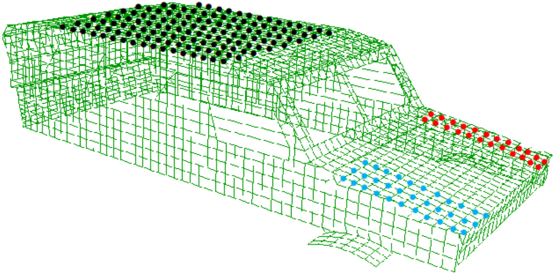
# A Comparison of Antenna Placement Algorithms

Abhinav Jauhri, Jason D. Lohn, Derek S. Linden

# Antenna Placement Example



- $A_1$ has 24 possible antenna placements
- $A_2$ has 33 possible antenna placements
- $A_3$ has 136 possible antenna placements

Size of search space $= m^n$

Goal: Find a placement for each of three antennas.

# The Problem

Given:

- platform $P$ with its surface gridded so that grid points represent possible antenna placement

- set of $m (m > 1)$ antennas $A = A_1, A_2, \ldots, A_m$

- for each $A_i$, a set of $n$ possible placement locations $(n > 1)$; $A_i = \{(x_{i1}, y_{i1}, z_{i1}), (x_{i2}, y_{i2}, z_{i2}) \ldots (x_{in}, y_{in}, z_{in})\}$

Find: A set of $m$ optimal antenna locations on $P$

# Antenna Placement Objectives

Antenna Placement Issues

- → Coupling among antennas
- → Parasitic effects and reflections from the host platform
- → Loss of efficiency
- → Difficulty conforming to aerodynamic, thermal, other enovironment factors

Desired Antenna Placement Objectives

- → Gain in radiation pattern
- → Minimize coupling

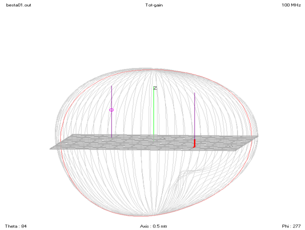
# Fitness Functions - I

To minimize difference in gain:

$$F_{RP}(A_i) = \sum_{\theta} \sum_{\phi} \| ISG_i(\theta, \phi) - FSG_i(\theta, \phi) \|^2, \qquad (1)$$

where

- $\theta, \phi$ spherical and cylindrical coordinates
- $ISG(\cdot)$ returns in-situ gain pattern
- $FSG(\cdot)$ returns free-space gain pattern



# Fitness Functions - II

To minimize coupling:

$$F_{MC} = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} CP(A_i, A_j), \tag{2}$$

where

- $CP(\cdot)$ computes the coupling between two antennas

# Overall Fitness Function

For an individual/hypothesis, fitness is defined as:

$$F = \alpha F_{MC} + \beta \sum_i F_{RP}(A_i), \tag{3}$$

where $\alpha + \beta = 1$

# Experimental Setup

- Create individual(s) such that each individual is defined by a placement for each of the $m$ antennas
- Run all individuals through *NEC* simulator * to get fitness parameters
- Apply EA operators
- Repeat...

Algorithms explored: Simple GA, Simulated Annealing, Evolutionary Strategy, and Hill Climber †

*http://www.nec2.org

†https://github.com/ajauhri/evol-ant-placement

# Experiments: Test Cases

| ID | Antennas | Total allowable placements |
|---|---|---|
| tc1 | 2 | 7,056 (83x83) |
| tc2 | 3 | 50,625 (45x45x25) |
| tc3 | 3 | 126,025 (71x71x25) |
| tc4 | 4 | 20,736 (12x12x12x12) |

*Allowable placements for each antenna are provided within parenthesis

# Results: Mean Evaluations

Mean number of evaluations to reach the best solution (over 10 runs):

| method / test case | GA | ES | SA | HC |
|---|---|---|---|---|
| tc1(7056)‡ | 2350 | 1728 | 667 | 164 |
| tc2(50,625) | 31 680 | 11 165 | 1653 | 174 |
| tc3(126,025) | 45 900 | 26 880 | 4809 | 227 |
| tc4(20,736) | 6150 | 4466 | 423 | 90 |

- Simulated Annealing was the fastest
- Evolutionary Strategy always found optimal, but was relatively slow

‡Total number of possible evaluations within parenthesis

# Results - Mean Best Fitness

- Lower fitness is better
- Mean taken over 10 runs
- In all test cases, antennas were subjected to same frequency

| method / test case | Exhaustive($H^*$) | GA | ES | SA | HC |
|---|---|---|---|---|---|
| test case 1 | 0.4968 | 0.4993 | 0.4968 | 0.4994 | 0.5015 |
| test case 2 | 0.4968 | 0.4979 | 0.4968 | 0.5042 | 0.5138 |
| test case 3 | 0.4974 | 0.4976 | 0.4974 | 0.4974 | 0.4987[§] |
| test case 4 | 0.4992 | 0.4992 | 0.4992 | 0.4992 | 0.4992 |

[§] Best performing individuals lie within a small fitness range

# Equivalence of fitness to efficiency

For a particular test case, fitness change of 0.01 is equivalent to either the corresponding value under expected gain ($\mathbb{E}_g$) column, or difference in coupling ($\Delta_c$).

| ID | $\mathbb{E}_g$ | $\Delta_c$ (dB) |
|---|---|---|
| tc1 | 872.277 | 0.5474 |
| tc2 | 862.082 | 1.3034 |
| tc3 | 861.845 | 1.5180 |
| tc4 | 871.049 | 0.5693 |

$\mathbb{E}_g = \frac{1}{N \cdot m} \sum_i^m F_{RP}(A_i)$, where $N = \mid \theta \mid \cdot \mid \phi \mid$

Thanks!