Guide to Simulating NMR Probe Circuits

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1. Introduction. Many publications have appeared over the past four decades presenting approximate analytical solutions for many different simple NMR probe circuits. While analytical solutions of simple circuits – perhaps up to three coils, maybe a dozen capacitors, and several resistors – are clearly the place to begin, real circuits in high-field multi-nuclear probes are far more complex. They may include dozens of leads, stray capacitances, and couplings that make accurate analytical solutions impossible. Fortunately, there are several excellent numerical options for accurate solutions of real, complex NMR probe circuits. Of course, rf and microwave engineers are well versed in using these tools to solve the kinds of problems they typically encounter, but their objectives are generally rather different from those needed in NMR probe optimization. Moreover, most graduate students called upon to design a special purpose NMR probe are not electrical engineers, and there are very few good references to help them use available tools effectively to design and optimize a complex NMR rf probe circuit.

There appears to be a need within the NMR community for a tutorial-type treatment of circuit simulations using both linear circuit simulators and 3D full-wave simulators. That is the purpose of what we are beginning in the December 2015 issue of our Newsletter. Our intent is to present another chapter, usually with a circuit and solution, in each issue going forward for the next few years. We will keep a list of the topics presented in prior issues for reference, and they will be permanently available on our website, along with example simulation files, ready to run. These articles will generally not be of the style and format expected in professional journals, and they may not be like most wiki articles, summarizing material widely available in standard texts and many other on-line references. Many may be more like technical help manuals.

The first few chapters in this series are not likely to enable the novice to proceed effectively into optimization of a very complex circuit, but they will introduce the basics and show how to determine the pw90 in a simple example simulation. Subsequent issues will present additional concepts and show progressively more complex examples. Eventually we expect to have a very complete treatment of this important subject.

The software we are using for circuit simulations is Agilent-Genesys. There may be other products that are better – it just happens to be an adequate option. Two requirements that are *not* present in all circuit simulators are: a good graphical interface for building and modifying the schematic, and the ability to easily attach fairly complex programs to the schematic that smoothly communicate with it in both directions, as the S parameters calculated by the circuit solvers themselves are never sufficient. Thankfully, gone are the days of inputting node-list codes! All circuit simulators should give exactly the same results for the same circuit model, and all modern simulators probably have excellent graphical display capabilities for calculated results.

We've compiled a "Getting Started" guide to Genesys that is available at our website to complement the tutorials and manuals the vendor provides – and point out it's many "Gotcha's". (One of the more significant limitations of Genesys is its simple one-pass interpreter of user-written programs attached to the schematics. Another is its poor handling of error conditions – and there are others!) That guide is specifically for new users of Genesys and is completely orthogonal to this series on probe simulations, which is intended to be useful to all probe builders using any modern linear circuit simulator.

This series will be posted on our web site and available for download, along with the Genesys circuit files presented, though a license would need to be purchased from the vendor to read or run them. The first three chapters, now available, are: