

Synthesizing MIMO Antennas for Compact Devices with AntSyn

Upcoming 5G and IoT devices will rely heavily on customized antenna solutions optimized for performance, cost, and size. Multiple-in-multiple-out (MIMO) is a technique that uses multiple antennas on a single device, thus providing greater throughput and performance reliability for wireless devices.

SpecSheet (xymesh demo incl mimo array>dual band mimo array 3port 5 shorts match-1)

Frequency

Band Start 2.4 GHz Stop 2.5 GHz Num Freqs Auto

Input

VSWR 2 Connected to Load Impedance: Z real 50 Ohms Z imag 0 Ohms

Max coupling to inactive ports: -15 dB

Geometry and Environment

Antenna axis points toward X Y Z

Dimension units: mm

Constrain Antenna Geometry (Applies to full antenna unless separate constraints are applied to Built-in Ground)

Max Shape: Box X 89 Y 20 Z 3 mm

Apply Separate Constraints to Built-in Ground

Built-in Ground Size Max Shape: Box X 90 Y 50 Z 3 mm

Built-in Ground Size Min Shape: Box X 90 Y 50 Z 3 mm auto

Location on Ground (if applicable): top_center (0, +Y)

Ground Type (advanced): auto

Infinite Ground

Mast/Standoff Min Max mm

Use dielectric, if applicable

Dielectric constant Loss tangent

Only design antennas that use a dielectric substrate

Matching Network

Use matching network Match each band separately

Elements 1 4

L 0.1 100 nH C 0.1 100 pF

Figure 1: AntSyn spec sheet for MIMO

However, this requires not only good antennas, but also high isolation between them. This can be achieved by separating the antennas but doing so can make the device quite large and/or require external antennas. High isolation can also be achieved between closely-spaced internal antennas by using chokes, matching networks, and other techniques, each having their own advantages and drawbacks.

Optimizing antennas by hand to meet multiple performance metrics such as impedance matching, coupling, radiation efficiency,

and operating bandwidth is a time-consuming process involving numerous iterative simulations and a significant amount of design knowledge. This application note presents an alternative method using NI AWR Design Environment platform, specifically AntSyn antenna synthesis module, which enables designers to synthesize compact MIMO antenna arrays automatically from user requirements, saving significant design time and allowing even inexperienced designers to design antennas that successfully meet size, cost, and performance requirements.

Antenna Design by Requirements

AntSyn software combines advanced optimization algorithms, expert systems, and electromagnetic (EM) simulation into a user-friendly tool that operates on a “what you want is what you get” principle, where the user inputs the antenna requirements rather than a (parameterized) physical design. For this application, the specifications are items like frequency band, target impedance match (return loss), size/form factor, and coupling. These requirements are

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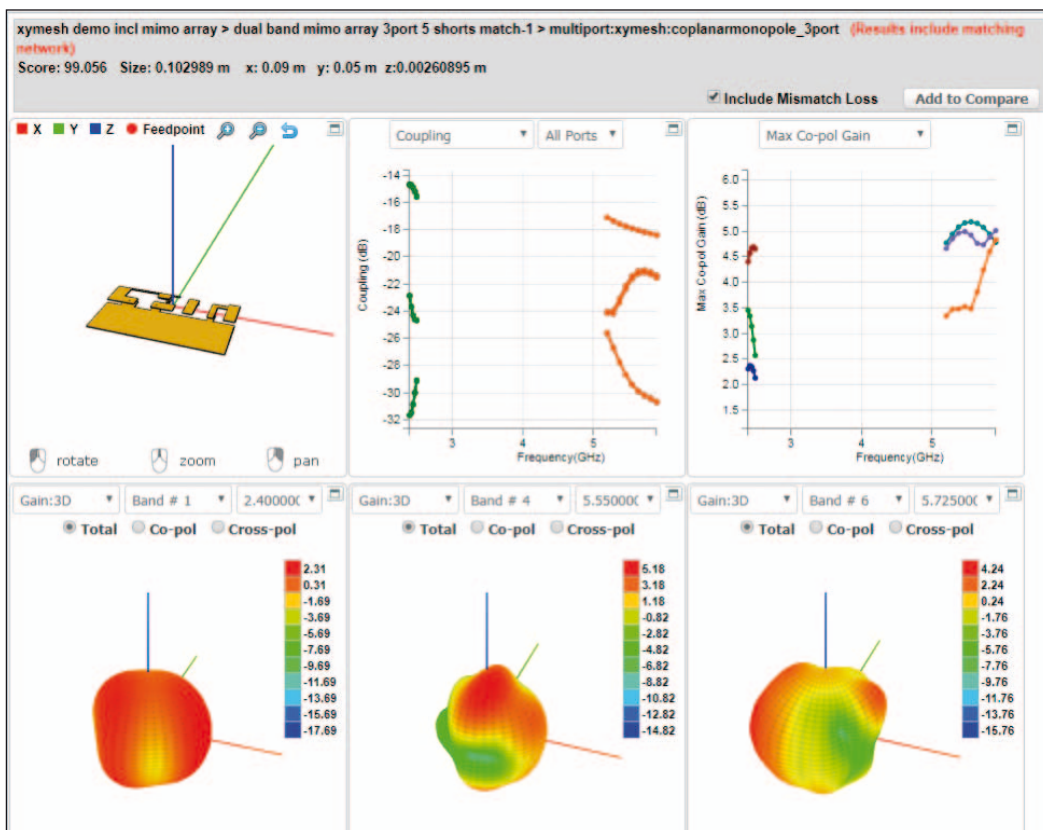


Figure 2: AntSyn software returns one or more optimized antenna designs

input into the intuitive “spec sheet” user interface, which is automatically organized into a project file. A partial spec sheet, showing a sample of the relevant specifications for MIMO, is shown in Figure 1.

By running the spec sheet, AntSyn software returns one or more optimized antenna designs, the results of which are viewed using a customizable dashboard for rapid evaluation, as shown in Figure 2.

The user-specified dashboard can be set to view the proposed 3D model, input impedance (match) versus frequency in several formats, maximum gain versus frequency, radiation pattern cuts, and qualitative star rating, all of which help identify good performers quickly. AntSyn software has been used to develop a wide range of antenna types such as single band, dual band, multi-band, broadband/ultra-wideband (>100:1), high efficiency, loaded, electrically small, phased array, wire, patch, conformal, handset,

horn, dual-polarized, and multifunction.

AntSyn software offers antennas and provides features that are made specifically to generate compact MIMO designs, including multi-function computer-generated mesh antennas with multiple ports, augmented matching network optimization that allows each port to be separately matched and optimized, and improved accuracy and features for ground planes.

The mesh antennas are particularly unique and flexible. They are a set of four antenna types, with either two and three ports (more ports to be supported). These ports can be independently assigned to different bands, which can have very diverse RF requirements such as different polarization, gain patterns, and frequencies. The antenna mesh is optimized by AntSyn software for the specifications given and it is sufficiently flexible to enable the software to essentially invent new antennas.



Figure 3: Sample mesh antennas

Images of these antennas are shown in Figure 3. The two standard versions of the mesh antenna can be placed on any corner or edge on the ground, or they can be placed in the center as shown. The ground can be solid beneath these antennas or it can be an optimized mesh as well. The coplanar monopole version does not have a ground beneath the mesh but is expected to project over one edge of the ground, which can be useful in many device applications.

The following examples use the coplanar monopole, which is known to have excellent bandwidth and flexibility for this application. The examples demonstrate how AntSyn software is able to use these antennas to synthesize high-performance MIMO arrays with good isolation and impedance matches.

Examples

AntSyn software was used to create both a two-port and a three-port MIMO antenna on a notional compact device. This notional device had the following characteristics and requirements:

- Dual-band WiFi
- 2.4 and 5 GHz bands
- IoT device package
- Compact, planar geometry
- Approximate size of a standard business card, 90 mm x 50 mm
- Antenna integrated with electronics
- Antennas placed along long edge

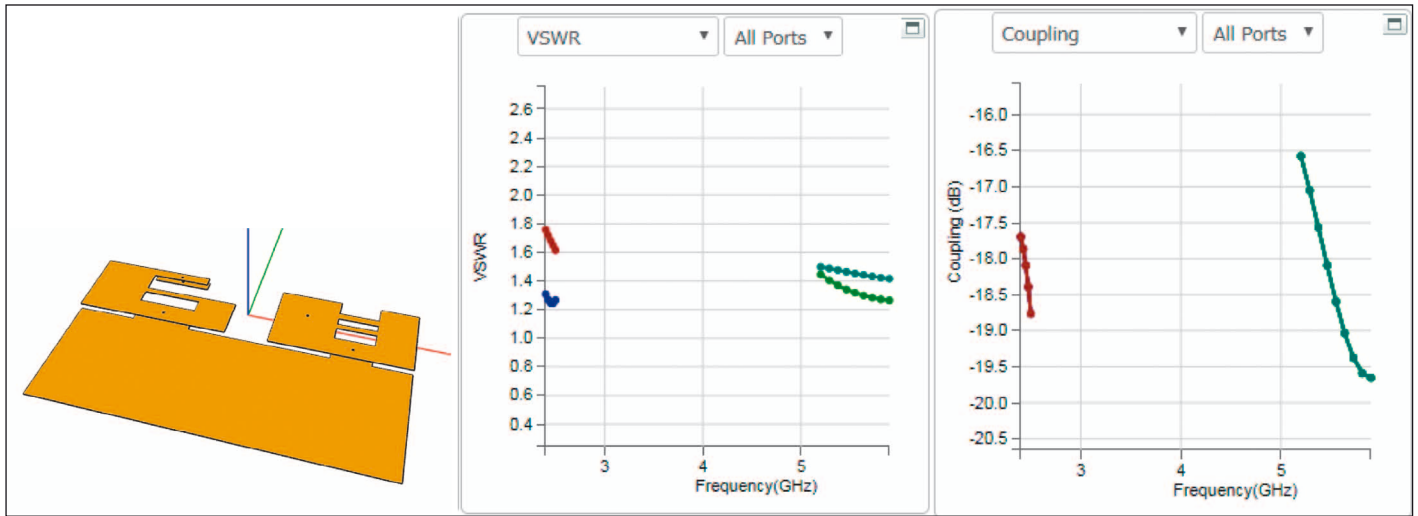


Figure 4: Two-port MIMO antenna with voltage standing wave ratio (VSWR) and coupling performance predicted by AntSyn software

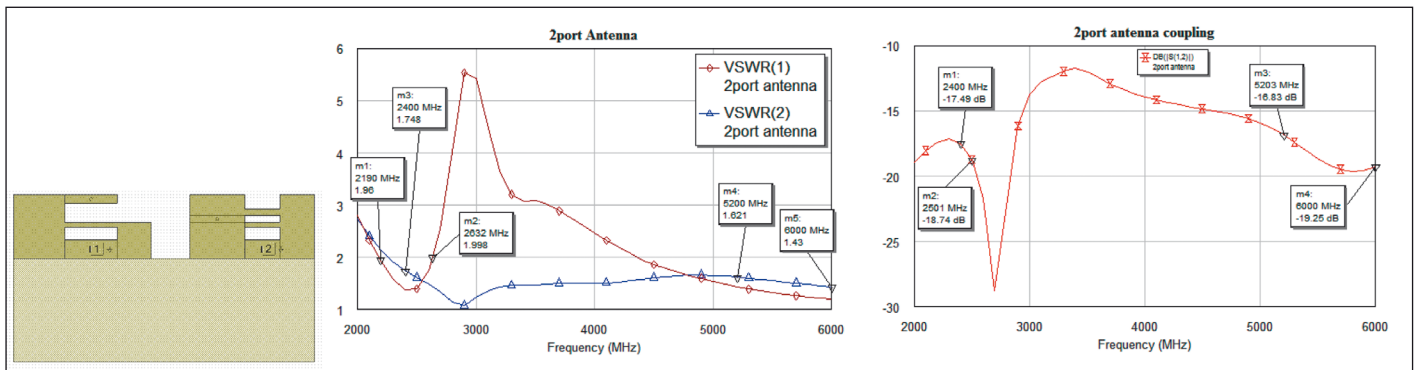


Figure 5: AXIEM simulation results

The MIMO device had the following characteristics:

- Two or three ports/antennas for transmit and receive on each device

- Maximized isolation between ports to create de-coupled channels

Two-Port MIMO

First, a two-port MIMO antenna using the multi-function mesh coplanar monopole type was

optimized using AntSyn software. The specifications shown in Figure 1 were used to define the desired performance of the MIMO antenna in this example

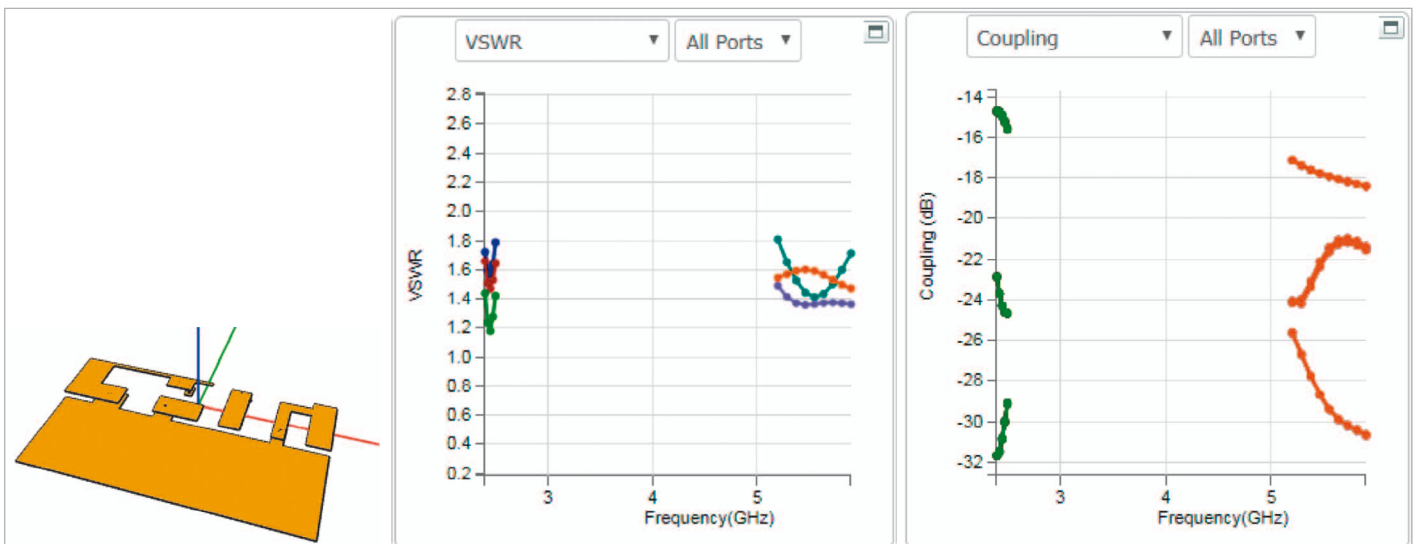


Figure 6: Three-port MIMO antenna performance as predicted by AntSyn software

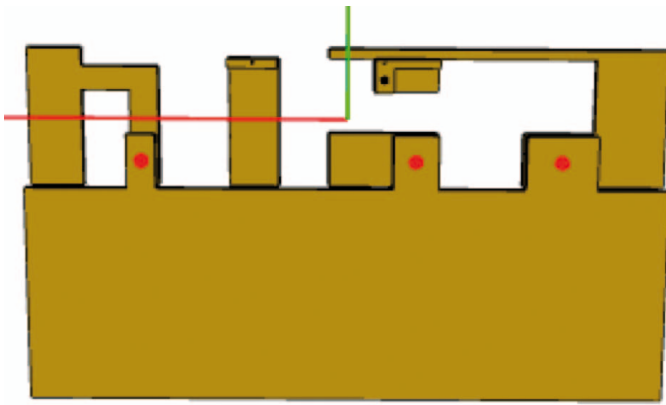


Figure 7: Bottom view of three-port MIMO antenna

(note - with the exception that a matching network was not used). This particular antenna used air as its dielectric. The resulting antenna and its predicted performance is shown in Figure 4.

This antenna has reasonably good standing wave ratio (SWR) and isolation performance for the dual-band WiFi frequencies for both ports, with a maximum SWR of about 1.8:1 and a maximum coupling of about -16.5 dB. At the lowest frequency, the

antenna edges are separated by less than 0.093 wavelengths and the ports themselves are only 0.41 wavelengths apart. As can be seen, the shapes of these two elements have some similarities, but are not identical. This is expected and helps improve the isolation.

This antenna was imported into NI AWR Design Environment, specifically Microwave Office circuit design software, and further simulated using AXIEM

3D planar EM solver across the full range of frequencies from 2 to 6 GHz. The results, shown in Figure 5, match well with AntSyn software predictions, with worst-case coupling of -16.8 dB. Note that although coupling and VSWR do rise in between the Wi-Fi bands, in-band performance is very good.

Three-Port MIMO

AntSyn software was also used to optimize a three-port antenna using the specifications and size limitations shown in Figure 1. This time, a matching network was used to help improve performance with the tighter spacing.

The maximum VSWR was about 1.8:1, while the maximum coupling was -14.7 dB, which occurs between the two ports that are closest together, shown in Figure 6 as the right and center ports. Note that the spacing is only 0.163 wavelengths (at 2.4 GHz) between these ports, with a minimum spacing of 0.048 wavelengths between the elements. The distance from the center to

the left port in Figure 7 is also only 0.31 wavelengths.

The shapes of these antennas are even more diverse than the two-port antenna. Essentially, AntSyn software created a different antenna for each port and a parasitic fence was placed between the center and left ports. All this complexity was created automatically by AntSyn software, demonstrating the inherent strength and robustness of the genetic algorithm to fully explore more of the design space and produce optimal performance MIMO antennas.

Conclusion

Demand is escalating for high-performance, low-cost antennas to provide reliable connectivity for upcoming 5G and IoT wireless devices. AntSyn software enables designers of antennas, including compact MIMO arrays, to address the challenges of next-generation antenna design and integration within mobile devices and IoT components. ◀