Microwave Simulation, Macro Benefits

Electromagnetic simulation finds applications in high-performance antenna systems and electronics.

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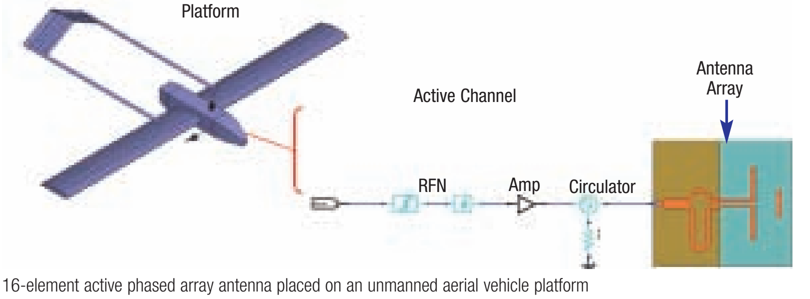
Engineers have long relied on Maxwell's equations to model the high-frequency performance of wave-guiding structures, such as stripline and microstrip transmission lines, connectors and coaxial lines. Analytical expressions for specific discontinuities, such as the impedance step, open- and short-circuited lines, coupled lines, bends, gaps and junctions, are used by microwave engineers to create matching networks, couplers, power distribution networks, filters and antennas. In the final layout, these models may couple to one another through parasitic electromagnetics, thus creating circuit performance that is different than was intended. Additionally, an engineer may wish to create new components for which there are no available models in the circuit library.

For these and other reasons, electromagnetic field solvers were created that allow the direct solution of Maxwell's equations to extract accurate models of distributed and parasitic effects. The best electromagnetic simulation tools are capable of full 3-D simulation, allowing engineers to design, analyze and refine microwave components virtually, avoiding costly and time-intensive prototypes and experimental work. Engineers use these tools for Simulation Driven Product Development in order to visualize the electromagnetic fields in their device, understand the device's electrical behavior to an unprecedented degree, and build virtual products that work as predicted when manufactured.

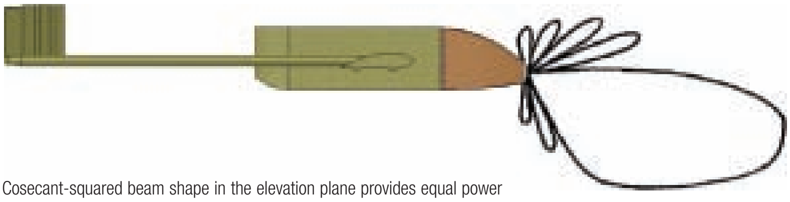


16-element active phased array antenna placed on an unmanned aerial vehicle platform

Today's microwave and radio frequency (RF) design challenges go far beyond the addition of a few electromagnetics-based models to a circuit. The trend in RF, microwave and high-performance electronics product design is toward accurate prediction of comprehensive system-level behavior with electromagnetic simulation at the core. Engineers now simulate larger and more sophisticated design problems. For phased array antenna systems, for example, designers can simulate the antenna elements as well as the supporting feed network and active circuits behind the array. Other antenna system designers are focusing on the environment in which the antenna operates — the performance of an antenna beneath a radome, for example, or the interaction of a mobile handset and the body of an automobile.

A phased array antenna system, like those on an unmanned aerial vehicle, presents an excellent case study that illustrates the larger system-level designs that are possible today. The ultimate goals of the simulation are to design the antenna and its electronic feed network and then integrate the antenna subsystem into an unmanned aircraft.

Ideally, the ground-mapping X-band antenna system would deliver a flat, equal power versus distance radiation pattern. Achieving the shaped beam is highly dependent upon very precise control of the relative amplitude and phase at each element. This control is often limited by the performance of nonlinear, real-world power amplifiers. To achieve the desired radiation pattern, each antenna in the array receives a different amplitude and phase. As a result, amplifier gain compression will vary among the transistor-based amplifiers in the array. A typical power amplifier will produce a fixed gain and flat phase as a function of input power until a certain point is reached. It cannot produce ever-increasing output power as the input power is increased. Eventually, the device exhibits nonlinear behavior, and its output power compresses while the gain decreases. Using the Nexxim results from harmonic balance circuit simulation of a simple bipolar junction transistor (BJT) power amplifier circuit,



Cosecant-squared beam shape in the elevation plane provides equal power illumination versus distance for ground mapping radar.

the resulting plot of the circuit gain versus input power shows that the gain is nearly constant until roughly -8 dBm input. Beyond -8 dBm, the gain rolls off quickly.

Transmit power is important to the design of an airborne radar system. Greater power translates into a longer range over which the aircraft can sense aggressors and targets. However, increased power also may result in undesired degradation to the radiation patterns caused by nonlinear behavior of the power amplifiers.

Ideal elevation plane radiation pattern exhibits a shaped-beam region to provide equal power illumination on the ground. Ripples in the main beam are permitted to make the array excitation more realizable. In this case, the pattern's first four side lobes were suppressed to -30 dB to avoid radiation along and above the horizon. To achieve this pattern, a very specific amplitude and phase distribution along the array was required. Indeed, the amplitude distribution has a dynamic range of over 15 dB. As the input power to the feed is increased, some of the power amplifiers will experience gain compression before others, thus disrupting the prescribed distribution, which in turn degrades the far-field radiation pattern. When the input power increases over 10 dBm, simulation within the Ansoft Designer environment shows that the shaped main beam region is mostly unaffected. However, the first four side lobes begin to rise above the -30 dB level. When the input power reaches 14 dBm, the far-field shows significant degradation due to the nonuniform gain compression across the array.

Powerful 3-D electromagnetic field solvers have long been used by engineers to design complex microwave components. These solvers continue to transform and extend product design, especially when linked with advanced circuit simulation. RF, microwave and high-performance electronics product design now demands accurate prediction of system-level behavior and can include rigorous electromagnetic simulation at the core. Simulations of an active-phased-array antenna system were performed using coupled harmonic balance and finite element simulation.

The effect of the nonlinearities of the transmit power amplifiers was observed to degrade the far-field radiation pattern as the input power was increased. This advanced simulation method allows engineers to fully understand the effects of electromagnetics and nonlinear circuits so that specific design choices can be made. ■

References

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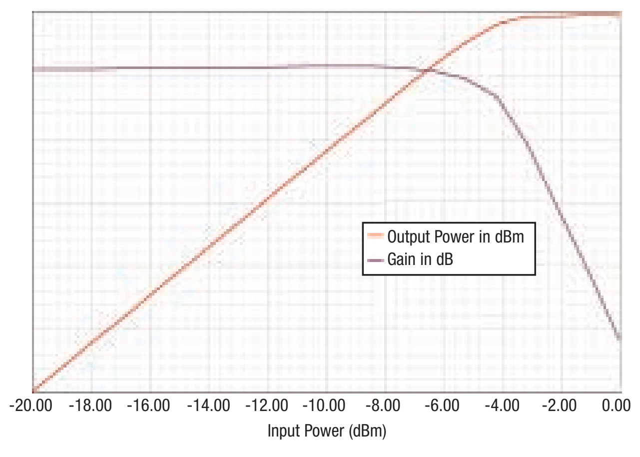
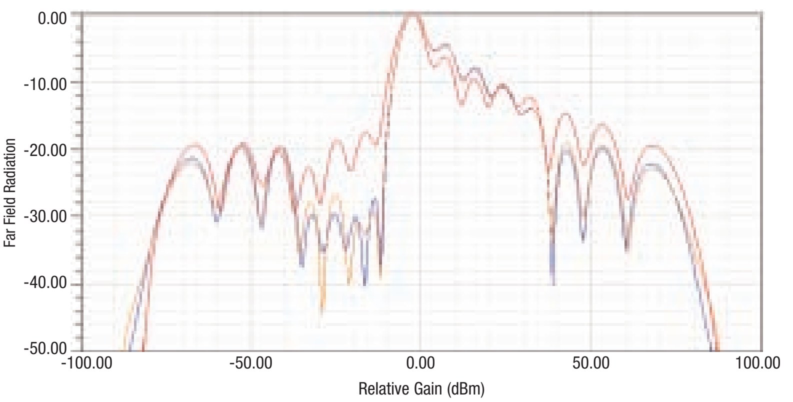


Plot of gain and output power as a function of input power, at 10 GHz, demonstrating gain compression



Far-field radiation simulation using HFSS software (elevation cut) for 0 dBm (blue), +10 dBm (orange) and +14 dBm (red) input. At 0 dBm, the pattern's first four side lobes are suppressed to -30 dBm to avoid radiation along and above the horizon. At higher inputs, the far-field radiation rises above the -30 dBm level, increasing aircraft visibility and vulnerability.