Using a Network and Impedance Analyzer to Evaluate 13.56 MHz RFID Tags and Readers/Writers

Application Note

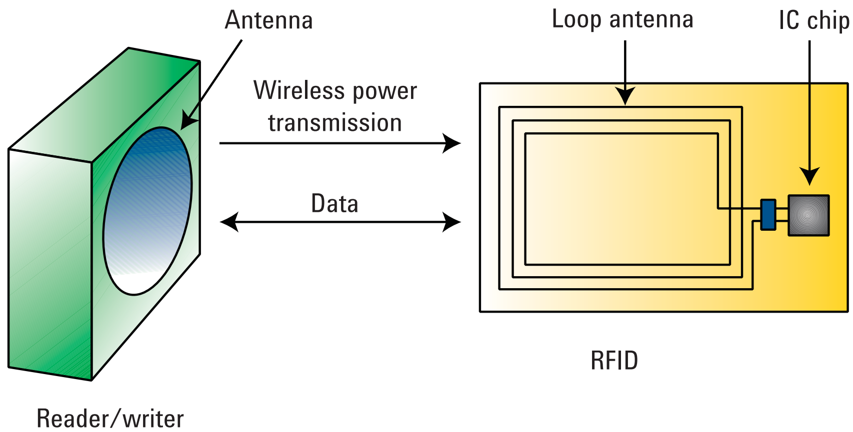


Figure 1. Simplified RFID system

Introduction

RFIDs, also called non-contact IC cards or ID tags, are devices that make it possible to detect the presence of objects and verify their identification without contacting them. RFIDs have been used since the 1980's but initially their use was limited to maritime transports, traffic information systems, and other special applications. Since the middle of 1990's, RFIDs have been miniaturized at an accelerated rate and they are now widely used. Currently, a number of standards exist that define the frequencies, communication methods, and purposes of RFIDs. This document gives an overview of how to evaluate the electrical characteristics of mass-produced 13.56 MHz RFID tags and readers/writers and their components.

Overview of an RFID

Figure 1 shows a simplified RFID system. The loop antenna in the reader/writer communicates with the loop antenna in the RFID tag; these are electromagnetically coupled. The reader/writer outputs RF signals, which are received by the RFID tag via its loop antenna. The RFID tag gains power by detecting DC signals through a detector circuit integrated in its IC chip. This power is used to drive the IC chip.

Typically, data communications between readers/writers and RFID tags use ASK modulation at a frequency of 13.56 MHz.

Agilent Technologies

Evaluating RFID Tags

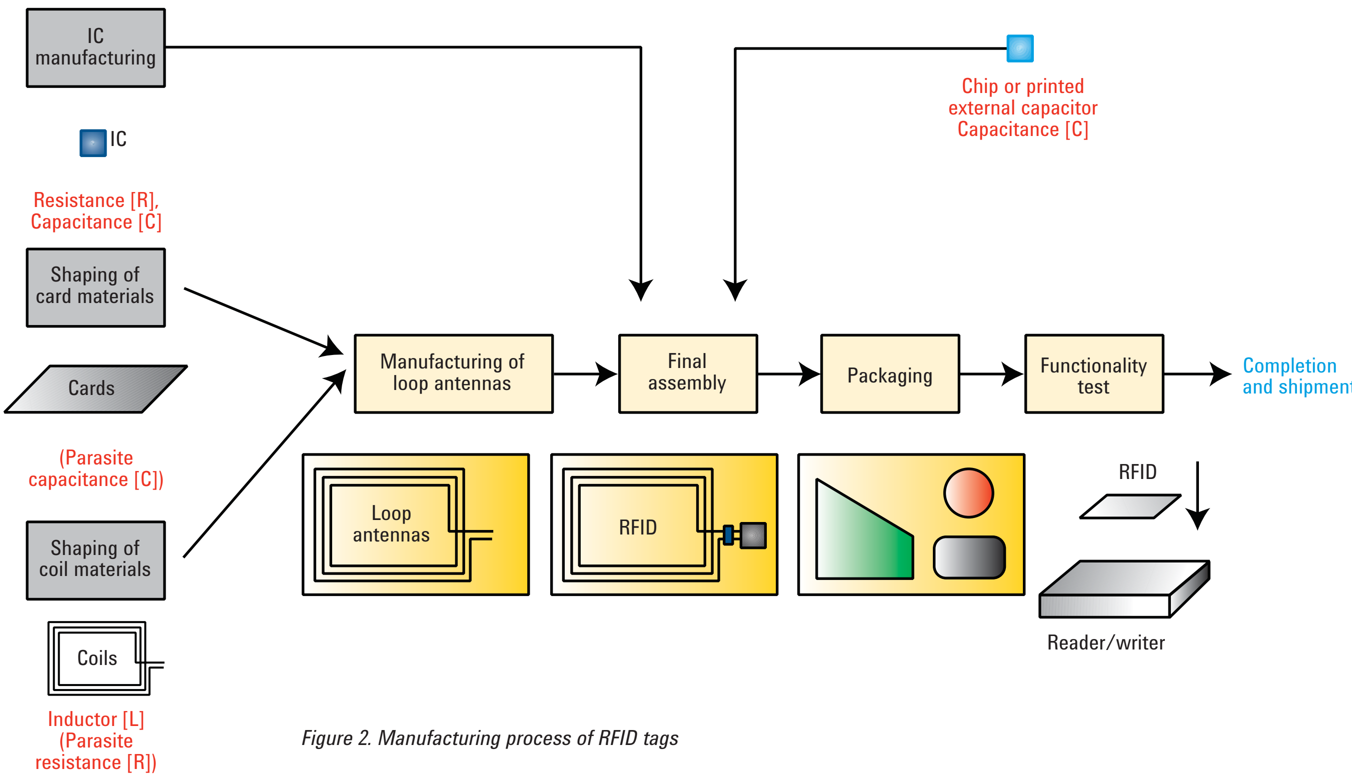


Figure 2. Manufacturing process of RFID tags

Figure 2 shows a typical manufacturing process of card type RFID tags. This process involves printing or otherwise forming a loop antenna on the card and subsequently placing an IC chip and chip capacitor on the same card. Printing may also be used to form the capacitor on the card. Finally, the tag is appropriately packaged and tested before shipping.

Figure 3 is a circuit diagram which represents a completed RFID tag. Basically, an RFID tag consists of an L-C-R parallel circuit (where “L” stands for a loop antenna, “C” for a chip capacitor, and “R” for an IC chip). The resonant frequency of an RFID tag, f0, is given by the expression 1/(2π√LC). If an RFID tag has a resonant frequency close to 13.56 MHz, then the RFID tag is considered to communicate well with a reader/writer. It is very important to verify that the completed tag in its entirety resonates at 13.56 MHz.

Also, measuring the characteristics of L and C component parts will help improve the yield of completed RFID tags.

Another consideration is the sharpness of resonance (communication bandwidth), which is determined by the R value of the IC chip or the parasitic resistance, “R”, of the loop antenna. An excessively high sharpness of resonance makes communications difficult when the modulation signal bandwidth is wide; on the other hand, an excessively low sharpness of resonance results in worsened communication distance characteristics. It is important to measure the resonance characteristics of the completed tag in its entirety, and measuring these resistance values on a part by part basis will help improve the communication performance of the RFID tag.

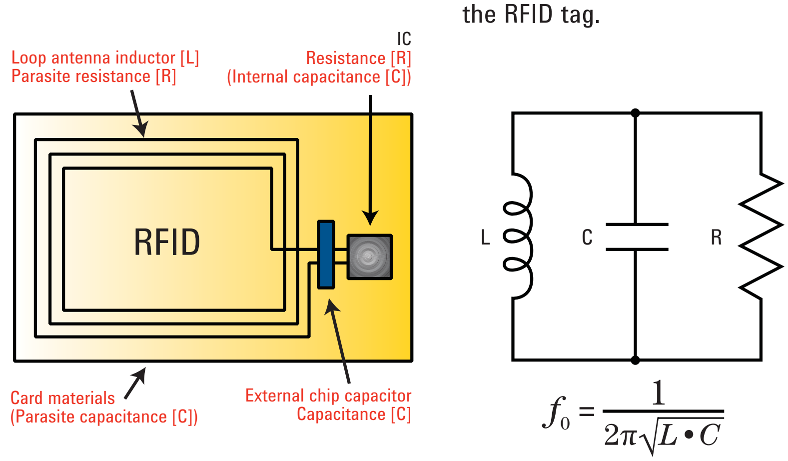


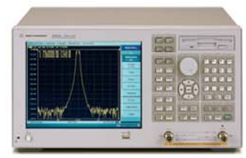
Figure 3. RFID tag components and its equivalent circuit

Component-Level Measurements

Agilent solution - impedance measurement instruments

4294A precision impedance analyzer + 42941A impedance probe kit

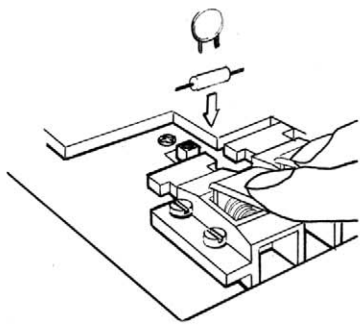
4395A combination analyzer + 43961A RF impedance test kit



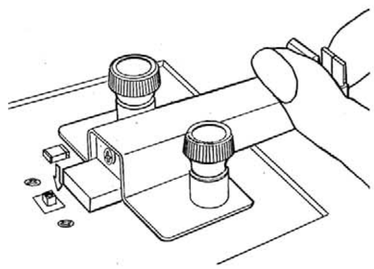
E5061A ENA network analyzer

E5071C ENA network analyzer

Agilent solution - impedance measurement test fixtures



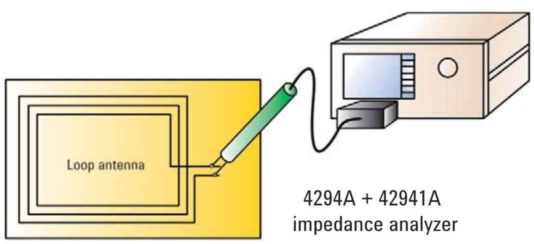
For axial-lead components



For SMD components

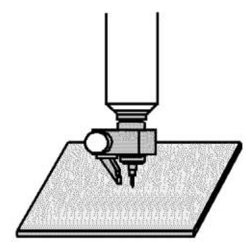
Choose an appropriate test fixture along with the DUT dimension

Agilent solution - impedance measurement probes



4294A + 42941A impedance analyzer or 4395A combination analyzer + 43961A RF impedance test kit + 42941-60002 pin probe

42941A impedance probe kit for 4294A



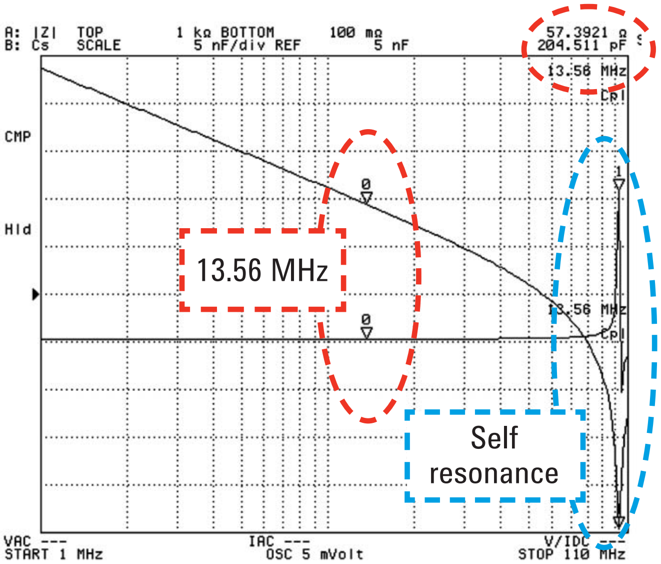
pin probe (42941-60002) for either 4395A or network analyzers

Figure 4. Recommended instruments and accessories

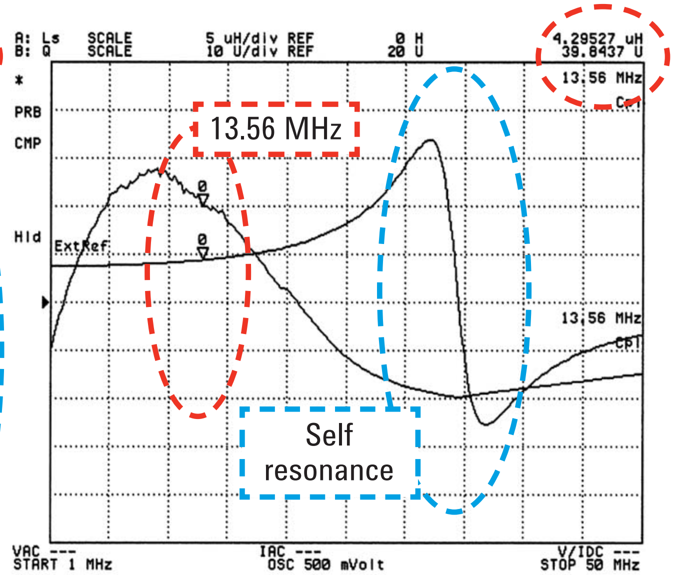
Basic components of L, C, and R make up an RFID tag as well as the RF portion of a reader/writer. The 4294A impedance analyzer is an optimum choice for measuring the electrical characteristics of these components.

You may also want to use the 4395A combination analyzer which combines an impedance, network, and spectrum analyzer in a single box. If you do not need the wide impedance measurement range provided by an impedance analyzer you can use a network analyzer instead.

RFID tags do not have coaxial connectors, instead, many of their components have electrodes or lead terminals. Therefore, you should use a test fixture that matches the shape of the tag to connect the RFID tag under test to the analyzer. If the RFID tag has a loop antenna formed on the card, you should use a probe to connect the tag to the analyzer.



Example: Chip capacitor characteristics measured with the 4294A



Example: Loop antenna characteristics measured with the 4294A

Figure 5. Examples of measurements

Figure 5 shows examples of measurements carried out on a chip capacitor and a loop antenna. The two graphs indicate that the chip capacitor and loop antenna resonate at approximately 100 MHz and 30 MHz, respectively.

Each of these components can only be used at or below the resonant frequencies indicated. Also, the results obtained at 13.56 MHz for these components are:
C = approximately 204 pF and
L = approximately 4.3 uH. These values determine the resonant frequencies.

After testing each component, you can use a probe to measure the resonance characteristics of the entire RFID tag complete with all its components.

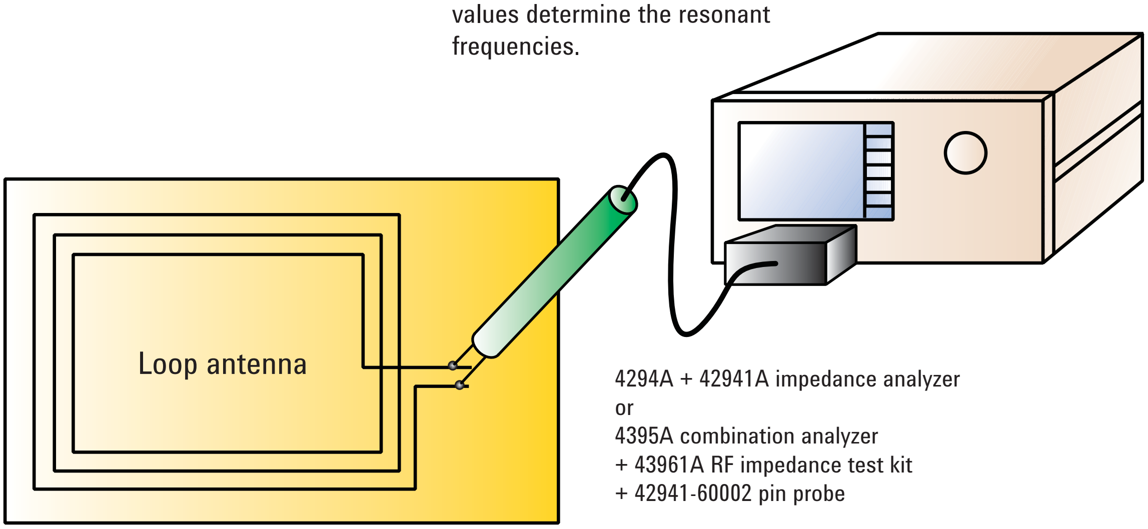


Figure 6. RFID measurement with impedance probe

Non-Contact Measurements of Resonant Frequencies

Once an RFID tag is packaged, you cannot test it with a probe. You can, however, use a non-contact measuring method. In this method you hold an RFID tag in front of a loop antenna connected to an analyzer. This allows you to measure the resonant frequency of an RFID tag without having to disassemble the RFID tag. Non-contact measurements are typically carried out with a network analyzer, which provides higher measuring speeds than other types of analyzers. The non-contact method makes it possible to perform resonant frequency measurements on all RFID tags during the final stage of mass production.

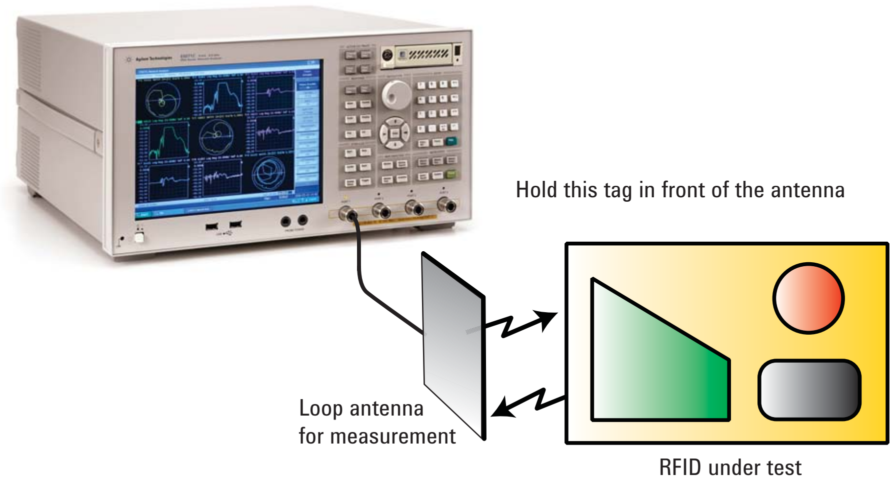


Figure 7. Non-contact measurements of resonant frequencies

The resonance characteristics of certain RFID tags may change depending on the RF power they receive from the analyzer. The ENA network analyzer is an optimum choice when you need a higher power during measurements. You can connect the ENA network analyzer with an external amplifier or similar circuit to produce a higher power than the analyzer itself can output. Also, the ENA network analyzer provides a function called "Power Meter Calibration" that allows you to accurately set the RF power level when performing measurements.

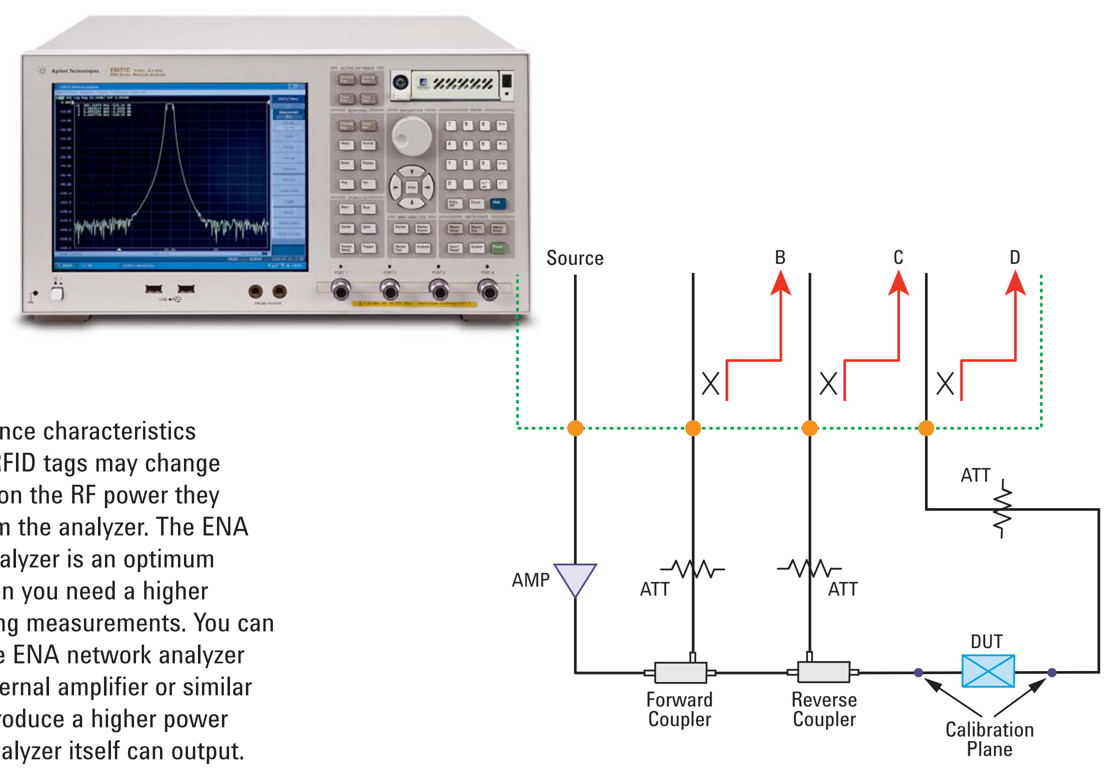


Figure 8. High power configuration of ENA network analyzer

Evaluating a Reader/Writer

Figure 9 is a simplified circuit diagram of an RFID reader/writer. The impedance of the power amplifier contained in a reader/writer should match that of the loop antenna so that the power amplifier can effectively transmit the power to the loop antenna. When the power amplifier's output impedance (Zpa) is R-jX, you should adjust the loop antenna's impedance (Zin) to R+jX. A typical setting is: Zpa=Zin=50Ω.

The goal is to determine the capacitors values by adjusting values on both C1s and C2p to achieve impedance matching. You should connect capacitors to the loop antenna in serial or parallel, and adjust the capacitance values of these capacitors so that impedance matching is achieved. It is common practice to use an analyzer or simulator program in Smith Chart mode while measuring and adjusting the capacitance values of these capacitors.

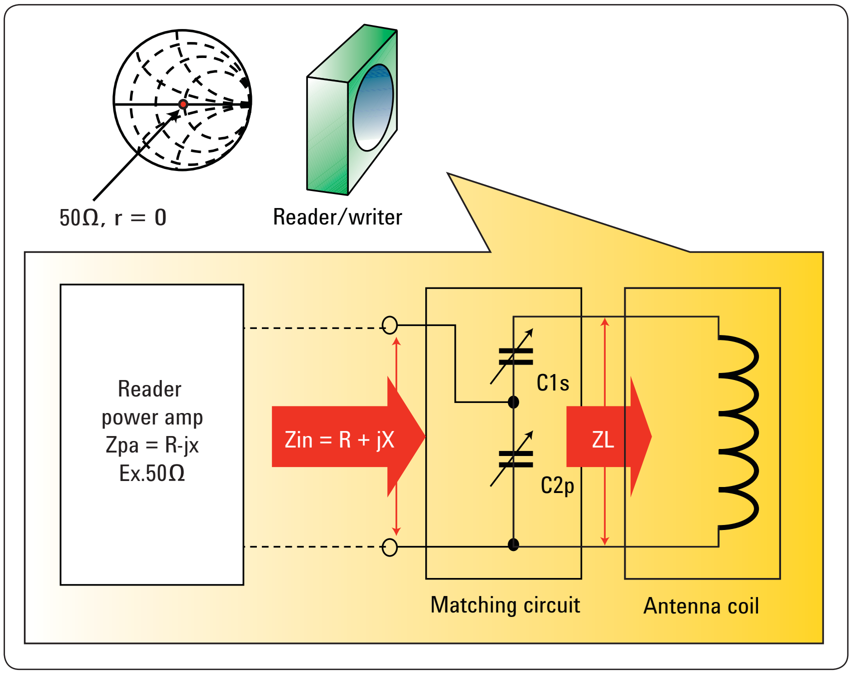
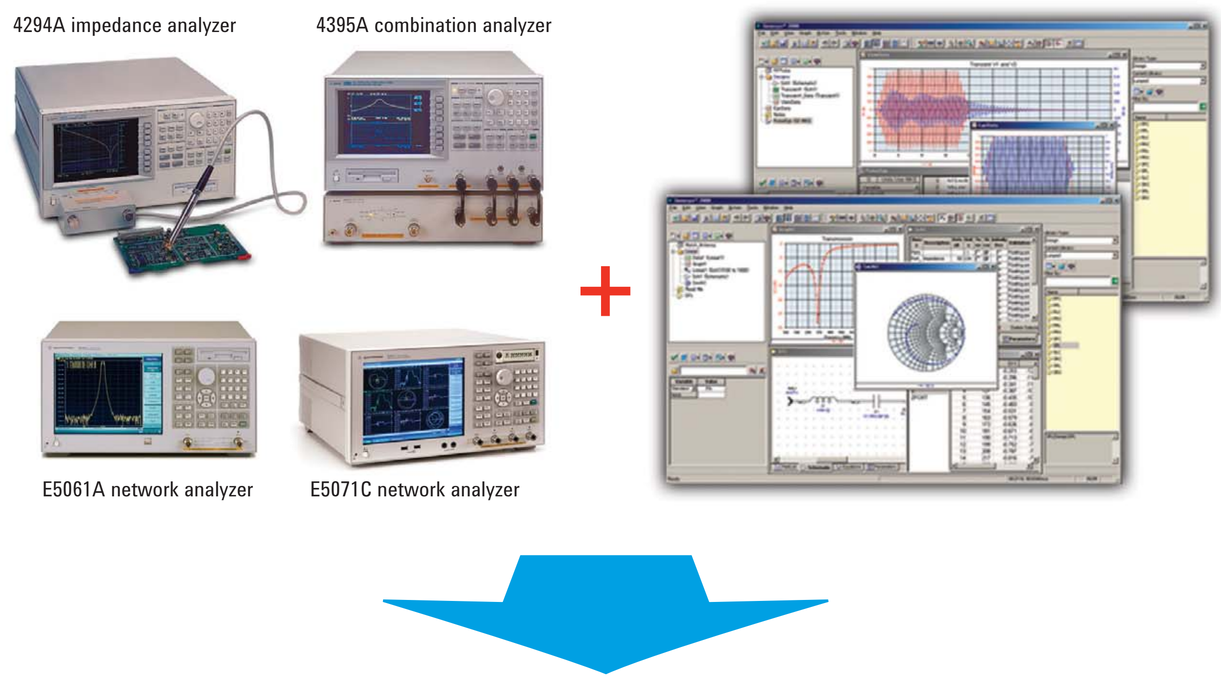


Figure 9 Simplified circuit diagram of an RFID reader/writer



Integrating an analyzer with Agilent Genesys Core software provides analysis functions beyond the built-in analyzer functions.

Figure 10. Design integration with Genesys

When your desired analysis is not available on your analyzer, you can use an inexpensive software simulation program called Genesys Core. Easily perform various types of measurement analysis by transferring measurement results to Genesys Core installed on a PC. For example, the 4294A impedance analyzer is not able to display a Smith chart, but you can generate one by just transferring measurement results to Genesys Core.

Note: The E5061A, E5071C, and 4395A analyzers come with built-in Smith Chart mode.

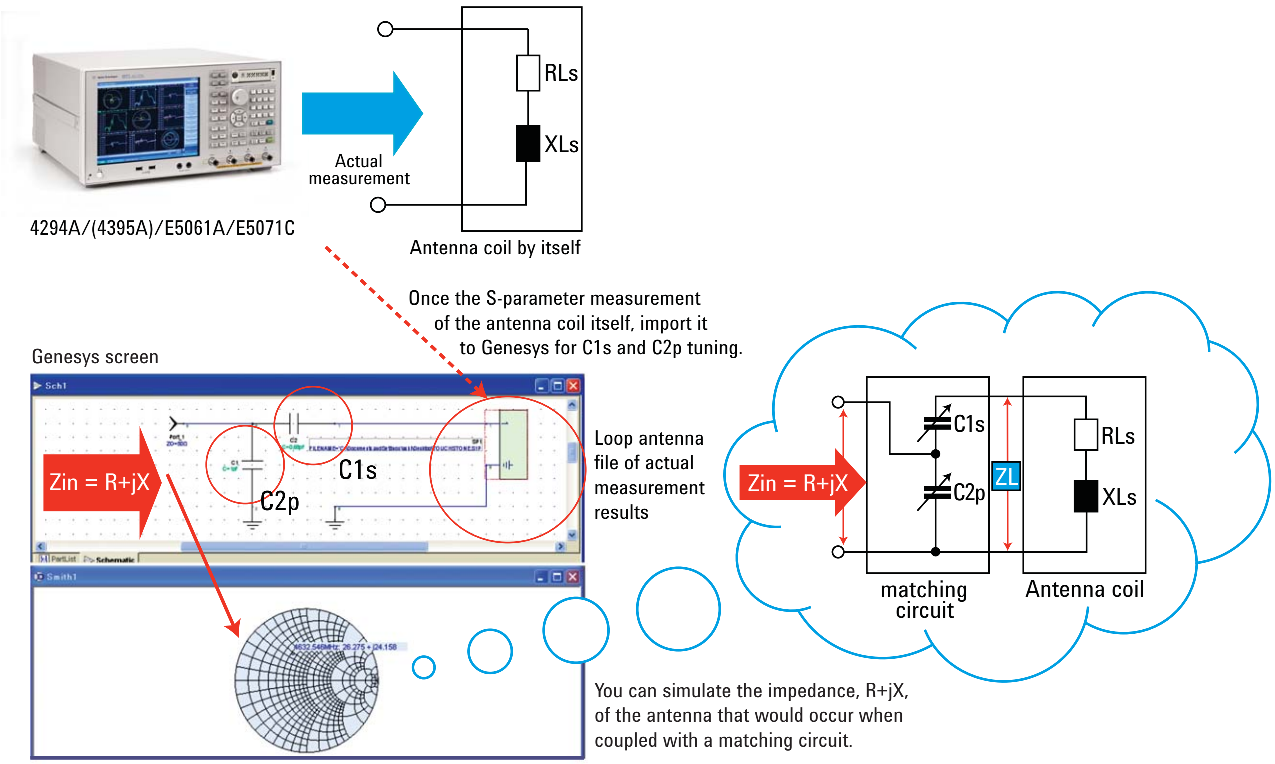


Figure 11. Matching circuit simulation using Genesys

For example, suppose you measure the characteristics of a loop antenna without a matching circuit using your analyzer. You can then transfer the measurement results to Genesys to simulate how the loop antenna would behave when coupled with a certain matching circuit. Thus the simulator program allows you to estimate what characteristics will be obtained with each of possible circuit configuration without having to create different matching circuits by repeatedly rebuilding the actual circuit. By combining an impedance analyzer with Genesys, you can also perform different types of analysis on the electrical characteristics of RFID tags and readers/writers.

Related literature

Non-Contact measurement method of 13.56 MHz RFID using the ENA/ENA-L Application Note, 5990-3443EN

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