproduce and pass on traits to the next generation

## ▲ First generation Individuals

- ▲ Chosen at random

## ▲ Individuals

- ▲ Represented as binary strings
  - ▲ Similar to chromosomes
- ▲ Easier combination when mating



# GA - Fitness

- ▲ Each individual
- ▲ Tested for fitness
- ▲ Fitness criteria
- ▲ Determined by the user

***Fitness*** – a measure of the proximity of the individual results to the overall design goal



# GA - Selection

- ▲ Individuals selected to reproduce
  - ▲ Traits passed on
  - ▲ Several techniques to select best mates
    - ▲ Natural
      - ▲ Roulette, Tournament
    - ▲ Artificial
      - ▲ Truncation
- ▲ Selected Individuals become Parents



# GA - Reproduction

- ▲ Crossover
  - ▲ Recombination of parental binary string
    - ▲ Creates child string
  - ▲ Passes best traits to next generation
- ▲ Mutation
  - ▲ Introduces random changes
    - ▲ Into child binary string
  - ▲ Prevents repeated mating
    - ▲ From converging to a single Individual
      - ▲ Genetic diversity
  - ▲ Can introduce desired traits
    - ▲ May not have been present in initial generation



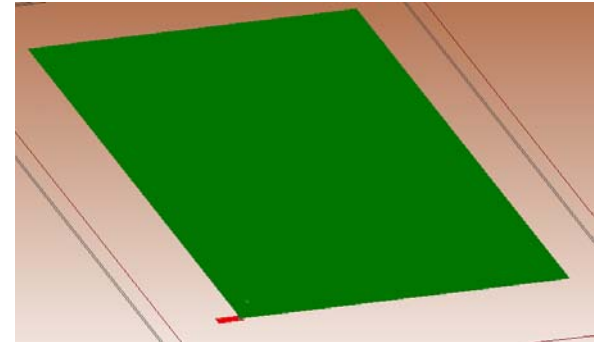
# GA – New Generation

- ▲ Form new generation
  - ▲ From Children of previous generation
- ▲ Elitism
  - ▲ Select Best individual from previous generation
    - ▲ Part of new generation
      - ▲ Randomly inserted
  - ▲ Guarantees that “best” solution is never lost
- ▲ Repeat process
  - ▲ As many times as desired
  - ▲ Locate optimal design



# Original Patch Antenna

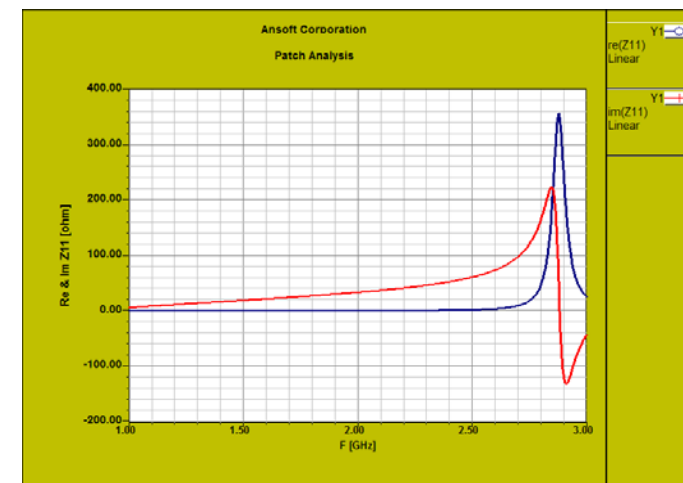
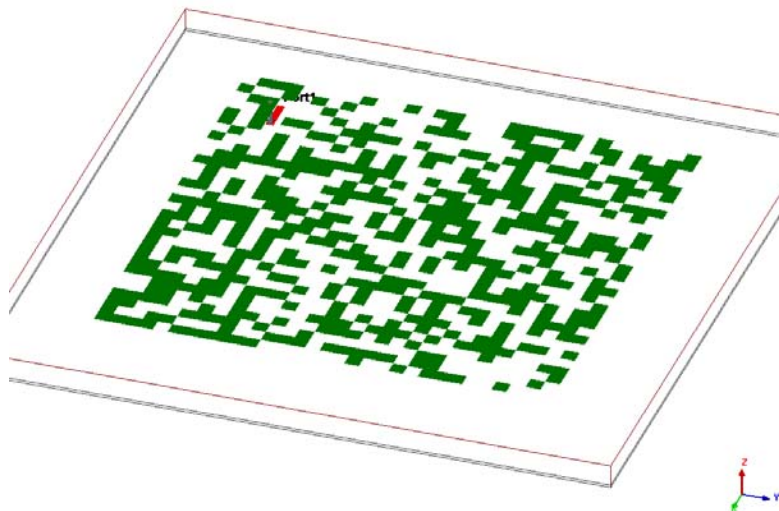
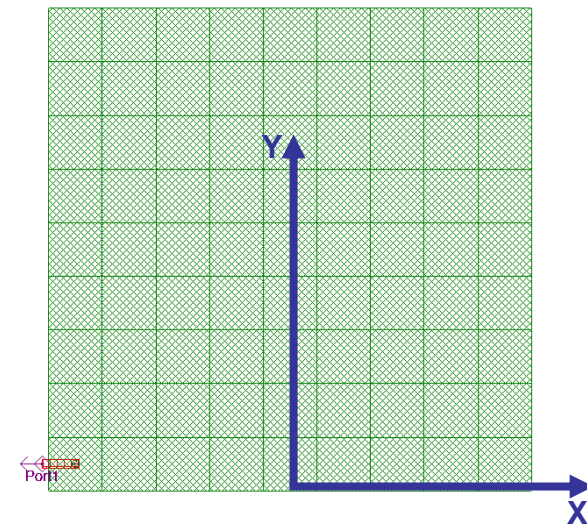
- ▲ Perpendicular Probe Feed
- ▲  $\lambda_g/2 \times \lambda_g/2$  at 3 GHz
- ▲ 62 mil Duroid



# Minimization of the Resonance Frequency

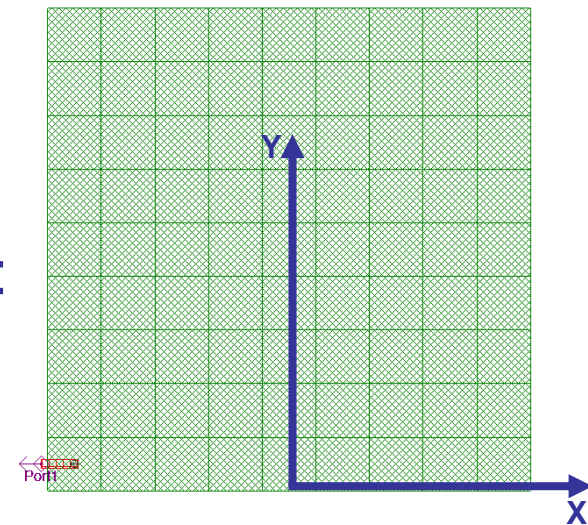
- ▲ Patch divided into "bits"
- ▲ Bits turned on and off
  - ▲ Determined by GA

9 X 9 case

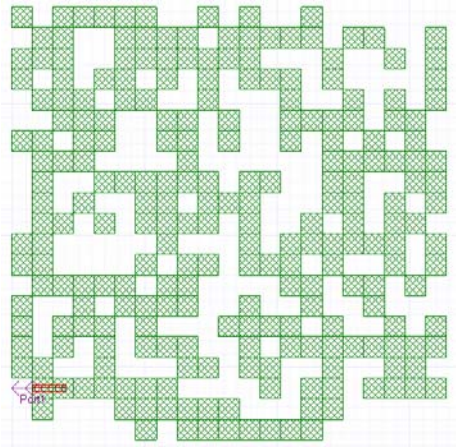


# Minimization of the Resonance Frequency

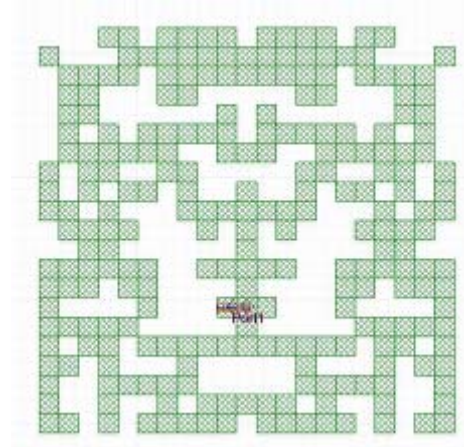
- ▲ Resonance Definition: Peak of the  $\text{Re}[Z_{in}]$
- ▲ Optimization *does not include* the location of the feed point
- ▲ Cases investigated:
  - ▲ Symmetry NOT imposed
  - ▲ Symmetry imposed in the y-axis
  - ▲ Two different level of discretization:
    - ▲ 21 by 21
    - ▲ 41 by 41



# Symmetry



**Asymmetric Patch**

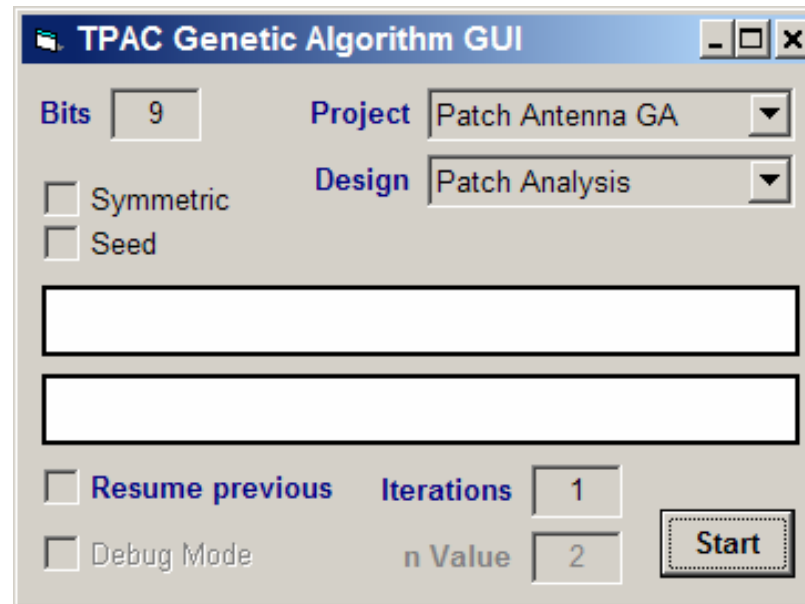


**Symmetric Patch**



# Genetic Algorithm GUI

- ▲ Runs genetic algorithm
- ▲ Interfaces with Designer



The screenshot shows a window titled "TPAC Genetic Algorithm GUI" with the following controls:

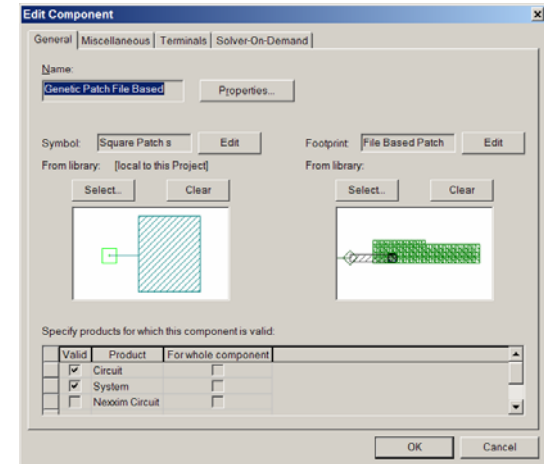
- Bits:** A text box containing the value "9".
- Project:** A dropdown menu with "Patch Antenna GA" selected.
- Design:** A dropdown menu with "Patch Analysis" selected.
- Symmetric:** An unchecked checkbox.
- Seed:** An unchecked checkbox.
- Resume previous:** An unchecked checkbox.
- Iterations:** A text box containing the value "1".
- Debug Mode:** An unchecked checkbox.
- n Value:** A text box containing the value "2".
- Start:** A button with a dotted border.

There are two empty rectangular text boxes located below the "Symmetric" and "Seed" checkboxes.



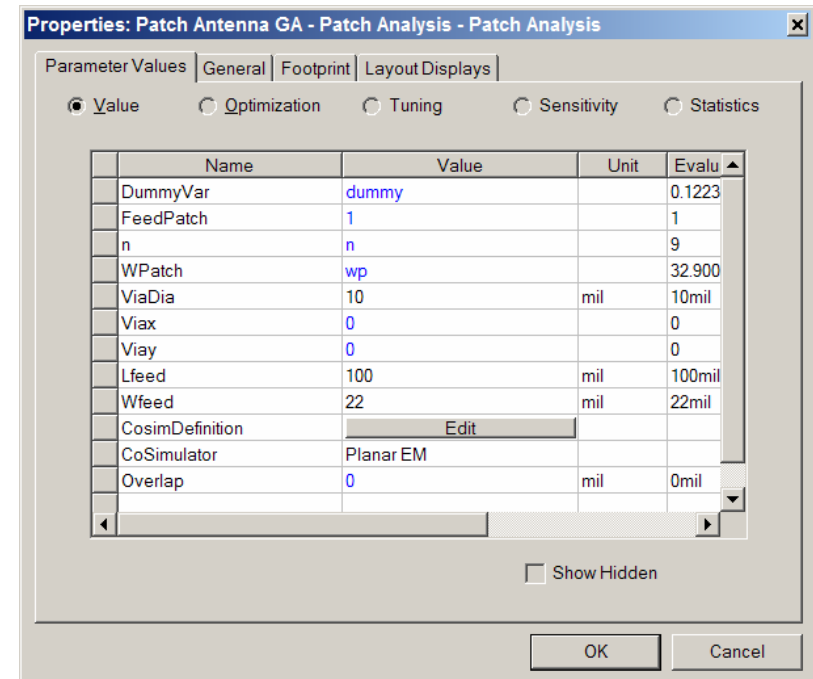
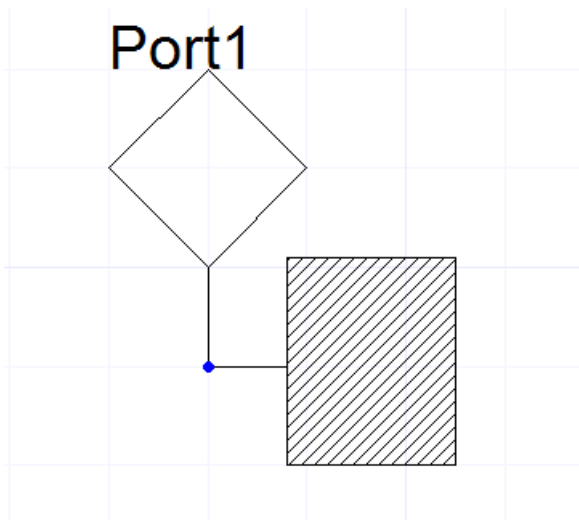
# Component Details

- ▲ Scripted footprint
  - ▲ Footprint reads data from file
- ▲ "Bit" data read from file
  - ▲ "Input\_Designer.txt"
  - ▲ Series of 0's and 1's
- ▲ "Transitional" property used
  - ▲ Change to notify of geometry change



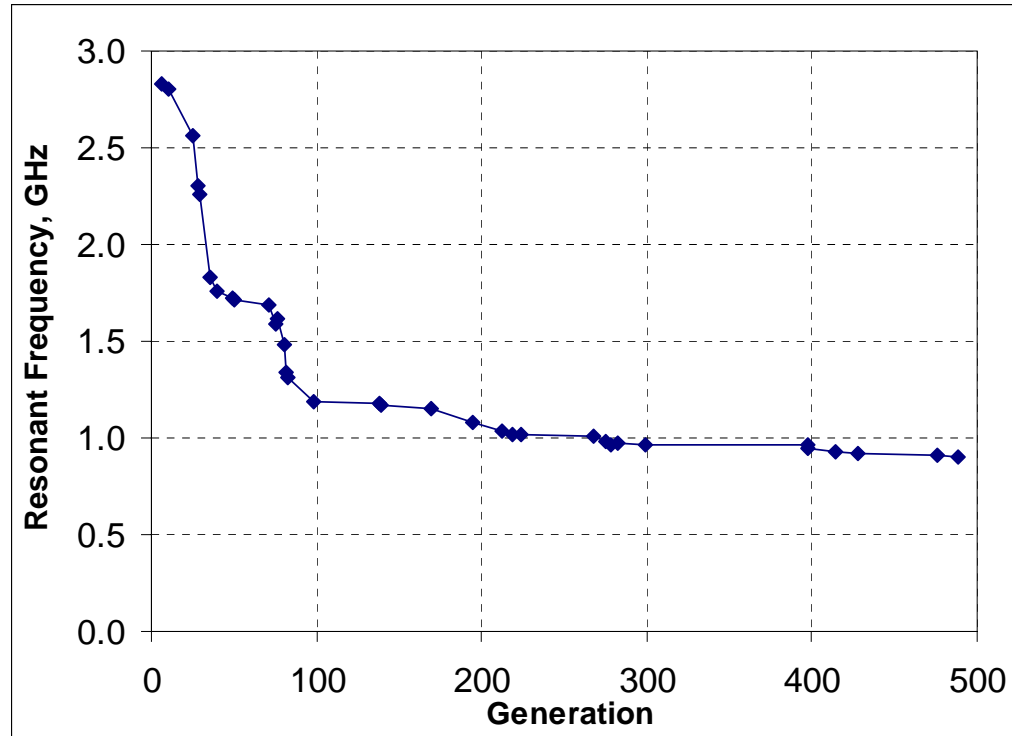
# Component Properties

## ▲ Fully parameterized patch



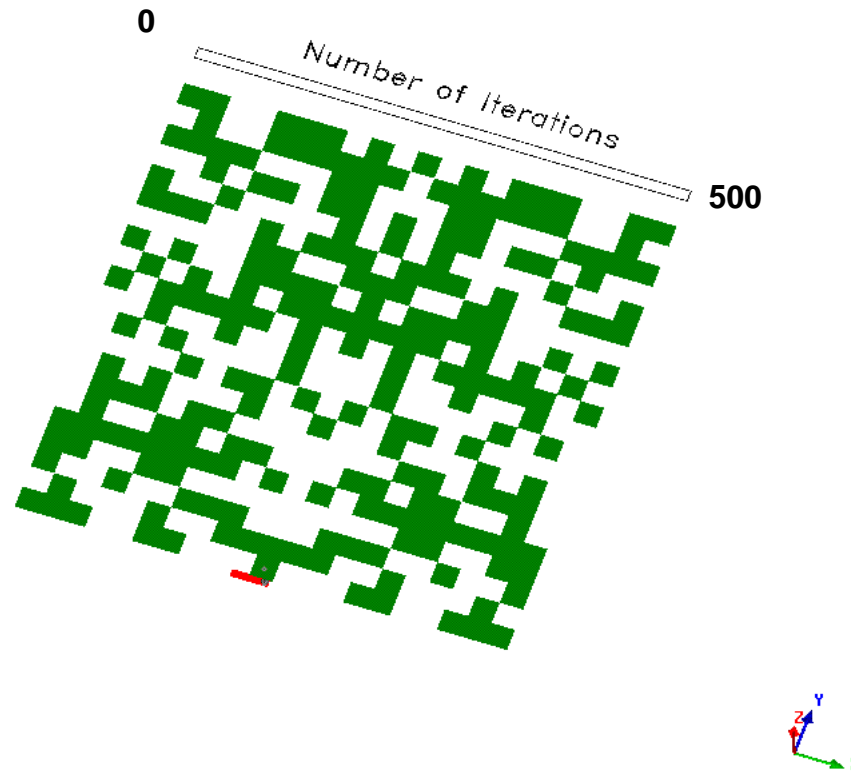
# Resonant Frequency vs Generation

## 21 X 21 Symmetric Patch

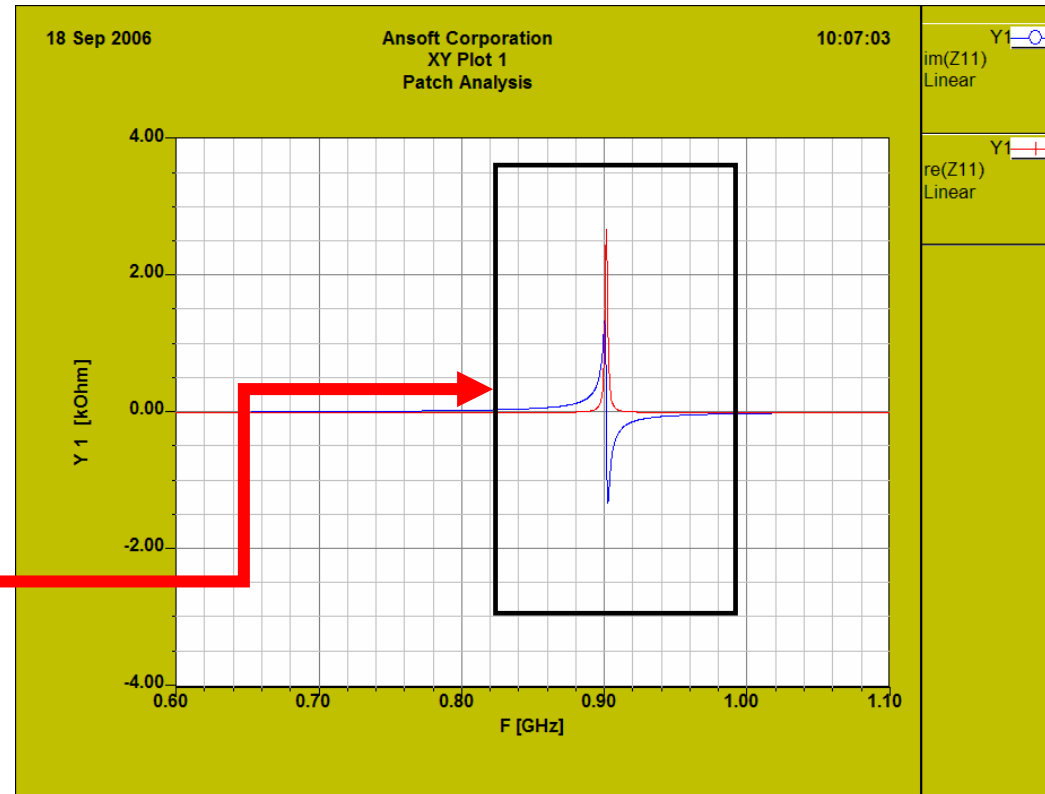


# Animation of Geometric Solution Convergence

## ▲ 21 X 21 Symmetric Patch

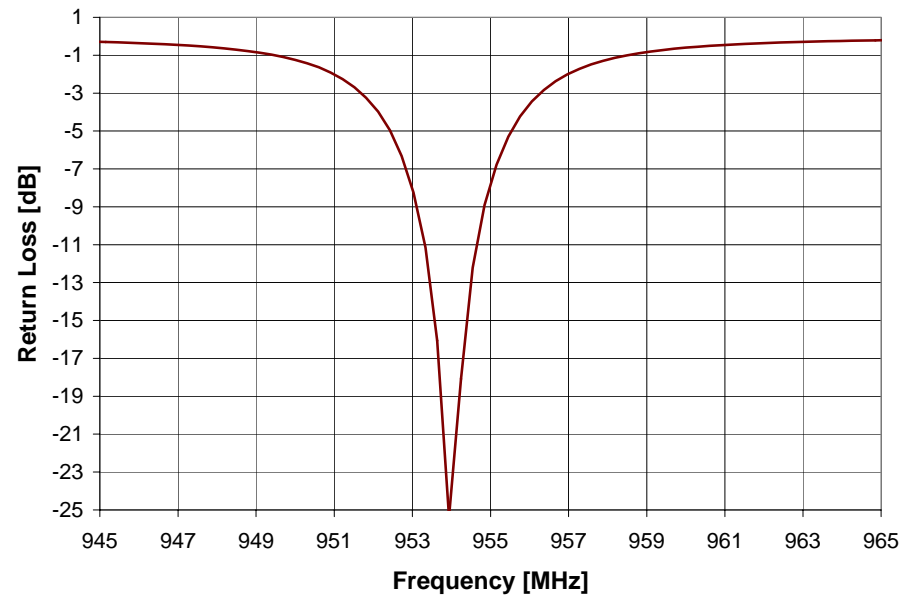
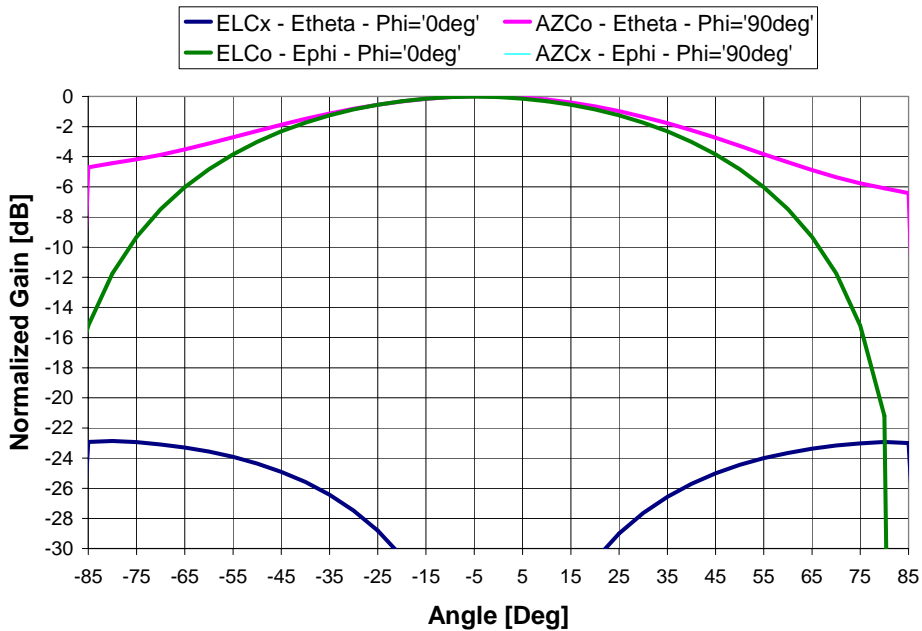


# 21 X 21 Symmetric Patch Results



# GA Patch Results

## Optimized Feed location



# Conclusion

## ▲ Genetic Algorithms

- ▲ Efficient means to discover non-intuitive geometries
- ▲ Not limited to antennas

## ▲ Ansoft Designer

- ▲ Flexible scripting
- ▲ Automation
- ▲ Robust Planar tool

## ▲ Patch Antenna

- ▲ New geometry discovered
- ▲ Resonant frequency reduced to less than 1/3 size

