Design Example:

MIMO Dualband WiFi Antenna

This article describes the design of an electrically-small antenna project for WiFi applications.

Multiple-in-multiple-output (MIMO) antenna technology is regarded as a key technology enabler for mobile radio services because of its ability to multiply the capacity of a radio link using multiple transmit and receive antennas, thus exploiting multipath propagation. A dualband WiFi antenna was recently developed through the collaborative efforts of three companies specializing in electronic design automation (EDA) software and dielectric materials.

This article describes the design of an electrically-small antenna project for WiFi applications using the NI AWR Design Environment platform, specifically the AXIEM 3D planar electromagnetic (EM) analysis simulator, as well as the AntSyn automated antenna design, synthesis, and optimization tool, along with Optenni Lab RF design automation platform for the antenna system optimization, and Premix Group's PREPERM dielectric plastic materials for the antenna and its feed network. To minimize the losses at higher frequency bands, a high-quality dielectric material was first selected. The design process is shown in Figure 1.

Design Flow

A dualband MIMO WiFi antenna and associated matching circuitry operating at 2.4 and 5 GHz was designed, the purpose being to exercise materials and techniques to demonstrate antenna designs at S and C bands that could be leveraged and scaled for future millimeter wave (mmWave) stationary and mobile platforms at higher frequencies. PREPERM PPE370, which has a dielectric constant of 3.7 was used for the antennas. The associated matching circuitry was designed on PREPERM 255 with dielectric constant = 2.55. The PPE370 contains more ceramic filler than PREPERM 255 in order to obtain a higher dielectric constant. The substrate size was 90 x 50 mm and the nominal frequencies were 2.4 and 5...6 GHz. To enhance isolation, a decoupling network was designed between the two antennas. An overall efficiency of -2 dB or better was achieved.

Efficiency is defined as:

$$\eta = \frac{R_{rad}}{R_{rad} + R_{loss}}$$

R_{rad} ... radiation resistance

R_{loss} ... loss resistance which includes loss in the antenna structure and loss in the matching circuit R_{loss}

The initial designs (Figure 2) were developed using the AntSyn antenna synthesis module, which has a unique capability to synthesize antenna geometries to a given specification. The performance metrics used were pattern efficiency and impedance match. No specific gains were given

Original: MIMO Dual-Band WiFi Antenna Using NI AWR Software, Optenni Lab, and Premix PREPERM Materials by Jaakko Juntunen, Optenni Ltd; Jan Järveläinen, Premix Group; Derek Linden, AWR Group, NI

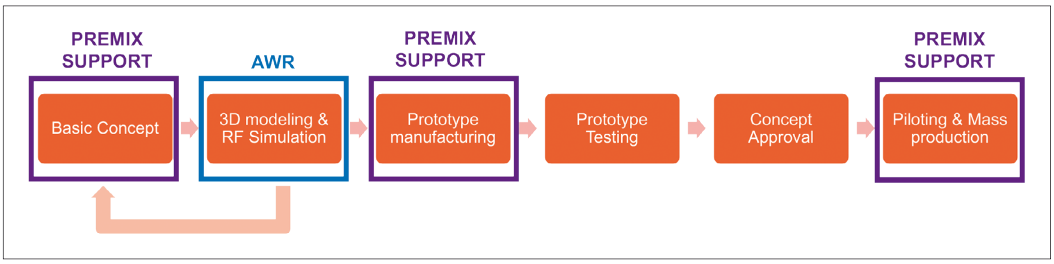

Figure 1: Example of prototyping with Premix PREPERM and NI AWR software

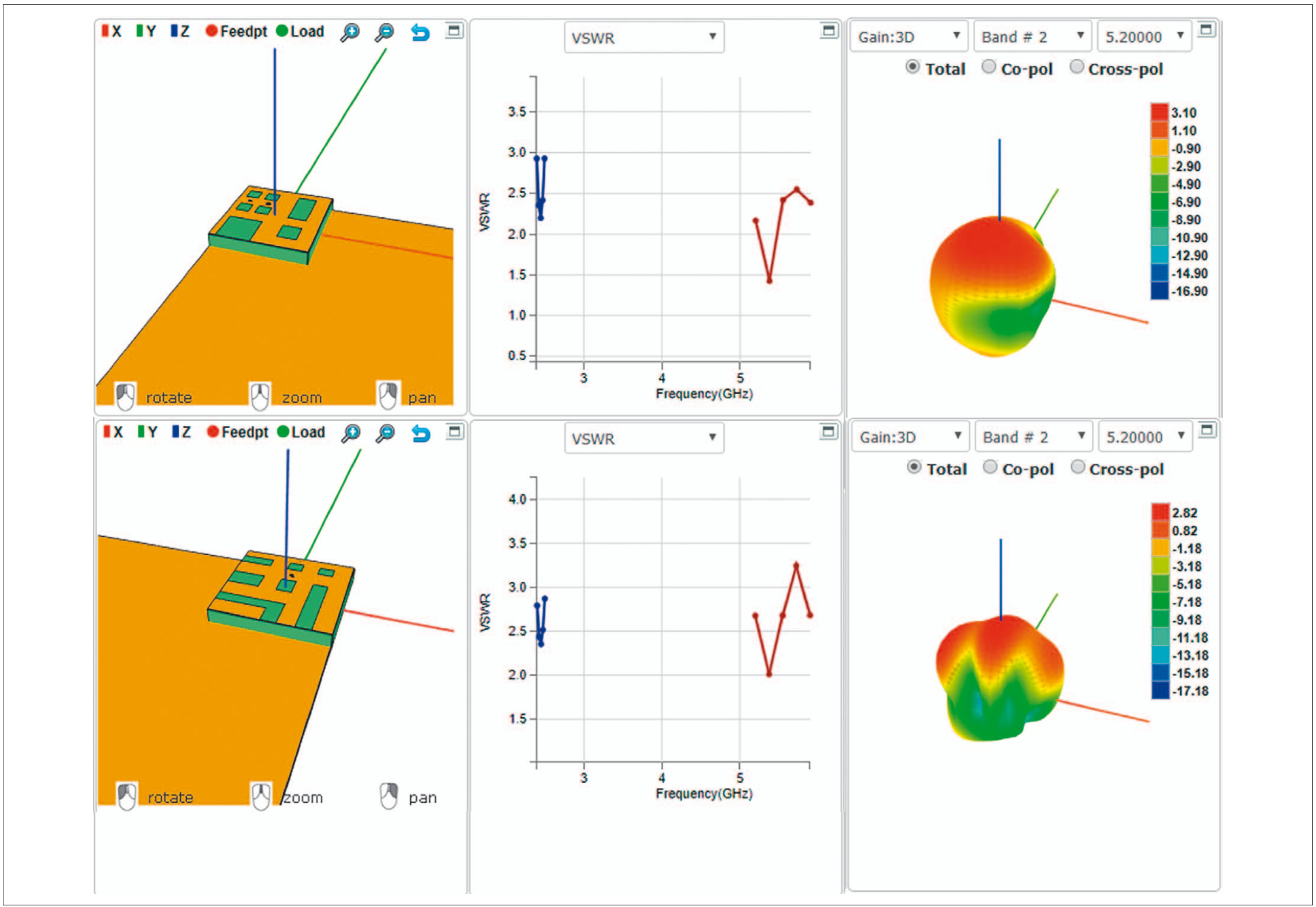

Figure 2: The antennas were synthesized using AntSyn according to the specifications

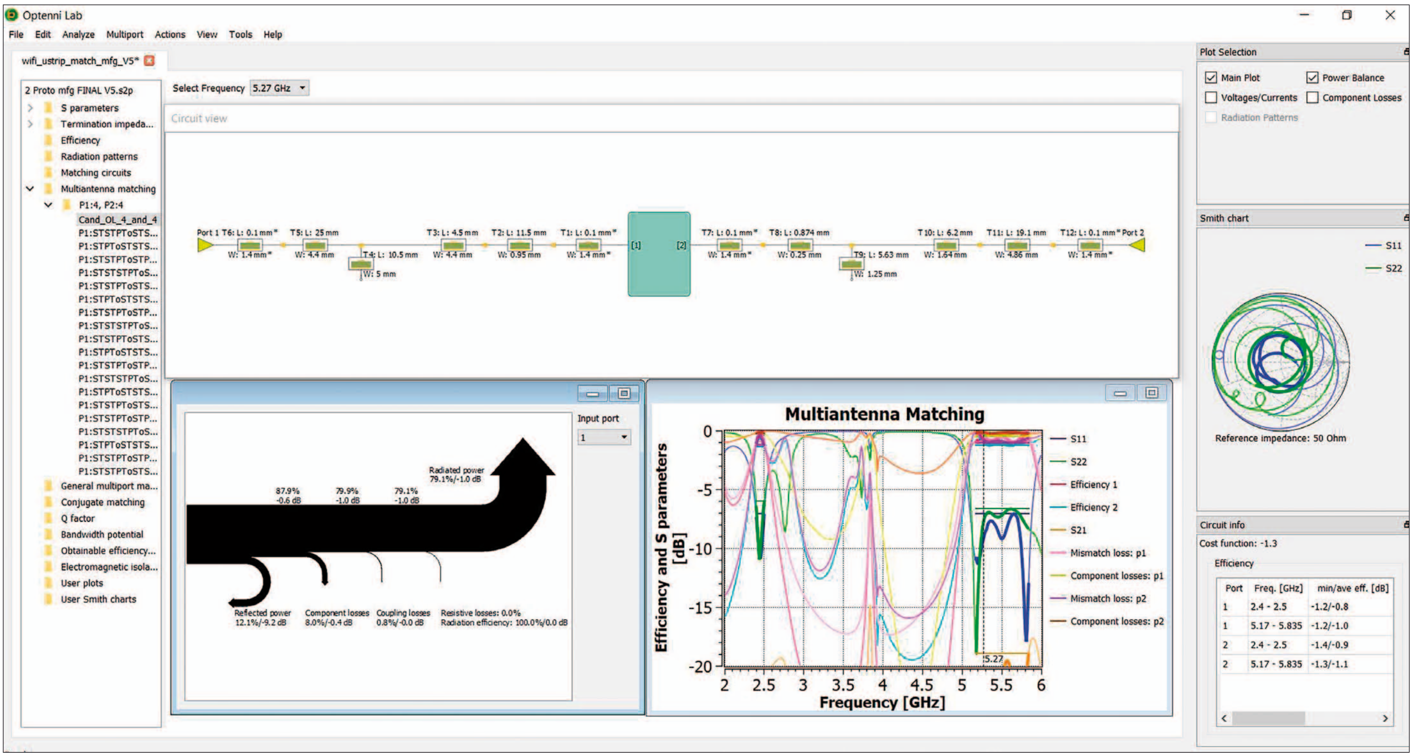

Figure 3: Optenni Lab synthesizes automatically many microstrip matching circuits that optimize the total efficiency. The circuits proposed by Optenni Lab were implemented in the prototype

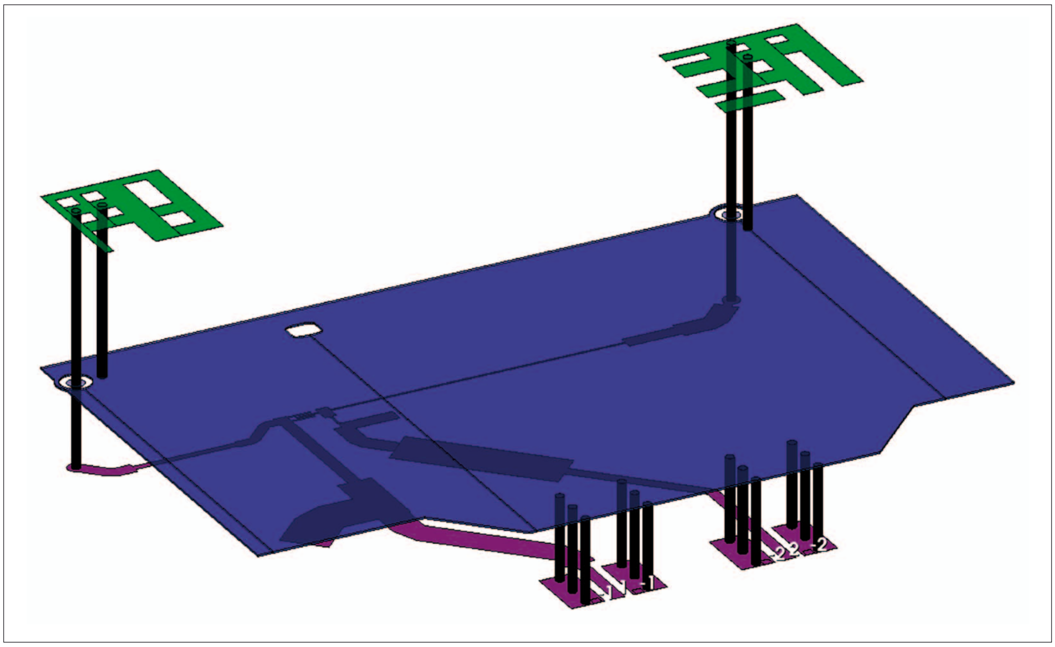

Figure 4: AXIEM layout showing the placement of the antennas (green) and matching circuit with feed network

Figure 5: Anritsu ShockLine MS46322B series 2-port VNA used for the measurements of the prototype

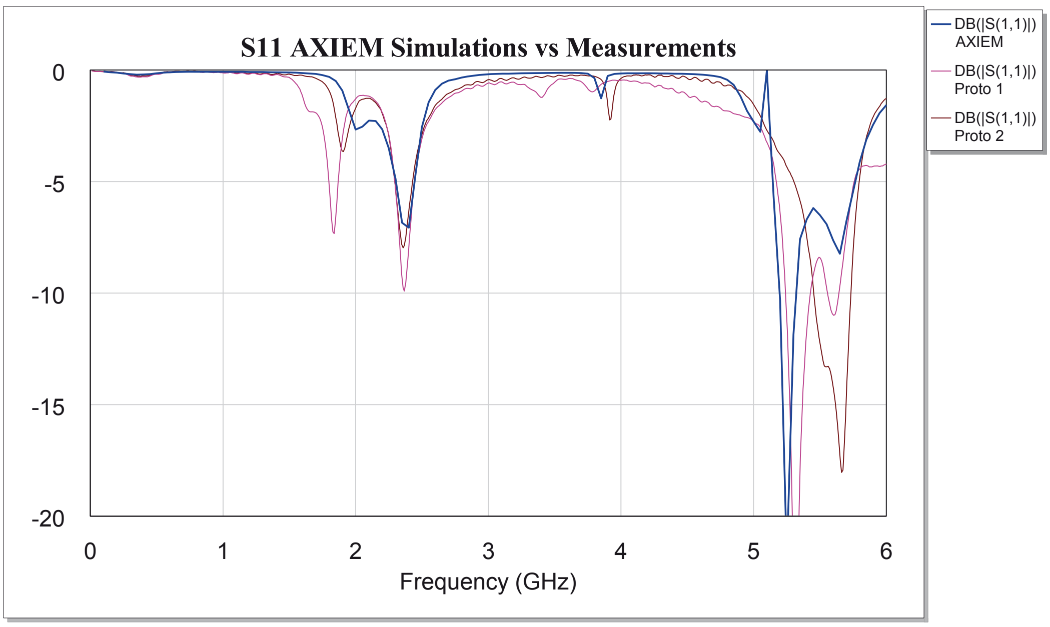

Figure 6: Predicted versus measured performance up to 6 GHz

as the antenna size was electrically small, thus, the pattern was more or less omnidirectional by default. The emphasis on each metric was balanced in the optimization process, however, the better the impedance match, the better the efficiency would tend to be, so in reality the two criteria were highly related and mutually cooperative.

With a dualband requirement, not only was the optimization process more complicated, but also each run took longer to complete. However, while a singleband antenna would have been easier to optimize, with better performance in just one band of interest and smaller size, there was not enough space on the device to accommodate four single-band antennas (two bands times two antennas each). In addition, using multiple singleband antennas would require the addition of diplexers that would increase loss, size, and complexity and might not perform as well for diversity/MIMO channelization as coupling might increase.

About a dozen AntSyn software runs were conducted to explore the trade space and determine what size, height, and RF parameters would yield the best result. Many of the runs were conducted to optimize the tradeoff between size and performance. AntSyn software uses a proprietary advanced genetic algorithm to synthesize antennas that employs an iterative process, enabling the tool to search very difficult and general design spaces with multiple performance criteria. Full 3D simulations are used to calculate the performance of each design. (Note: At the time this design was synthesized, each antenna had to be optimized separately, but AntSyn software can now optimize multi-port antennas like this all at once and can include coupling as a metric.) The AntSyn results were almost sufficient for design closure, however the antennas were fed individually and orthogonally through the PREPERM substrate, which had a solid ground plane. This

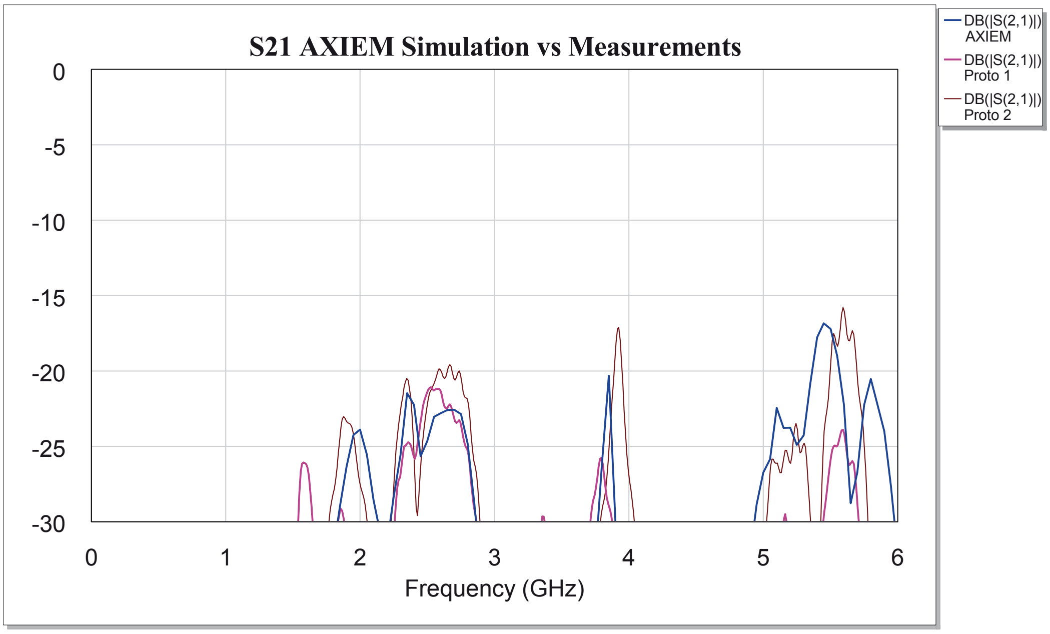

Figure 7: Predicted versus measured performance up to 6 GHz

introduced some performance changes that required slight printed-circuit modifications.

The synthesized antenna design was then exported to Microwave Office circuit design software and simulated using the AXIEM planar method-of-moments (MoM) EM solver. A matching network (Figure 3) was designed using Optenni Lab and then fine-tuned with the AXIEM simulator.

It was decided to place the matching circuitry on an inverted substrate on the opposite surface from the antennas.

Addition of the supporting substrate layer detuned the antennas, thus Optenni Lab was again used to synthesize and retune the matching circuits, and the performance of the resulting structure was validated with an AXIEM simulation (Figure 4.) A decoupling structure was also implemented to improve the isolation at 2.4 GHz, which somewhat complicated the microstrip feed circuitry.

High isolation between ports was desirable, therefore the circuitry was tested up to 6 GHz. Return loss on the respective ports was 20 dB (1.22 standing-wave ratio while isolation was at least 16 dB. For bandwidth considerations, 10 dB was deemed an acceptable return loss.

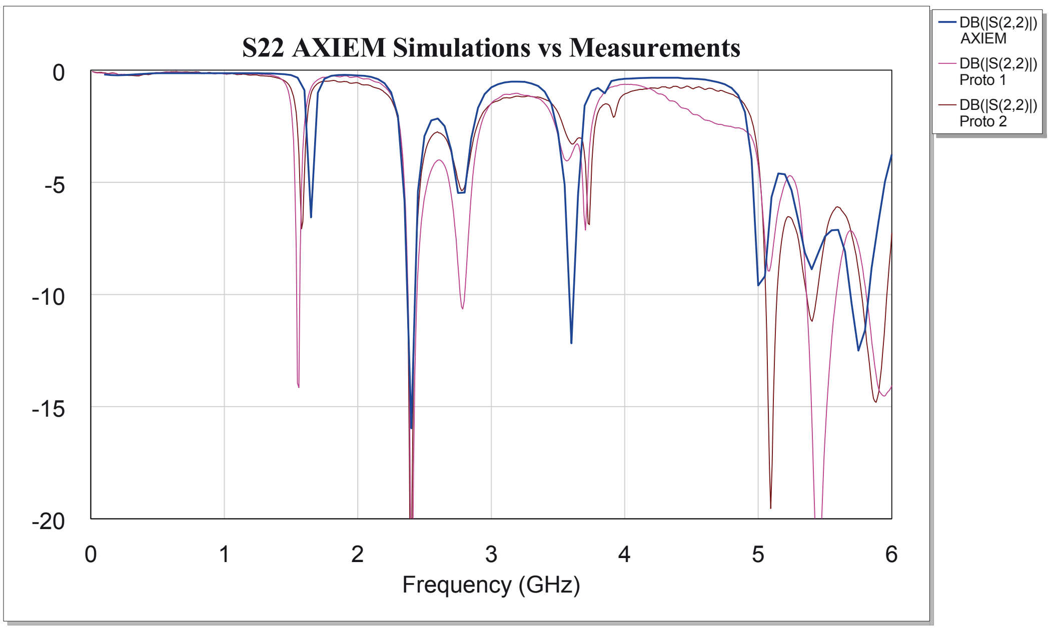

Figure 8: Predicted versus measured performance up to 6 GHz

Antenna gains of 2.5 to approximately 5 dB were realizable. The radiation pattern is basically omnidirectional with spherical coverage, with examples shown in Figure 2.

Simulated Versus Measured Results

In order to verify the simulation results, two prototypes were manufactured. The PREPERM 255 and PREPERM PPE370 sheets were first metallized from both sides with roughly 18 µm thick copper. The metallized sheets were then cut to the correct substrate size and the antenna patterns and matching circuitry were obtained by etching. Finally, the PREPERM 255 and PREPERM PPE370 substrates were combined.

The antenna measurements were performed with the Anritsu ShockLine MS46322B series 2-port vector network analyzer (Figure 5). The measured data agreed well with the AXIEM EM simulation. This confirmed that the PREPERM material properties such as dielectric constant, were well established. Figures 6, 7 and 8 show the predicted versus measured performance up to 6 GHz.

Conclusion

A complex dualband WiFi MIMO antenna was simulated, designed, built, and tested using NI AWR software tools and Optenni Lab. The antenna system had an efficiency better than -2 dB and antenna-to-antenna isolation better than -20 dB for all frequencies at 2.4 GHz and 5 GHz WiFi bands (except isolation degradation to -17 dB for one of the prototype samples for a narrow band around 5.6 GHz). The PREPERM materials have essentially constant permittivity and ultra-low loss (the loss tangent at 2.4 GHz is 0.0009 for both materials) up to mmWave frequencies, so a similar design process as outlined here could be applied to any other frequency band as well, such as the mmWave bands in 5G networks. ◄