

# Concept to Product for a 3D Mesh Antenna

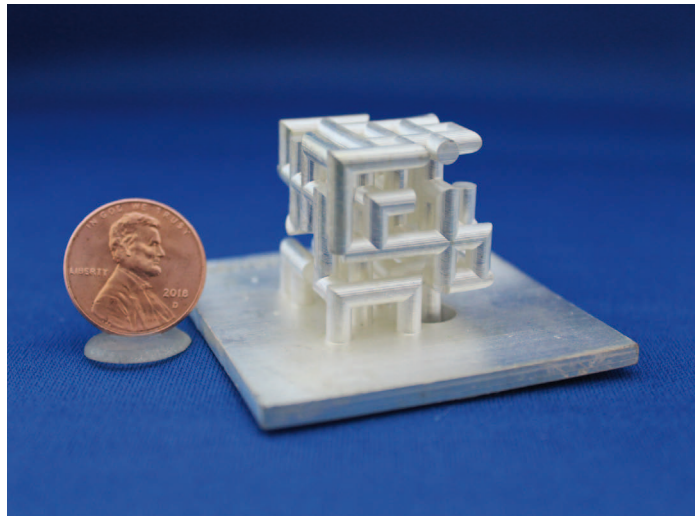


Figure 1: 3D-mesh antenna prototype (silver-coated).

**This application note presents a unique antenna design based on synthesis and simulation technologies made possible with the most recent capabilities found within NI AWR software.**

Advancing communication and sensor technologies for 5G, internet of things (IoT), and radar-enabled smart vehicle applications require more capable antennas and RF front-end components, pushing engineers to create novel designs based on evolving techniques and materials, advanced device integration, and greater exploration of the design space with unique topologies and architectures.

## Antenna Synthesis Example

To demonstrate the power of these emerging technologies, a 3D-mesh antenna was designed (Figure 1) using AntSyn software antenna design, synthesis, and optimization software, which utilizes genetic algorithms<sup>1</sup> and simulates on Amazon's computing cloud. A 3D-mesh antenna is in the class of evolved antennas consisting of the rod-shaped conductor (in straight or 90° bending), intersected in a way that is synthesized by a computer-aided design (CAD) program, s. references, which can then be imported into a 3D EM analysis program such as the Analyst finite element method (FEM) simulator for additional EM verification and tuning. 2

AntSyn software was designed by antenna engineers to be used by all levels of experience, from experts to those who are relatively new to antenna design. The self-guiding templates are intuitive and easy to use, supporting dozens of antenna types ranging from spirals to patch antennas to Yagi and Vivaldi styles. The straightforward design process starts with the creation of a new project and spec sheet, which enables the user to provide antenna specifications such as frequency band, target impedance match (return loss), gain pattern, and physical constraints and materials (if required). The antenna specifications ultimately impact the attributes of the antenna's physical design.

To generate a physical design that meets the requirements of the application, AntSyn software allows designers to specify key physical attributes such as the antenna axis, maximum size (bounding volume) on the antenna design, constrain the antenna geometry size, minimum and maximum dimensions for a ground plane, and dielectric material.

Synthesis results in a number of candidate antenna designs, each with an assigned quality rating that reflects how well the design met the antenna requirements. Users can review the results in the AntSyn software and then export any of the model

geometries to an EM simulator of choice for further analysis. The AntSyn software-generated structure and the resulting radiation pattern are shown in Figure 2.

The Analyst EM simulator offers a full-3D FEM solver technology with adaptive volumetric tetrahedral meshing, direct and iterative solvers, and discrete and fast-frequency sweeps. The software accurately and rapidly characterizes interconnect structures, dense circuitry, and antenna structures of all sizes, including patch antennas and antenna arrays on finite dielectrics, plot near- and far-field radiation patterns (Figure 3), and simulates key antenna metrics such as gain, directivity, efficiency, side lobes, return loss, surface currents, and more.

## Fabrication

The 3D-mesh antenna, due to its highly complex structure, can be costly and difficult to build using the traditional machining method, however, it can be easily realized with 3D printing. The antenna in this example was designed to be compatible with the 3D printer available to the authors, but smaller and more complex structures are possible with alternative 3D printers. The antenna was designed to operate between 5 and 5.1 GHz with gain >5 dBi on the boresight and >3 dBi to 45° off the boresight. For

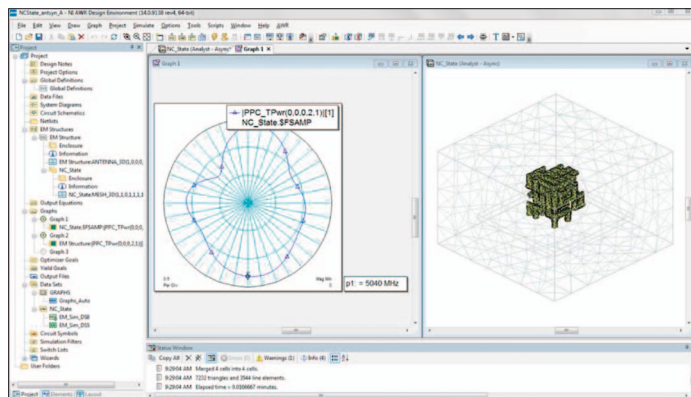


Figure 2: Synthesized antenna is imported into Analyst software for further EM analysis.

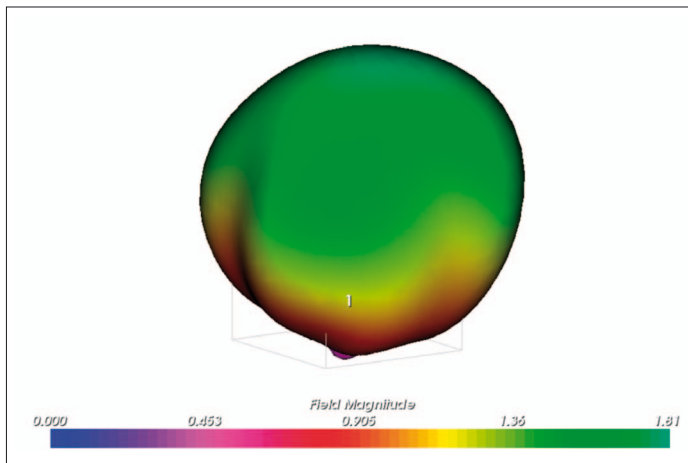


Figure 3: Far-field radiation pattern generated by Analyst software.

>135°, gain was <-10 dBi. The return loss across the frequency band was better than 10 dB and the overall dimensions (for printing) within 6 × 6 × 6 cm.

Figure 1 shows the AntSyn software synthesis result of the 3D-mesh antenna. The simulated return loss is better than 18 dB across the frequency band. The simulated gain of the antenna at the boresight is 5 dBi. The pattern tapers smoothly from the boresight to 90° off the boresight. The total model size is within 6 × 6 × 3 cm. All specifications met the requirements.

The fabrication process for the 3D-mesh antenna is shown in Figure 4. The AntSyn software model with minor modifications on the feeding port can be directly used for 3D printing. The input port of the antenna in the simulation model in Figure 4a was disconnected from the ground structures in order to manually add a coaxial connector port designed based on a standard SMA bulkhead mount connector. The model was 3D printed using a digital light processing (DLP) 3D printer and acrylate-based resin material. The resolution setting was 50 × 50 × 50 μm. A 45° orientation of the model was chosen, as shown in Figure 4b, allowing the number of external support structures to be minimized. The 3D printed antenna part was

metalized (Figure 4c) by using a method developed by the authors, s. references, which is an electroless plating process adapted for 3D printing material coating the surface with ~100 nm thickness of silver. The metal layer thickness was increased to ~30 μm by using electrolytic copper plating.

### Test

The fabricated antenna was then mounted on a rotary station in the anechoic chamber for the pattern testing (Figure 4d). The S-parameters, gain, and radiation pattern of the 3D-mesh antenna were measured and compared to the EM simulation result, as shown in Figure 5. The measured return loss shows the wideband matching from 4.6 to 5.4 GHz. The measured gain is around near 5 GHz. The measured patterns at E- and H-plane are consistent with the simulation result at 5 GHz. The discrepancy between the simulation and measurement could be raised by the dimension errors during the 3D printing process or the effect of coaxial feeding, which was not included in the simulation.

### Conclusion

A unique antenna design based on the new synthesis and simulation technologies within NI AWR software has been presented, which produces a high-performance, novel antenna

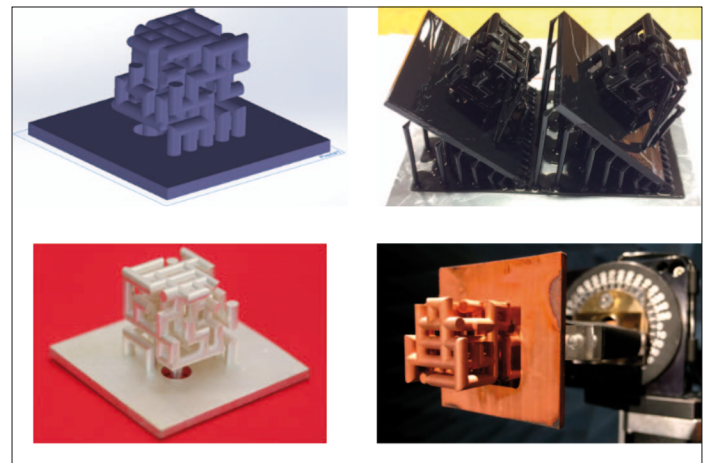


Figure 4: 3D-mesh antenna prototyping: a) CAD model, b) 3D printed antenna, c) silver-coated antenna, d) plated antenna under test (image courtesy of J. Shen and D. S. Ricketts).

through greater exploration of the design space than would be possible through older, traditional approaches. The simulated design provided the physical information required to create actual hardware through 3D printing.

The resulting measured versus simulated radiation data showed excellent agreement, further validating this approach for future antenna development.

### References

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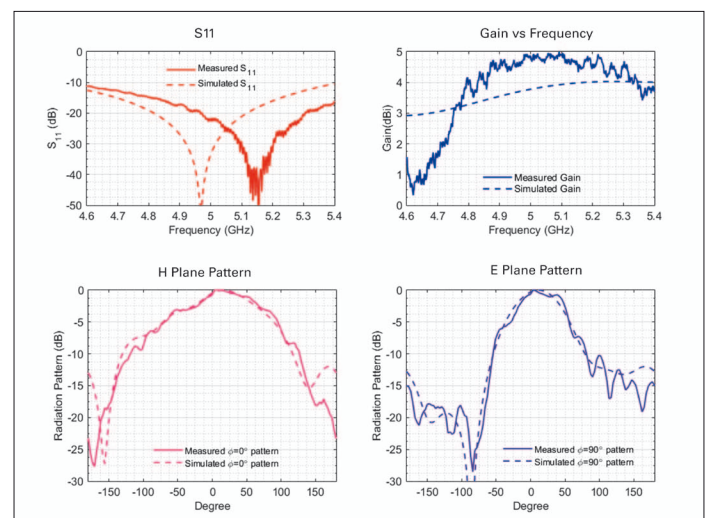


Figure 5: Comparison of measurement and Analyst result of the 3D-mesh antenna (image courtesy of J. Shen and D. S. Ricketts).