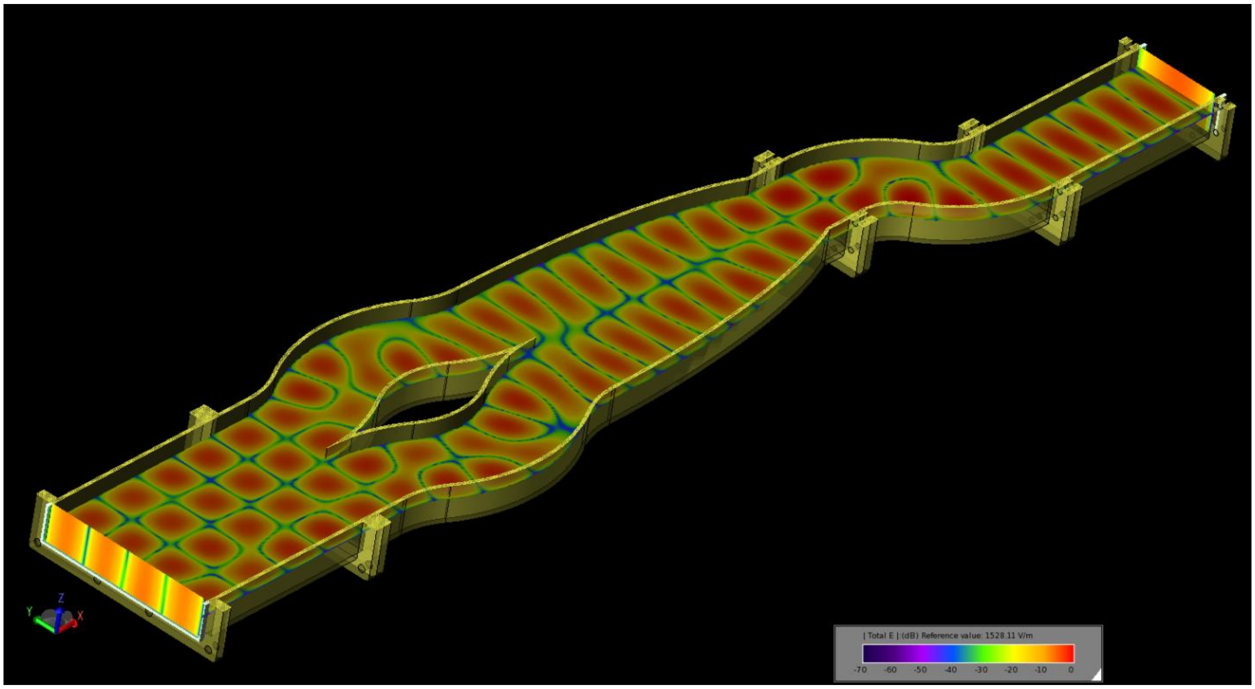

Figure 6.20 — A complex rectangular waveguide mode converter as analyzed by FDTD. Electric field is shown with red (or bright) indicating high field strength. Input is on the right. [Courtesy Remcom, used with permission]

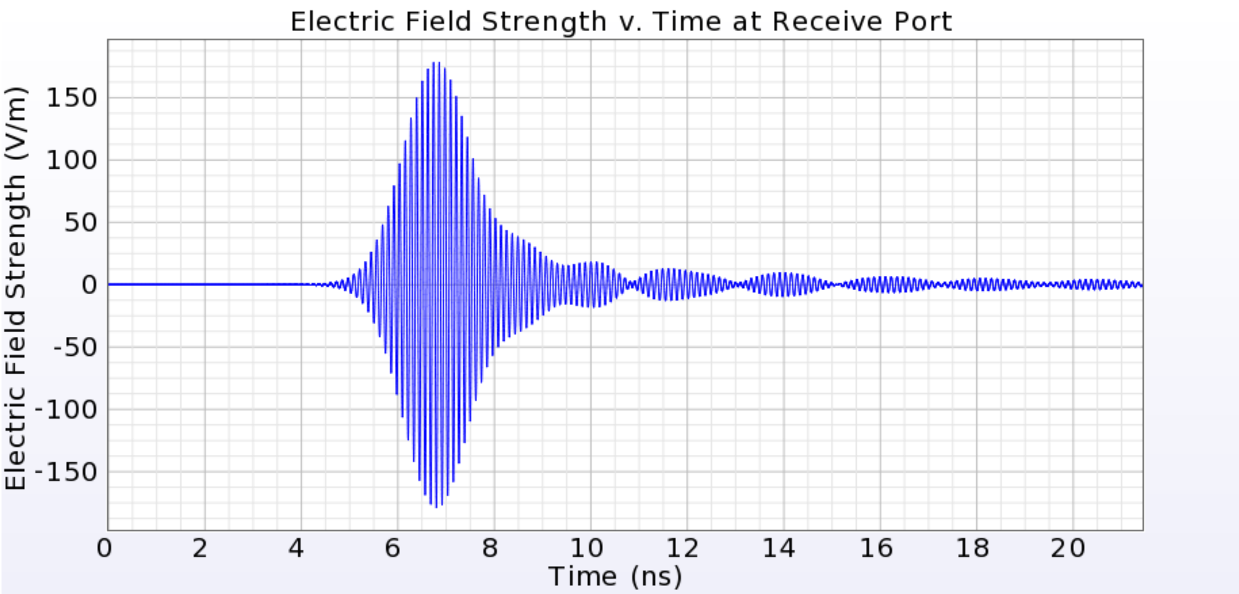

Figure 6.21 — The FDTD calculated time-domain response to a brief RF pulse on the input of the mode converter of Figure 6.20 resembles the ringing of a bell. This is called the "impulse response". [Courtesy Remcom, used with permission]

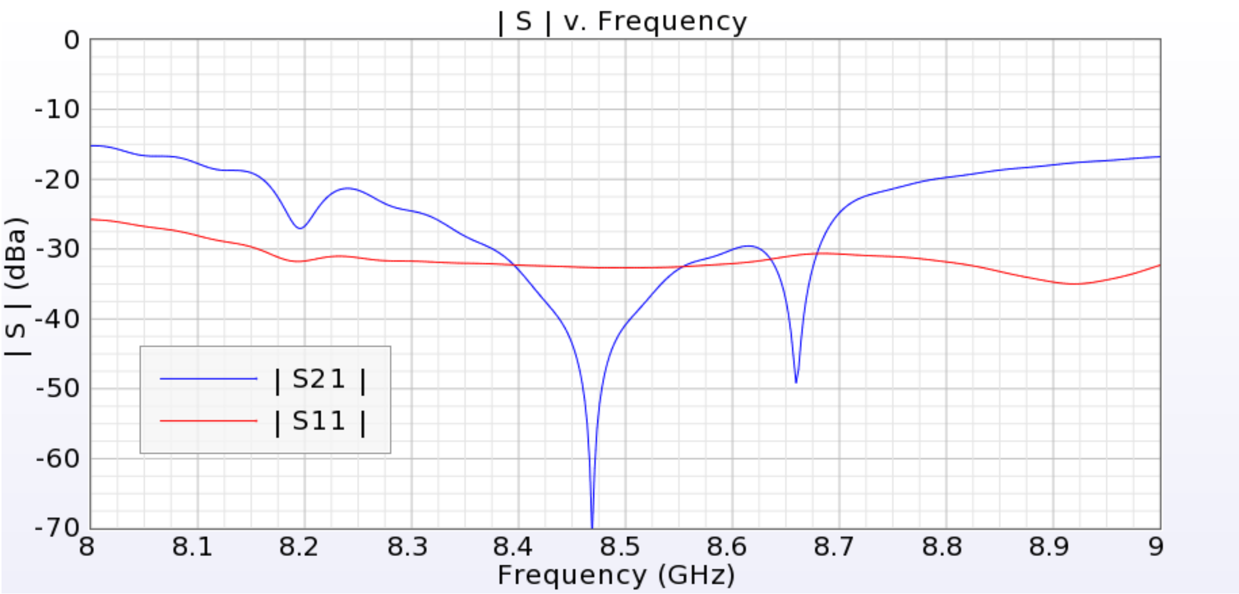

Figure 6.22 — Performing a Fourier transform on the circuit response is equivalent to using a spectrum analyzer to see the frequency domain response of the mode converter given the broad band impulse used to excite the filter. [Courtesy Remcom, used with permission]

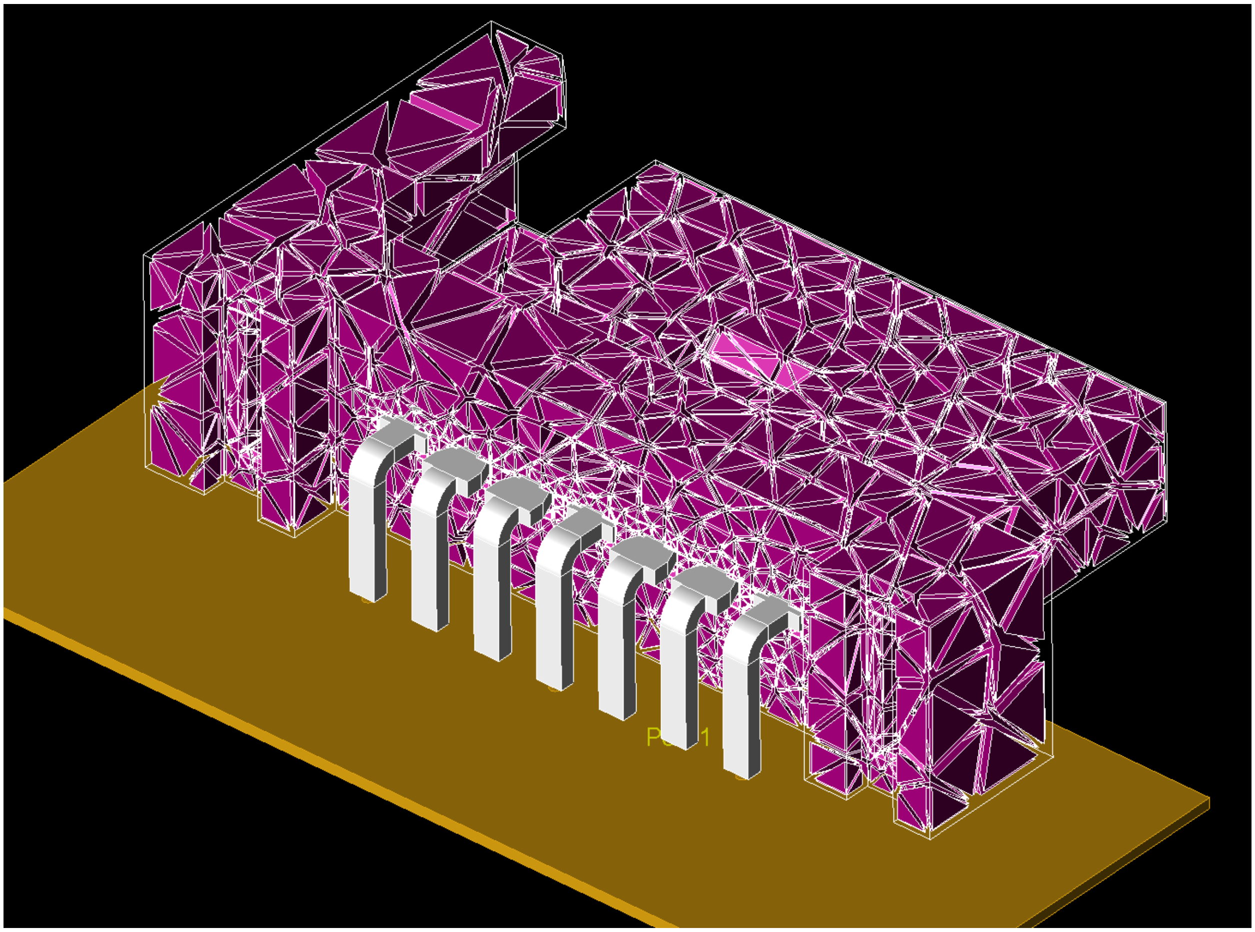

Figure 6.23 — Extremely arbitrary structures can be analyzed with FEM. Here we see the meshing for a PCB multi-pin connector. High accuracy analysis at high frequency is critical when high performance is needed. The entire volume is meshed with tetrahedra. For clarity, the tetrahedra used for meshing are outlined only where they intersect with a surface of the connector. [Courtesy Keysight, used with permission]

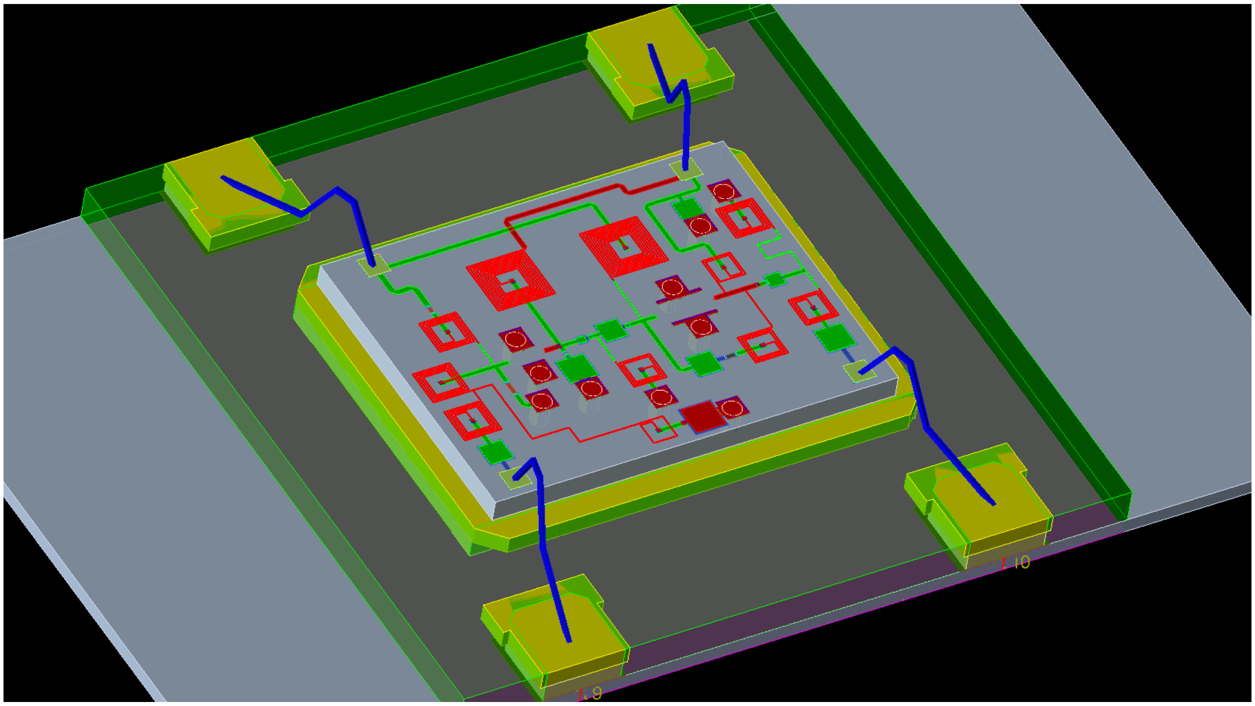

Figure 6.24 — This RF integrated circuit is mounted on a carrier with wire bonds making connections to the outside world. This is a view of the circuit prior to meshing. FEM can analyze the entire structure including all electromagnetic interactions. [Courtesy Keysight, used with permission]

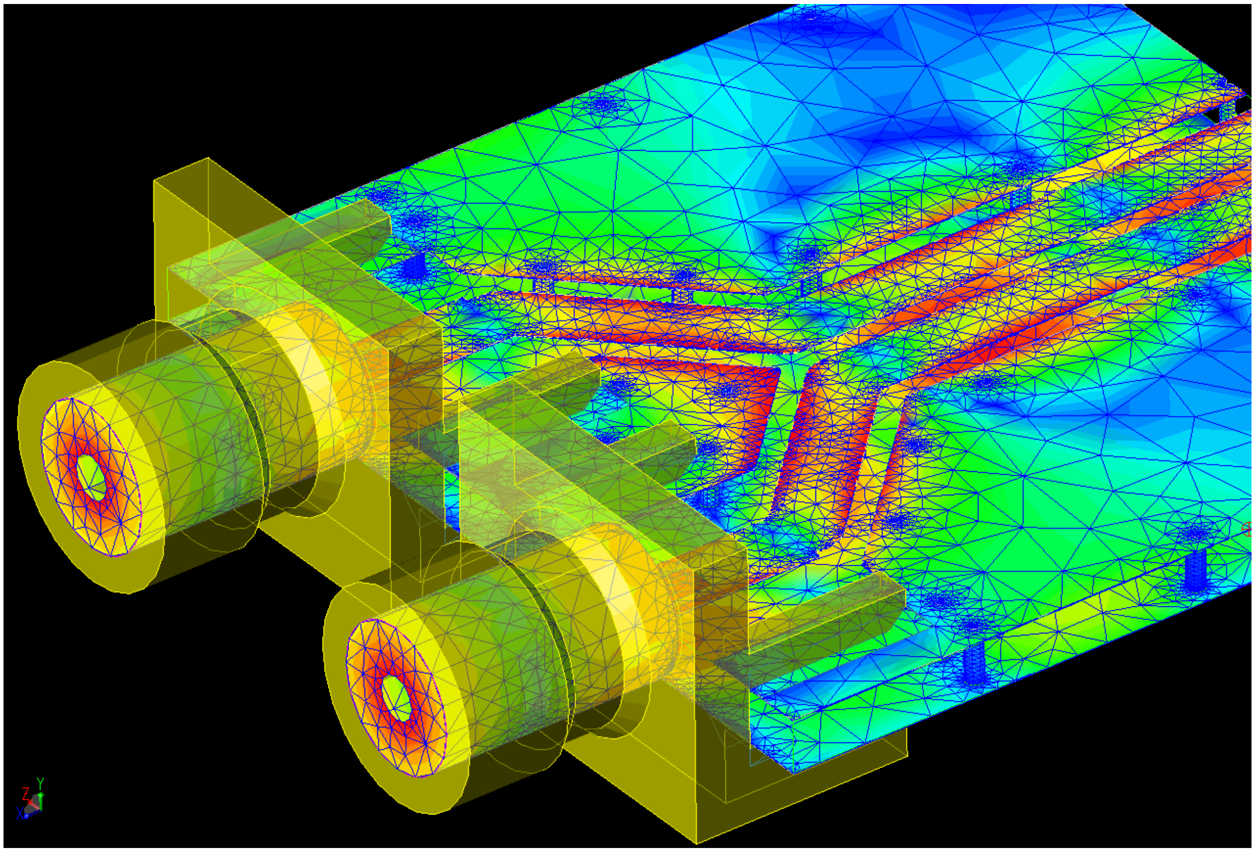

Figure 6.25 — FEM has meshed a circuit with two coaxial connectors transitioning to two PCB conductors. The PCB conductors then come close to each other to form the start of a coupled line. The color coding shows current density on the conductors with red (or bright) indicating high current. This includes a ground plane on the underside, which we can see through the narrow slots between the PCB conductors and the ground plane that surrounds them on the top side of the substrate. This is known as CPW, or coplanar waveguide. Note that the current is smooth with high current on the edges, indicating a high quality result. [Courtesy Keysight, used with permission]

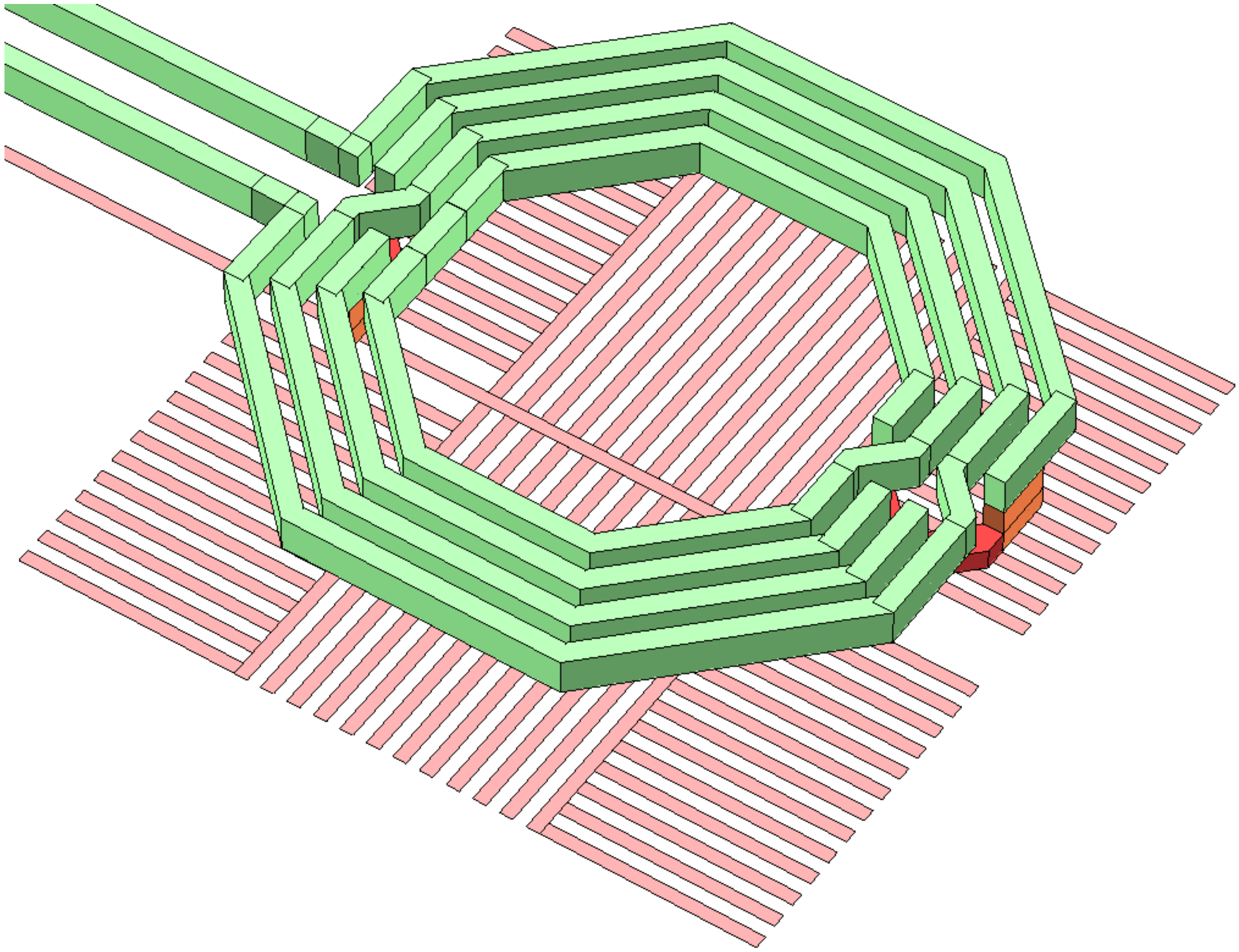

Figure 6.26 — Method of Moments can be used to analyze planar 3D circuits like this spiral inductor over silicon. Many such inductors are present in the RF chip set for every cell phone. Silicon dioxide insulator (not shown) gives some separation between the bottom of the inductor and the top of the semi-conducting silicon. To reduce inductor losses, a grid-like ground shield is placed directly on the silicon to try to keep the inductor fields out of the silicon. [Courtesy Sonnet, used with permission]

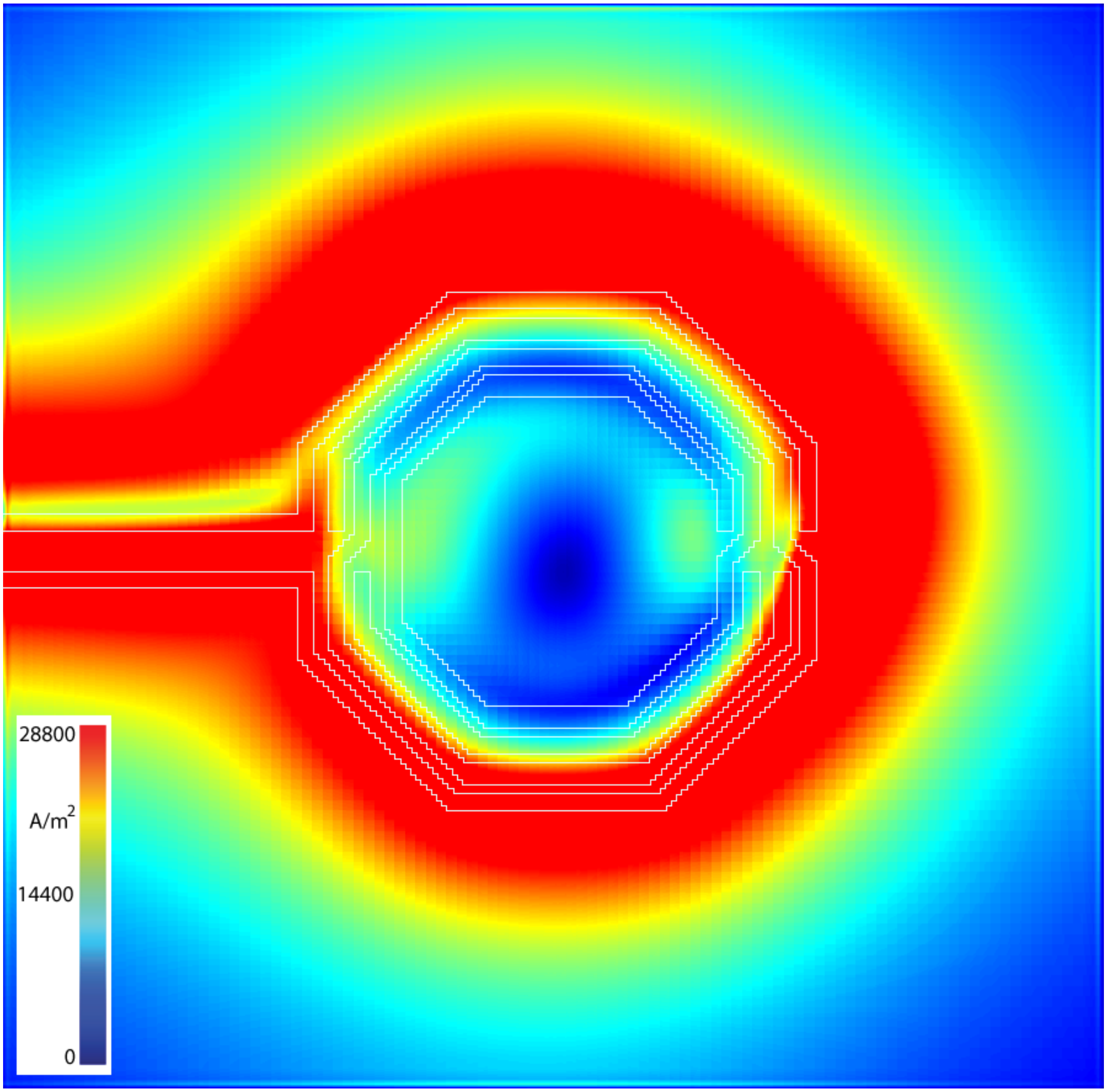

Figure 6.27 — The spiral inductor, here without the ground shield, induces current in the silicon. This current increases loss and must be minimized. [Courtesy Sonnet, used with permission]

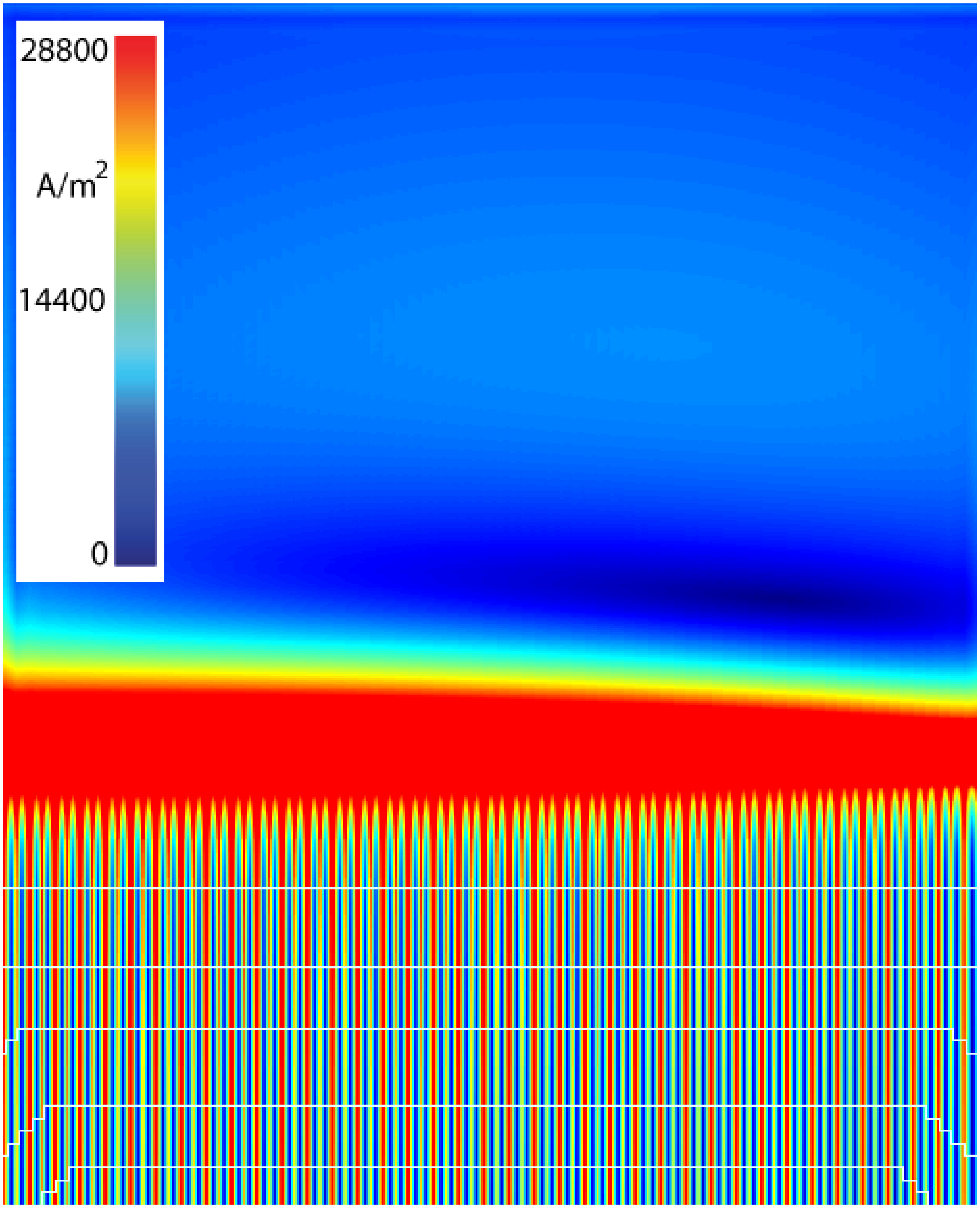

Figure 6.28 — A small section of the current in the silicon under the inductor with ground shield in place shows a strongly modified current in the silicon. Whether or not inductor loss is actually decreased, or increased, strongly depends on the ground shield design. [Courtesy Sonnet, used with permission]

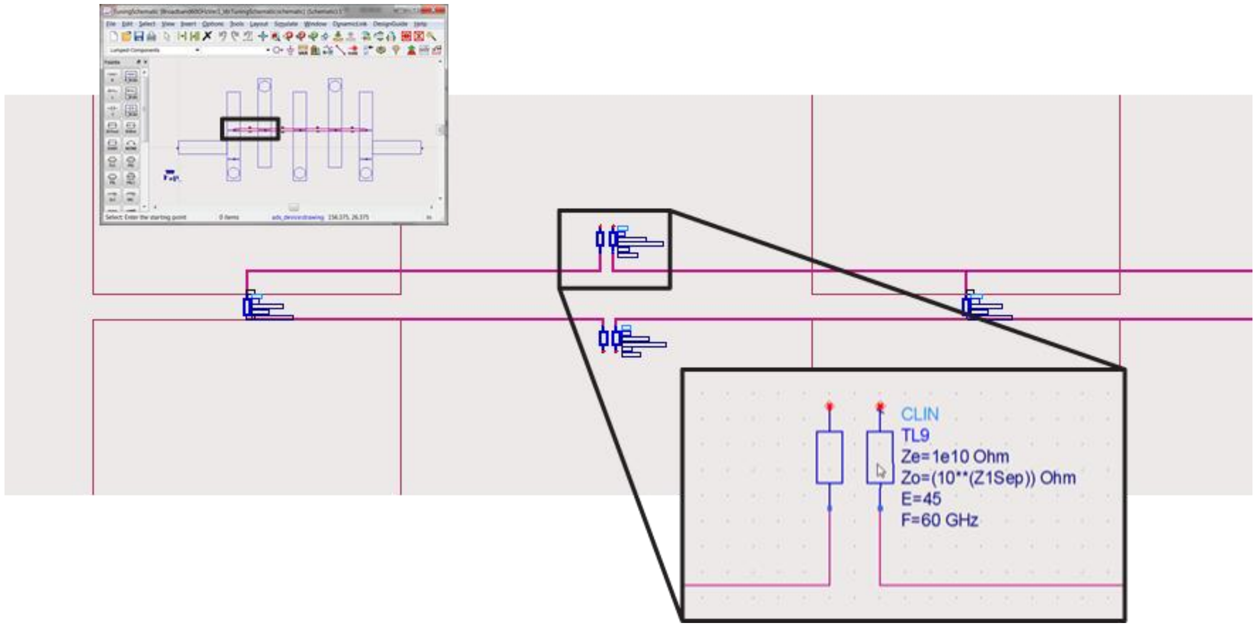

Figure 6.29 — For professional use, port tuning can be used to tune all resonator lengths and couplings between resonators in order to obtain the desired response. This illustrates a filter tuned using Keysight ADS and Sonnet EM analysis. The lower right detail illustrates a circuit theory coupled line used to fine tune the coupling between two resonators. [Courtesy Sonnet, used with permission]

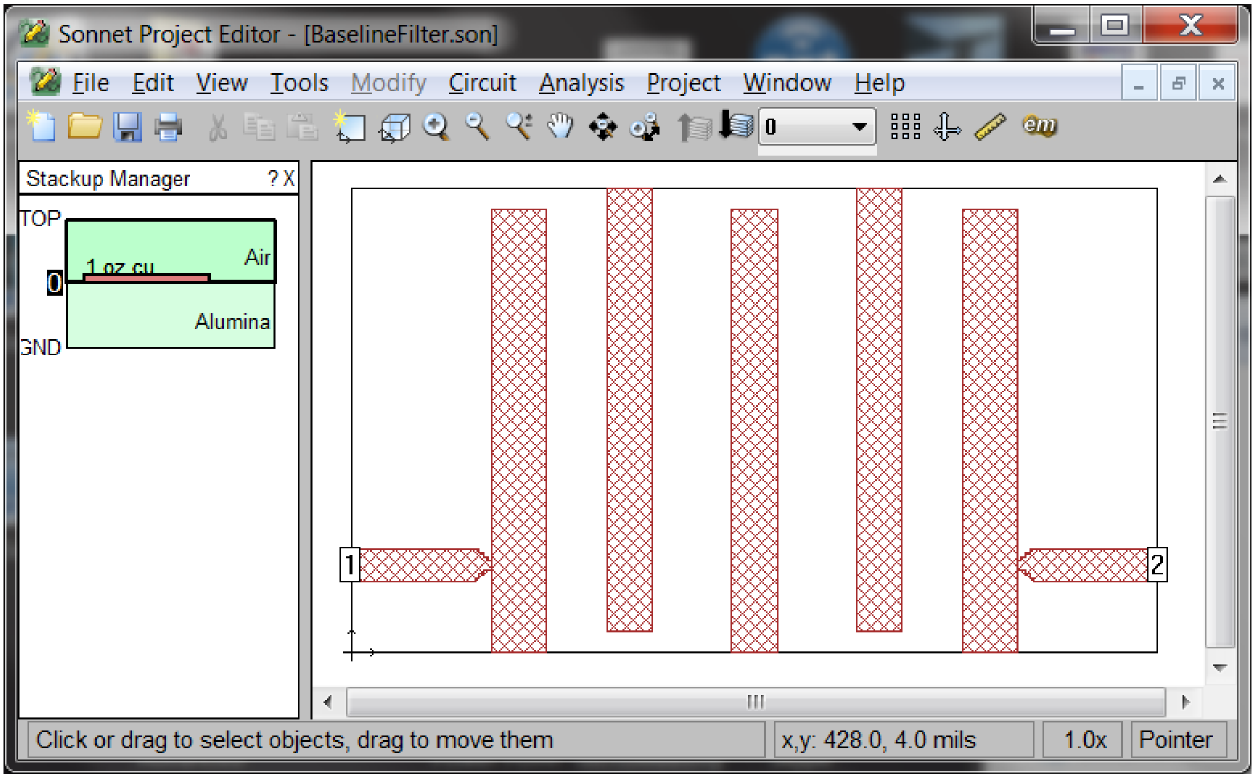

Figure A — The baseline filter that we use to illustrate port tuning is made of quarter wavelength resonators, each grounded at one end to a perfectly conducting sidewall that is present at the edge of the substrate. [Courtesy Sonnet, used with permission]

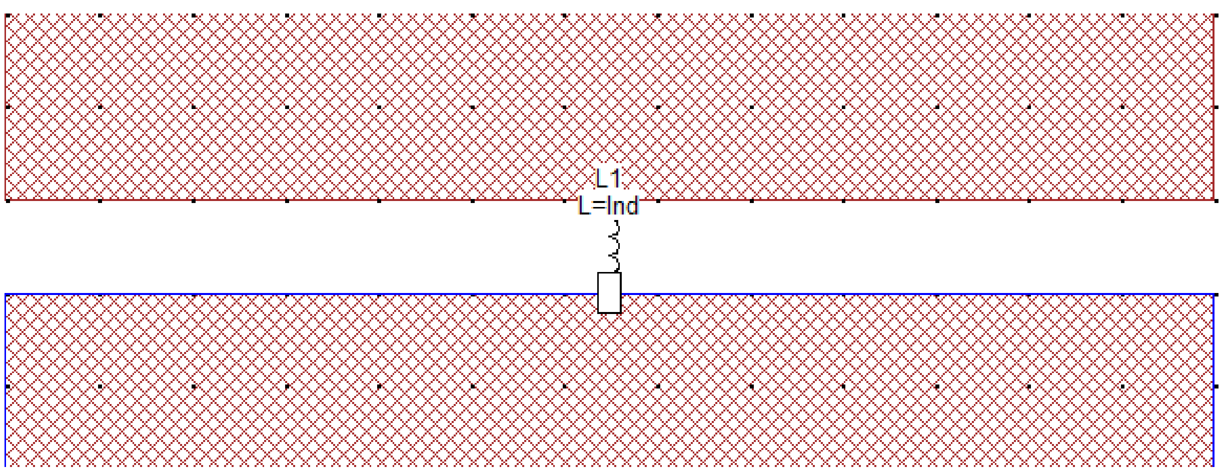

Figure B — Following instructions in the text, a gap is placed halfway along the length of the first (left) resonator. This is a zoomed detail of the inductor component that was inserted in that gap. The value of the inductance, “Ind”, is a variable parameter that will be tuned. [Courtesy Sonnet, used with permission]

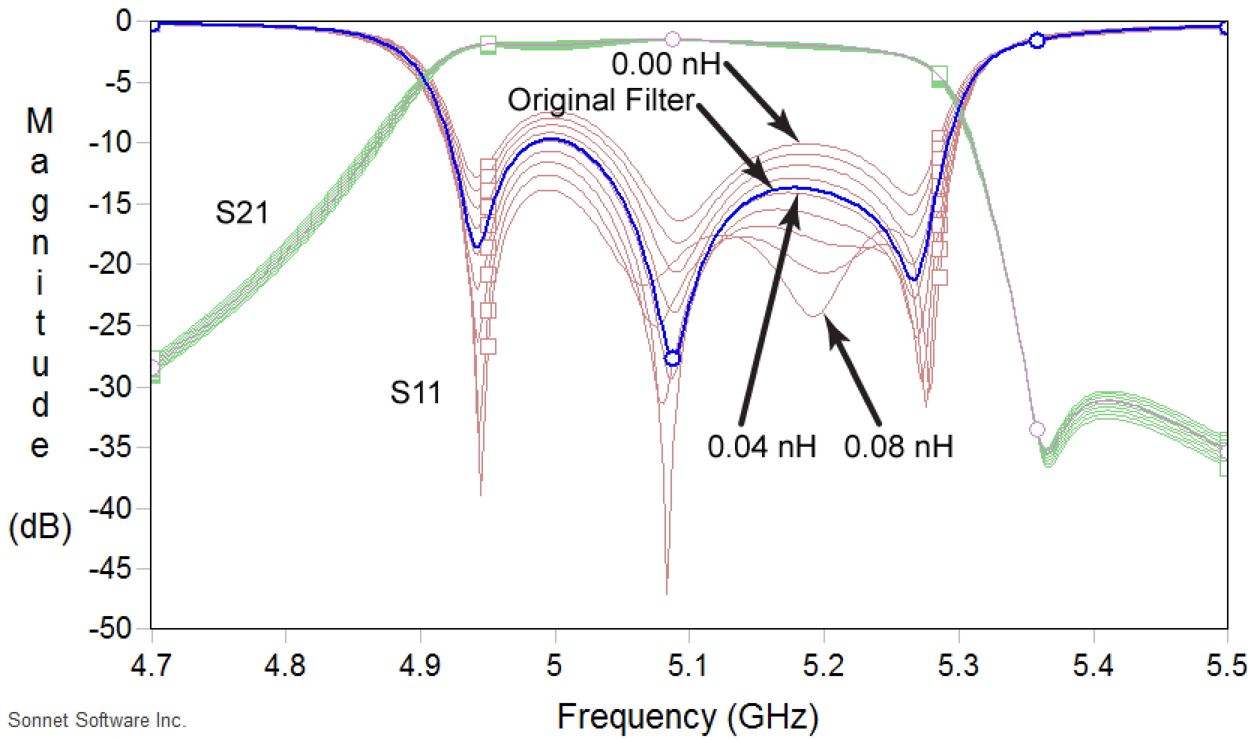

Figure C — Results of running a parameter sweep for the value of "Ind" from 0 to 0.08 nH shows that 0.04 nH gives almost the same response as the original (untuned) filter. A value of 0.08 nH gives an improved reflection coefficient ("S11") and indicates the first resonator should be made 0.002 inch longer (see text for details). [Courtesy Sonnet, used with permission]