Simplicity Study for a Self-Structuring Antenna in an Automobile Environment

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As in all design problems, the tradeoff between cost and functionality plays a major role in the design of the self-structuring antenna (SSA). To this end, a study was undertaken to determine the minimum number of switches required for proper functionality of the SSA in an automobile. We consider the simulation of a FM band self-structuring antenna placed in the upper part of the rear window of an automobile. Included in the simulations are the car body and the heater grid, which is located in the lower portion of the rear window, as well as the self-structuring antenna.

The simplification scheme used for this study involved decreasing the number of switches in the SSA template in several stages from 16 to 12, 8, and finally 4. This was done while maintaining the same overall size for the SSA template. Wire segment spacing inside the SSA template was increased with each simplification step in order to fill the template in a nearly uniform fashion.

Analysis was done using the Numerical Electromagnetics Code in the FM band (88-108 MHz), utilizing the standing wave ratio to determine the suitability of a given SSA configuration for use in the automobile. In the cases of 12 and 16 switches, a genetic algorithm was used to optimize the states of the self structuring antenna. This was done using GA-NEC, a software package developed by John Ross & Associates. For the cases of 4 and 8 switches, exhaustive searches were used to evaluate every possible self-structuring antenna configuration.

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URSI B Session 43: Reconfigurable Apertures and Novel Beamsteering Techniques
Monday June 21, 2004 16:30 De Anza I

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Overview

- Self-Structuring Antenna (SSA) Overview
- Motivation and Goals
- Automobile Environment
- Simplification Scheme
- Simulation Results
- Conclusions and Future Work

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SSA Overview

- **The SSA automatically configures itself to accommodate changes in signal strength, orientation, and atmospheric conditions through the control of simple on/off switches**

- **Changes in switch states cause the electrical shape of the antenna to be altered, allowing it to adjust to changes in its electromagnetic environment**

- **The effect of different antenna configurations is unknown to the designer, only a statistical approach is utilized in testing**

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Motivation / Goals of Research

- **Motivation:**
  - **The tradeoff between cost and functionality plays a major role in the design of the self-structuring antenna**
  - **Likely reduction in the number of switches used in the design of the self-structuring antenna template**

- **Goals:**
  - **Evaluate the minimum number of switches required to give acceptable performance of a self-structuring antenna in an automobile environment**

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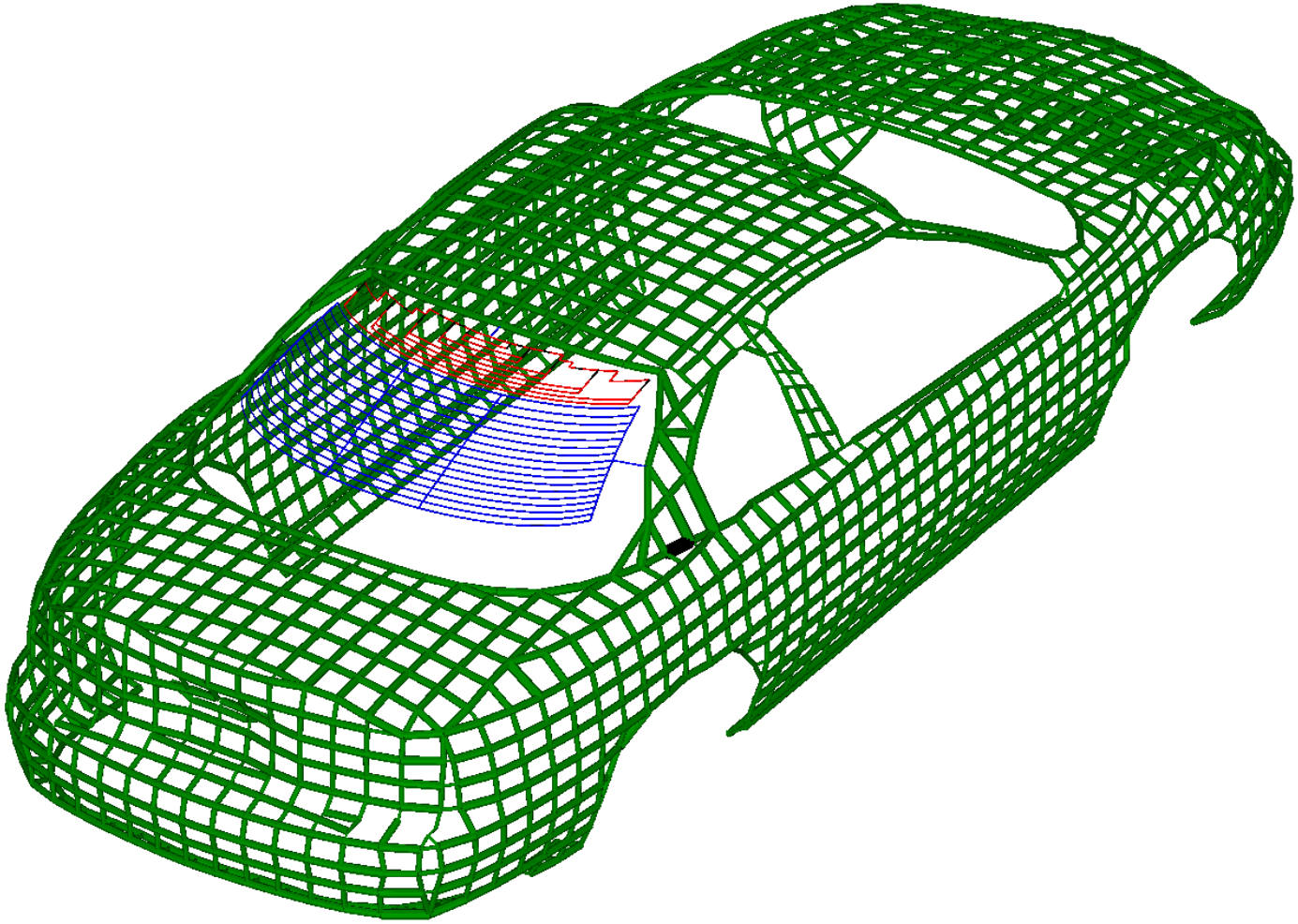
Automobile Environment



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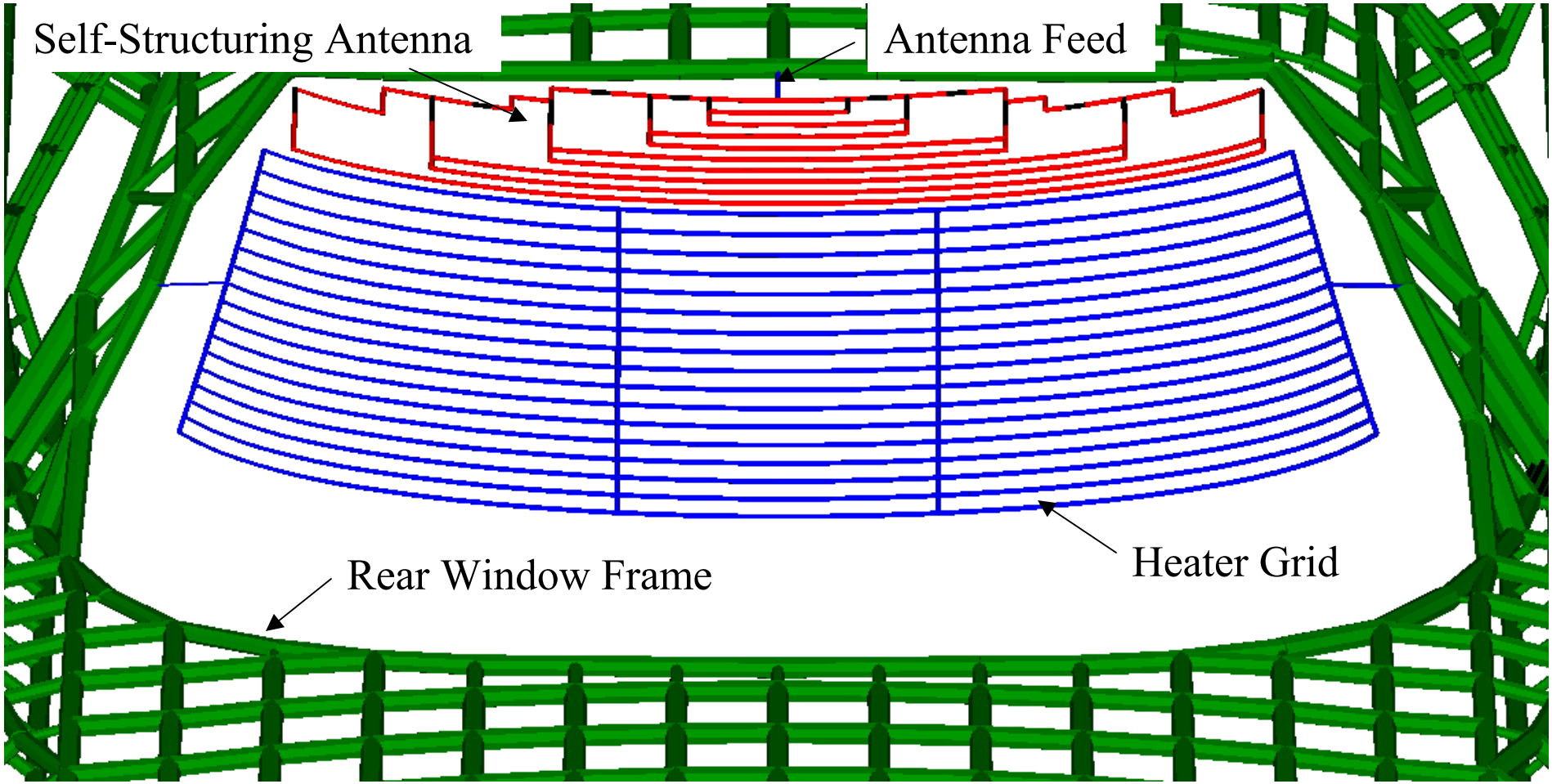
Automobile Environment



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Simplification Scheme

- **Begin with a 16 switch SSA template**
  (as presented at the 2003 IEEE AP-S / URSI meeting)

- **Reduce the number of switches to 12, 8 and finally 4 while maintaining the overall size of the antenna which is approximately 0.33λ by 0.05λ (at 100 MHz)**

- **Fill the antenna template with wire elements in a nearly uniform fashion with each change in number of switches**

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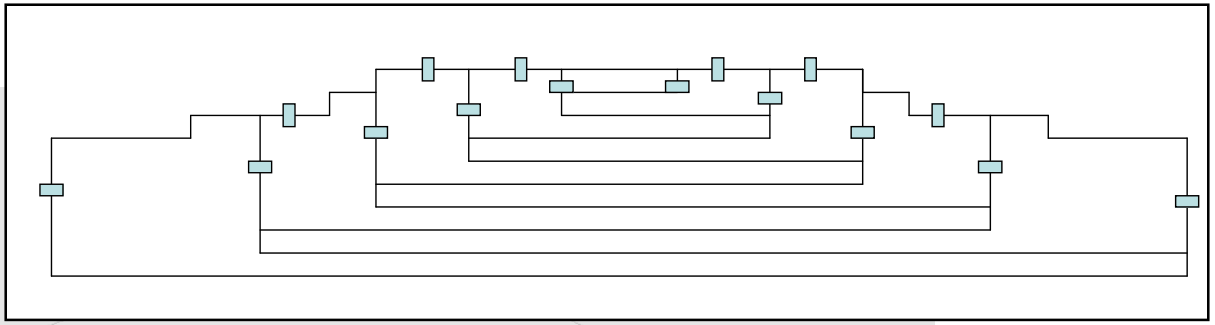
16 Switch Template



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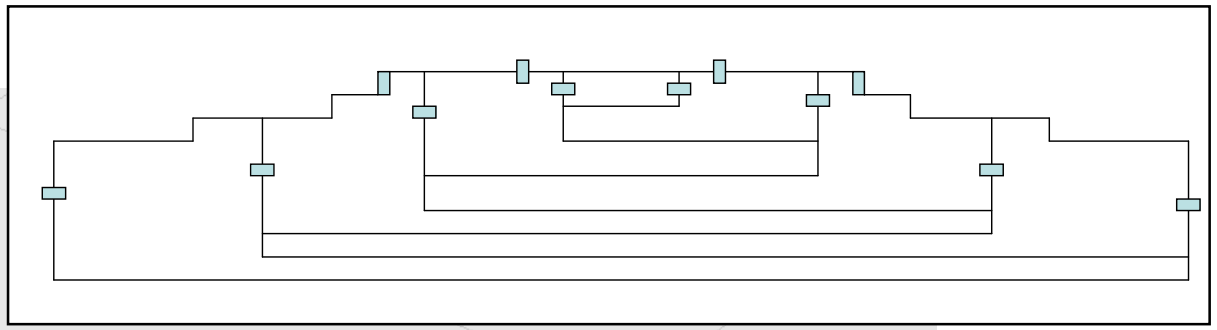
12 Switch Template



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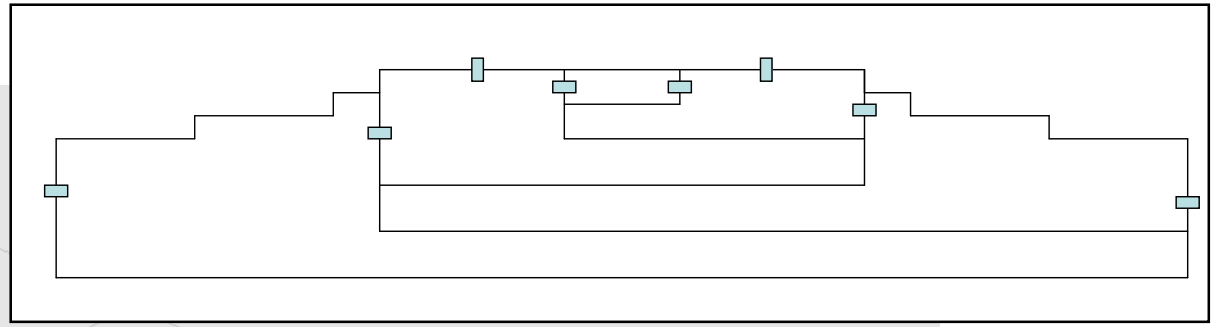
8 Switch Template



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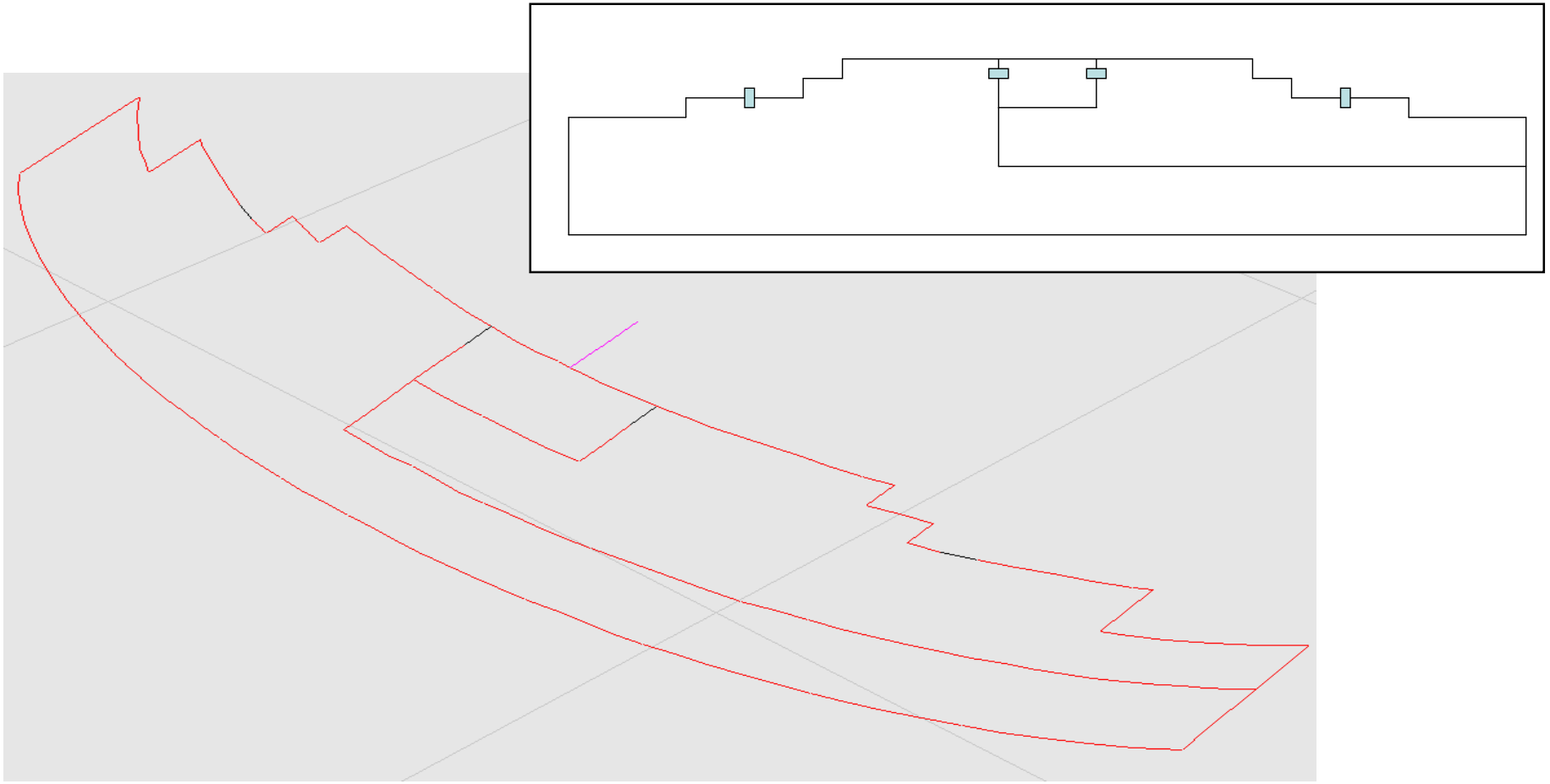
4 Switch Template



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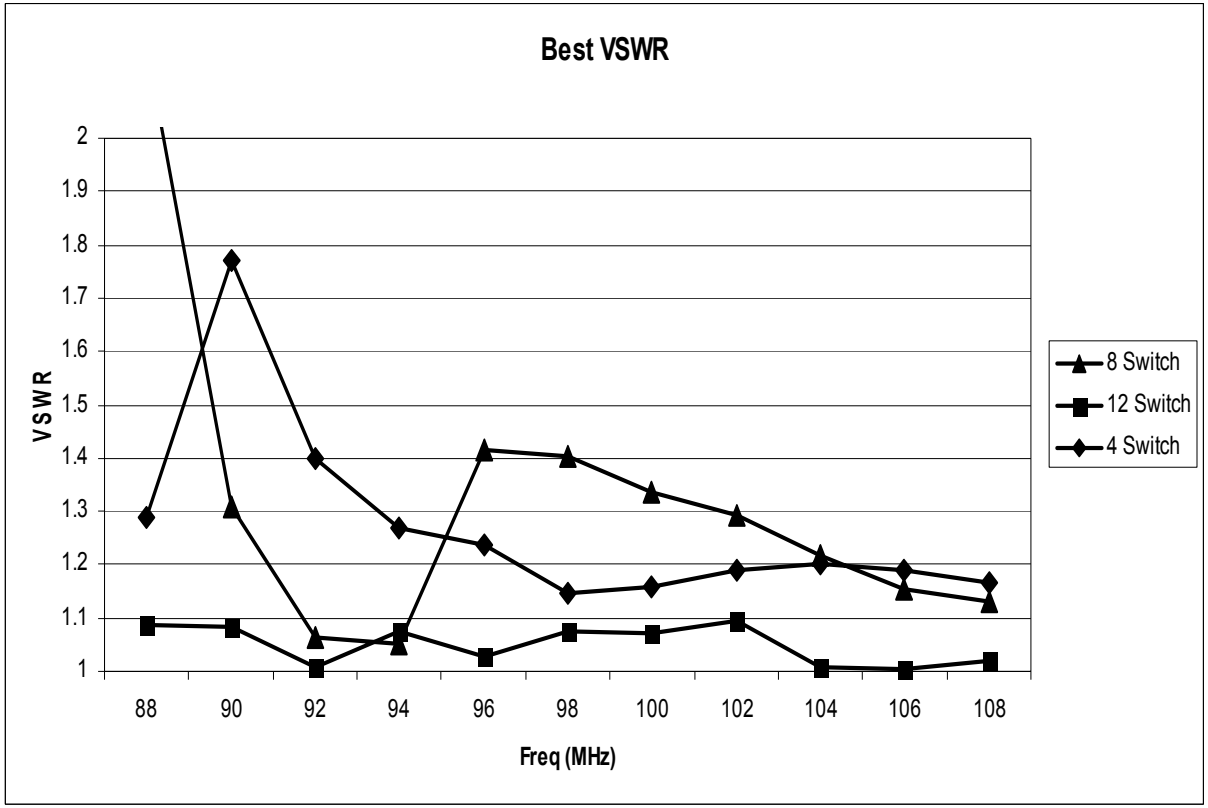
Simulation Results

- **4 and 8 switch cases**
  - **Lack diversity to provide suitable VSWR across the frequency band**
- **12 switch case**
  - **Diversity of the SSA allows for VSWR below 1.1 across the FM band**



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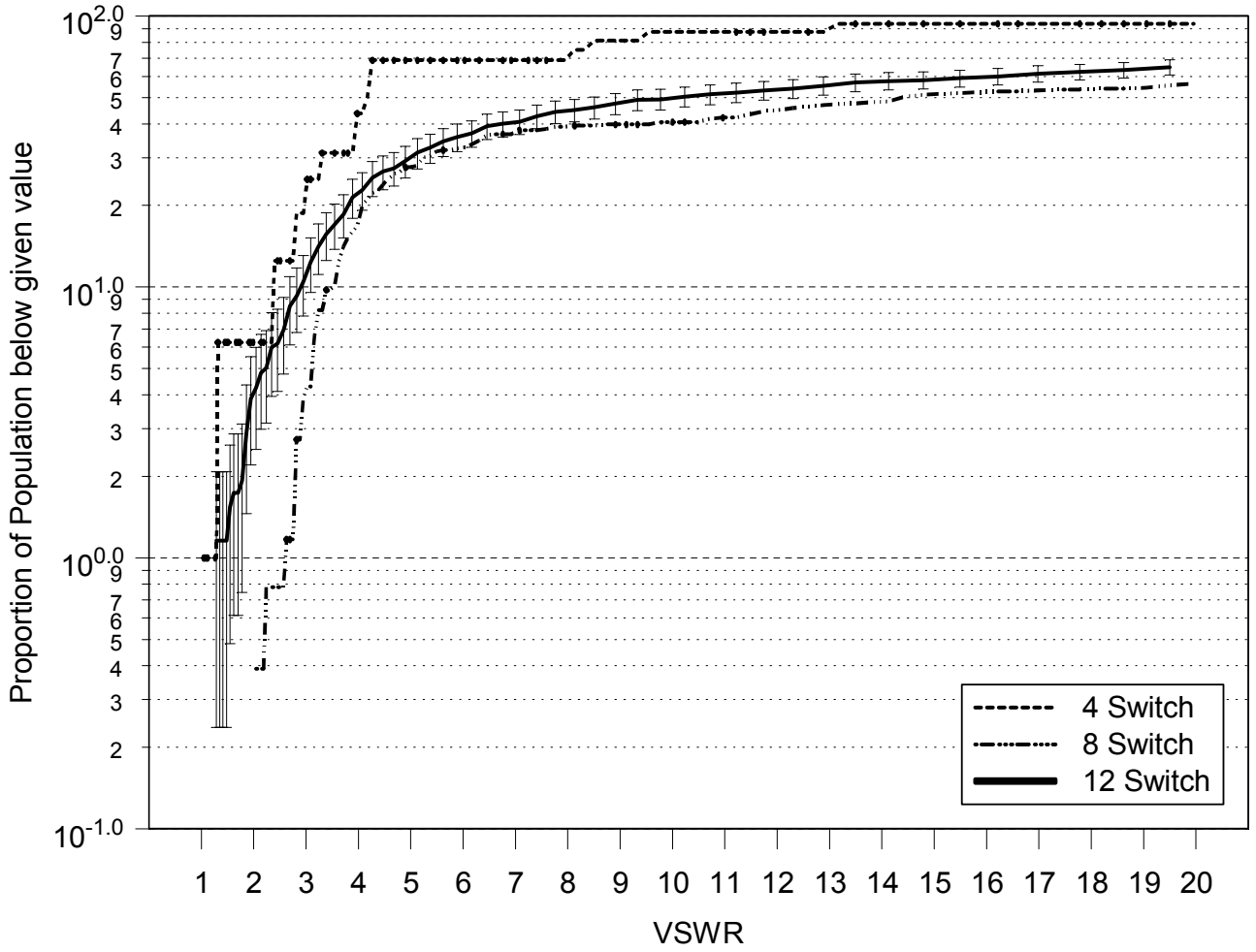
Simulation Results

88 MHz

- **4 switch case**
  - **Exhaustive search of 16 combinations**
- **8 switch case**
  - **Exhaustive search of 256 combinations**
- **12 switch case**
  - **Shown with 95% confidence intervals**



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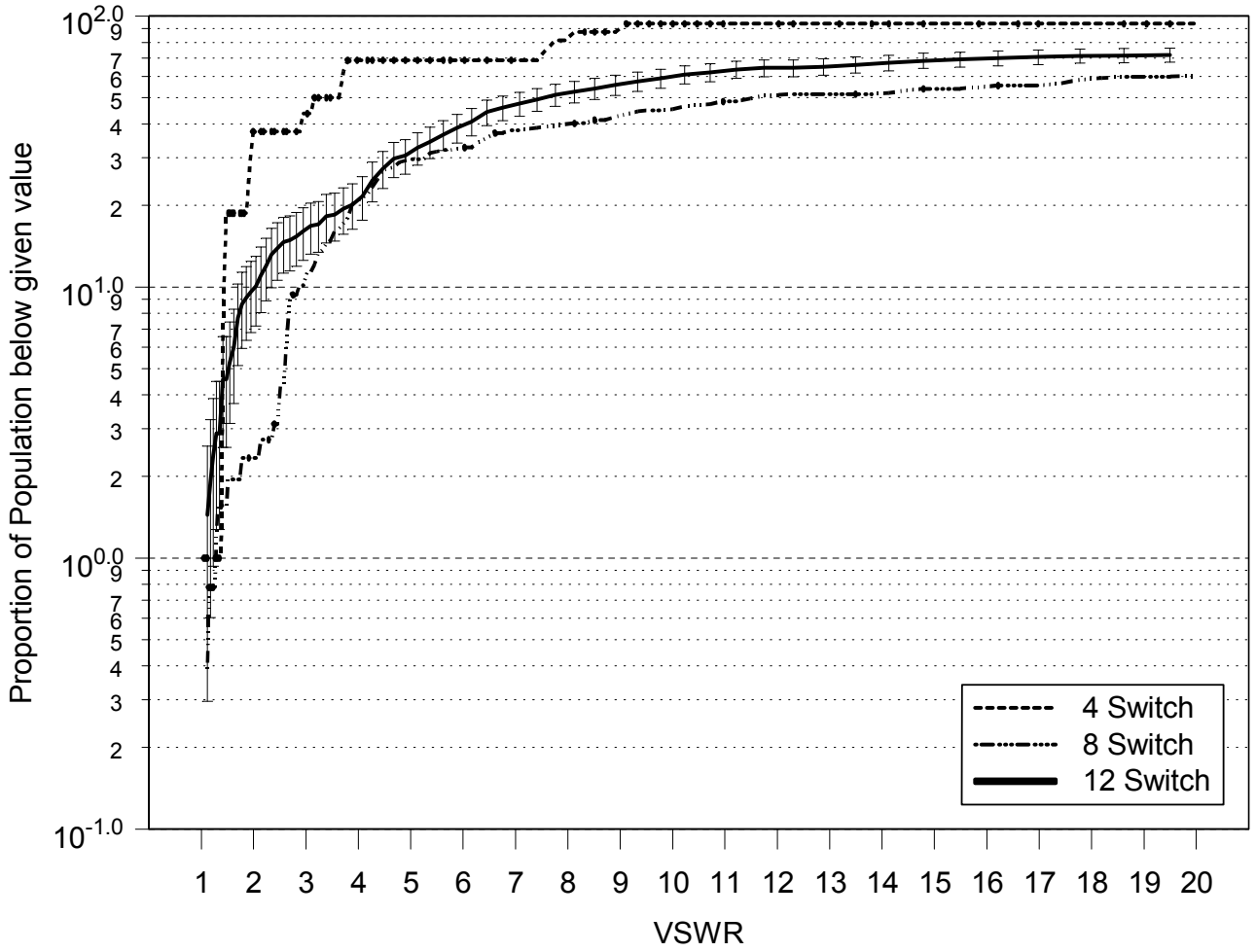
Simulation Results

92 MHz

- **4 switch case**
  - **Exhaustive search of 16 combinations**
- **8 switch case**
  - **Exhaustive search of 256 combinations**
- **12 switch case**
  - **Shown with 95% confidence intervals**



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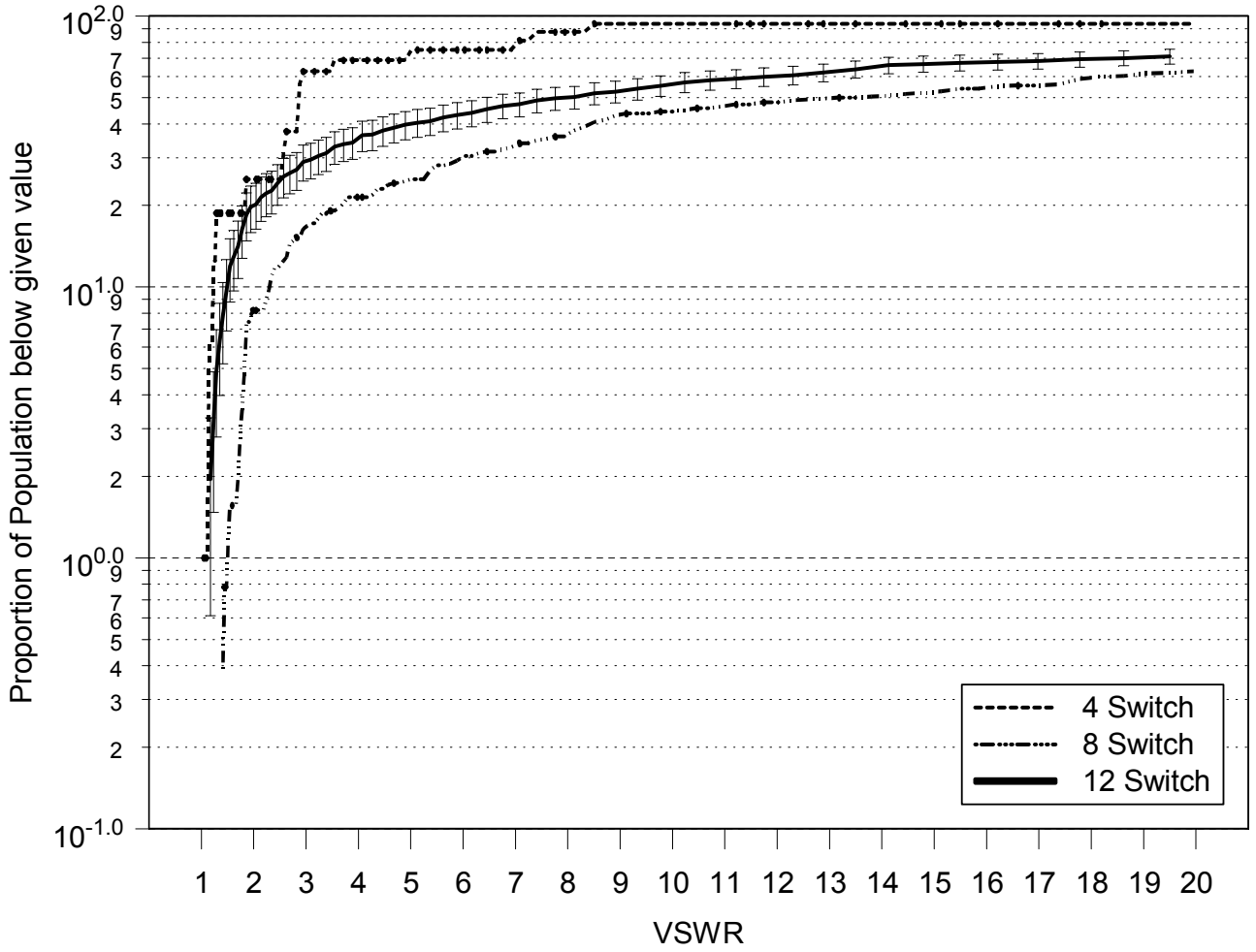
Simulation Results

98 MHz

- **4 switch case**
  - **Exhaustive search of 16 combinations**
- **8 switch case**
  - **Exhaustive search of 256 combinations**
- **12 switch case**
  - **Shown with 95% confidence intervals**



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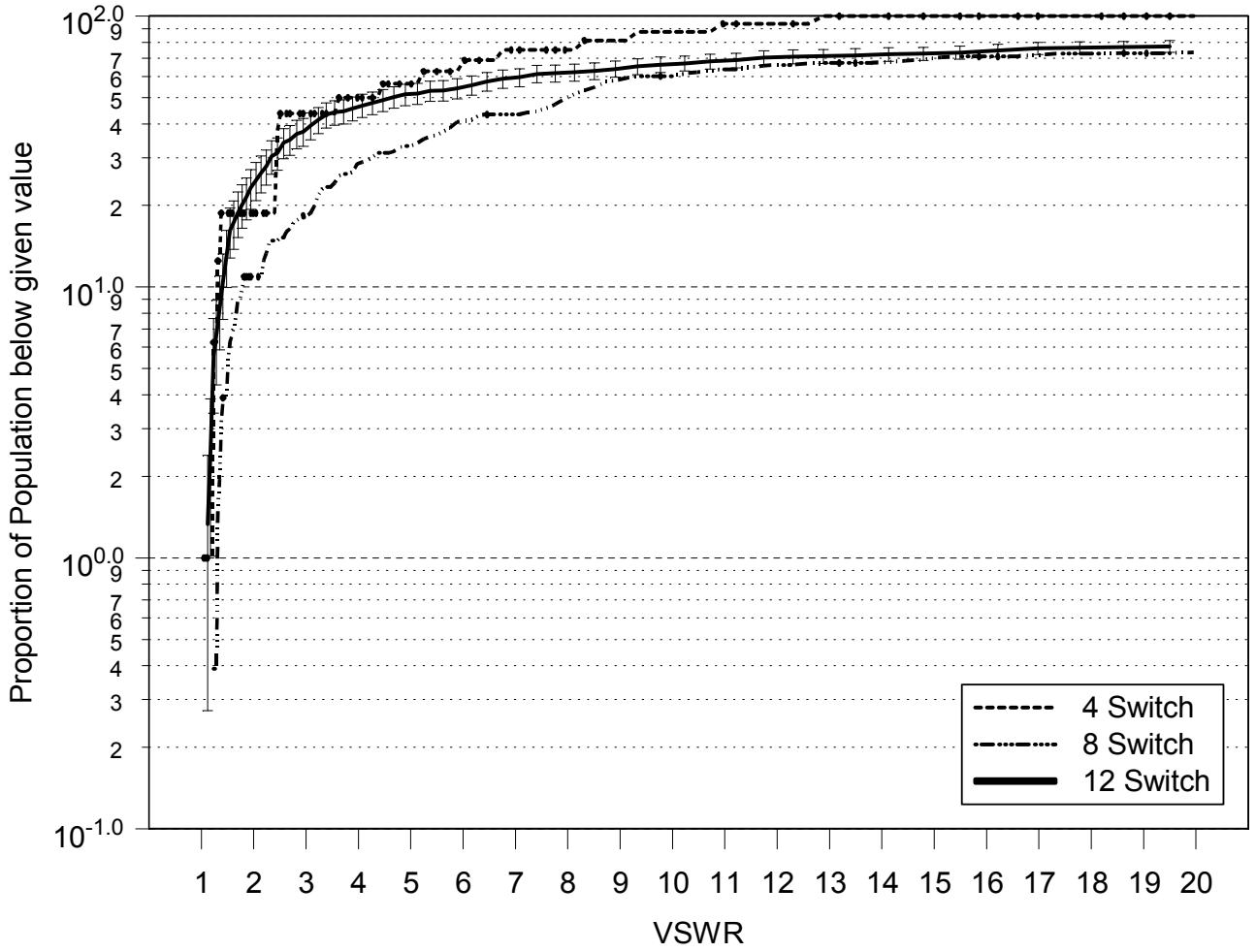
Simulation Results

104 MHz

- **4 switch case**
  - **Exhaustive search of 16 combinations**
- **8 switch case**
  - **Exhaustive search of 256 combinations**
- **12 switch case**
  - **Shown with 95% confidence intervals**



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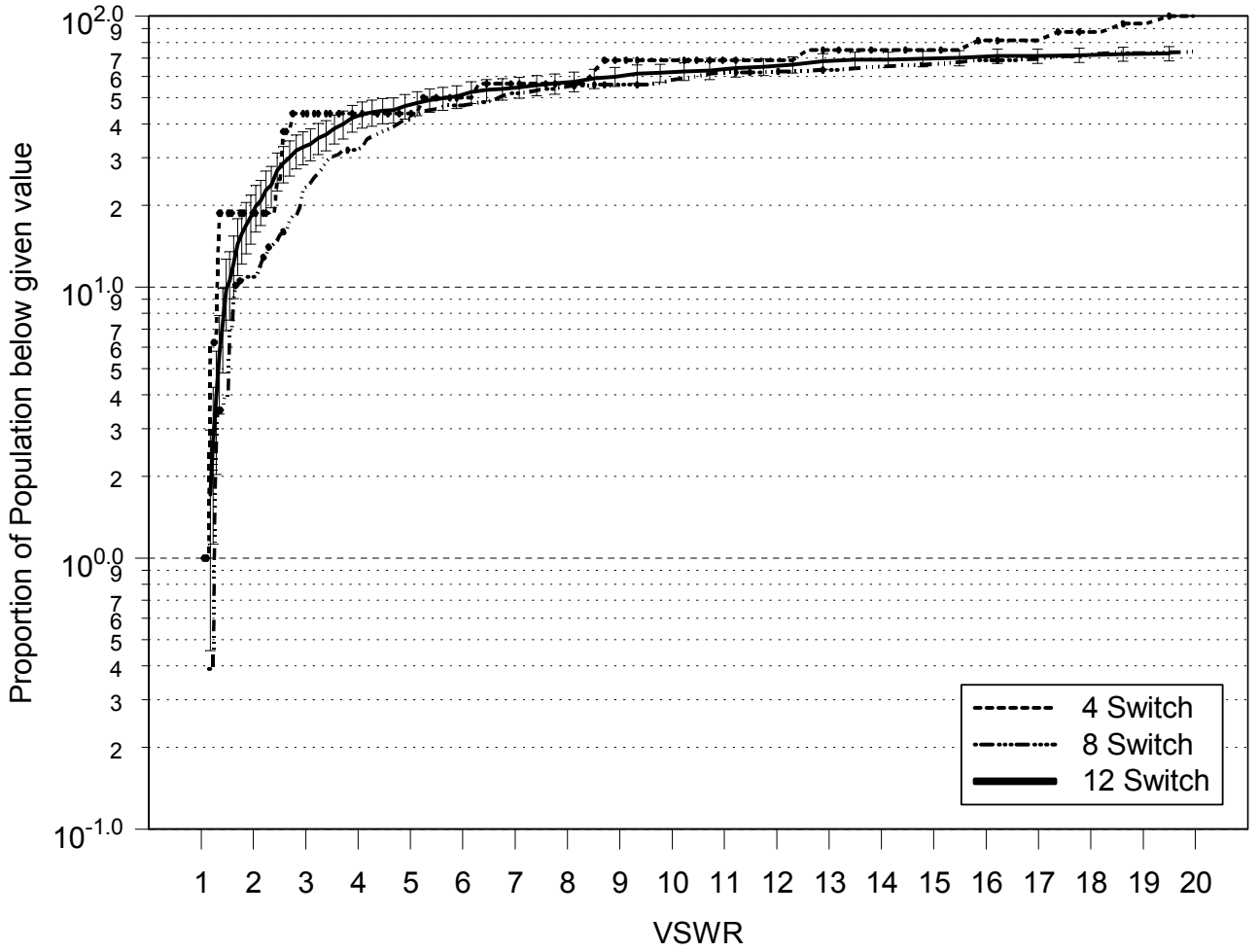
Simulation Results

108 MHz

- **4 switch case**
  - **Exhaustive search of 16 combinations**
- **8 switch case**
  - **Exhaustive search of 256 combinations**
- **12 switch case**
  - **Shown with 95% confidence intervals**



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Conclusions / Future Work

- **Proportions of population for the 4, 8 and 12 switch cases converge to the same graphs as the frequency increases in the FM Band**
  - **4 switch template is best suited for the low end of the FM Band**
  - **As frequency increases, the spacing and antenna element size for the 4 switch template become too large to change the electrical shape of the antenna effectively to provide lower VSWR values**
  - **8 switch template is best suited for the high end of the FM Band**
  - **As frequency increases, the element size and spacing of the 8 switch template provide enough diversity to provide better performance in terms of VSWR**
  - **12 switch template has enough built in diversity to perform consistently across the FM Band**

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Conclusions / Future Work

- **4 and 8 switch Self-Structuring Antenna templates lack the diversity to consistently provide suitable "best VSWR" values across the FM Band**

- **12 switch Self-Structuring Antenna template has ample diversity built in to provide suitable "best VSWR" values for the FM Band**

<u>Future Work</u>

- **Further investigation including pattern comparison for self-structuring antennas employing various numbers of switches**