UM2513
User manual

Firmware for the ST25R3916-DISCO board

Introduction

This document describes the features of the STSW-ST25R011 firmware, developed to demonstrate the capabilities of the ST25R3916-DISCO board, based on the ST25R3916 device.

The ST25R3916 is a high-performance NFC universal device and EMVCo reader that can be controlled by a microcontroller through SPI or I^2C interfaces.

This reader supports all standard NFC protocols to communicate with tags, smartphones or any other reader.

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1 List of acronyms and notational conventions

1.1 Acronyms

APB: Advanced peripheral bus

DPO: Dynamic power output

GUI: Graphical user interface

IEC: International electro-technical commission

ISO: International organization for standardization

MCU: Micro controller unit (microcontroller)

NFC: Near-field communication

RF: Radio frequency

RFID: Radio frequency identification

RISC: Reduced instruction set computer

RSSI: Received signal strength information

SPI: Serial peripheral interface

URI: Uniform resource identifier

URL: Uniform resource locator

USB: Universal serial bus

1.2 Representation of numbers

The following conventions and notations apply in this document unless otherwise stated:

- Binary numbers are represented by strings of 0 and 1 digits shown with the most significant bit (MSB) on the left, the least significant bit (LSB) on the right, and “0b” added at the beginning. Example: 0b11110101.
- Hexadecimal numbers are represented by using numbers 0 to 9 and characters A to F, and adding “0x” at the beginning. The most significant byte (MSB) is shown on the left and the least significant byte (LSB) on the right. Example: 0xF5.
- Decimal numbers are represented without any trailing character. Example: 245.

2 Hardware overview

2.1 ST25R3916

The ST25R3916 is a high-performance NFC universal device and EMVCo reader for contactless applications.

It manages the RF communication with tags, smartphones and other readers, supporting:

- As a Reader, all standard NFC tag communication protocols:
  - NFC Forum NFC-A, NFC-B, NFC-F and NFC-V
  - ISO14443A
  - ISO14443B
  - FeliCa™
  - ISO15693
- Card emulation as a NFC Forum Type 4A or Type 3 tag
- All NFC Forum Peer-to-peer modes:
  - Initiator and target roles
  - Passive and active modes

Other features of the ST25R3916 are:

- Stream modes to implement custom protocols
- Integrated capacitive sensing system for low power tag presence detection
- Integrated inductive sensing system for low power tag presence detection using phase or amplitude
- High output power
- User selectable and automatic gain control
- SPI up to 10 Mb/s
- I^2C up to 3.4 Mb/s

2.2 STM32L476

The STM32L476xx devices are ultra-low-power microcontrollers based on the high-performance Arm®(a) Cortex®-M4 32-bit RISC core operating at a frequency of up to 80 MHz. The Cortex®-M4 core features a floating-point unit (FPU) single precision, which supports all Arm® single-precision data-processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) that enhances application security.

arm

a. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

The STM32L476xx devices embed high-speed memories (Flash memory up to 1 Mbyte, up to 128 Kbytes of SRAM), a flexible external memory controller (FSMC) for static memories (for devices with packages of 100 pins and more), a QuadSPI Flash memory interface (available on all packages) and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

The STM32L476xx devices feature several protection mechanisms for embedded Flash memory and SRAM: readout protection, write protection, proprietary code readout protection and firewall.

The devices offer up to three fast 12-bit ADCs (5 Msps), two comparators, two operational amplifiers, two DAC channels, an internal voltage reference buffer, a low-power RTC, two general-purpose 32-bit timer, two 16-bit PWM timers dedicated to motor control, seven general-purpose 16-bit timers, and two 16-bit low-power timers. The devices support four digital filters for external sigma delta modulators (DFSDM).

In addition, up to 24 capacitive sensing channels are available. The devices also embed an integrated LCD driver 8x40 or 4x44, with internal step-up converter.

They also feature standard and advanced communication interfaces:

- three I^2Cs
- three SPIs
- three USARTs, two UARTs and one Low-Power UART.
- two SAIs (Serial Audio Interfaces)
- one SDMMC
- one CAN
- one USB OTG full-speed
- one SWPMI (single-wire protocol master interface)

2.3 ST25R3916-DISCO kit

The ST25R3916-DISCO is a kit designed to evaluate the performance of the ST25R3916 reader. This kit is composed of two boards:

- ST25 Discovery motherboard, with the firmware (STSW-ST25R011) already flashed in
- ST25R3916 Discovery antenna daughter board

The ST25R3916-DISCO kit also provides two ST25TV02K tags.

2.3.1 ST25 Discovery motherboard

The ST25 Discovery motherboard is powered through one of the USB buses (micro and mini connectors), no external power supply is required.

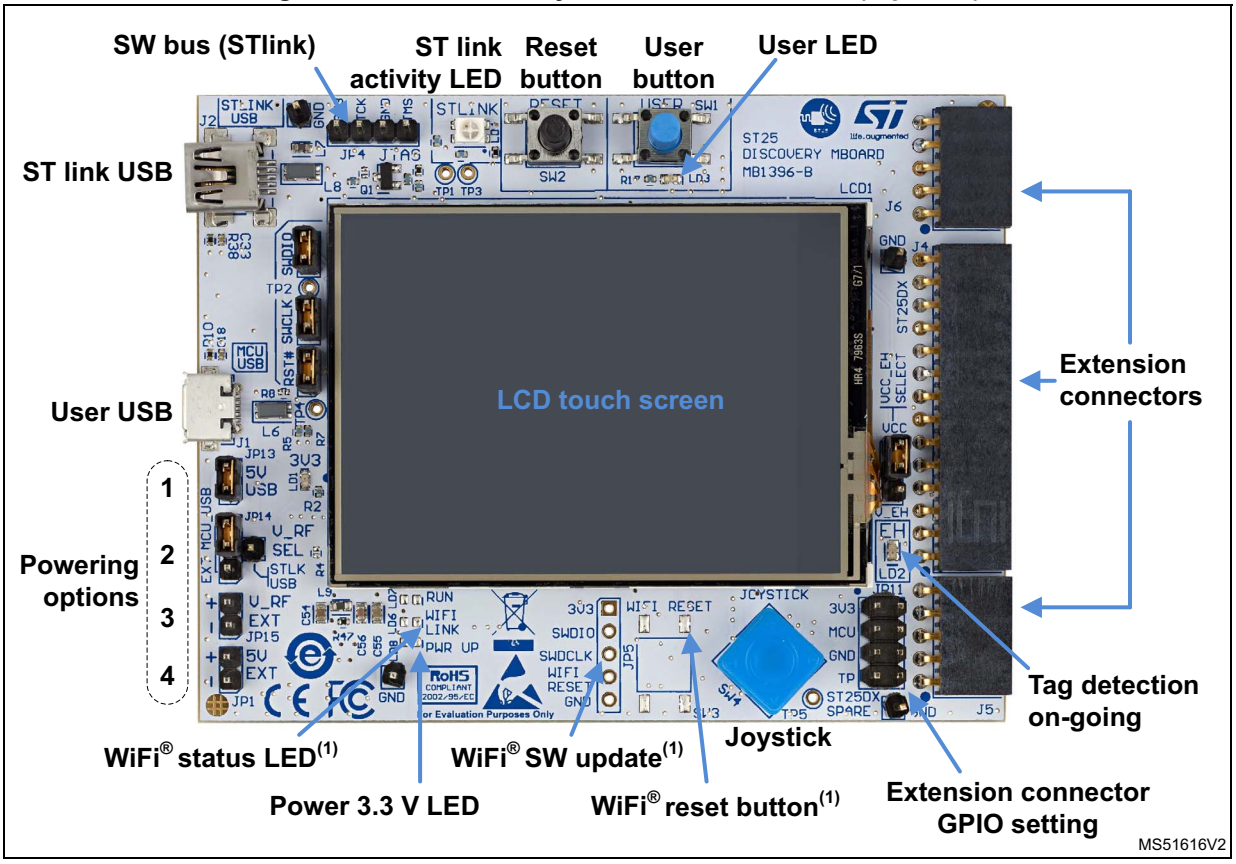
Note: The default setup of the ST25R3916-DISCO kit requires to power the ST25 Discovery motherboard through the USB-Micro port.

This motherboard embeds the STM32L476VG microcontroller and different peripherals:

- LCD display and touchscreen to interface with the user
- USB connectors to connect to a PC (mini-USB for the ST-LINK debugger and micro-USB available for the user application)
- Optional modules: Wi-Fi® and Bluetooth® Low Energy (BLE) to connect with a smart phone.

The connector on the right side of the board is dedicated to daughter boards based on ST25 NFC devices.

Figure 1. ST25 Discovery motherboard MB1396 (top view)



1. Available only on demonstration edition.

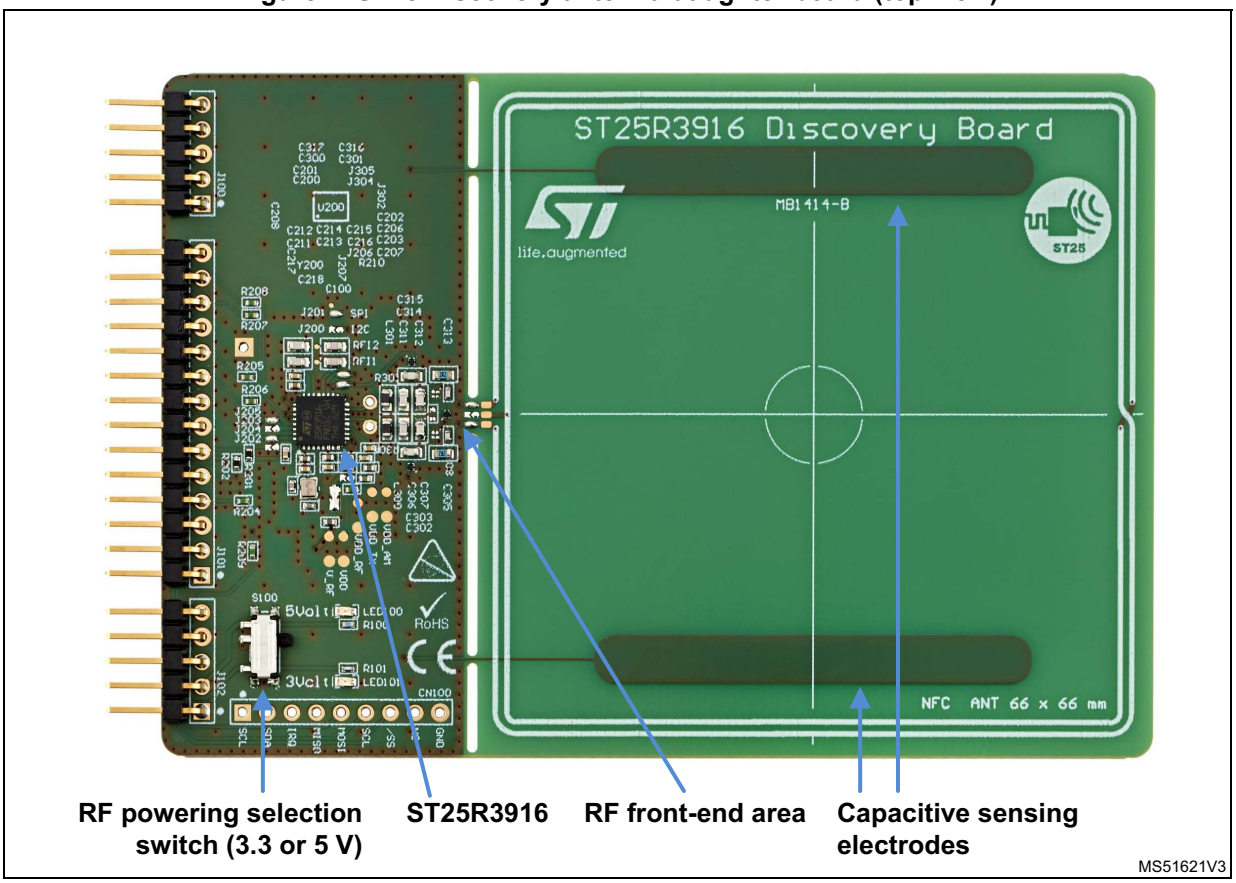
2.3.2 ST25R3916 Discovery antenna daughter board

This board embeds the ST25R3916 NFC reader device and a 67 x 67 mm^2, 13.56 MHz single layer copper etched antenna.

The ST25R3916 can communicate with the STM32L476VG 32-bit MCU via the SPI or I^{2}C bus.

The board also features a switch to select the RF voltage (3.3 V or 5 V).

Figure 2. ST25 Discovery antenna daughter board (top view)



2.3.3 ST25TV02K tag

The ST25TV02K tags contactless interface is compatible with the ISO/IEC 15693 standard and with the NFC Forum Type 5 tag. These tags feature a digital signature used to prove the origin of the chip in cloning detection.

These tags embed a configurable EEPROM with 60-year data retention, and can be operated from a 13.56 MHz long-range RFID reader or from an NFC phone.

3 ST25R3916-DISCO demonstrations

3.1 Prerequisite

To run the demonstrations described below it is required to have the following hardware:

- ST25R3916-DISCO kit (motherboard + antenna daughter board)

  Make sure that the JP14 jumper on the ST25 Discovery motherboard is positioned as shown here 

  .

- An USB Micro cable to connect to a PC, required for two purposes:
  - Power supply
  - Control of the demonstrations from a PC when in USB mode, see *Section 3.7*.
- Optionally USB mini cable to connect to a PC in order to make use of the ST-LINK to flash the program memory of the STM32L476 MCU.
- The Reader / Writer demonstration requires to have NFC tags, like the ones provided with the ST25R3916-DISCO kit.

Some demonstrations (Card emulation, Peer to peer) require another reader, such as:

- a smartphone with NFC feature
- a second ST25R3916-DISCO kit

On the software side, the following packages can be downloaded from *www.st.com*:

- STSW-ST25R011: firmware for the ST25R3916-DISCO kit (binary and source code available)
- STSW-ST25R010: PC installer for the ST25R3916 Discovery GUI, used for USB mode.

3.2 Main menu

The main menu is composed of four icons, intended to access sub-menus.

Figure 3. Main menu display

Each item allows the user to start the corresponding demonstration, as indicated below.

Table 1. Available demonstrations

Demonstration	Icon	Reference
Reader / Writer		*Section 3.3*
Card emulation		*Section 3.4*
Peer to peer		*Section 3.5*
Automatic antenna tuning		*Section 3.6*

To start a demonstration, touch the screen on one demonstration icon. A long touch on an icon will display, in the top line, the name of the corresponding demonstration.

In any demonstration it is possible to go back to the previous screen by touching the bottom line of the screen, which usually displays the message: “Touch here to exit”.

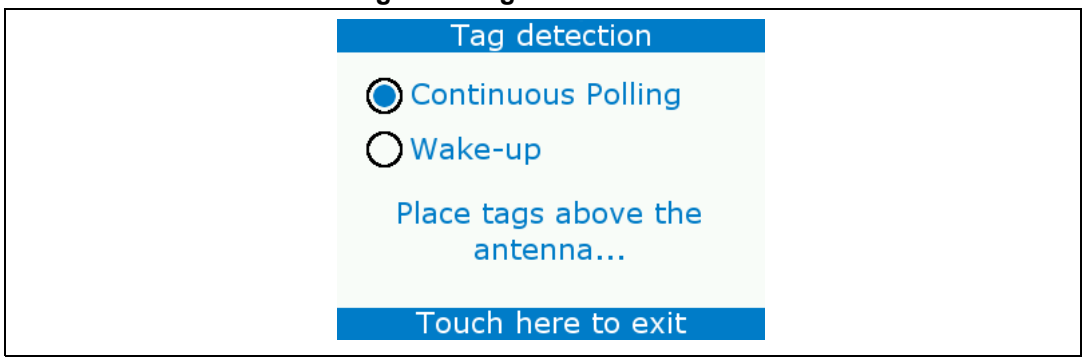
3.3 Reader / Writer demonstration

3.3.1 Tag detection screen

As shown in *Figure 4*, this demonstration starts with the Tag detection screen, proposing two types of detection (touch the screen to select the detection mode):

- Continuous polling (default), which continuously executes the NFC Forum tag detection algorithm. In this mode, the led LD2 on the ST25 Discovery motherboard blinks as the RF field is periodically turned ON/OFF.
- Wake-up, which enables to detect the presence of a tag while the RF field is OFF thanks to the ST25R3916 inductive sensing system. In this mode the led LD2 on the ST25 Discovery motherboard is OFF until a tag is detected.

Figure 4. Tag detection screen



3.3.2 Tag inventory screen

When the demonstration is in the tag detection screen, any tag placed above the antenna will be inventoried and displayed on the screen with basic information (*Figure 5*):

- the NFC protocol supported by the tag
- the first 4 bytes of the tag UID.

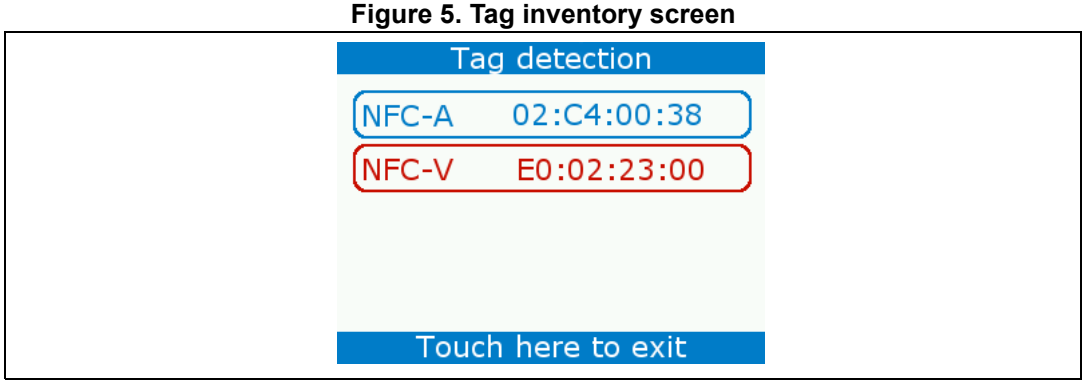
Up to four tags can be displayed on the LCD.

Different colors are used to display the tag, depending on the supported communication protocol:

- blue for NFC-A
- green for NFC-B
- brown for NFC-F
- red for NFC-V

The user can continue the demonstration by touching the area used to display a tag, this will open the information screen for the selected tag.

Figure 5. Tag inventory screen



3.3.3 Tag information screen

The tag information screen displays more information on the selected tag (see *Figure 6*):

- the type of the tag.
- its complete UID.
- the communication speed for reception / transmission.
- the RSSI displayed as a bar which enlarges as the signal strength increase. RSSI is measured by regularly reading data from the tag.
- the DPO profile, displayed in the top right box. Only two DPO profiles are defined for this demonstration:
  - full power: maximum RF power delivered, when the tag is far from the antenna
  - low power: RF power is divided by approximatively 4, when the tag is near the antenna.

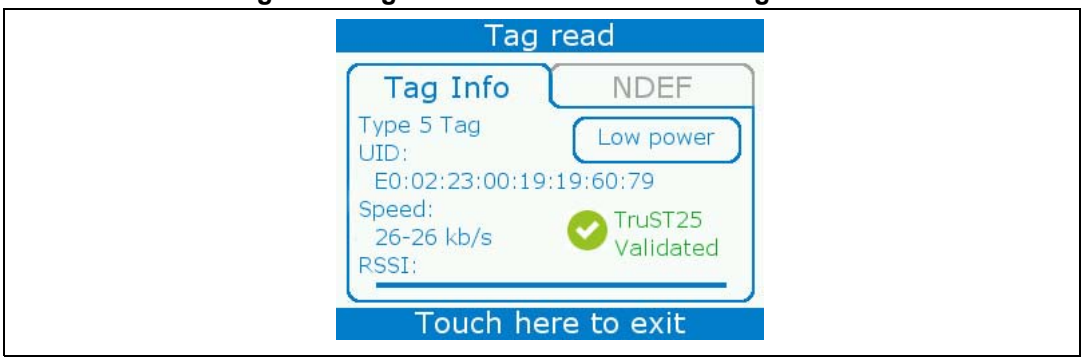
  The DPO profile is automatically selected depending upon the distance between the tag and the reader.
- If the selected tag has a valid TruST25 signature (making it possible to authenticate a tag), the valid icon is also displayed on the screen (see *Figure 7*).

The display is regularly refreshed to display measured RSSI and resulting DPO values, moving the tag in front of the antenna will thus be immediately reflected on the display.

Note: Some tags advertise a very long transmission timeout to the reader. Consequently, if the tag goes out of the field, the GUI may seem to freeze waiting for the tag response timeout. In this situation it is possible to interrupt the running transfer by touching the screen (either the exit area, or any other area if the tag is back in the field).

Figure 6. Tag information screen

Figure 7. Tag information with TruST25 signature



3.3.4 NDEF screen

By touching the gray NDEF tab from the Tag information screen, it will enter the NDEF demonstration screen. This demonstration makes it possible to read and write NDEF messages from / to the selected tag.

This demonstration first reads the data in the tag, and if this data is an NDEF message, displays it such as in *Figure 8* for an URI or *Figure 9* for a vCard.

If the data is not an NDEF messages, only the first bytes of raw data are displayed (see *Figure 10*).

The NDEF message write icon  is present only if the selected tag supports NDEF. Touch it to write an NDEF URI message to the tag memory (http://www.st.com/st25r).

Figure 8. NDEF URI read

Figure 9. NDEF vCard read

Figure 10. No NDEF present

3.4 Card emulation demonstration

This demonstration configures the ST25R3916 to act as a NFC Forum Type 4A card.

Note: More card emulation options are available by using the STSW_ST25R010 PC software.

As shown below, the screen displays the message: “CE mode running”, and three icons:

When selected the ST25R3916 emulates an NDEF URI message.

When selected the ST25R3916 emulates an NDEF vCard message (~ 8 Kbytes, including a picture).

- Enabled (colored) after the emulated card has received data from a smartphone or reader. When enabled, touch it to see the received data.
- Inactive (gray) before any data is received.

For this demonstration, the user can bring a smartphone with NFC enabled or a reader above the ST25R3916 antenna. An Android® smartphone will natively read the emulated card content and open the corresponding application (a Web browser for the URL, a Contact app for the vCard).

An iOS® smartphone (iPhone Xs/Xr or newer), will natively read the emulated URI and open a web browser (Safari), other ones may require an NFC application like the ST25 NFCTap (to be downloaded from the App Store).

To write the emulated card with an Android® smartphone, the user has to install an application such as the ST25 NFCTap (available on the Play Store, referred to as STSW-ST25001 on *www.st.com*). In this demonstration, the maximum size of an NDEF to be written is set to 3 Kbytes.

Any reader supporting the NFC Forum Type 4 tag protocol can be used to write data to the card emulated by the ST25R3916. For instance, it is possible to use a second ST25R3916-DISCO kit in Reader/Writer mode to write an URI (see *Section 3.3.4*).

Figure 11. Card emulation demonstration

3.5 Peer to peer demonstration

This demonstration configures the ST25R3916 in the different NFC Forum peer to peer modes:

- Initiator and target roles
- Active and passive modes

The ST25R3916 searches for a peer device before moving to next mode.

As shown below, the screen displays the message: “Wait connection…”, and three icons:

When selected the ST25R3916 will send an NDEF URI message to the peer device.

When selected the ST25R3916 will send an NDEF vCard message to the peer device (~ 8 Kbytes, including a picture).

- Enabled (colored) after the ST25R3916 has received data from a peer device (smartphone or reader). When enabled, touch it to see the received data.
- Inactive (gray) before any data is received.

Put an Android® smartphone above the ST25R3916-DISCO kit antenna to natively connect in peer to peer mode.

The role and mode of the ST25R3916 is shown in *Figure 13*. The mode can be one among the following ones:

- Initiator
- Target (P): for passive target (waiting for the field)
- Target (A): for active target (enabling its RF field for communication)

Once connected to a peer device, the selected NDEF message is automatically sent.

If the peer device is an Android smartphone, it will natively open the corresponding application (a Web browser for the URI, or a Contact app for the vCard).

Alternatively another reader, with NFC Forum peer to peer support, can be used as peer device. For instance a second ST25R3916-DISCO kit, with peer to peer demonstration started, can be used for that purpose.

Note: This demonstration only implements a limited support of the peer-to-peer mode, for a full support it is recommended to use the ST25R3916-DISCO PC GUI (see Section 3.7).

Note: If the peer device is in passive target mode, when it goes out of the field, the GUI may seem to freeze waiting for the peer device response timeout. In this situation it is possible to interrupt the running transfer by touching the screen (either the exit area, or other area if the peer device is back in the field).

Figure 12. Peer to peer demonstration

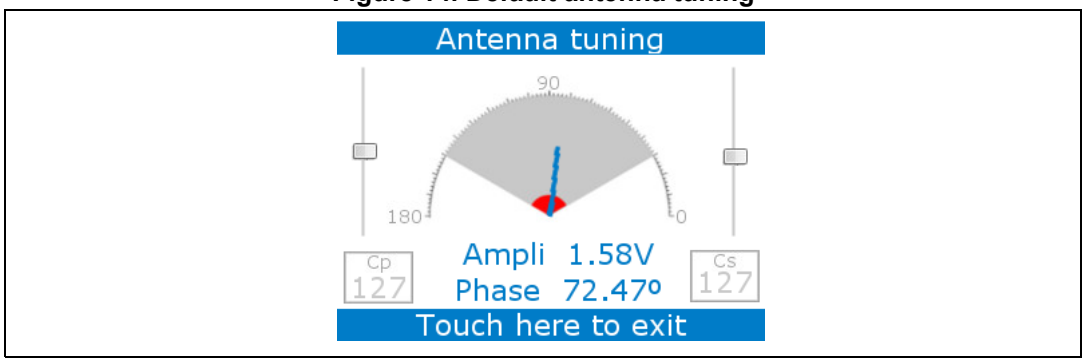
Figure 13. Peer to peer connected as initiator

3.6 Automatic antenna tuning demonstration

The ST25R3916 allows the user to control variable capacitances to perform a fine tuning of the antenna and to obtain the best setup in any environment. For the tuning, three variable capacitances are used, two (Cs) connected serially, the third one (Cp) in parallel to the antenna.

When entering the demonstration, the capacitances are set to their default values, and the corresponding antenna measurements (amplitude and phase) are displayed both by a needle on a gauge and numerically on the screen (see *Figure 14*).

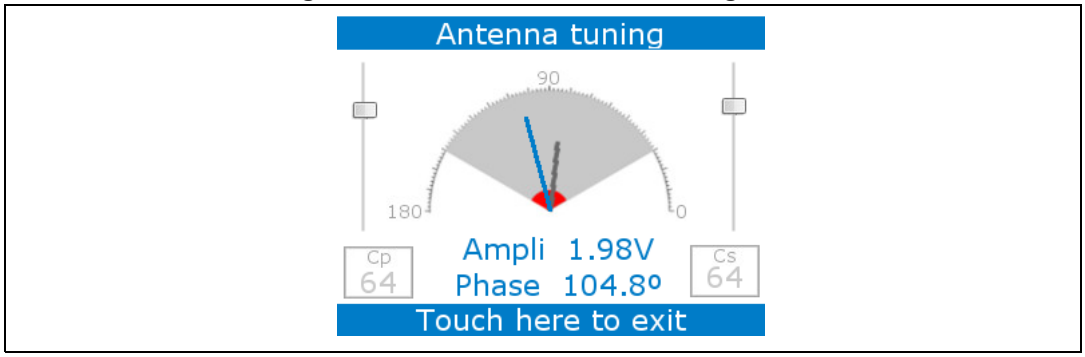
Figure 14. Default antenna tuning



Touch the screen to run the automatic antenna tuning, thus improving its performance. New capacitances are displayed along with the updated antenna measurement.

The needle corresponding to the previous values (before tuning) is now displayed in gray, while the new antenna metrics are displayed by the blue needle and the message on the screen (see *Figure 15*).

Figure 15. Automatic antenna tuning done



Push the user button (blue) on the ST25 Discovery motherboard to reset the capacitances to their default values.

The user can also manually explore the result of different capacitance settings by touching the slide bars on the right and left side of the screen. The display is then immediately refreshed with new antenna measurements.

3.7 USB mode

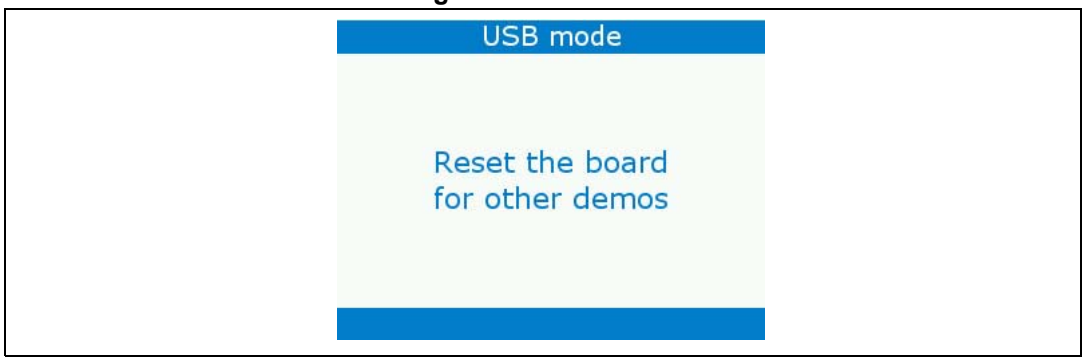
To enter USB mode the user must reset the motherboard while keeping the user button (blue) pushed. The screen must be as shown in *Figure 16*. To leave this mode, another reset is required, while leaving the user button not pushed.

The USB mode is used to allow a PC to control the ST25R3916-DISCO kit through the USB-micro connector present on the motherboard.

The user must first download and install the software STSW-ST25R010 (available on *www.st.com*) on a PC, and then connect the ST25 Discovery board to it with the micro USB port. Then, it must ensure that the jumper JP14 on the ST25 Discovery motherboard is positioned on MCU_USB, as indicated in *Section 3.1*.

In this mode the ST25R3916 Discovery GUI PC software has full control over the ST25R3916-DISCO kit. Refer to the *ST25R3916-DISCO reference graphical user interface* user manual (UM2517) to learn about the demonstrations available with the ST25R3916 Discovery GUI.

Figure 16. USB mode



4 Revision history

Table 2. Document revision history

Date	Revision	Changes
20-Dec-2018	1	Initial release.
22-Feb-2019	2	Document scope updated from *ST Restricted* to *ST Public*.
21-May-2019	3	Updated *Section 3.6: Automatic antenna tuning demonstration*. Updated *Figure 2: ST25 Discovery antenna daughter board (top view)*, *Figure 11: Card emulation demonstration* and *Figure 13: Peer to peer connected as initiator*.