Basic Tests of NFC Enabled Devices Using R&S Test Equipment

Application Note

Products:

- R&S®SMBV100A
- R&S®FSL
- R&S®SMBV-K89
- R&S®FSV
- R&S®FS-FS-K112PC
- R&S®FSW
- R&S®RTO
- R&S®ZVL
- R&S®RTO-K11
- R&S®CSNFC-B8

This application note describes how to perform basic NFC analog tests of NFC-enabled devices and NFC tags. The tests are carried out with R&S test instruments and R&S NFC Measurement Software, using the NFC Forum Reference devices available from R&S.
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1 Abstract

This application note explains how to carry out basic tests as defined by the NFC Forum Analog Specification, of NFC-enabled devices in listening and polling mode. NFC Tags which support only listening mode are tested the same way.

Test antennas, the NFC Forum Reference Devices, are required to carry out the tests. R&S offers antennas R&S®CSNFC-B8 which are compliant to the NFC Analog specification. For NFC signal generation an SMBV with option Digital Standard NFC-A/B/F SMBV-K89 is used. Poller signals are available at the RF output of the SMBV, listener signals are available at the baseband I-output on the rear side of the generator.

The NFC Measurement Software FS-K112PC controls an RTO oscilloscope with RTO-K11 (or alternatively an R&S Signal or Spectrum Analyzer) which captures the NFC signals and delivers I/Q data to the FS-K112PC. The FS-K112PC analyses the signal and delivers pass/fail information for both poller and listener signals. Where this application note refers to an RTO a suitable analyzer FSV, FSW, FSL or ZVL could also be used.

The NFC Measurement Software FS-K112PC can be controlled remotely and thus all its functions can be integrated in a customer’s test software.

Note: For some more advanced tests (which are not described in the following e.g. testing Modulation Sensitivity in polling mode) a specific NFC Trigger is necessary which is provided by the RTO but not with R&S signal- and spectrum analyzers).

The following abbreviations are used in this application note for R&S® test equipment:

- The R&S®RTO is referred to as the RTO.
- The R&S®SMBV100A is referred to as the SMBV.
- The R&S®FSW is referred to as the FSW.
- The R&S®FSV is referred to as the FSV.
- The R&S®FSL is referred to as the FSL.
- The R&S®ZVL is referred to as the ZVL.
- The R&S®FS-K112PC is referred to as the FS-K112PC.
2 Test Setup

2.1 NFC Reference Devices

2.1.1 Reference Polling Devices

When connected to the RF output of a suitable signal generator like the SMBV100A via connector J1, an NFC Forum Reference Polling Device sends commands to a listening device. The response from a listening device can then be captured and analyzed by measurement equipment, for example an RTO connected to the J2 connector, controlled by the NFC Measurement Software FS-K112PC.

NFC Forum Reference Polling Devices with 3 different antenna coil designs are defined (poller 0, poller 3 and poller 6) and are part of the "NFC Forum Reference Equipment" R&S®CSNFC-B8.

![NFC Forum reference poller 3](image)

Fig. 2-1:: NFC Forum reference poller 3 (part of R&S®CSNFC-B8)

2.1.2 Reference Listening Devices

A NFC Forum reference listening device is used to capture the signal transmitted by a polling device. For analyzing the frequency and wave-shapes of captured signals, the NFC Forum reference listening device is equipped with an integrated sense coil, the received signal is available at the sense coil output connector J4 which has to be connected to the RTO controlled by the NFC Analysis Software FS-K112PC.

The NFC Forum reference listening device can also send information back to a polling device, using various levels of load modulation generated by the SMBV baseband I-output on the rearside.

The power transferred by the polling device under test is measured via the VDC out connector J1 where the rectified induced voltage of the listener coil is output. The RTO
(channel 2, DC coupling, 1 MOhm) has to be connected via a probe RT-ZP10 and an adapter like the R&S®RT-ZA10 to this connector.

The VDC output voltage measurement is not supported by FS-K112PC but can easily be done by the RTO directly.

NFC Forum Reference Listening Devices with 3 different antenna coil designs are defined (listener 1, listener 3 and listener 6) and are part of the R&S®CSNFC-B8.

Fig. 2-2: NFC Reference Listener 3 (part of R&S®CSNFC-B8)

### 2.2 Operating volume – geometric test points

NFC analog tests have to be carried out on certain test points (14 points in total) within the so-called operating volume which is a truncated pyramid like shown in Fig. 2-3.
Ideally the Reference Mark should be marked on the rearside of an NFC enabled device but often is not marked up to now (in this case try to find a point where the power transfer is optimum, see chapter 3.2 for power transfer measurement).

The test points are defined by 3 coordinates $z$, $r$, $\phi$ like shown in Fig. 2-4 whereas $z$ can be 0 (vertical distance from Reference Mark = 0 mm) or 1 (vertical distance from Reference Mark = 5 mm).

![Fig. 2-4: Target test points and coordinates (z, x, y)](image)

The R&S NFC Reference antennas have a cross mark centered on the geometrical center of the antenna so the devices can be easily aligned to a Reference Mark of a NFC enabled device. The orientation of the R&S NFC Reference antennas versus the NFC enabled devices is shown in Fig. 2-5 (The component side of the Reference antennas is opposite to the NFC Enabled device under test).

![Fig. 2-5: Orientation of NFC Forum Reference Equipment](image)

Within the NFC Analog Specification there is a setup configuration defined, mainly to adjust the RF level input to connector J2 of the NFC Reference Pollers as a function of the position $(z, r, \phi = 1,0,0$ which means centered position with 5 mm distance) and the DC voltage measured at connector J1 (VDC OUT) of the according reference listeners. Fig. 2-6 shows the relative orientation of the NFC Reference antennas during setup.
2.3 Test Setup for Tests on NFC-enabled Devices in Listening Mode or for NFC Tags

The test setup for tests on NFC-enabled devices in Listening Mode or for NFC Tags is shown below. One of the NFC Reference Pollers (part the R&S®CSNFC-B8) is used to couple to the NFC enabled device under test and to connect the instruments. An SMBV with option SMBV-K89 NFC-A/B/F Digital Standard generates the necessary polling Signal. An RTO with option IQ-software interface RTO-K11 (or as an alternative a signal analyzer in IQ mode) controlled by the NFC Measurement Software FS-K112PC records the sense signal. FS-K112PC analyses in-depth the recorded IQ-data including pass/fail information and command decoding.
2.4 Test Setup for Tests on NFC-enabled Devices in Polling Mode

The test setup for simple tests on NFC-enabled devices in polling mode is shown in Fig. 2-8 below. One of the NFC Reference Listeners (part the R&S®CSNFC-B8) is used to couple to the NFC enabled device under test and to connect the instruments.

The sense output is connected to channel 1 of an RTO (or as an alternative to the RF input of a signal analyzer). The VDC output is connected via a 10:1 probe, like the RT-TP10, to channel 2 of the RTO scope (set coupling for channel 2 to DC, 1MΩ). If a signal analyzer instead of an RTO is used to record the IQ data, use any other oscilloscope. For basic tests in polling mode, the “Mod In” input of the reference listener is not used.

For testing load modulation sensitivity, an appropriate answer signal SENS_RES (SENSE RESPONSE) to a SEL_REQ (Select Request) sent by the NFC device is generated by an appropriate RF signal generator with arbitrary waveform capability like the SMBV100A using its baseband I output. The signal generator is triggered by the oscilloscope. A DC-coupled power amplifier is necessary between I-output and Mod-In input of the reference listener if testing to the limits is desired. For measuring the NFC modulation sensitivity it is necessary to extend the test setup (Fig. 2-8) with a signal generator and an external amplifier (e.g. Tabor A10150) as shown in Fig. 2-9.
Test Setup

Test Setup for Tests on NFC-enabled Devices in Polling Mode

Fig. 2-8: Test Setup for simple polling tests on NFC-enabled devices. Instead of an RTO a spectrum analyzer controlled by the NFC Measurement Software FS-K112PC could be used plus an additional simple oscilloscope.

Fig. 2-9: Test Setup for the load modulation sensitivity test with additional vector signal generator SMBV.
3 Basic polling tests

3.1 Setting up the Test

Connect a reference listener (e.g. listener 3) as shown in Fig. 2-8 respectively Fig. 2-9 for the load modulation sensitivity test and place the device under test (e.g. a mobile phone) with its back on the NFC Forum Reference Listener as shown below.

Some tips for setting up the phone:
- Switch NFC on
- Set screen timeout to maximum because for most NFC devices the NFC polling is switched off in parallel with the screensaver

3.2 Power Transfer and Carrier Frequency Test - Done with basic RTO functions

Power Transfer and Carrier Frequency test on an NFC enabled device are not supported by the FS-K112PC NFC Measurement Software but can be done easily using the RTO basic functions.

Power Transfer is tested by measuring the DC voltage via a probe at J1 (VDC during the un-modulated part of the poller signal).

Carrier Frequency is tested using the Sense output (J4) again during the un-modulated part of the poller signal

Steps for setting up the RTO:
1. Preset
2. Horizontal: Time Scale 200us/div
3. Channel 1: DC 50 Ohm
4. Adjust vertical scale so that signal is within scale
5. Trigger: NFC (NFCA)
6. Adjust trigger level to about 50% of max. positive amplitude
7. Trigger Mode: Normal
8. Open 2nd window at RTO screen
9. Channel 2: DC 1MOhm (default setting)
10. Adjust vertical scale so that DC is within scale
11. Draw Measurement 1 window at upper diagram and setup Frequency measurement
12. Draw Measurement 2 window at lower diagram and setup RMS measurement

Measurement Windows 1 shows the measured carrier frequency during the CW part.
Measurement Window 2 shows the RMS value of the DC voltage at J1.

Fig. 3-2: Example of a power transfer measurement (upper trace) on an NFC enabled device in polling mode in parallel with a carrier frequency measurement (lower trace) with the Digital Oscilloscope R&S®RTO. Measurement window 2 shows the DC voltage and measurement window 1 the carrier frequency.
3.3 Tests Using the NFC Measurement Software FS-K112

3.3.1 Setting up the NFC Measurement Software

Start the NFC Measurement software on the PC and set up a LAN connection with the RTO (or signal analyzer). The connection can be tested in FS-K112PC under “Settings” with the Check Connection button.

![Settings window for the NFC Measurement software FS-K112PC](image)

Fig. 3-3: The Settings window for the NFC Measurement software FS-K112PC. “Trigger Type” is set to “NFC-A” by default and “Trigger Event” to “SENS_REQ” (with an signal analyzer use “Trigger Type” “IF Power”) Change “Capture Length” to “100 ms” and “Auto Level Track Time” to at least “300 ms”.

*Trigger Type* is set to *NFC-A* by default and *Trigger Event* to *SENS_REQ* (with a signal analyzer use *Trigger Type* *IF Power*), there is no specific NFC trigger available.

Change the parameter *Auto Lvl Track Time* to at least about 300 ms within **Tools-Settings** in FS-K112PC to be sure that the auto ranging of the scope finds the correct range and trigger level. For some NFC enabled phones an even longer *Lvl Track Time* may be needed dependent on the pauses of the polling.

Setup the *Capture Length* to about 100 ms to capture all different polling signals in one trace. Select the used RTO input (normally input 1) connected to the sense output of the reference listener.
### 3.3.2 Start the NFC Measurement Software

Start the measurement and analyze the captured signal by clicking the ▶ button as shown below.

![Start measuring with NFC Measurement Software FS-K112PC by clicking the ▶ button](image)

A typical result should look like this:

![Typical result for the NFC Measurement Software FS-K112PC on a polling NFC device](image)

Fig. 3-5: Typical result for the NFC Measurement Software FS-K112PC on a polling NFC device. The result overview is shown on left side. An NFC-A signal was detected and analyzed and an NFC-B and two NFC-F signals were detected. The capture buffer display on right side shows the leading NFC-A signal and 3 further NFC Signals, followed by some spikes.
Basic polling tests
Tests Using the NFC Measurement Software FS-K112

Fig. 3-6: Zoom to a certain section of the Capture buffer display using the left mouse key to see, for example, the leading NFC-A poller signal in detail.

Fig. 3-7: Zoomed part of the Capture Buffer display

Instead of the Capture Buffer display you can choose the Poller Values display which shows the timing parameters of the poller signal whereas Poller PvT shows the detailed slopes of the poller signals. No Listener Signal was detected therefore there are no Listener Values or Poller PvT signals displayed.
Basic polling tests

Tests Using the NFC Measurement Software FS-K112

Fig. 3-8: Timing Values of the poller signal are displayed with Poller Values. All pulses of the analyzed poller signal are taken into account to get the minimum, maximum and average timing values.

Fig. 3-9: Poller PvT display of the analyzed poller signal. All pulses of the signal are overlaid to average minimum and max traces to show variations between the different pulses.
3.3.3 Analyze a captured signal according to a fixed standard (NFC-A, NFC-B or NFC-F)

In *Auto Detect* mode the first NFC signal found in the capture buffer is automatically detected and analyzed. Select a certain standard (e.g. NFC-B) to search for such a signal in the capture buffer and analyze it.

Fig. 3-10: Select “NFC-B” detection to detect and analyze an NFC-B signal within the capture buffer.

Fig. 3-11: Refresh analyzing the captured signal by clicking on the “Refresh” button.

Fig. 3-12: With NFC Standard set to NFC-B the second signal in the capture buffer is detected as an NFC-B SENS_REQ signal and analyzed accordingly.
Fig. 3-13: The reason for the fail info is that the modulation index is slightly above the upper limit of 15%.

### 3.3.4 Selecting a different burst within the capture buffer manually

Depending on the device under test, there may be different polling signals (NFC-A, NFC-B or NFC-F) in different bursts. By default FS-K112PC analyzes only the first burst found. But with the refresh function also the second or third burst can be selected manually to analyze using the *Burst No* function.

Fig. 3-14: Selecting the second burst within the capture buffer (Burst no. 2) to be analyzed. A SENSF_REQ signal was found and analyzed.
3.3.5 Load modulation sensitivity NFC-A test

1. Use the test setup shown in Fig. 2-9. With this setup it is possible to test whether the polling device correctly receives and decodes sense responds load modulation signal at a minimum specified level.

Steps for setting up the SMBV:

2. PRESET
3. Enter the NFC center frequency, f=13.56 MHz
4. Select AWGN/IMP config…
5. Choose I/Q Settings… from the list

![Fig. 3-15: Selection of the I/Q Out Settings menu](image)

6. Set I/Q Analog Output Settings as shown below:

![Fig. 3-16: Settings for the analog I/Q output](image)
7. Select Baseband config… and choose NFC/EMV standard

8. Activate NFC-A Listen command:

9. Select Sequence Configuration… and check whether the trigger event command NFC-A SENS_RES is configured as shown below:
10. Select *Trigger/Marker…* and make the settings shown below:

![Trigger/Marker settings](image1)

11. Select *Modulation Settings…* and ensure that the *Base Band Output* is switched on.

![Modulation settings](image2)

12. Set up the test how it is describes under 3.1.

13. Start the NFC Measurement software FS-K112 on the PC and perform a *PRESET*:

![Software preset](image3)
Basic polling tests

Tests Using the NFC Measurement Software FS-K112

14. Start the measurement and analyze the captured signal by clicking the ▶ button as shown below.

Fig. 3-17: Start measuring with NFC Measurement Software FS-K112PC by clicking the ▶ button

15. The picture below shows the correct response of the polling device under test to a Sens_Res command fed into Mod In input of reference listener with SDD REQ CL1. All tests passed.

16. Lower the I level of the SMBV until the polling device under test does not longer respond to SENS_RES command fed into Mod In input of the reference listener:

Fig. 3-18: Lower the I level by increasing the I/Q level attenuation
Basic polling tests

Tests Using the NFC Measurement Software FS-K112

Fig. 3-19: At lower I level the FS-K112 can no longer decoded the SENS_RES command. The polling Device under test still respond to the SENS_RES command.

Fig. 3-20: At a still lower level, in this case with 15 dB I/Q level attenuation, the polling device under test does no longer respond the SENS_RES signal fed into Mod In input of reference listener.
Basic listener tests

For a listener test a stimulation poller signal is necessary. This is generated by the vector signal generator SMBV with option Digital Standard NFC SMBV-K89. The test setup shown in chapter 2.3 is used in combination with one of the reference pollers for testing the listening function of an NFC-enabled device or an NFC tag.

4.1 How to generate polling signals using the SMBV

4.1.1 Setting up an NFC-A polling sequence

1. Press Menu Hardkey/Baseband at the SMBV:

   ![Menu Hardkey/Baseband](image1)


   ![NFC A/B/F](image2)
4.1.1.1 Using ready to use predefined sequences

3. Select Predefined Sequence: NFC-A Poll: IDLE, SENS_REQ, IDLE, BLANK (default) and select: Apply

Continue with step 9

4.1.1.2 Alternatively: Setup a sequence manually

4. Check (Edit) NFC-A Timing Parameters by selecting Modulation Settings. (The default parameters need to be changed e.g. for testing the receiving characteristic of NFC enabled devices or NFC tags at the limits)

5. Select in Sequence Configuration: SENS_REQ (default setting)
For a useable polling sequence idle signals have to be inserted before and after the SENS_REQ command then concluded by a blank signal.

6. Select **INSERT/ IDLE**

7. Set **Duration** to at least 5000 us
8. Append another IDLE signal of 10000 us followed by a Blank signal of at least 1000 us:

9. Switch NFC-A/B/F State ON, set Frequency: 13.56 MHz, Level to at least 17 dBm and switch RF ON (Mod On)
Now the SMBV generates a SENSA_REQ sequence which can be used to stimulate a NFC-A tag or a suitable NFC-enabled phone (Note: Neither the Samsung Galaxy S3 nor Google Nexus S or Sony Xperia P are suitable, they respond only to an SENSF_REQ signal. However there are already different NFC-A tags available that respond to a SENSA_REQ).

4.1.2 Example: Setup an NFC-F poller signal with 212 kB/s

The NFC-A polling sequence previously generated can be modified to an NFC-F poller sequence as shown below.

10. Select Technology NFC-F: Divisor(Bit Rate): 2 (212kbps)

11. Select Predefined Sequence: NFC-F Poll, IDLE, SENSA_REQ, IDLE, BLANK
Basic listener tests
Examples for executing listener tests

12. Press *Apply*

13. Now the SMBV generates a SENSF_REQ sequence which can be used to stimulate a NFC-F tag or a suitable NFC-enabled phone (e.g. the Samsung Galaxy S3, Google Nexus S or Sony Xperia P).

4.2 Examples for executing listener tests

Test Setup shown in chapter 2.3 is used for listener tests.

4.2.1 Testing an NFC-A tag

Generate an NFC-A Sens_Req Sequence with SMBV as described in chapter 4.1.1.

Place the NFC-Tag to test on the back of the NFC Reference Poller approximately in the middle of the coil (preferably use Poller 3) as shown below.

![Figure 4-1: Put the NFC-Tag to test to the back of the NFC Reference Poller approximately to the middle of the coil](image-url)
Basic listener tests
Examples for executing listener tests

Setup the NFC Measurement Software to **NFC-A Trigger, Capture Length 25 ms, Auto Level Track Time** could be reduced to **100 ms** for increased measurement speed.

![Settings window](image)

**Fig. 4-2:** Settings for NFC Measurement Software for Testing an NFC-A tag,

![Start measuring](image)

**Fig. 4-3:** Start measuring with the NFC Measurement Software FS-K112PC by clicking the button

**Fig. 4-4** shows a typical result for an NFC-A tag. On the left side the **Result Overview** displays the pass indication for poller RF and Listener RF test and a successful **Functional Test**. On the right side the capture buffer voltage is displayed.
Basic listener tests

Examples for executing listener tests

Fig. 4-4: Example of a result for an NFC-A tag (Result Overview and Capture Buffer)

Fig. 4-5: The zoomed part of capture buffer showing in detail a SENSA_REQ signal followed by the SENS_RES answer of the NFC-A Tag
4.2.2 Testing an NFC Phone in Listening Mode

Generate an NFC-F 212kB/s Sens_Req Sequence with the SMBV as described in chapter 4.1.2

Place the NFC-Phone to test back to back with the NFC Reference Poller (preferably use poller 3).

Select Trigger Type NFC-F 212kB/s
Basic listener tests

Examples for executing listener tests

Fig. 4-8: Select Trigger Type NFC-F 212kB/s

Fig. 4-9: Start measuring with the NFC Measurement Software FS-K112PC by clicking the button

Fig. 4-10 shows a typical result for an NFC-enabled phone. On the left side the Result Overview displays the pass indication for Poller RF and Listener RF test, and a successful Functional Test. On the right side the capture buffer voltage is displayed showing the poller signal followed by the listener response of the NFC phone.

Fig. 4-10: Result for an NFC phone in listening mode, Result Overview and Capture Buffer (Envelope Voltage in % of CW over Time)
Basic listener tests

Examples for executing listener tests
5 Literature

[1] NFC Analog Specification Analog 1.0, NFC Forum™

6 Additional Information

This Application Note is subject to improvements and extensions. Please visit our website in order to download new versions. Please send any comments or suggestions about this Application Note to TM-Applications@rohde-schwarz.com.
## 7 Ordering Information

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<td>Spectrum Analysis Option</td>
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1) Basic model. Models with higher upper frequency range are also suitable.

2) Basic model. Models with higher upper frequency range and more channels are also suitable.
About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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- ISO 14001-certified environmental management system

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