Designing microwave devices from scratch using computer simulations

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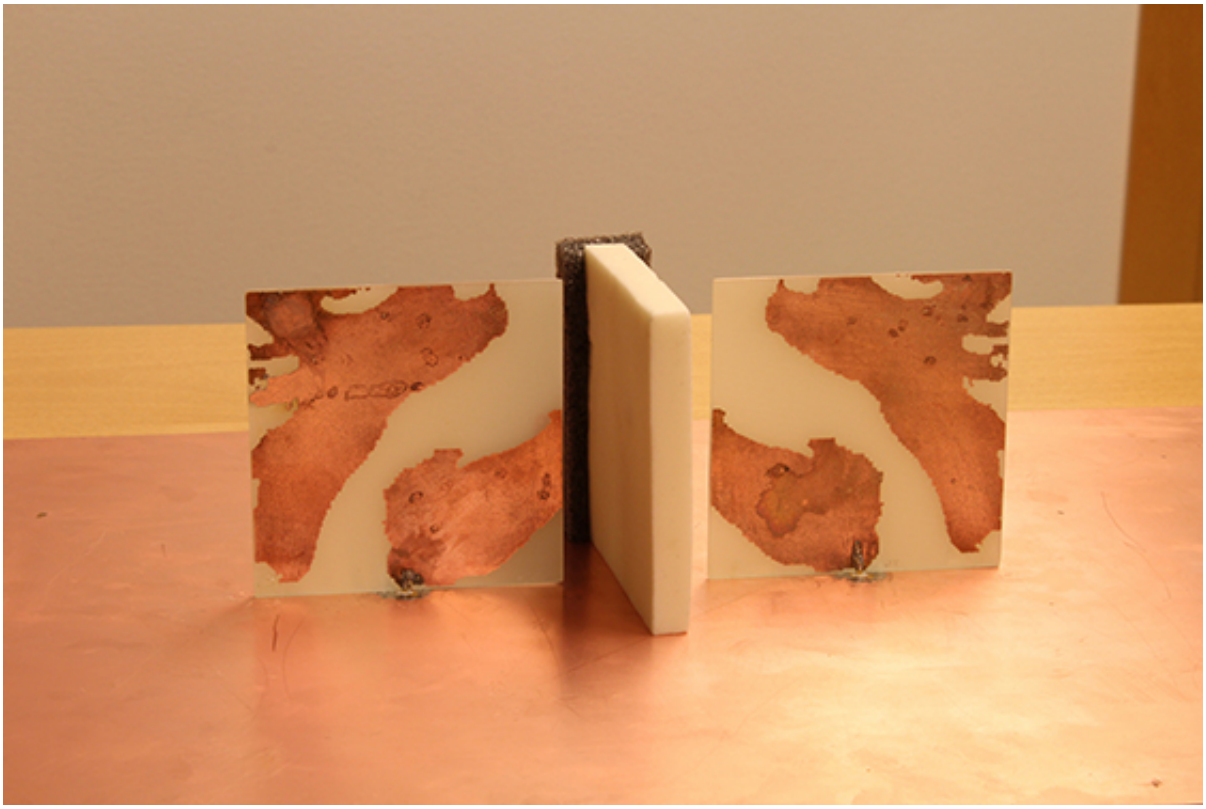

For decades, the fundamental design of microwave devices, such as antennas for mobile communication and waveguides used in radars, has essentially relied on the inventiveness of a professional designer. Computer simulations are usually used only in final design stages to fine-tune details in the design. This classical approach to microwave device

design is challenged in the PhD thesis of Emadeldeen Hassan, which he defends at Umeå University, 26 May.

"When computers are properly used also in the initial design phase, not only can we shorten decade-long design processes down to a few hours, we can also obtain new, revolutionary designs with outstanding performance as well," Emadeldeen Hassan says.

The classical design process starts from an initial, conceptual layout for the device, conceived by a human designer. Performance improvements are then achieved through modifications of details in the design, where nowadays computer simulations and optimization algorithms often are employed. For instance, in 1979 Peter Gibson introduced an antenna he named the Vivaldi antenna. This antenna has a high sensitivity to detect weak signals, and has therefore widely been investigated for use in medical applications, such as in attempts to use microwaves for early detection of breast cancer.

"The basic concept of a Vivaldi antenna has been extensively worked on and tweaked in various ways during the last 36 years, but the question is whether it is reasonable to spend all this time on a single conceptual shape," Emadeldeen Hassan says.

The question addressed in his thesis is the following: What would happen if we start from scratch, not being biased by any initial device layout? Can computer algorithms automatically recreate designs similar to the ones that humans have come up with before? Can we obtain even better devices than the ones conceived so far?

"The answer turns out to be yes to both these questions," Emadeldeen Hassan declares.

The thesis explores a diverse set of tools—accurate numerical algorithms

for simulation and optimization implemented on powerful computing systems—and integrate these to allow for efficient from-scratch design of microwave devices. The method has then been used, for instance, to design an antenna sensitive for detecting nearby objects.

"The algorithm revealed in a few hours of computing time, many favourable designs. Among them, one antenna was similar to the classical Vivaldi antenna, Emadeldeen Hassan says. However, this was not the best performing design; a new family of much more sensitive antennas appeared from the algorithm.

Another application of the method was to design a key part of radar systems: a matching transition between components in the microwave circuit. A well-designed matching transition improves the energy efficiency of the system and reduces the risk of overheating. Novel matching transitions were found by the methodology, and measurements on a manufactured prototype confirmed the high performance of the transitions.

More information: "Topology Optimization of Antennas and Waveguide Transitions." umu.diva-portal.org/smash/record.jsf?pid=diva2%3A808378&dswid=4199

Provided by Umea University

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