



**INCREASING  
THE TEST COVERAGE  
OF NFC DEVICES WITH**

**ACTIVE LOAD MODULATION**



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## Abstract

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NFC device design is guided by objectives such as reliability, stability, low-energy consumption, ultra-compact design, and at the same time, providing the best user experience with a large operational area during the transaction. There is nothing more frustrating than searching for the right position of your mobile phone to make a payment.

In mobile devices, the available clearance for an antenna is very limited. Hence, NFC-based communication uses smaller form factor antennas than historical RFID antennas. This implies some changes in the physical communication layer to ensure a stable and reliable communication. Active Load Modulation (or ALM) has been introduced by device manufacturers to achieve this goal and KEOLABS has developed a tool that uses this technology to provide more in-depth terminal testing.

This new communication technology has a direct impact on terminal design, to comply with ISO requirements. In this paper, we will see how to verify if a reader is ready to interact with an NFC mobile device in card emulation mode.

## Introduction

In the last two decades, NFC has become a mature and widely-used technology. Most applications operate according to ISO/IEC 14443-A/B which defines how a terminal (or reader) can interact with an ID1-size transponder using the inductive coupling effect. The transponder is powered by the reader's electromagnetic field and uses load modulation to transmit data back to the reader. Load modulation involves connecting a passive load to the transponder antenna and switching it on and off to modulate the power transfer from the reader to the transponder. The data transmitted by the transponder is synchronous with the RF field generated by the reader, thereby facilitating the transponder response decoding.

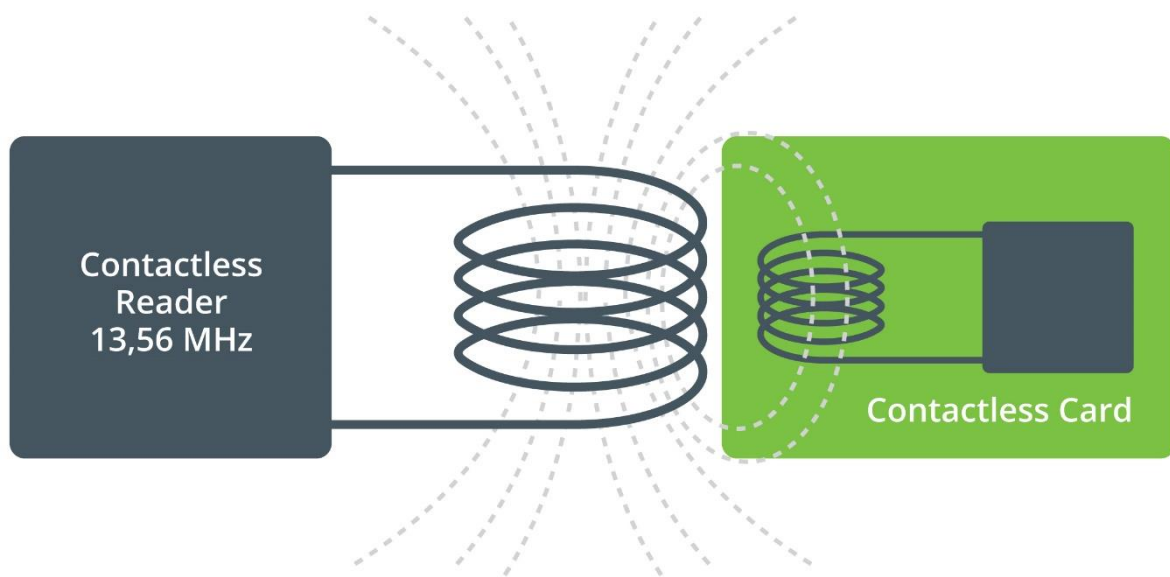


Figure 1 : Power transfer from reader to card

The ISO14443-A/B standard gradually became the generic contactless interface standard for consumer devices, changing the antenna size and shape requirements from class 1 (ID-1 credit card format) to a much smaller class 6. The advent of metal unibody mobile phones is pushing the requirement for even smaller, sub-class 6 antennas.

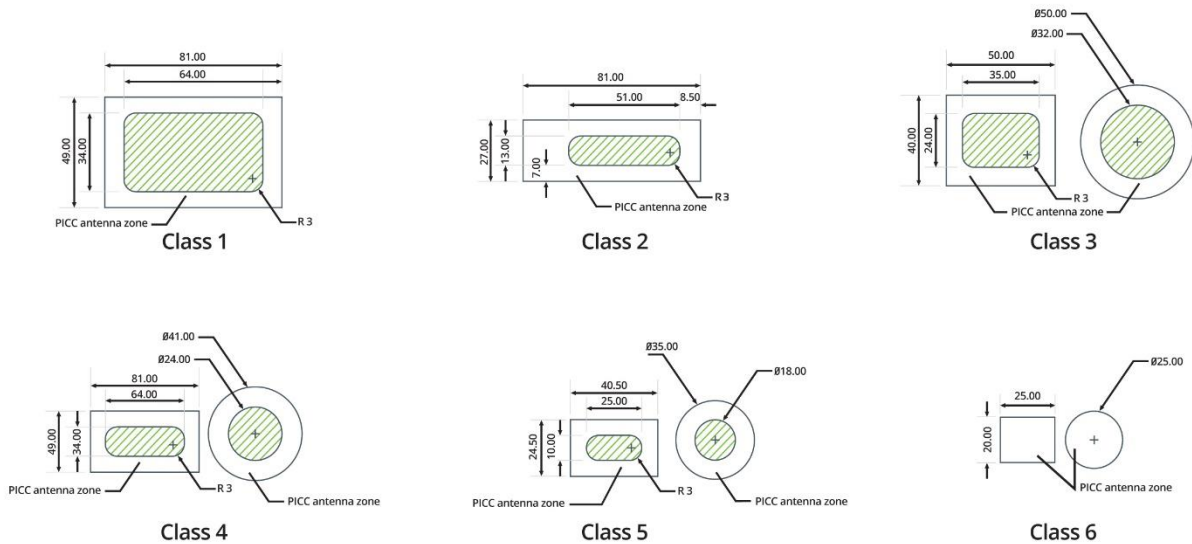


Figure 2: ISO/IEC 14443 PICC Class Definitions

Using a small antenna is technically challenging. As the size of the transponder antenna becomes smaller, the coupling factor decreases (electromagnetic link strength), the ratio of energy transfer from the terminal to the transponder decreases, and the operating distance reduces until no more communication is possible. Reciprocally it also defines the ability of the transponder to send data back to the terminal.

Active load modulation provides a solution for NFC devices to overcome those physical limitations.

## Active Load Modulation

As physical restrictions on smaller-and-smaller antenna size cannot be changed, one of the solutions to solve this communication issue is to use a different power supply for the transponder to ensure it has enough energy to perform a full transaction.

If the transponder is battery-powered, it can generate a signal with passive load modulation characteristics and actively transmit this signal to the reader. If the transponder signal is coherent with the RF field, it will generate destructive interference and result in synchronous modulation. From the reader's point of view, the received data looks like an amplitude-modulated signal, the same as a classic battery-less card would send.

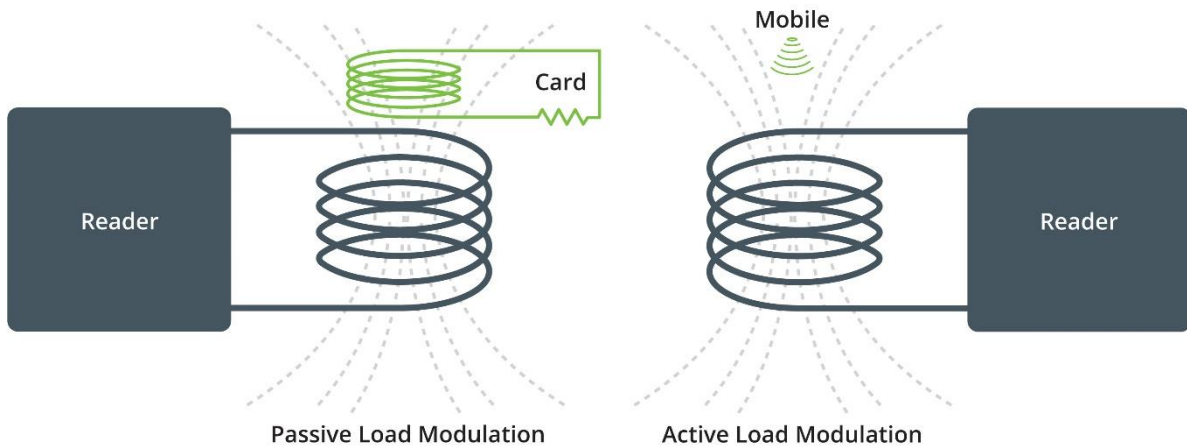


Figure 3: Passive Modulation vs. Active Modulation

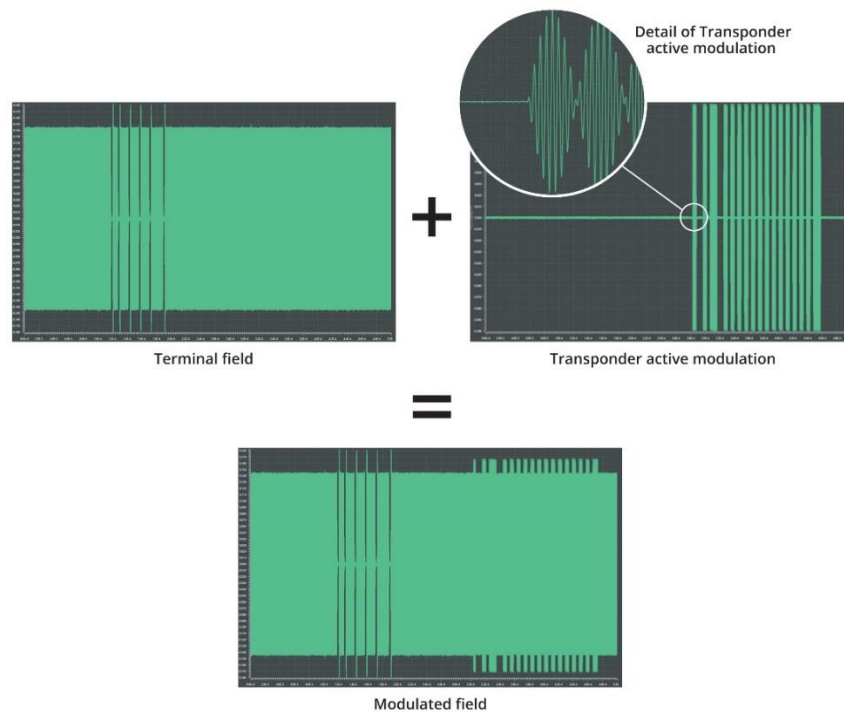


Figure 4: ALM Response Signal Construction

When correctly implemented and tuned, this technology can replicate passive load modulation and the reader cannot determine if the received signal has been generated by a passive or an active load modulation.

If not perfectly mastered, this technology can lead to side effects that cause interoperability issues.

The main problems are linked to the relative phase of the load modulation to the field and to the drift of this phase. These synchronism issues may have several sources, for instance mobile internal PLL desynchronization on long commands. Indeed the active load modulation necessitates the ability to synchronize on an external clock (reader field), using PLL most of the time, which will switch to freewheel during data transmission.



This, added with the fact that the Reader and Transponder internal clock sources are not at the same value (while being within the ISO tolerance), might result in a nonsynchronous transponder response and thus a phase drift in the signal received by the reader.

Generally, a nonsynchronous transponder response can be observed as a shift from I to Q signal when demodulated with respect to the reader signal. In the baseband, this phase drift appears as a change in amplitude of the transponder modulation (second part of the figures below). In some cases, the load modulation may even appear as zero amplitude envelope modulation.

Below are two examples of badly generated active modulation:

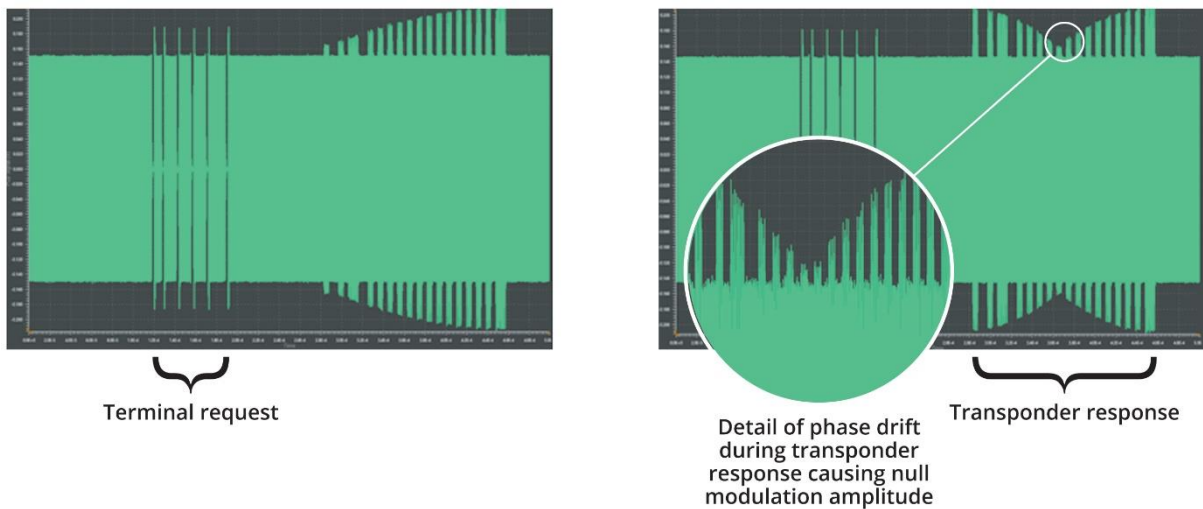


Figure 5: Influence Of Phase Drift During ALM Communication

NB: This white paper focuses on NFC mobile devices which may exhibit load modulation phase drift, but it is also of interest as a method to increase interoperability with passive cards which may have different initial phases (chip on module vs historical cards).

## Terminal Phase Drift Immunity Testing Tool

One of the many useful tools provided within the KEOLABS' Quest environment is the PCD Phase Drift Immunity. As the name suggests, this tool has been design to test the capability of the terminal to support various combinations of initial phase and phase drift that a transponder could exhibit.



Figure 6: Quest's Tool For PCD Phase Drift Immunity Testing

This characterization tool uses a Shmoo-plot dedicated to ALM. In one glance, the user can see the result of a full test campaign while having the capability to get detail on a particular test condition.

## The Setup

To use the tool, let's have a look at the hardware setup.

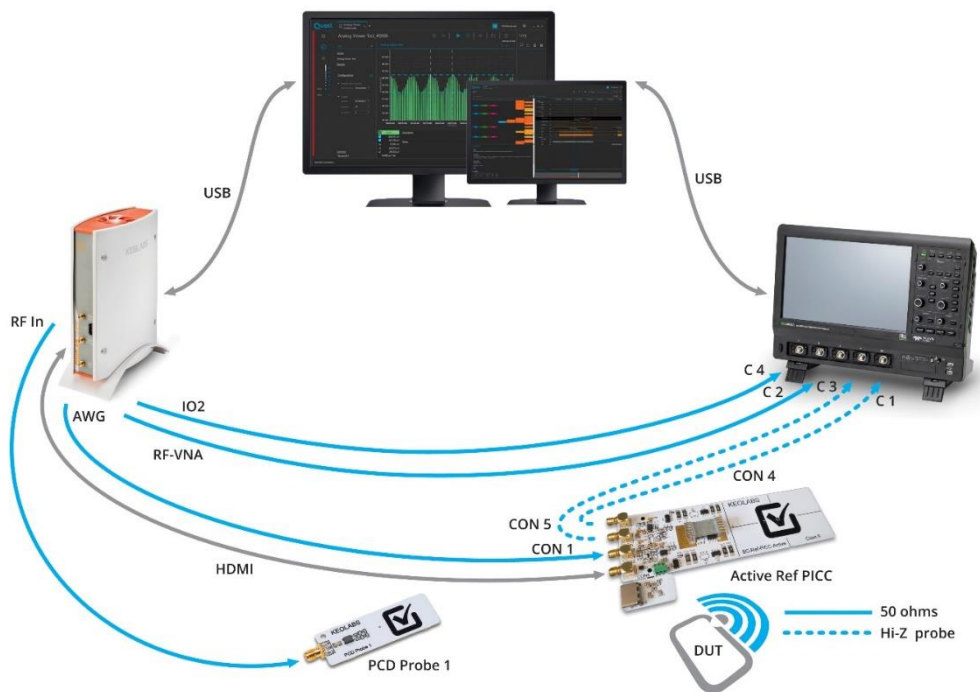


Figure 7: Complete Hardware Setup To Simulate Phase Drift During ALM Communication

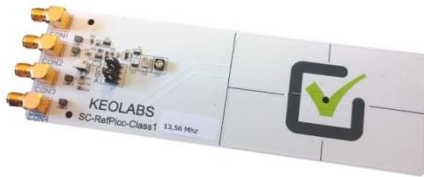




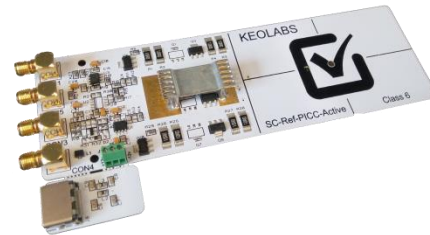
The user will need:

- A ProxiLAB Quest - contactless testing station
- An Active ISO Reference PICC
- A demodulation probe
- An oscilloscope
- And of course, a computer running Quest.

Just few words about the Active ISO Reference PICC



**Reference PICC**



**Active ISO Reference PICC**

According to ISO10373-6, the Reference PICC is defined to test the ability of a Terminal to:

- Generate a field strength of at least  $H_{min}$  and not exceeding  $H_{max}$ ,
- Transmit a modulated signal to a transponder,
- Receive a load modulation from a transponder at minimum level,
- Be immune against EMD signals from the transponder.

ISO10373-6 edition 4 defined a new reference PICC, called the Active Reference PICC, to be used in phase drift immunity tests. This Active Reference PICC can only be used with a powerful test tool like ProxiLAB to generate a modulation signal.

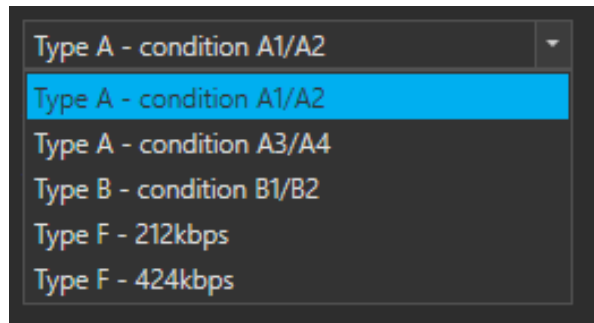
## How to use the tool

Connect all the hardware together as shown in the Setup image, then start the Terminal Phase Drift Immunity testing tool.

### Step 1: - Configure the parameters

Several parameters can be configured such as:

- Tx coil (active PICC or simple ID1 coil)
- Standard (ISO14443 or EMVCo)
- Phase drift type (several protocols and phase drift pattern supported)



- Phase drift start/stop/step conditions to test
- Initial phase start/stop/step conditions to test
- DUT timeout (terminal turn over after failed reception)
- Number of iteration per measurement point
- Digital trace acquisition (Y/N)
- Analog trace acquisition (Y/N)

### Step 2 - Perform the measurement test campaign

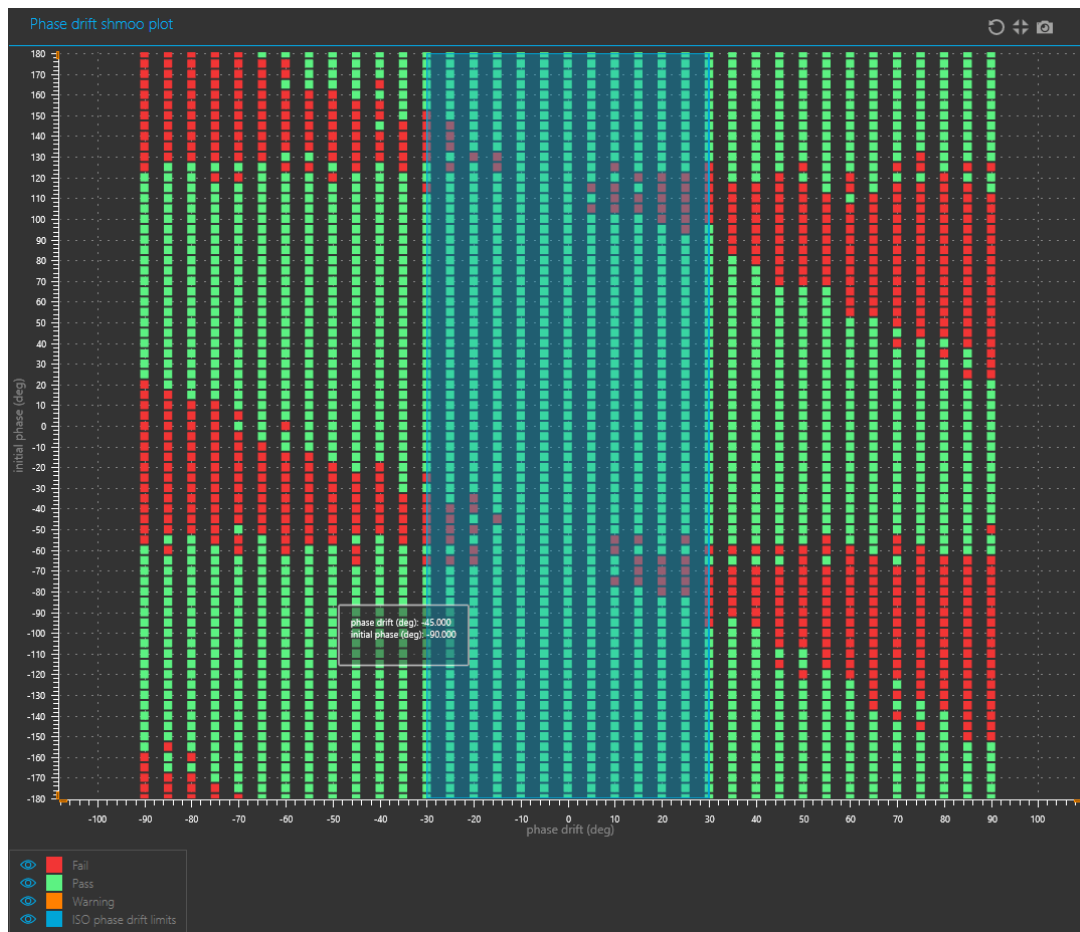
The measurement test campaign tests the capability of the reader to correctly handle the transponder response for each defined configuration. Depending on the quantity of measurement points, number of iterations, trace acquisition options and terminal behavior, it can take a significant time to complete the campaign (from few seconds to several hours!).

### Step 3 - Result analysis

The results are presented according to 3 different views: Phase drift, I/Q and constellation.



## Shmoo-Plot Comparing Various Initial Phase / Phase Drift Test Conditions



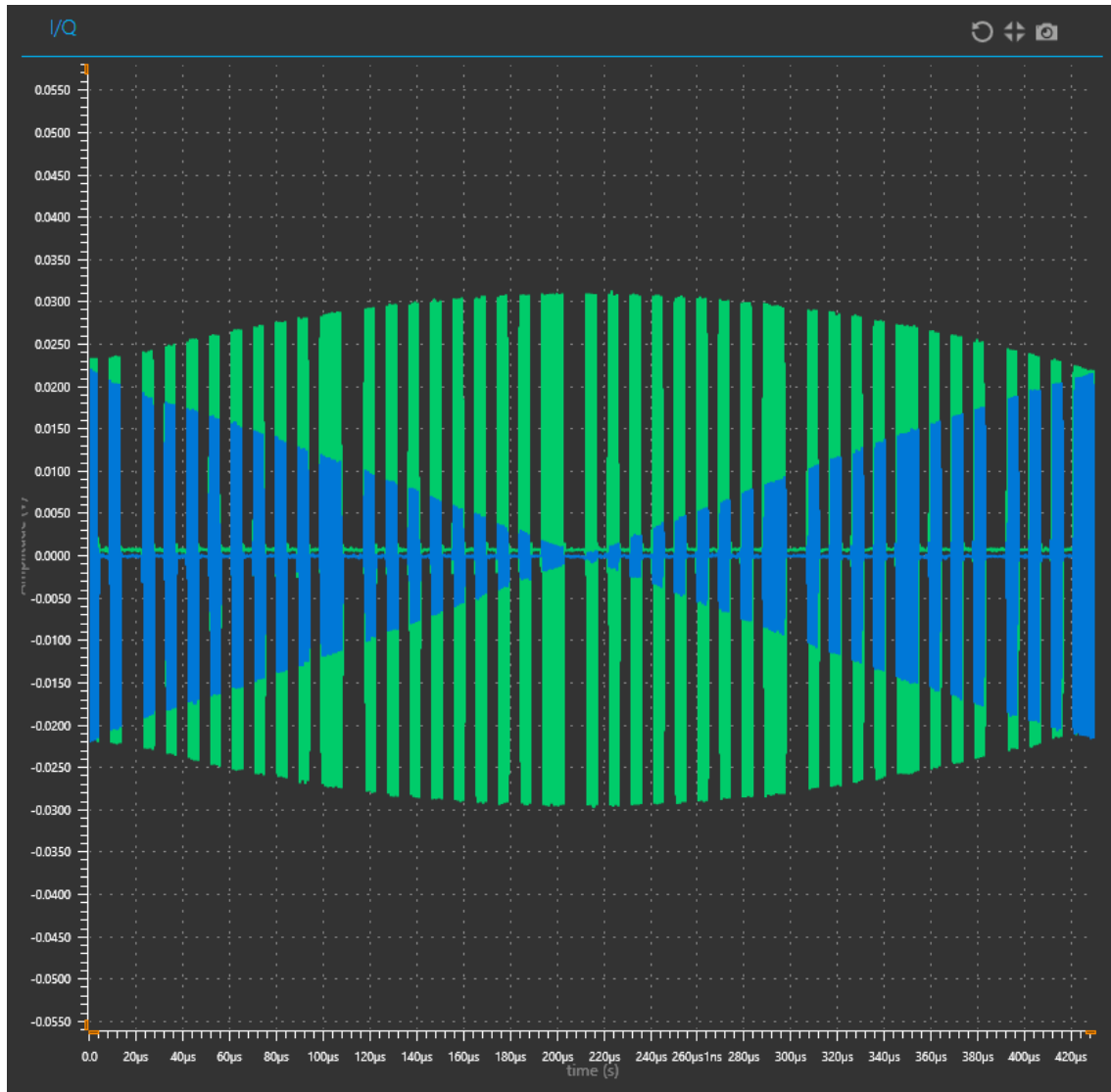
This Shmoo Plot of Phase Drift presents the test campaign result:

- Phase drift is on the abscissa axis
- Initial phase is on the ordinate axis
- Red square is 0% successful transaction
- Orange square is 1% - 99% successful transaction (iteration must be >1)
- Green square is 100% successful transaction
- Blue rectangle shows the ISO limits (i.e.  $\pm 30^\circ$  allowed phase drift)

Analog acquisition for a given point can be observed by double clicking on the corresponding square.



### I/Q Signal View



The I/Q view uses Cartesian coordinates to present the presents the test campaign result, with the PICC signal demodulated with the reader field (in-phase and quadrature components) versus time.

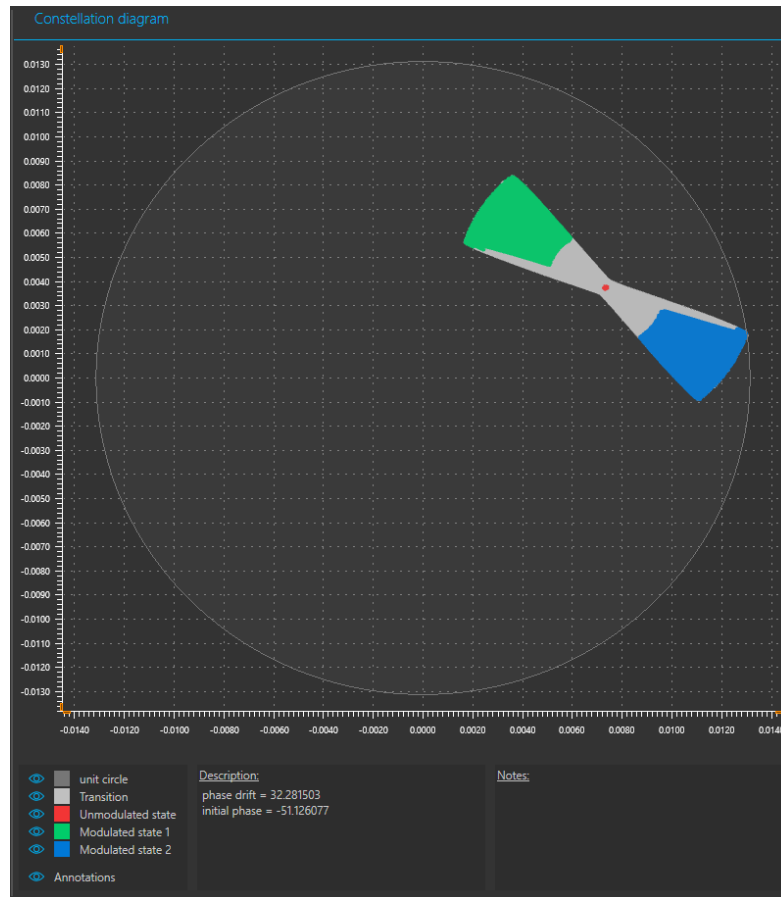


Figure 8: Constellation View

The Constellation View shows a polar representation of I/Q data.

It provides visual proof that the phase drift condition is correctly applied by the tool during test.



## Conclusion

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Available space is extremely limited in mobile devices. This implies the usage of very small form factor RFID antennas. To avoid communication issues with these small antennas, Active Load Modulation is a good technology. However, as the transponder can't observe the reader's RF field, their frequencies may become desynchronized. This creates a drift of the transponder communication phase and may lead to errors while receiving and decoding the data.

The Phase Drift Immunity tool can check:

- If the reader complies with the ISO limits,
- If there is some margin beyond the ISO limits,
- If there are non-functioning areas within the ISO limits.

Testing the limits is important but having a full view of the complete behavior of the reader will provide you with more confidence in your equipment.



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