From Theory to Hardware: The Reality of Electronic Design and Realization

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Objective

The goal was to use an electronic realization process (Figure 1) to develop a low-noise amplifier (LNA) for GPS reception.

Need or Idea → Requirements → Design Concept → Detailed Design → Fabrication → Engineering Testing → Verification and Validation Testing → Delivery.

Figure 1: Electronics realization process (feedback cycles not shown)

The concept of the device is displayed in Figure 2. The overall purpose of the device is to amplify the signal with the introduction of the least amount of noise possible.

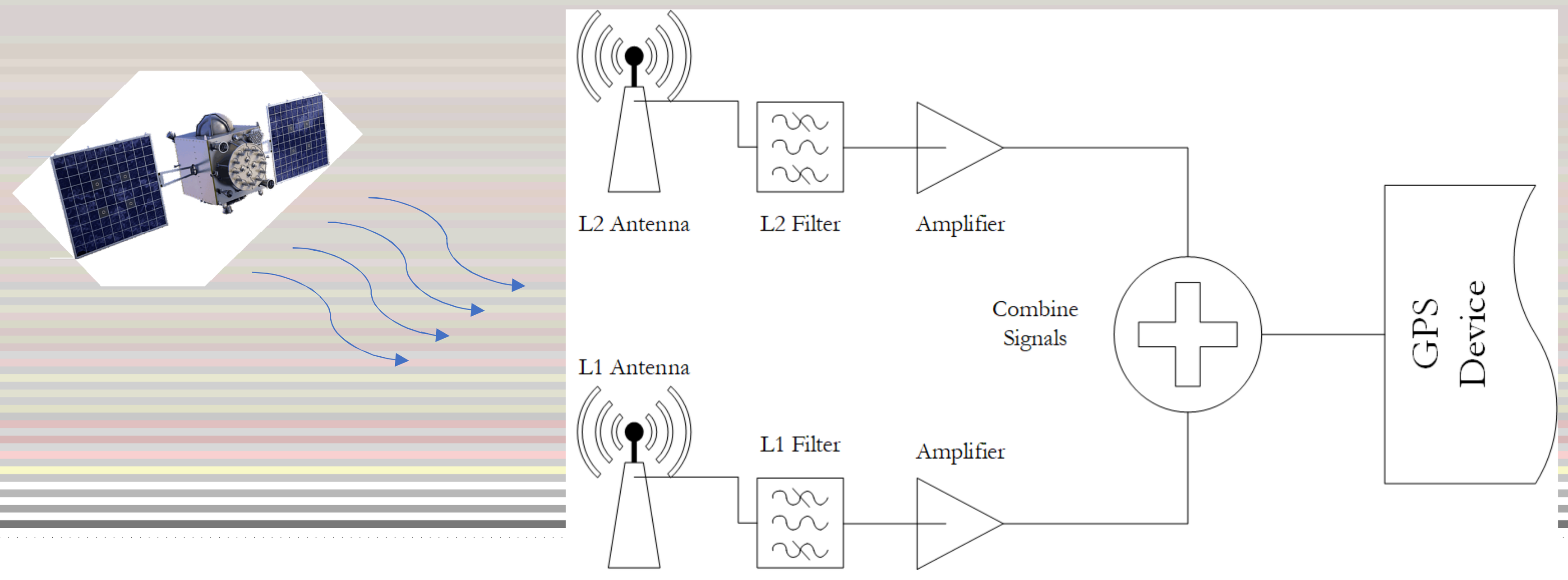

Figure 2: LNA High Level Overview

Design

The design of the LNA was done in a circuit CAD program. Before fabrication, however, the design was evaluated using the Keysight Genesys RF/Microwave design software. This tool allows the user to simulate RF networks and observe how they will theoretically work. After deciding on the preliminary parts that will be used, the S-parameters for the parts can be found online and uploaded into the tool to see how the device will perform as a whole, including its composite S-parameters and noise figure. This allows the user to optimize the circuit assembly and choose the best parts for the application. The graph of the theoretical S-parameters was simulated using the Genesys tool and is in Figure 3.

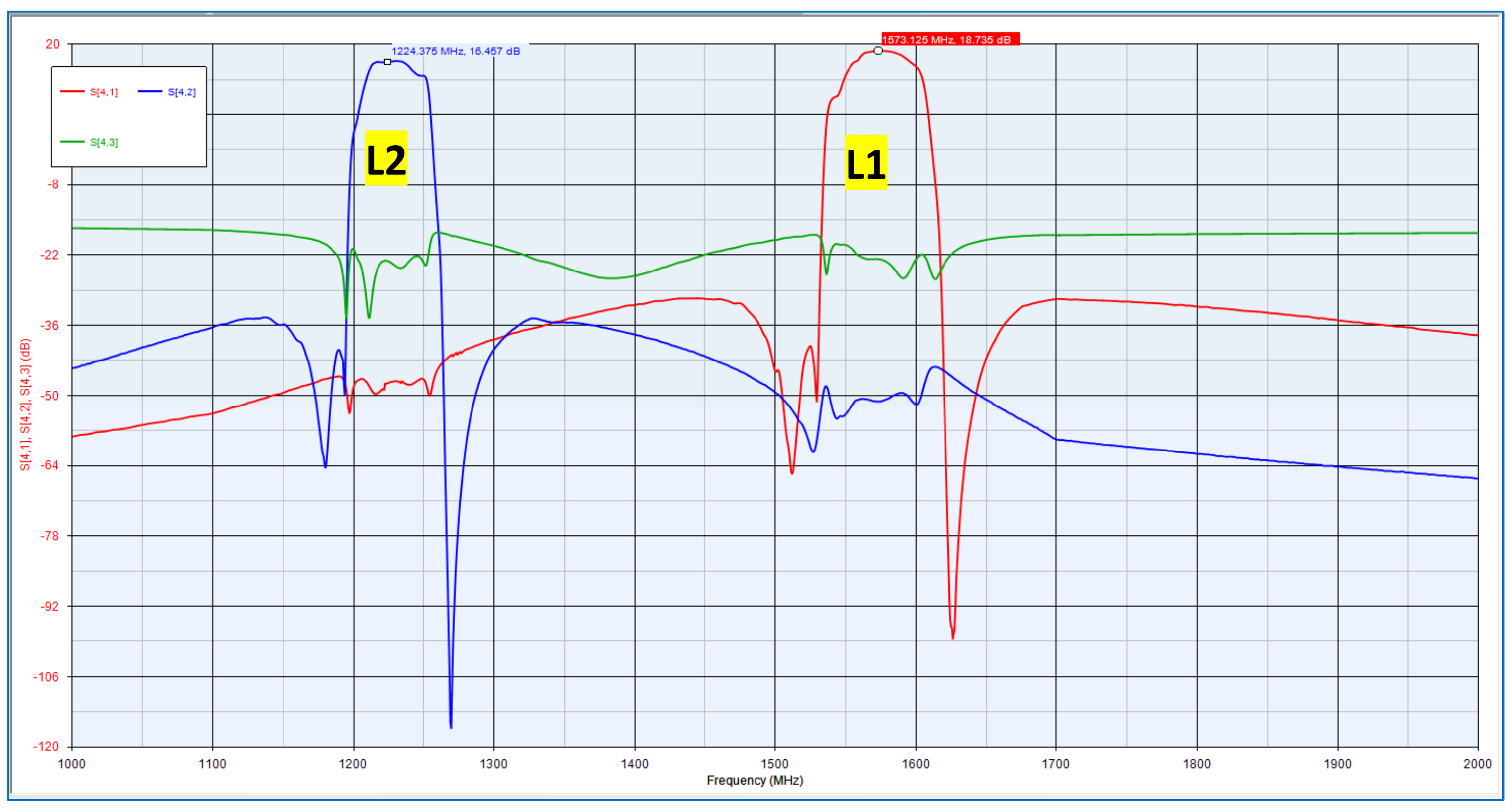

Figure 3: Simulated composite S-parameters

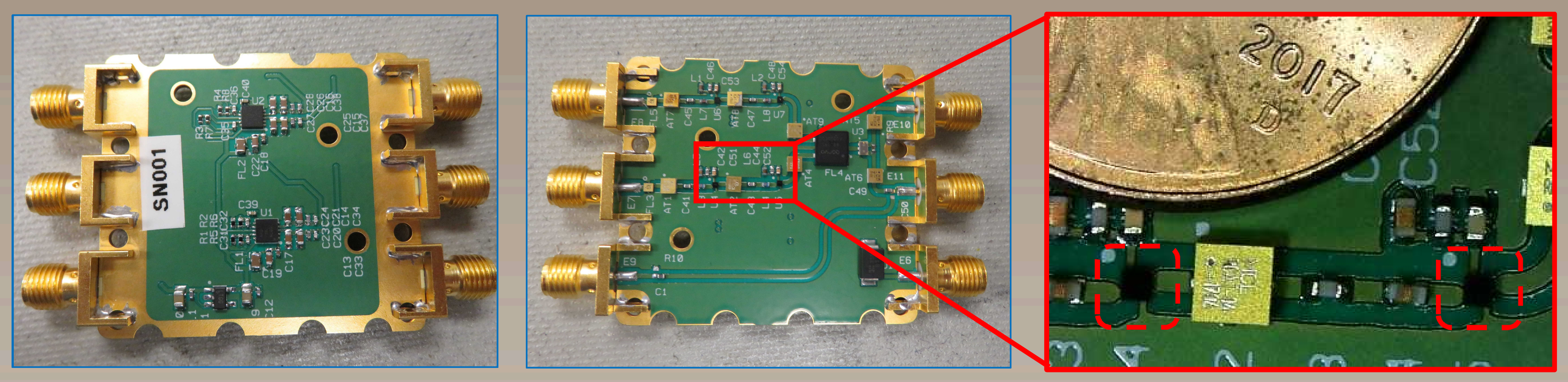

Figure 4: Finished circuit board DC (left), RF (middle), two of four amps (right).

Testing

Although the circuit design and simulation suggested that the circuit itself should work once fabricated, that was not the case. The constituent amplifier integrated circuits did not work. This was not due to the operation of the parts, rather it was their packages. The amps are packaged in an 0.86mm x 0.86mm base with four contacts, each attached with a small lead-free ("RoHS") solder ball. See Figure 4 for relative sizes. Due to their size and high melting temperature (due to pure tin composition), it was challenging to hand solder the parts to the board. In order to properly place and solder them, a hot air gun or infrared beam was used to heat up the solder balls and flow them with the board. However, because they were lead-free solder balls, this required significantly more heat than traditional tin-lead solder, and the board's copper planes prevented flow.

It was decided to remove the amps and short the outputs to inputs. That way the filters could be analyzed to see if they met specifications. RF network analyzer and Genesys data compare quite well as can be seen in Figure 5.

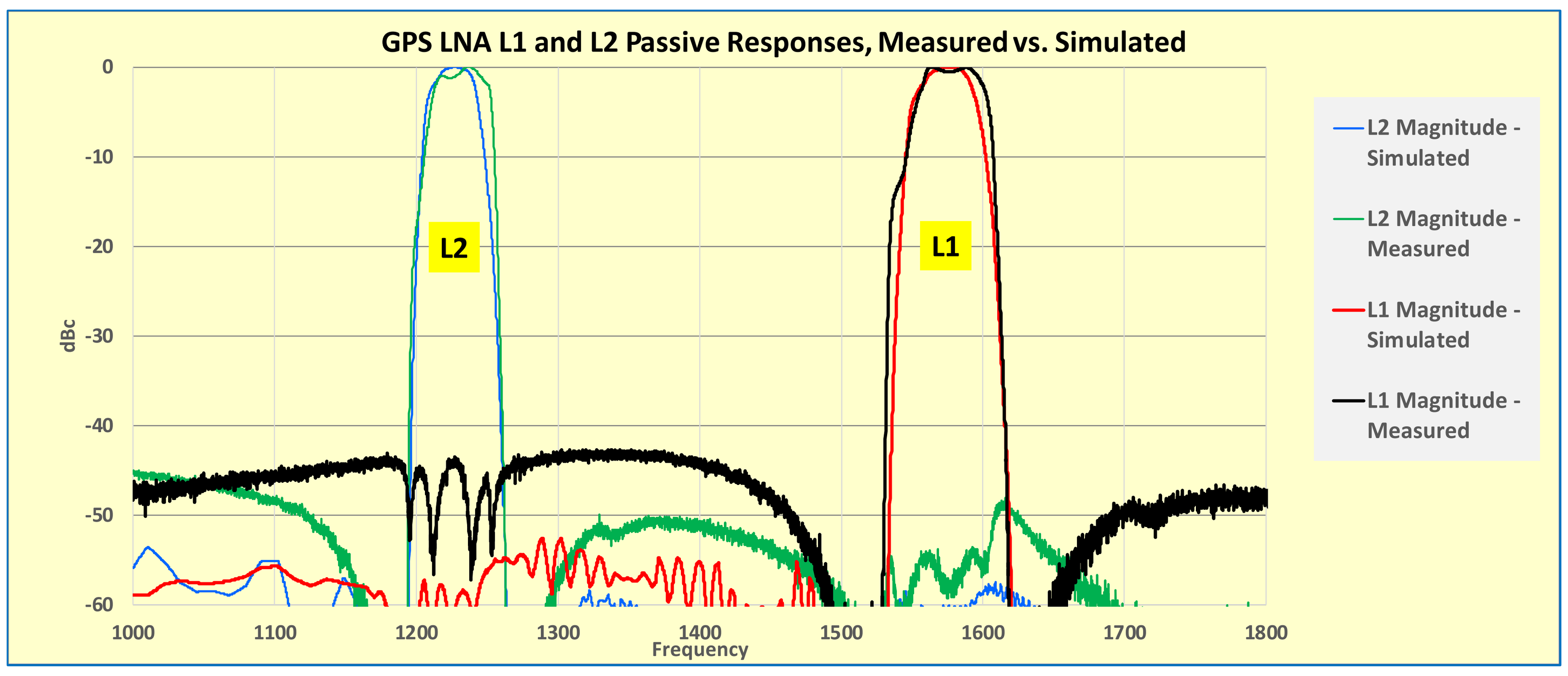

Figure 5: Measured and simulated passive composite S-parameters

Now what?

When an initial design fails to meet specifications, alternative solutions are required. Based on lessons learned and test data, the amplifiers were sent to a third-party to have tin-lead solder balls attached to the amplifiers so that a new batch of boards can be assembled. Fabrication is in process at this time. Ultimately, a new amplifier IC may be needed.

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