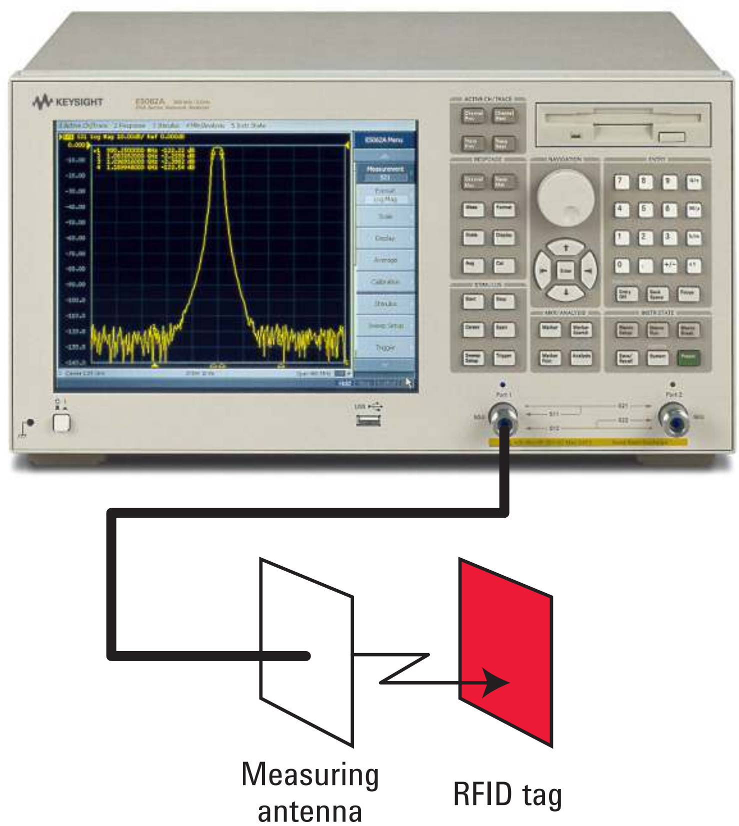
Keysight Technologies
Non-Contact Measurement Method for 13.56 MHz RFID Tags

Using the ENA/ENA-L Network Analyzer

Application Note



KEYSIGHT TECHNOLOGIES

Non-Contact Measurement Method for RFIDs

RFIDs, also called IC cards or ID tags, are devices that make it possible to detect the presence of objects and verify their identifications without contacting them. RFIDs have been used since the 1980's but initially their use was limited to maritime transports, traffic information systems, and some 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 perform non-contact measurements of the resonant frequencies of 13.56 MHz RFID tags. The measurement method introduced in this application note has a proven track record in the fields of development, manufacturing, and maintenance.

Figure 1 shows a simplified setup. A loop antenna used to measure the frequencies is connected to the coaxial end(s) of one or two cables extending from a network analyzer. You can measure the resonant frequency of an RFID tag by holding the RFID tag in front of the measuring antenna.

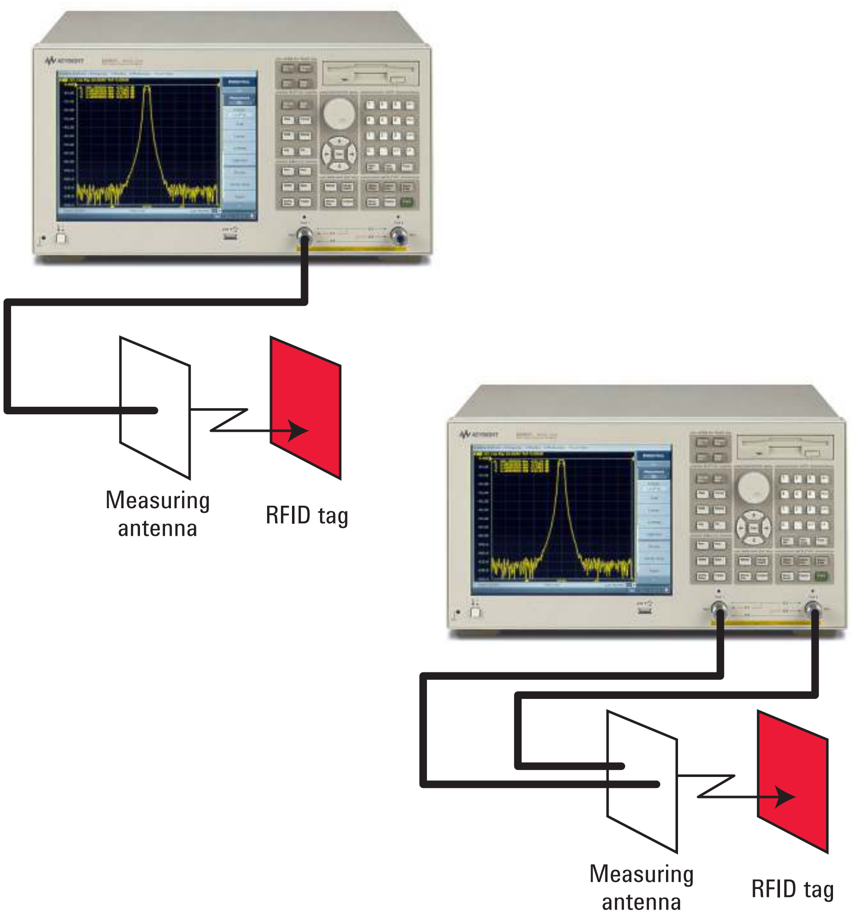


Figure 1. Measurement setup with reflection or transmission measurement

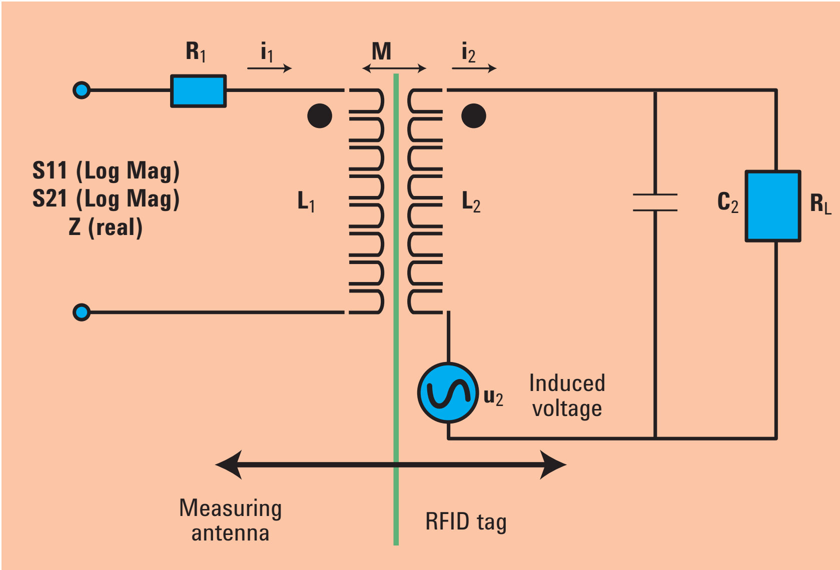


Figure 2. RFID tag electric circuit diagram

There are two common practices: one is to perform S11 (reflection) measurements by connecting the antenna via a single coaxial cable to the analyzer and the other is to perform S21 (transmission) measurements by connecting the antenna via two coaxial cables to the analyzer.

Figure 2 is a simplified circuit diagram that represents a measuring antenna and RFID tag connected to a network analyzer. If the RFID tag under test is regarded as a simple LCR parallel resonant circuit, Thomson's equation gives its resonant frequency as follows:

$$f_0 = \frac{1}{2\pi\sqrt{L_2 C_2}}$$

$$\omega_0 = \frac{1}{\sqrt{L_2 C_2}}$$

The reflection coefficient, transmission coefficient, and impedance of the loop antenna connected to the network analyzer change significantly at frequencies in the vicinity of this RFID tag's resonant frequency, f0. The resonant frequency of the RFID tag can be determined by measuring the frequencies at which these changes reach their peaks.

Recommended Instruments

ENA/ENA-L network analyzer

The ENA/ENA-L network analyzer (E5061A/E5062A/E5071C) is an optimum choice for measuring RFID resonant frequencies. The ENA/ENA-L network analyzer provides the following features which help perform RFID resonant frequency measurements:

- **Very fast measuring speed**
  The ENA/ENA-L network analyzer boasts an extremely fast measuring speed enabling it to measure the resonant frequencies of multiple RFID tags within one second.
- **Extremely low trace noise**
  Generally, the trace noise characteristics of an analyzer significantly affect the accuracy of resonant frequency measurements. The ENA/ENA-L network analyzer has extremely low trace noise characteristics (as detailed in this application note).
- **Supports both scalar and vector measurements**
  There are two primary methods to measure RFID resonant frequencies: one is based on the scalar quantities (loss) and the other is based on vector quantities (impedance). By using the ENA series, you can perform both the traditional scalar-based analysis and more accurate vector-based analysis.
- **Automatically searches for resonant frequencies**
  The marker search function automatically searches for the resonant frequency of an RFID tag.
- **Supports communications with carrier machines**
  Typical mass production plants use carrier machines to transport tags, which are then held in front of a measuring antenna one after another. Signals for communicating with carrier machines can be output from the handler I/O port on the rear panel of the ENA/ENA-L network analyzer. You can use this port to synchronize the analyzer with a carrier machine or supply a carrier machine with PASS/FAIL results based on obtained measurements.
- **Built-in VBA enables full automation**
  The ENA/ENA-L network analyzer comes with a built-in VBA editor. This means that you can automate measurement processes by creating programs within the analyzer, without the need for a PC or external controller.

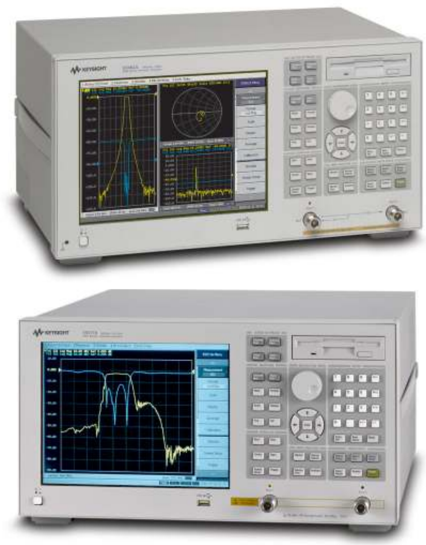


Figure 3. Keysight ENA/ENA-L network analyzer

ECal electronic calibration

Electronic calibration (ECal) modules consist of connector-specific calibration standards that measure the known devices of the system over the frequency range of interest to detect systematic errors. With simple one-connection operation, they offer excellent accuracy without sacrificing time to calibrate.

ECal electronic calibration kit which provides you with the following benefits.

- Significantly shortens measuring time
- Significantly simplifies measuring procedures
- Significantly reduces connector wear

Figure 4. Keysight Ecal kit

Differences Between Network and Spectrum Analyzers

Another approach to measuring RFID resonant frequencies is to use the tracking generator function of a spectrum analyzer. This section compares the differences between network analyzer and spectrum analyzer based evaluations.

1. Tracking errors

RFID resonant frequency measurement setups are different: A network analyzer requires calibration while a spectrum analyzer requires normalization. Once the initial measurement setup has been done, the characteristics of amplifiers and other components contained in the analyzer change over time. This produces a measurement error called "tracking error." A network analyzer performs ratio measurements and therefore it is possible to minimize tracking errors. A spectrum analyzer does not perform ratio measurements which makes it difficult to reduce tracking errors.

2. How measurement repeatability is affected by trace noise

Figure 5 compares RFID resonance characteristics (loss) measured by the ENA-L network analyzer with those measured by the tracking generator function of a spectrum analyzer (both analyzers are configured to complete a measurement cycle at the same elapsed time). As shown in the graph, measurements obtained with the spectrum analyzer have far higher trace noise than those obtained with the network analyzer. The minimum value indicated in the graph is the resonant frequency (delta frequency) of an RFID; when trace noise is too high, a frequency with the minimum value cannot be correctly determined.

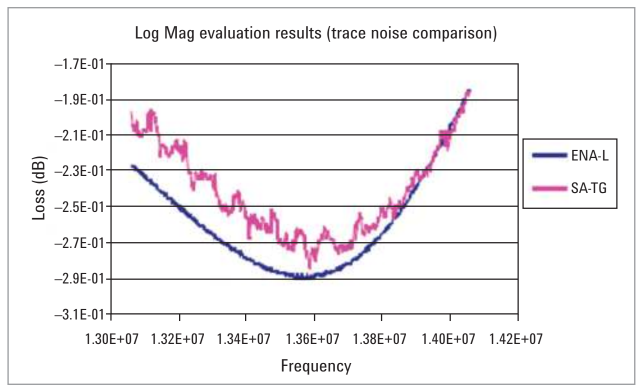


Figure 5. Trace noise comparison

Figure 6 shows the repeatability evaluations for RFID resonant frequency measurements obtained with the ENA-L and spectrum analyzer by repeating measurement cycles. As shown, resonant frequencies measured with the spectrum analyzer with a tracking generator option have several fold larger differences between repetitions than those measured with the ENA-L network analyzer.

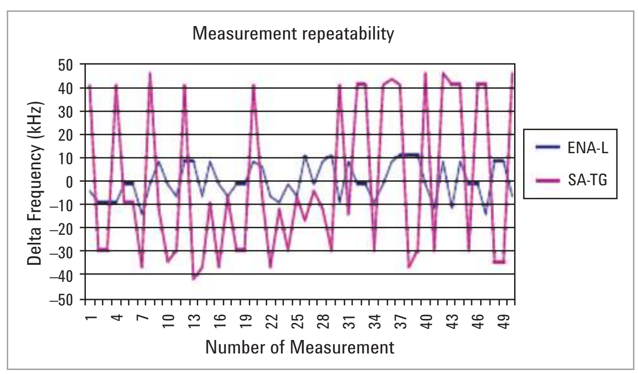


Figure 6. Measurement repeatability

3. Measuring speed

The trace noise must be reduced to measure resonant frequencies with better repeatability. Reducing the trace noise requires more averaging steps or a smaller IF bandwidth, either of which results in a longer measuring time. Thanks to its extremely low trace noise characteristics, the ENA/ENA-L network analyzer provides several fold faster measuring speed than a spectrum analyzer.

Customer Use

Sony Corporation's FeliCa Evaluation Lab provides an environment where developers of FeliCa enabled products/solutions can make performance evaluations for various products and how they communicate with other devices.

The ENA-L network analyzer (E5061A) is being effectively used in the FeliCa Evaluation Lab. FeliCa is a contactless IC card technology developed by Sony Corporation

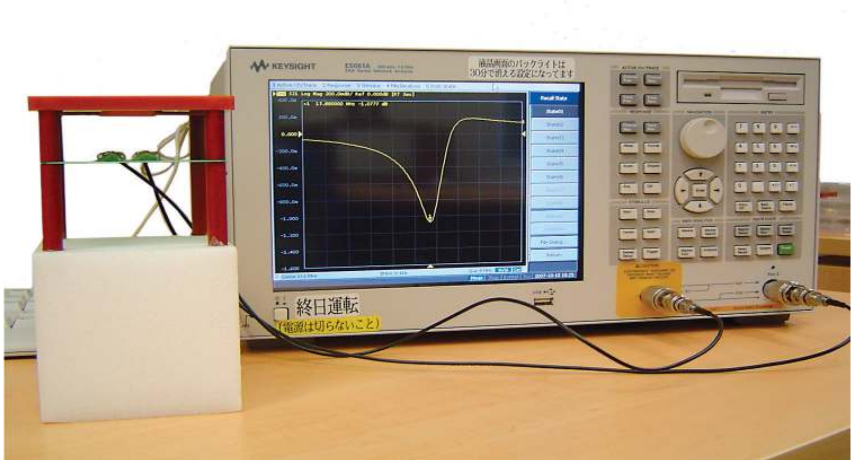


Figure 7. Sony Corporation FeliCa Evaluation Lab uses Keysight ENA-L

ENA-L Highlights

Frequency		
	E5061A	300 kHz to 1.5 GHz
	E5062A	300 kHz to 3 GHz
Test set		T/R or S-parameter
Port impedance		50 or 75 Ω
Port output power		–5 to 10 dBm –45 to 10 dBm with extended power range
Dynamic range		>120 dB
Trace noise		0.005 dB rms
Sweep types		Linear, log, segment, power
Display		10.4-inch color LCD Optional touch screen
ECal support		Yes
Measurement channels		4
Limit lines		Yes
Save recall		Yes
VBA programming		Yes

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Published in USA, December 5, 2014
5990-3443EN
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