NFC Analog Specification

Technical Specification

NFC Forum™

ANALOG 1.0

NFCForum-TS-Analog-1.0

2012-07-11

RESTRICTIONS ON USE

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1 Introduction

1.1 Objectives

The scope of this document covers the analog interface of the NFC Forum Device in its four roles (Peer Mode Initiator, Peer Mode Target, Reader/Writer Mode and Card Emulation Mode) for all three technologies (NFC-A, NFC-B, and NFC-F) and for all the different bit rates (106kbps, 212kbps, and 424kbps).

This specification addresses the analog characteristics of the RF interface of the NFC Forum Device. The purpose of the specification is to characterize and specify the externally observable signals for an NFC Forum Device without specifying the design of the antenna of an NFC Forum Device. This includes power requirements (determining operating volume), transmission requirements, receiver requirements, and signal forms (time/frequency/modulation characteristics).

In order to define the analog characteristics it is necessary to specify the characteristics of the signal measurement equipment. The specification defines only the minimum equipment necessary to specify the analog interface. This will consist solely of the equipment that has a direct interaction with the RF field. The various analog signals will need to be measured by separate measurement equipment which is not defined by this specification.

This specification assumes that the same requirements apply independent of the mode in which the NFC Forum Device is operating (for example, devices that are self-powered may be capable of operation once that power has been depleted).

This document is intended for use by manufacturers wanting to implement an NFC Forum Device.

1.2 Purpose

The purpose of this document is to specify the RF characteristics in such a way that interoperability issues arising from the radio link are minimized, providing a specification that can be used as the basis for testing and approvals and which draws upon the experience of related work.

1.3 Applicable Documents or References

The following documents contain provisions that are referenced in this specification. The latest version including all published amendments applies unless a publication date is explicitly stated.

[ACTIVITY]	NFC Activity Technical Specification, Version 1.0, NFC Forum
[ANALOG_TC]	Test Specification/Cases for NFC Analog Technical Specification, In progress, NFC Forum
[DIGITAL]	NFC Digital Protocol Technical Specification, Version 1.0, NFC Forum

[EMV_CLESS]	EMV Contactless Communication Protocol Specification, Version 2.0.1, EMVCo
[ISO/IEC_14443]	Identification cards – Contactless integrated circuit cards – Proximity cards Includes: [ISO/IEC 14443-1:2008], Identification cards – Contactless integrated circuit cards – Proximity cards – Part 1: Physical characteristics [ISO/IEC 14443-2:2010], Identification cards – Contactless integrated circuit cards – Proximity cards – Part 2: Radio frequency power and signal balance [ISO/IEC 14443-3:2001], Identification cards – Contactless integrated circuit cards – Proximity cards – Part 3: Initialization and anticollision [ISO/IEC_14443-3:2001/Amd.1], Identification cards -- Contactless integrated circuit(s) cards -- Proximity cards -- Part 3: Initialization and Anti-collision, 1 February 2001 with Amendment 1: Bit rates of fc/64, fc/32 and fc/16, 15 June 2005; Amendment 3: Handling of reserved fields and values, 22 March 2006; and Corrigendum 1: Amendment 1 - Corrigendum, 29 August 2006 [ISO/IEC 14443-4:2008], Identification cards – Contactless integrated circuit cards – Proximity cards – Part 4: Transmission protocol ISO/IEC
[JIS_X_6319-4]	JIS X 6319-4 Specification of implementation for integrated circuit(s) cards – Part 4: High speed proximity cards 2005 JIS
[RFC2119]	Key words for use in RFCs to Indicate Requirement Levels, March 1997.
[T1TOP]	NFC Forum Type 1 Tag Operation Specification Version 1.0, NFC Forum
[T2TOP]	NFC Forum Type 2 Tag Operation Specification, Version 1.0 NFC Forum
[T3TOP]	NFC Forum Type 3 Tag Operation Specification, Version 1.0, NFC Forum
[T4TOP]	NFC Forum Type 4 Tag Operation Specification, Version 2.0, NFC Forum

1.4 Administration

The NFC Analog Specification is an open specification supported by the Near Field Communication Forum, Inc., located at:

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The NFC Forum, Inc., maintains this specification. Comments, errors, and other feedback can be submitted at http://www.nfc-forum.org/public_group_terms?document_id=12473.

1.5 Name and Logo Usage

The Near Field Communication Forum's policy regarding the use of the trademarks *NFC Forum* and the NFC Forum logo is as follows:

- Any company MAY claim compatibility with NFC Forum specifications, whether a member of the NFC Forum or not.
- Permission to use the NFC Forum logos is automatically granted to designated members only as stipulated on the most recent Membership Privileges document, during the period of time for which their membership dues are paid.
- Member's distributors and sales representatives MAY use the NFC Forum logo in promoting member's products sold under the name of the member.
- The logo SHALL be printed in black or in color as illustrated on the Logo Page that is available from the NFC Forum at the address above. The aspect ratio of the logo SHALL be maintained, but the size MAY be varied. Nothing MAY be added to or deleted from the logos.
- Since the NFC Forum name is a trademark of the Near Field Communication Forum, the following statement SHALL be included in all published literature and advertising material in which the name or logo appears:

  NFC Forum and the NFC Forum logo are trademarks of the Near Field Communication Forum.

1.6 Intellectual Property

The NFC Analog Specification conforms to the Intellectual Property guidelines specified in the NFC Forum's *Intellectual Property Rights Policy*, as outlined in the NFC Forum *Rules of Procedure*. These documents are available on the NFC Forum website.

1.7 Special Word Usage

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.8 Requirement Numbering

Requirements in this document are uniquely numbered with the number appearing next to each requirement. Requirements can include informative statements. In this case the statement is written in the italic font and MAY instead of MUST is used. For example:

1.8.1.1 A car MUST have four wheels.

A car MAY have five wheels, a jet engine and a rocket.

A requirement can have different numbers in different versions of the specifications. Hence, all references to a requirement MUST include the version of the document as well as the requirement's number.

1.9 Notational Conventions

The notational conventions as defined in Table 1 apply to this document.

Table 1: Notational Conventions

Notation	Description
XYh	Hexadecimal notation. Values expressed in hexadecimal form are followed by a lower case "h". For example, 27509 decimal is expressed in hexadecimal as 6B75h.
xyb	Binary notation. Values expressed in binary form are followed by a lower case "b". For example, 82h hexadecimal is expressed in binary as 10000010b.
[…]	Optional part
xx	More than one value possible
STATE	States are written in **COURIER FONT** and in bold to distinguish them from the text.

1.10 Abbreviations

The abbreviations as used in this document are defined in Table 2.

Table 2: Abbreviations

Abbreviation	Description
ASK	Amplitude Shift Keying
BPSK	Binary Phase Shift Keying
CMR	Common Mode Rejection
DC	Direct Current
etu	Elementary time unit
f_c	Carrier Frequency
f_s	Subcarrier frequency
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission
JIS	Japanese Industrial Standard
NFC	Near Field Communication
NFC-A	Near Field Communication – NFC-A Technology
NFC-B	Near Field Communication – NFC-B Technology
NFC-F	Near Field Communication – NFC F Technology
NFCIP-1	Near Field Communication Interface and Protocol according to [NFCIP-1]. Specific protocol of the NFC Peer Mode.
NRZ-L	Non-Return to Zero, (L for Level)
n.a.	Not Applicable
OOK	On-Off Keying
RF	Radio Frequency
RFU	Reserved for Future Use

1.11 Glossary

1.11.1 Device and Communication

Command

An instruction from one device to another device in order to move the other device through a state machine.

High Level

Carrier signal without modulation applied.

Listen Frame

A frame sent by an NFC Forum Device in Listen Mode.

Low Level

Carrier signal with modulation applied.

Lower Level

Term used in [DIGITAL] to mean $\mathbf{V_2}$ for NFC-A.

Modulation Index

The modulation index of an amplitude modulated signal is defined as

mi = ([A(t)]MAX – [A(t)]MIN) / ([A(t)]MAX + [A(t)]MIN)

where A(t) is the envelope of the modulated carrier.

NFC Forum Device

A device that supports the following Modus Operandi: Initiator, Target, and Reader/Writer. It may also support Card Emulator.

NFC Forum Reference Equipment

A set of NFC Forum Reference Poller and NFC Forum Reference Listener devices in conjunction with which the RF characteristics of this specification are valid.

NFC Tag

A contactless tag or (smart) card.

Operating Volume

The three-dimensional space, as defined by the NFC Forum, (in an appendix to this specification), in which an NFC Forum Device in Poll Mode can communicate with an NFC Forum Device in Listen Mode or has to be able to communicate with a responding device.

Passive Communication

A communication mode in which one device generates an RF field and sends Commands to a second device. To respond, this second device uses load modulation, i.e., it does not generate an RF field but it draws more or less power from the incident RF field.

Poll Command

A Command to query an NFC Forum Device in Listen Mode or an NFC Forum Tag:

- ALL_REQ or SENS_REQ Command for NFC-A
- ALLB_REQ or SENSB_REQ Command for NFC-B
- SENSF_REQ Command for NFC-F

Poll Frame

A frame sent by an NFC Forum Device in Poll Mode.

Reset

For a polling device, switching off and on the carrier to cause the transition of a listening device to its NO_REMOTE_FIELD state and back to the IDLE state

For a listening device, the transition to its NO_REMOTE_FIELD state and back to the IDLE state caused by the polling device switching off and on the carrier.

Response

Information sent from one device to another device upon receipt of a Command. The information received by the other device should allow this other device to continue the data exchange.

Technology

A group of transmission parameters defined by the NFC standard that make a complete communication protocol. A non-exhaustive list of transmission parameters is: RF carrier, communication mode, bit rate, modulation scheme, bit level coding, frame format, protocol, and Command set. NFC defines three groups and therefore three Technologies: NFC-A, NFC-B, and NFC-F. The three Technologies use the same RF carrier (13.56 MHz). Each Technology uses its own modulation scheme, bit level coding and frame format, but may have the same protocol and Command set.

Technology Subset

A legacy platform supporting a subset of a Technology. A Technology Subset supports at least the Poll Command of the Technology. The four Technology Subsets described in this specification are:

- Type 1 Tag platform, which uses a particular subset of NFC-A, excluding anti-collision.
- Type 2 Tag platform, which uses a particular subset of NFC-A, including anti-collision.
- Type 3 Tag platform, which uses a particular subset of NFC-F, including anti-collision.
- Type 4 Tag platform, which uses a particular subset of NFC-A or NFC-B, including anti-collision.

1.11.2 Field

Operating Field

The radio frequency field created by the NFC Forum Device or NFC Forum – Reference Polling Device in Poll Mode.

Operating Field Off

A condition of the Operating Field when the field strength is below a well-defined threshold. See Section 4.7.

Operating Field On

A condition of the Operating Field when the field strength is above a well-defined threshold for a minimum period of time. See Section 4.2.

Remote Field

The radio frequency field sensed by the NFC Forum Device in Listen Mode.

Remote Field Present

A condition of the Remote Field being stable and strong enough to put the NFC Forum Device in a state that it can operate in Passive Communication mode. See Section 4.6.

No Remote Field Sensed

A condition of the Remote Field that indicates the absence of remote devices. See Section 4.8.

Unmodulated Carrier

A condition of the Operating Field with no modulation present. For the purposes of this specification an unmodulated carrier is defines as one with no discernible, detectable or measurable modulation.

1.11.3 Protocol and Mode

Activity

A process within an NFC Forum Device with well-defined pre-conditions and post-conditions, as defined in [ACTIVITY]. An Activity can only start when its pre-conditions are fulfilled. When an Activity ends, its post-conditions are fulfilled.

Card Emulator

A role of an NFC Forum Device, reached when an NFC Forum Device in Listen Mode has gone through a number of Activities and in which the NFC Forum Device behaves as one of the Technology Subsets.

Initiator

A role of an NFC Forum Device reached when an NFC Forum Device in Poll Mode has gone through a number of Activities; in this mode the NFC Forum Device communicates using the NFC-DEP Protocol.

Listening Device

An NFC Forum Device in Listen Mode.

Listen Mode

Initial mode of an NFC Forum Device when it does not generate a carrier; in this mode the NFC Forum Device listens for the RF field of another device.

NFC-DEP Protocol

Half-duplex block transmission protocol defined in [NFCIP-1].

Polling Device

An NFC Forum Device in Poll Mode.

Poll Mode

Initial mode of an NFC Forum Device when it generates a carrier and probes (“polls”) for other devices.

Reader/Writer

Role of an NFC Forum Device reached when an NFC Forum Device in Poll Mode has gone through a number of Activities. In this mode, the NFC Forum Device behaves like a legacy contactless reader and uses Commands from one of the Technology Subsets.

State

A Technology independent state of the NFC Forum Device in Listen Mode. The States used in this document are: **NO_REMOTE_FIELD** and **IDLE** are described in [ACTIVITY].

Target

Role of an NFC Forum Device, reached when the NFC Forum Device has gone through a number of Activities in which the NFC Forum Device communicates using the NFC-DEP Protocol.

1.11.4 Errors

Protocol Error

A Semantic Error or Syntax Error.

Semantic Error

A Correct Frame with no Syntax Error is received when it is not expected.

Syntax Error

A Correct Frame is received with an invalid content. In this case, the coding Command or the block within the frame is not consistent with this specification.

Timeout Error

No Response has been received within the Response Waiting Time (RWT).

Transmission Error

An incorrect frame is received. In this case, the signal modulation, the bit coding frame format, the timing, or the checksum is not consistent with this specification.

Correct Frame

A frame without Transmission Error.

Valid Block, Valid PDU

A block or PDU without Protocol Error within a Correct Frame.

Valid Command, Valid Response

A Command or Response without Protocol Error within a Correct Frame.

2 Overview

2.1 NFC Forum Devices

The NFC Forum Device is assumed to be equipped with an antenna connected to an electronic circuit. During operation, the combination of two NFC Forum Devices (Polling Device and Listening Device) behaves like a transformer. An alternating current passes through a primary coil (Polling Device antenna) and creates an electromagnetic field, which induces a current in the secondary coil (Listening Device antenna). The Listening Device may use the electromagnetic field (or RF field) transmitted by the Polling Device to power itself. The configuration and tuning of both antennas determines the coupling efficiency from one device to the other.

The Polling Device and Listening Device are shown in Figure 1.

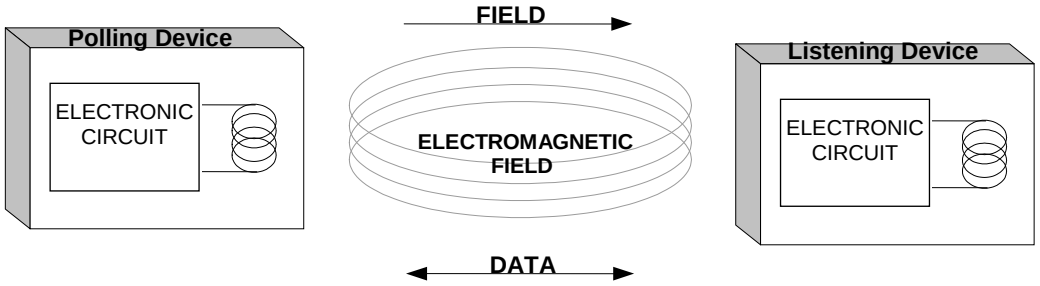


Figure 1: Polling Device and Listening Device Configuration

The addition of information to a signal carrier is called modulation. A signal carrier is characterized by means of its amplitude, phase, and frequency. Therefore, information can be added to the carrier by means of changing one or more of these characteristics. Modulation methods used in this document are:

- Amplitude modulation: the level of the signal carrier is varied over time.
- Phase modulation: the flow of the signal carrier is either advanced or delayed temporarily, giving a change in phase.

The RF energy transmitted by the Polling Device and received by the Listening Device activates or wakes up the Listening Device and is also used to transport the data through modulation of the carrier. The Listening Device decodes and processes the data and responds to the Polling Device by means of load modulation.

Load modulation is based on the electromagnetic coupling (i.e., mutual inductance) between Listening Device and Polling Device similar to the power transfer and communication from Polling Device to Listening Device. The Listening Device changes the current in its antenna.

The current variation in the Listening Device antenna is sensed by the Polling Device as a small change in the current in its antenna, typically sensed as a small increase in voltage across a resistor in series with the Polling Device antenna.

2.2 NFC Forum Reference Equipment

The RF power and signal interface part of the specification is specified in terms of the NFC Forum Reference Equipment. NFC Forum Reference Equipment consists of "NFC Forum – Reference Polling Devices", and "NFC Forum – Reference Listening Devices". The purpose of the NFC Forum Reference Equipment is to act as Polling and Listening Devices that cover the variations (for example, at the extremes of parameters) in NFC contactless technology. A Polling Device can therefore be characterized in operation with an NFC Forum – Reference Listening Device, and a Listening Device can be characterized in operation with an NFC Forum – Reference Polling Device.

NFC Forum Devices, Legacy Reader/Writers, and PICCs and NFC Tags will all utilize a range of different antenna sizes and characteristics. It is unrealistic to adopt just one size of antenna for the NFC Forum Reference Equipment for the RF Analog specification to cover all modes of operation.

During interoperation, there will likely be "worst case" combinations of the *Initiator* device antenna relative to the *Target* device or tag antenna:

- Large relative to small (e.g., POS terminal to small handset, or large handset to small tag)
- Small relative to large (e.g., small to large handset or small handset to large tag)
- Same relative to same (mobile to mobile, due to interaction at close ranges)

There is no requirement to create NFC Forum Devices using the architecture, antenna layout, and resonance frequency used for the NFC Forum – Reference Polling Devices or the NFC Forum – Reference Listening Devices. The NFC Forum Reference Equipment is put in place only to specify an externally observable behavior.

The aim is that sufficient documentation will be available to allow users to construct and calibrate their NFC Forum Reference Equipment or to purchase it from vendors.

The design of the NFC Forum Reference Equipment is specified in Appendix C of this document.

2.2.1 NFC Forum – Reference Polling Device

When connected to a suitable signal generator and power amplifier, an NFC Forum – Reference Polling Device allows commands to be sent to a Listening Device. The response from a Listening Device may then be captured and analyzed by means of associated measurement equipment.

The NFC Forum – Reference Polling Devices with three different antenna coil designs are based on the standard [EMV_CLESS] PCD (for Poller-0) and compensated versions of two of the ISO standardized PICC antenna coil designs (Poller-3 and 6).

The NFC Forum – Reference Poller Devices; Poller-0, Poller-3, and Poller-6 are shown in Figure 2 presented in left to right order, and full design details are given in Appendixes C.1, C.2, and C.3. Mechanical dimensions are given in Appendix C.7.

Figure 2: NFC Forum - Reference Polling Devices

2.2.2 NFC Forum – Reference Listening Device

The NFC Forum – Reference Listening Devices are specified with three forms of antenna coil design geometry.

The coil geometries of Listener-1, Listener-3, and Listener-6 are based on the outside envelope measurements of the ISO referenced PICC-1, PICC-3, and PICC-6 antenna designations, respectively.

The PCB coil designs are not necessarily identical or revisions required to be synchronized.

The NFC Forum – Reference Listening Device allows the analysis of the signal as sent out by a Polling Device. For analyzing the frequency and waveshapes of these signals, the NFC Forum – Reference Listening Device is equipped with an integrated sense coil.

The NFC Forum – Reference Listening Device can also send information back to a Polling Device, using various levels of load modulation generated using a suitable signal source.

The NFC Forum – Reference Listening Device can be configured to use a number of fixed resistive loads. These resistive load settings can be used to represent both the typical and the worst-case scenarios to be encountered by a Polling Device.

The NFC Forum – Reference Listener Devices; Listener-1, Listener-3, and Listener-6 are shown in Figure 3 presented in left-to-right order, and full design details are given in Appendixes C.4, C.5, and C.6. Mechanical dimensions are given in Appendix C.7.

Figure 3: NFC Forum - Reference Listening Devices

2.3 Positioning Convention

The specification is based on the existence of Reference Marks presumed to be on the casing of the NFC Forum Device and against which parameters in the specifications are defined.

This specification assumes planar devices oriented in a parallel configuration.

2.4 Operating Volume

The Operating Volume of a Polling Device is the 3-dimensional space for which this specification imposes requirements with the aim of ensuring interoperability between NFC devices over at least this volume.

The geometry of the Operating Volume is shown in Figure 4.

The Operating Volume is measured from the Reference Mark, along an axis perpendicular to the device. Requirements on this geometry suppose that the Polling Device is stationary and that the Listening Device moves slowly (less than 1 m/s) through the Operating Volume or vice versa.

The position of a Listening Device within the Operating Volume is represented by the quadruplet (r,φ,z,θ). Positioning conventions for this are not defined here; please refer to the [ANALOG_TC].

The values of the symbols used in Figure 4 are defined in Appendix B.1.

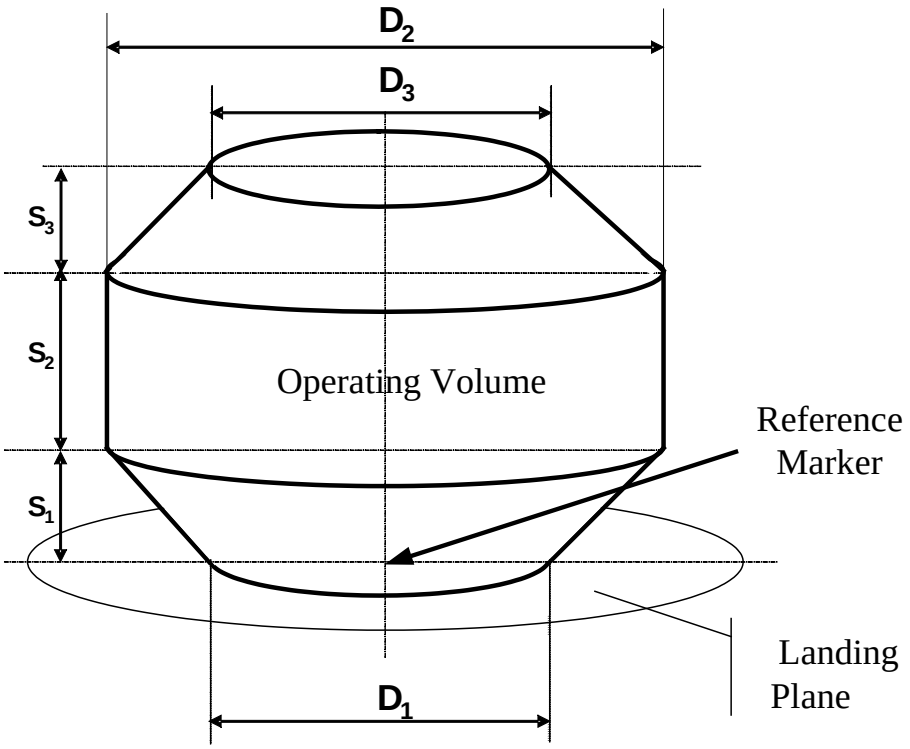


Figure 4: Operating Volume

The Polling Device uses the Reference Marker as the point to indicate the origin of the Operating Volume $(r,\varphi,z) = (0,0,0)$.

3 Principles (Informative)

3.1 General

This section describes the principles by which all of the requirements included in this document are specified with respect to the NFC Forum Reference Equipment as defined by the NFC Forum and presented in Appendix C.

Requirements are preceded by a description of the conditions under which the NFC Forum Reference Equipment is used and under which the specification requirements are valid.

The remainder of this section explains the approach used for writing the requirements.

3.2 Configurations for Transmission and Reception

An NFC Forum Device, which can be a Polling Device or a Listening Device, is either transmitting or receiving.

A Polling Device transmits power and data to a Listening Device and receives data from this Listening Device. A Listening Device may receive power as well as data from a Polling Device and can transmit data to the Polling Device. The configurations for transmitting and receiving for a Polling Device and a Listening Device are illustrated in Table 3.

Table 3: Configurations Transmit and Receive

	Polling Device		**Listening Device**	
	Transmit	Receive	Transmit	Receive
Power	√	n.a.	n.a.	√
Data	√	√	√	√

For each device, the requirements related to transmission are such that the value of a transmit parameter (X) must fall within a well-defined range $\mathbf{R_{tx}}$ from $\mathbf{X_{tx}}$ min to $\mathbf{X_{tx}}$ max. The requirements on reception are such that the receiver must properly work with the value of different parameters varying over a range $\mathbf{R_{rx}}$ from $\mathbf{X_{rx}}$ min to $\mathbf{X_{rx}}$ max relevant for each parameter. For interoperability, the ranges for corresponding transmission and reception parameters are defined so that the range of $\mathbf{X_{tx}}$ is contained within the range for $\mathbf{X_{rx}}$.

3.3 The Purpose of the NFC Forum Reference Equipment

The transmission requirements and characteristics of a NFC Forum Device are valid in the presence of the receiving antenna of the appropriate NFC Forum Reference Equipment. For example, whether the transmitter of a Polling Device meets the requirements is characterized by means of the NFC Forum – Reference Listening Device. Similarly, the quality of the transmitter of a Listening Device is characterized via the NFC Forum – Reference Polling Device.

Example:

A Polling Device must provide a certain level of field strength (power) to a Listening Device. The field strength delivered by the Polling Device is characterized by the voltage output from $\mathbf{J_1}$ of an NFC Forum - Reference Listening Device. The value of the field level characterized via an NFC Forum – Reference Listening Device must fall within the Min to Max range of $\mathbf{R_{tx,power}}$.

Whether a device meets the reception requirements or not, is characterized by having the transmitter of the appropriate NFC Forum - Reference Equipment create a range of values for a number of parameters. As an example, whether the receiver of a Polling Device meets the requirements is measured by having the NFC Forum – Reference Listening Device send out different levels of load modulation. The quality of the receiver of a Listening Device is verified by having the NFC Forum – Reference Polling Device send out levels of modulation which are slightly beyond the level of acceptability.

In order to set up the transmitter of the NFC Forum - Reference Equipment, the receiver of the matching NFC Forum - Reference Equipment is used. For example, the load modulation level of the NFC Forum – Reference Listening Device is set up by means of and with respect to the NFC Forum – Reference Polling Device. The modulation level of the NFC Forum – Reference Polling Device is set-up by means of and with respect to the NFC Forum – Reference Listening Device.

Example:

A Listening Device must work with a certain power level provided by a Polling Device. The NFC Forum – Reference Polling Device generates different power levels, varying over a Min to Max range of $\mathbf{R_{rx,power}}$. The power level of the NFC Forum – Reference Polling Device is set up with respect to the NFC Forum – Reference Listening Device. This means that $\mathbf{R_{rx,power}}$ is a value measured on the NFC Forum – Reference Listening Device and that the power level of the signal generator feeding the NFC Forum – Reference Polling Device is increased/decreased until the correct (voltage) level is reached on the NFC Forum – Reference Listening Device.

As each of the parameters is specified separately, it is intended that they are specified such that they may be observed independently as far as possible. For example when measuring a Listening Device's ability to respond to commands sent with a wide range of modulation indices these commands are sent using a 'nominal' power level which first needs to be established as described in Appendix B.6 .

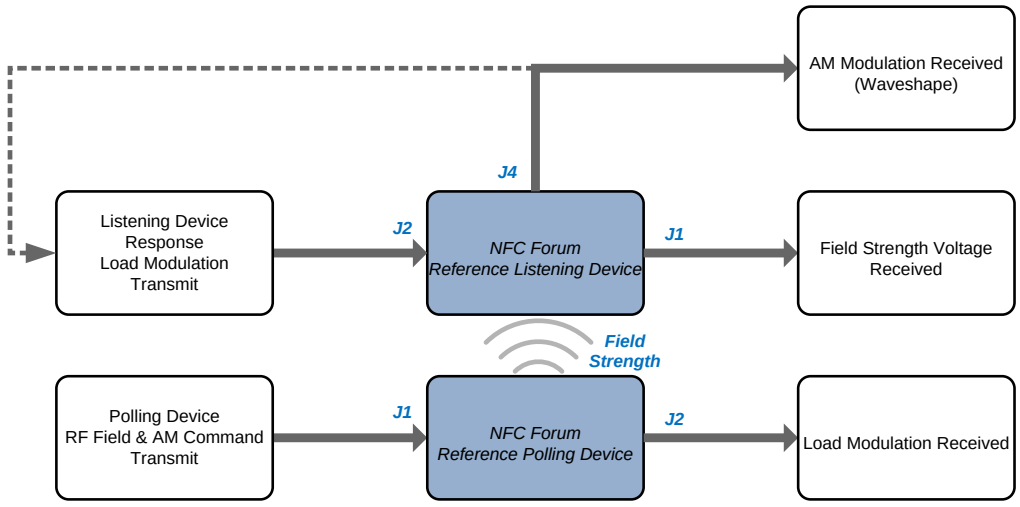


Figure 5: NFC Forum Reference Equipment Generic Configuration

3.4 Using the Reference Equipment

It is impractical to characterize an NFC Forum Device operating with all combinations of NFC Forum Reference Equipment. The philosophy proposed, therefore, is to always use the worst case counterpart for a parameter that may either be the “best-coupling” or “worst-coupling” device depending on the parameter.

For example, in considering minimum operating field power of a Polling Device, the “worst coupling” device would be used as all others should give better results than this. For the maximum operating field power situation, the “best coupling” device would be used as this represents the most stringent case for a listener because the power level received for all other NFC Forum Reference Listening Devices should be lower than this.

The procedure for determining the “best coupling” and “worst coupling” device as well as which to use for testing each parameter is specified in the Analog Test Specification.

3.5 Functions Properly

For both a Polling Device and a Listening Device, checking the data reception characteristics depends on some kind of acknowledgement by the device that the data was received. For a Polling Device, sending the next command (i.e, data transmission) in the overall flow implies that the response from the NFC Forum – Reference Listening Device was understood. For a Listening Device, responding to the command or a change in internal state implies that the command from the NFC Forum – Reference Polling Device was understood.

For the remainder of the document, the wording “function properly” will be used for a Polling Device sending the next command, following a response created by the NFC Forum – Reference Listening Device.

For the remainder of the document, the wording “function properly” will be used for a Listening Device receiving a command generated by the NFC Forum – Reference Polling Device that results in the Listening Device sending the expected response or changing its internal state corresponding to the command. A change in internal state is observed by the Listening Device being capable of processing the next command as anticipated.

3.6 Summary

The approach explained above leads to the following with regard to power and data transfer:

- Power provided by a Polling Device is specified as observed on the NFC Forum – Reference Listening Device.
- Data transmission by a Polling Device (e.g., modulation depth) is specified as observed on the NFC Forum – Reference Listening Device.
- Data reception by a Polling Device (load modulation sensitivity) is specified as observed by creating different signals through the NFC Forum – Reference Listening Device. To determine the levels and characteristics of the signal generated by the NFC Forum – Reference Listening Device, the signal is first set-up with respect to the NFC Forum – Reference Polling Device.
- Data transmission by a Listening Device is specified as observed on the NFC Forum – Reference Polling Device, with the NFC Forum – Reference Polling Device providing a ‘nominal’ power level to the Listening Device. Both the power level and the command characteristics produced by the NFC Forum – Reference Polling Device are set-up with respect to the NFC Forum – Reference Listening Device.
- Power and data reception sensitivity of a Listening Device are specified as observed by means of the NFC Forum – Reference Polling Device, with the NFC Forum – Reference Polling Device sending commands with power levels and modulation characteristics at the border of the tolerance interval $\mathbf{R_{rx}}$. Again, for setting these extreme values, the power and command characteristics produced by the NFC Forum – Reference Polling Device are set-up with respect to the NFC Forum – Reference Listening Device.

4 Radio Frequency Power and Signal Interface

This section specifies the requirements for the power transfer from Polling Device to Listening Device through the electromagnetic field created by the Polling Device with parameter values listed in Appendix B.2.

All specifications described in this section are only applicable in conjunction with the NFC Forum – Reference Polling Device and the NFC Forum – Reference Listening Device configured and set-up as specified in the particular specification context listed for the requirement. The set-up parameters and calibration procedures are given in Appendixes B.3, B.4, and B.5.

The position of a Listening Device within the Operating Volume is indicated according to the convention specified in sections 2.3 and 2.4 with parameter values given in Appendix B.1.

4.1 Polling Device Requirements for Power Transfer from Polling Device to Listening Device

This section specifies the Polling Device requirement for power transfer from Polling Device to Listening Device.

4.1.1 Specification Purpose

The purpose of this requirement is to ensure that the Polling Device provides an Operating Field with RF field strength according to the minimum and maximum limits in order to power a Listening Device.

4.1.2 Specification Context

- Polling Device is set to emit an Operating Field without any modulation – Operating Field On.
- NFC Forum – Reference Listening Device configured with a resistive load selected (see $\mathbf{R_L}$ for $\mathbf{V_{OV}}$ in Appendix B.2). See Appendix C.4 for design details.
- NFC Forum – Reference Listening Device is placed in the Operating Volume of the Polling Device.
- Load modulation transmit signal is not applied to $\mathbf{J_2}$ of the NFC Forum – Reference Listening Device.

Specification Requirements

Requirements 4.1 — Power Transfer from Polling Device to Listening Device (Polling Device Transmission)

Polling Device	
4.1.2.1	When the NFC Forum – Reference Listening Device is located within the Operating Volume of the Polling Device, under the conditions described in the specification context above, it SHALL generate an output voltage $\mathbf{V_{OV}}$ at $\mathbf{J_1}$ of the NFC Forum – Reference Listening Device. The average value over a small period of time (>10µs) at a fixed location of the voltage $\mathbf{V_{OV}}$ SHALL be characterized. Refer to Appendix B.2 for the range of Min &and Max values of $\mathbf{V_{OV}}$.

4.2 Listening Device Requirements for Power Transfer from Polling Device to Listening Device

This section specifies the Listening Device requirements for power transfer from Polling Device to Listening Device.

4.2.1 Specification Purpose

The purpose of these requirements is to ensure that the Listening Device functions properly in the Operating Field of the NFC Forum – Reference Polling Device with a defined range of field strength.

4.2.2 Specification Context

- NFC Forum – Reference Polling Device is generating an Operating Field, with no AM modulation applied, with frequency $\mathbf{f_{S,C}}$ (nominal value).
- NFC Forum – Reference Listening Device is configured with a fixed resistive load (see $\mathbf{R_{S,L}}$ in Appendix B.3) and with no load modulation transmit signal applied to $\mathbf{J_2}$.
- The carrier level of the NFC Forum – Reference Polling Device, with no AM modulation applied, is set-up such that the NFC Forum – Reference Listening Device in position (r=0, φ=0, z=$\mathbf{Z_{S,OV}}$, θ=0) of the Operating Volume has a voltage $\mathbf{V_{S,OV}}$ at $\mathbf{J_1}$, (between min and max) as specified in Appendix B.3.
- NFC Forum – Reference Polling Device is then set-up to modulate the carrier with **nominal** modulation characteristics, as detected from the sense coil via $\mathbf{J_4}$ of the NFC Forum – Reference Listening Device, as specified in Appendix B.3.
- The Listening Device is then placed into the operating volume of the NFC Forum – Reference Polling Device.

Specification Requirements

Requirements 4.2 — Power Transfer from Polling Device to Listening Device (Listening Device Reception)

Listening Device	
4.2.2.1	A Listening Device SHALL function properly within the Operating Volume of the NFC Forum – Reference Polling Device when the operating conditions have been established as described in the specification context above for NFC-A. See Section 3.4 for definition of "function properly".
4.2.2.2	A Listening Device SHALL function properly within the Operating Volume of the NFC Forum – Reference Polling Device when the operating conditions have been established as described in the specification context above for NFC-B.
4.2.2.3	A Listening Device SHALL function properly within the Operating Volume of the NFC Forum – Reference Polling Device when the operating conditions have been established as described in the specification context above for NFC-F.

4.3 Influence of the Listening Device on the Operating Field

Due to the electromagnetic coupling (i.e., mutual inductance) between the Listening Device and Polling Device antennas, the Listening Device changes the Operating Field created by the Polling Device when brought into its Operating Volume. The magnetic field strength within the Operating Volume will decrease due to the extra load caused by the Listening Device. This section specifies the Listening Device requirement limiting the maximum load a Listening Device is allowed to present to a Polling Device.

4.3.1 Specification Purpose

The purpose of these requirements is to specify a limit on the loading that a Listening Device may place on a Polling Device. If no limit was to be imposed, a Listening Device may cause so much influence on the operating field that attempting to measure the other analog parameters would be futile.

4.3.2 Specification Context

- NFC Forum – Reference Polling Device is generating an Operating Field, with no AM modulation applied, with frequency $\mathbf{f_{S,C}}$ (nominal value).
- NFC Forum – Reference Listening Device is configured with fixed resistive load (see $\mathbf{R_L}$ for $\mathbf{\Delta V_{OV}}$ in Appendix B.2) and with no load modulation transmit signal applied to J_2.
- NFC Forum – Reference Polling Device carrier level without modulation is set-up with the NFC Forum – Reference Listening Device in position (r=0, φ=0, z= $\mathbf{Z_{S,OV}}$, θ=0) of its Operating Volume such that the **minimum** voltage defined by $\mathbf{V_{S,OV}}$, as specified in Appendix B.3, is detected at $\mathbf{J_1}$ of the NFC Forum – Reference Listening Device.

Specification Requirements

Requirements 4.3 — Influence of the Listening Device on the Operating Field

Listening Device	
4.3.2.1	When placed in the Operating Volume of the NFC Forum – Reference Polling Device, the loading caused by the Listening Device SHALL result in a maximum voltage drop of ΔV_{OV} as detected across the sense resistor via J_2 of the NFC Forum – Reference Polling Device. The definition of the voltage drop is the difference in peak to peak voltage level before ($V_{OV,FREE\ AIR}$) and after ($V_{OV,Listening\ Device}$) the Listening Device is placed in the Operating Volume of the NFC Forum Reference Polling Device. $\Delta V_{OV} = V_{OV,FREE\ AIR} - V_{OV,Listening\ Device}$ detected at J_2 of the NFC Forum Reference Polling Device. Refer to Appendix B.2 for the value of ΔV_{OV}.

NOTE Here the loading effect of the Listening Device applies irrespective of power conditions, e.g. whether the device is battery-powered or not.

4.4 Polling Device Requirements for the Carrier Frequency f_C

This section specifies the Polling Device requirement for the frequency of the Operating Field (i.e., the carrier frequency f_C) created by the Polling Device.

4.4.1 Specification Purpose

The purpose of these requirements is to specify the limits on the carrier frequency of a Polling Device to ensure that it remains within the limits expected by a Listening Device.

4.4.2 Specification Context

- NFC Forum – Reference Listening Device configured with fixed resistive load (see R_L for f_C in Appendix B.2) and with no load modulation signal applied to J_2.
- Polling Device set to emit a carrier.
- NFC Forum – Reference Listening Device placed in the Operating Volume of the Polling Device and the sense coil of the NFC Forum Reference Listening Device is used to recover the carrier for frequency measurement on J_4.

Specification Requirements

Requirements 4.4— Carrier Frequency f_c (Polling Device Transmission)

Polling Device	
4.4.2.1	The frequency of the Operating Field (carrier frequency) generated by the Polling Device SHALL be within the range of Min and Max values of $\mathbf{f_C}$. Refer to Appendix B.2 for the Min and Max range values of $\mathbf{f_C}$.

4.5 Listening Device Requirements for the Carrier Frequency f_C

This section specifies the Listening Device requirement for the frequency of the Operating Field (i.e., the carrier frequency $\mathbf{f_C}$).

4.5.1 Specification Purpose

The purpose of this requirement is to specify the minimum and maximum carrier frequency for which a Listening Device must be able to function properly.

4.5.2 Specification Context

- NFC Forum – Reference Polling Device generating a carrier signal with frequency $\mathbf{f_{S,C}}$, where the range of $\mathbf{f_{S,C}}$ is defined in Appendix B.3.
- NFC Forum – Reference Polling Device is set-up to send a polling command with **nominal** power transfer and modulation characteristics as specified in Appendix B.3.

Specification Requirements

Requirements 4.5 — Carrier Frequency f_c (Listening Device Reception)

Listening Device	
4.5.2.1	When placed in the Operating Volume of the NFC Forum – Reference Polling Device, the Listening Device SHALL function properly with a carrier frequency between the Min and Max values of $\mathbf{f_{S,C}}$ as defined in Appendix B.3, being generated by the NFC Forum – Reference Polling Device.

4.6 Listening Device Requirements for Power-On

This section specifies the Power-On requirements for the Listening Device.

4.6.1 Specification Purpose

The purpose of these requirements is to ensure that the Listening Device will be able to respond to a Poll Command that is issued after a Power On condition within the limits of the Operating Field that may be applied by a Polling Device.

4.6.2 Specification Context

- NFC Forum – Reference Polling Device is generating an Operating Field, with no modulation applied, with frequency $f_{S,C}$ (nominal value).
- NFC Forum – Reference Polling Device is set to a power level between the minimum and maximum as specified in Appendix B.3.
- NFC Forum – Reference Polling Device is set to send a polling command with **nominal** modulation characteristics as specified in Appendix B.3 after a delay of GT_A, GT_B, and GT_F following activation of the carrier.

Specification Requirements

Requirements 4.6 — Power On (Listening Device Reception)

Listening Device	
4.6.2.1	If a Listening Device in NO_REMOTE_FIELD state is placed in the Operating Volume of the NFC Forum – Reference Polling Device set-up to be between the Min and Max power levels of Operating Field that may be provided by a Polling Device, it SHALL enter the IDLE state within a time GT_A, GT_B, and GT_F. Refer to [DIGITAL] for the values of GT_A, GT_B and GT_F. Refer to [ACTIVITY] for details on the NO_REMOTE_FIELD and IDLE states.

4.7 Polling Device Requirements for Resetting Listening Devices

This section specifies how the Polling Device must use the Operating Field to reset the Listening Device in order to ensure that the Listening Device is correctly reset.

4.7.1 Specification Purpose

The purpose of these requirements is to specify how the Operating Field is correctly managed by the Polling Device to induce a reset of the Listening Device. Specifically that any residual carrier emitted by the Polling Device during the reset is sufficiently low that the Listening Device correctly recognizes it as a reset and that the level is maintained at a low state for a sufficient duration to induce a reset.

4.7.2 Specification Context

- Polling Device is set to emit a carrier without any modulation.
- NFC Forum – Reference Listening Device is configured with fixed resistive load (see R_L for $V_{OV,\,RESET}$ in Appendix B.2) and with no modulation applied to J_2 is placed in the Operating Volume of the Polling Device and is used to capture the Polling Device signal on its sense coil on J_4.
- Polling Device is induced to perform a reset.

Specification Requirements

Requirements 4.7 — Listening Device Reset (Polling Device Transmission)

Polling Device	
4.7.2.1	When the NFC Forum - Reference Listening Device is within the Operating Volume of the Polling Device and the Polling Device resets the Operating Field, it SHALL generate a voltage less than or equal to Max $\mathbf{V_{0V,RESET}}$ (rms) for a time $\mathbf{t_{FIELD\_OFF}}$ defined by [ACTIVITY], characterized at the output of the sense coil on $\mathbf{J_4}$ of the NFC Forum - Reference Listening Device. Refer to Appendix B.2 for the value of $\mathbf{V_{0V,RESET}}$.

4.8 Listening Device Requirements for being Reset

This section specifies the reset requirements for the Listening Device such that it can be ensured that a Listening Device can be correctly reset by a Polling Device which is emitting worst case residual carrier level.

4.8.1 Specification Purpose

The purpose of these requirements is to ensure that a Listening Device will be correctly reset by a Polling Device operating according to this specification.

4.8.2 Specification Context

- NFC Forum – Reference Listening Device configured with a fixed resistive load (see $\mathbf{R_{S,L}}$ for $\mathbf{V_{S,OV,RESET}}$ in Appendix B.3) and with no modulation applied to $\mathbf{J_2}$.
- NFC Forum – Reference Polling Device emitting a carrier signal with frequency $\mathbf{f_{S,C}}$ (nominal value).
- NFC Forum – Reference Polling Device carrier level set-up such that when the NFC Forum – Reference Listening Device is placed in the Operating Volume at position ($r=0$, $\varphi=0$, $z=\mathbf{Z_{S,OV}}$, $\theta=0$), it generates a residual level of voltage $\mathbf{V_{S,OV,RESET}}$ (rms) at the output of the sense coil, J_4 of the NFC Forum – Reference Listening Device.

  The settings of the signal generator creating this voltage is further on referenced as $\mathbf{V_{GEN,RESET}}$.

  Refer to Appendix B.3 for the value of $\mathbf{V_{S,OV,RESET}}$.
- With the Listening Device in the Operating Volume of the NFC Forum – Reference Polling Device, the following sequence shall cause the Listening Device to finish in the **IDLE** state:
  - NFC Forum – Reference Polling Device is generating an Operating Field, with no modulation applied, with frequency $\mathbf{f_{S,C}}$ (nominal value).
  - NFC Forum – Reference Listening Device is configured with a fixed resistive load (see $\mathbf{R_{S,L}}$ for $\mathbf{V_{S,OV}}$ **minimum** level in Appendix B.3) and with no load modulation transmit signal applied to $\mathbf{J_2}$.

- The carrier level of the NFC Forum – Reference Polling Device, with no AM modulation applied and the signal generator is set-up such that the NFC Forum – Reference Listening Device in position (r=0, φ=0, z=$\mathbf{Z_{S,OV}}$, θ=0) of the Operating Volume now has the voltage according to the **minimum** level of $\mathbf{V_{S,OV}}$ in Appendix B.3 at its output $\mathbf{J_1}$. The settings of the signal generator creating this voltage is further on referenced as $\mathbf{V_{GEN,MINIMUM}}$.
- NFC Forum – Reference Polling Device sends the appropriate commands to put a Listening Device of NFC-A, NFC-B or NFC-F in to an appropriate state higher than the **IDLE** state are sent to the Listening Device from the NFC Forum – Reference Polling Device.
- The signal generator level is reduced from $\mathbf{V_{GEN,MINIMUM}}$ to $\mathbf{V_{GEN,RESET}}$ for a time $\mathbf{t_{RESET}}$ specified from [ACTIVITY] before re-applying the level previously called $\mathbf{V_{GEN,MINIMUM}}$.

Specification Requirements

Requirements 4.8 — Listening Device Reset (Listening Device Reception)

Polling Device	
4.8.2.1	When the Operating Field is switched off as simulated by the signal generator level being reduced from $\mathbf{V_{GEN,MINIMUM}}$ to $\mathbf{V_{GEN,RESET}}$ for a time $\mathbf{t_{FIELD\_OFF}}$ defined by [ACTIVITY], a Listening Device SHALL enter NO_REMOTE_FIELD state as defined by [ACTIVITY]. After the signal level is restored back to $\mathbf{V_{GEN,MINIMUM}}$, the Listening Device MUST be in IDLE state after a time $\mathbf{GT_A}$, $\mathbf{GT_B}$ and $\mathbf{GT_F}$. Refer to [DIGITAL] for the value of $\mathbf{GT_A}$, $\mathbf{GT_B}$ and $\mathbf{GT_F}$.

4.9 Polling Device Requirements for RF Collision Avoidance

This section specifies the listen before carrier generation “RF Collision Avoidance” requirement for a polling device.

4.9.1 Specification Purpose

The purpose of these requirements is to ensure that an NFC Device will be prevented from generating a carrier when in the presence of another Polling device already generating a carrier such that it will not cause interference to another Polling Device operating in close proximity.

4.9.2 Specification Context

- NFC Forum – Reference Polling Device emitting a carrier signal with frequency $\mathbf{f_{S,C}}$ (nominal value).
- NFC Forum – Reference Polling Device carrier level set such that when the NFC Forum – Reference Listening Device configured with fixed resistive load (see $\mathbf{R_{S,L}}$ for $\mathbf{V_{s,thresh\ RF\ Collision\ Avoidance}}$ in Appendix B.3), is placed at position (r=0, φ=0, z=$\mathbf{Z_{S,OV}}$, θ=0), it generates a voltage of $\mathbf{V_{s,thresh\ RF\ Collision\ Avoidance}}$ at the output $\mathbf{J_1}$ of the NFC Forum – Reference Listening Device.
- Refer to Appendix B.3 for the values of $\mathbf{R_{S,L}}$, $\mathbf{Z_{S,OV}}$, and $\mathbf{V_{s,thresh\ RF\ Collision\ Avoidance}}$.

Specification Requirements

Requirements 4.9 — Polling Device RF Collision Avoidance before Carrier Generation

Listening Device	
4.9.2.1	With the NFC Forum – Reference Polling Device, pre-set to generate an Operating Field level determined by $\mathbf{V_{s,thresh\ RF\ Collision\ Avoidance}}$, as given in Appendix B.3, and placed in the Operating Volume of the Polling Device at position (r=0, φ=0, z=$\mathbf{Z_{S,OV}}$, θ=0). When the Polling Device is instructed to switch-on its Operating Field, it SHALL not generate an Operating Field.

5 Signal Interface Polling Device to Listening Device

This section specifies the modulation methods used by NFC-A, NFC-B, and NFC-F for the communication from Polling Device to Listening Device. It deals with:

- The data transmission characteristics of the Polling Device are given as requirements listed in Sections 5.1, 5.2, 5.3, 5.4, and 5.5.
- The reception capabilities of the Listening Device to interpret the data transmission of the Polling Device are given as requirements listed in Section 5.6.

The [DIGITAL] specification defines three possible modulation types, called NFC-A, NFC-B, and NFC-F, for communication from Polling Device to Listening Device. All three types use Amplitude Shift Keying (ASK).

The amplitude of the carrier is switched between $\mathbf{V_1}$ and $\mathbf{V_2}$, creating a lower level when the field is at value $\mathbf{V_2}$. The requirements of the lower level, $\mathbf{V_2}$, as well as the envelope or wave shape of the carrier for the three modulation types, are defined in the following sections.

All specifications described in this section are characterized in conjunction with the NFC Forum – Reference Polling Devices and the NFC Forum – Reference Listening Devices set-up and calibrated as specified in the appendixes to this document.

The following requirements SHALL apply within the whole Operating Volume.

5.1 Polling Device Requirements for Modulation Polling Device to Listening Device – NFC-A

NFC-A communication from Polling Device to Listening Device uses the modulation principle of ASK nominally 100%. The carrier is turned on and off, creating a lower level when turned off. In practice, it will result in a modulation depth of 95% or higher. The lower level for NFC-A modulation is referred to as “pause” by [ISO/IEC_14443] and NFCIP-1.

5.1.1 Specification Purpose

The purpose of these requirements is to ensure that a Polling Device produces NFC-A modulation characteristics that are within a Listening Device’s receiver capability so that the Polling Device’s transmission can be reliably received by any Listening Device.

5.1.2 Specification Context

- The NFC Forum – Reference Listening Device is configured with two independent values for the fixed resistive load (see $\mathbf{R_L}$ for “Modulation Poller→Listener (NFC-A)” in Appendix B.2) and no modulation transmit signal is applied to $\mathbf{J_2}$.
- Polling Device is configured to send a ALL_REQ or SENS_REQ command.
- NFC Forum – Reference Listening Device placed in Operating Volume of the Polling Device.
- ALL_REQ or SENS_REQ signal transmitted by the Polling Device is received and characterized at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D.

For this section, V represents the envelope of the signal monitored at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D with the NFC Forum – Reference Listening Device placed in the Operating Volume of the Polling Device.

$\mathbf{V_1}$ is the initial value measured immediately before the first modulation is applied by the Polling Device. $\mathbf{V_2}$, $\mathbf{V_3}$, and $\mathbf{V_4}$ are defined as follows:

$\mathbf{V_2} = 0.05V_1$

$\mathbf{V_3} = 0.6V_1$

$\mathbf{V_4} = 0.9V_1$

The falling edge is that part of the envelope **V**, where **V** decreases from $\mathbf{V_4}$ to $\mathbf{V_2}$. The rising edge is that part of the envelope **V**, where **V** increases from $\mathbf{V_2}$ to $\mathbf{V_4}$.

A representation of the wave shape and position of parameters is shown in Figure 6.

Specification Requirements

Requirements 5.1 — Modulation Polling Device to Listening Device – NFC-A (Polling Device Transmission)

Polling Device	
	When measured as described in the specification context above the Polling Device SHALL modulate the Operating Field in the Operating Volume in such a way that the signal monitored at the output J_4 of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D has the following characteristics:
5.1.2.1	The time between V_4 of the falling edge and V_2 of the rising edge SHALL be $\mathbf{t_1}$.
5.1.2.2	If V does not decrease monotonically with time from V_4 to V_2, the time between a local maximum and the time of passing the same value before the local maximum SHALL be $\mathbf{t_5}$. This SHALL only apply if the local maximum is greater than V_2.
5.1.2.3	Ringing following the falling edge SHALL remain below $\mathbf{V_{OU,A}} \times V_1$.
5.1.2.4	V SHALL remain less than V_2 for a time $\mathbf{t_2}$.
5.1.2.5	V SHALL increase monotonically with time from V_2 to V_3 in a time $\mathbf{t_4}$.
5.1.2.6	V SHALL increase monotonically with time from V_2 to V_4 in a time $\mathbf{t_3}$.
5.1.2.7	Overshoots immediately following the rising edge SHALL remain within $(1 \pm \mathbf{V_{OU,A}}) \times V_1$.
	Refer to Appendix B.2 for the values of $\mathbf{t_1}$, $\mathbf{t_2}$, $\mathbf{t_3}$, $\mathbf{t_4}$, $\mathbf{t_5}$ and $\mathbf{V_{OU,A}}$.

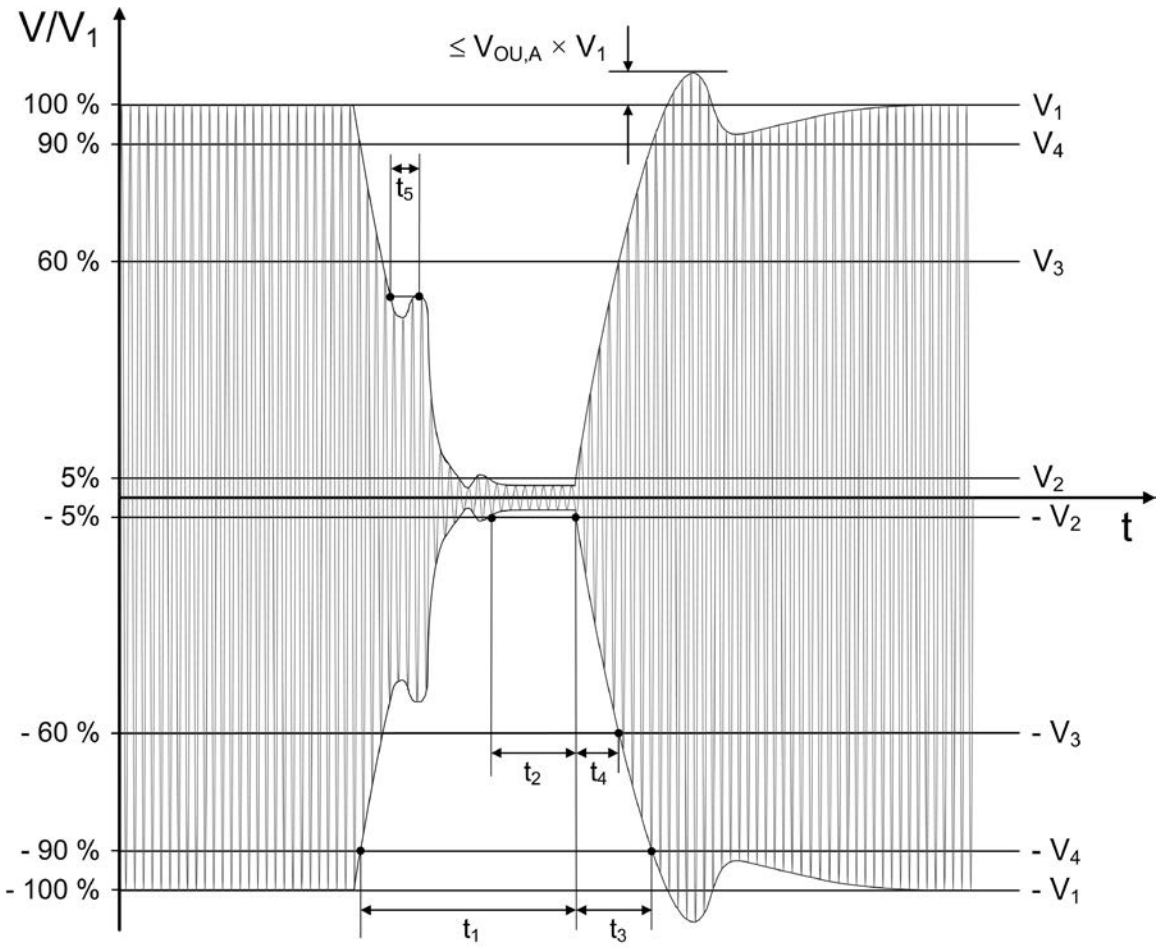


Figure 6: Modulation Polling Device to Listening Device for NFC-A

5.2 Listening Device Requirements for Modulation Polling Device to Listening Device – NFC-A

This section lists the requirements for the reception capabilities of a Listening Device of NFC-A.

5.2.1 Specification Purpose

The purpose of these requirements is to ensure that a Listening Device functions properly with an NFC Forum – Reference Polling Device that applies NFC-A modulation characteristics at the border of the tolerance interval.

5.2.2 Specification Context

- The NFC Forum – Reference Polling Device is set for nominal power as specified in Appendix B.6.
- The NFC Forum – Reference Listening Device is configured with fixed resistive load (see $\mathbf{R_{S,L}}$ for "Modulation Poller→Listener (NFC-A)" in Appendix B.3) and no modulation transmit signal is applied to $\mathbf{J_2}$.
- Polling Device configured to send an ALL_REQ or SENS_REQ command.
- With the NFC Forum – Reference Listening Device placed in the Operating Volume of the NFC Forum – Reference Polling Device, the modulation characteristics of the ALL_REQ or SENS_REQ signal transmitted by the Polling Device are adjusted to obtain modulation characteristics $\mathbf{t_{S,1}}$, $\mathbf{t_{S,2}}$, $\mathbf{t_{S,3}}$, $\mathbf{t_{S,4}}$, and $\mathbf{V_{S,OU,A}}$. The modulation characteristics are monitored at the sense coil $\mathbf{J_4}$ output of the NFC Forum – Reference Listening Device or 8-shaped coil. Refer to Appendix B.3 for the set-up values of $\mathbf{t_{S,1}}$, $\mathbf{t_{S,2}}$, $\mathbf{t_{S,3}}$, $\mathbf{t_{S,4}}$, and $\mathbf{V_{S,OU,A}}$.
- The Listening Device is placed in Operating Volume of the NFC Forum – Reference Polling Device.

Specification Requirements

Requirements 5.2 — Modulation Polling Device to Listening Device – NFC-A (Listening Device Reception)

Listening Device	
5.2.2.1	When placed in the Operating Volume of the NFC Forum – Reference Polling Device, a Listening Device of NFC-A SHALL function properly when the NFC Forum – Reference Polling Device has been set up as described in the specification context above.

5.3 Polling Device Requirements for Modulation Polling Device to Listening Device – NFC-B

NFC-B communication from Polling Device to Listening Device uses the modulation principle of ASK nominally 10%.

The amplitude of the carrier is reduced to create a lower level with a modulation index $\mathbf{m_i}$.

The requirements on the lower level as well as on the envelope of the carrier are defined below.

When using analog levels to derive digital timing characteristics, the rise time should be considered to be part of the not modulated section and excluded from the period when the modulation is applied. Conversely the fall time should be considered to be part of the modulated section and excluded from the period when the modulation is not applied.

5.3.1 Specification Purpose

The purpose of these requirements is to ensure that a Polling Device produces NFC-B modulation characteristics that are within a Listening Device's receiver capability so that the Polling Device's transmission can be reliably received by the Listening Device.

It is not the purpose of this section to define requirements on bit boundaries; this is defined in [DIGITAL].

5.3.2 Specification Context

- The NFC Forum – Reference Listening Device is configured with two independent values for the fixed resistive load (see $\mathbf{R_L}$ for "Modulation Poller→Listener (NFC-B)" in Appendix B.2) and no modulation transmit signal is applied to J_2.
- Polling Device configured to send a ALLB_REQ or SENSB_REQ command.
- NFC Forum – Reference Listening Device placed in Operating Volume of the Polling Device.
- ALLB_REQ or SENSB_REQ signal transmitted by the Polling Device is received and characterized at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D.

For this section, V represents the envelope of the signal measured at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D with the NFC Forum – Reference Listening Device placed in the Operating Volume of the Polling Device. $\mathbf{V_a}$ is the initial value measured immediately before the first modulation is applied by the Polling Device. $\mathbf{V_b}$ is the lower level. The modulation index ($\mathbf{m_i}$), $\mathbf{V_3}$ and $\mathbf{V_4}$ are defined as follows:

$$m_i = \frac{V_a - V_b}{V_a + V_b}$$

$$\mathbf{V_3} = \mathbf{V_a} - 0.1(\mathbf{V_a}-\mathbf{V_b})$$

$$\mathbf{V_4} = \mathbf{V_b} + 0.1(\mathbf{V_a}-\mathbf{V_b})$$

A representation of the wave shape and position of parameters is shown in Figure 7.

Specification Requirements

Requirements 5.3 — Modulation Polling Device to Listening Device – NFC-B (Polling Device Transmission)

Polling Device	
	When measured as described in the specification context above, the Polling Device SHALL modulate the Operating Field in the Operating Volume in such a way that the signal measured at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D has the following characteristics:
5.3.2.1	The modulation index ($\mathbf{m_i}$) of the signal SHALL be $\mathbf{mod_{i,B}}$.
5.3.2.2	V SHALL decrease from $\mathbf{V_3}$ to $\mathbf{V_4}$ (i.e., the falling edge) in a time $\mathbf{t_{f,B}}$.
5.3.2.3	V SHALL increase from $\mathbf{V_4}$ to $\mathbf{V_3}$ (i.e., the rising edge) in a time $\mathbf{t_{r,B}}$.
5.3.2.4	The rising and falling edges of the modulation SHALL be monotonic with time.
5.3.2.5	Overshoots and undershoots following the falling edge ($\mathbf{h_f}$) SHALL be less than $\mathbf{V_{OU,B}}$ x ($\mathbf{V_a}$-$\mathbf{V_b}$).
5.3.2.6	Overshoots and undershoots following the rising edge ($\mathbf{h_r}$) SHALL be less than $\mathbf{V_{OU,B}}$ x ($\mathbf{V_a}$-$\mathbf{V_b}$).
	Refer to Appendix B.2 for the values of $\mathbf{mod_{i,B}}$, $\mathbf{t_{f,B}}$, $\mathbf{t_{r,B}}$, and $\mathbf{V_{OU,B}}$.

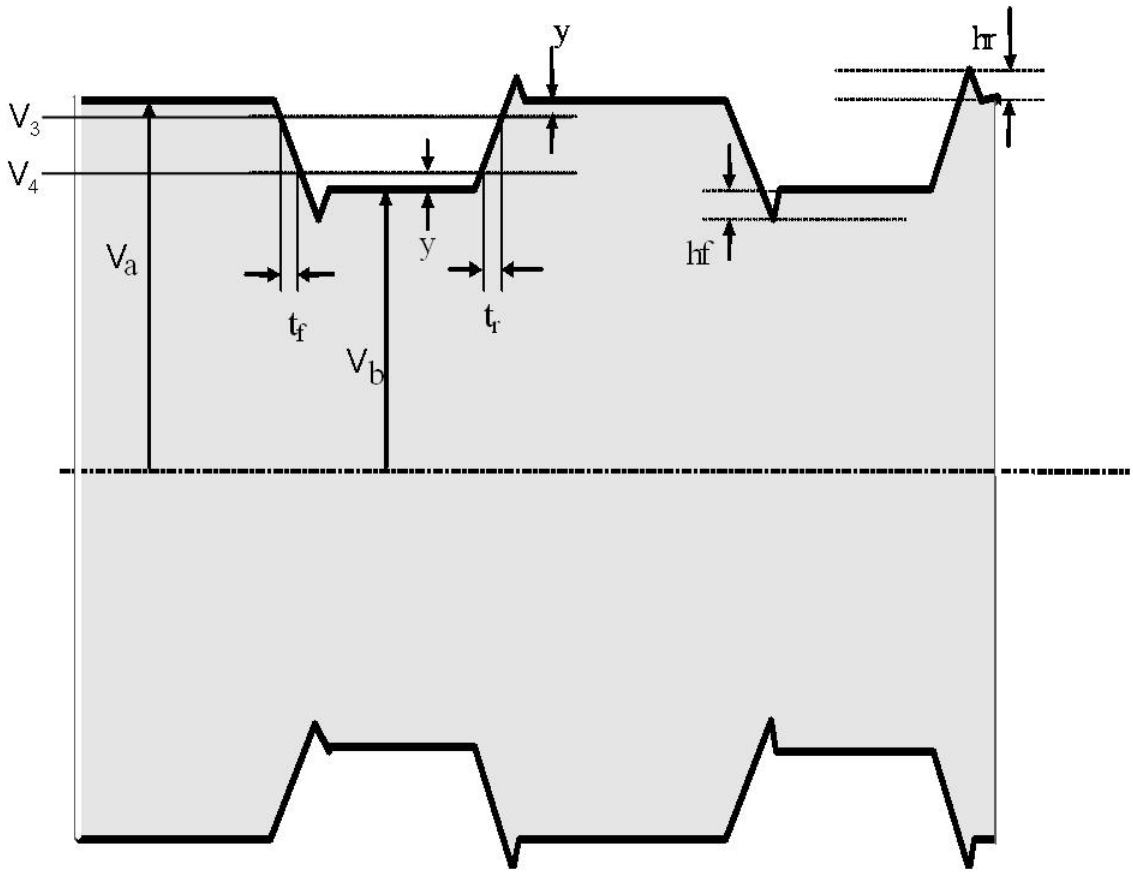


Figure 7: Modulation Polling Device to Listening Device for NFC-B

5.4 Listening Device Requirements for Modulation Polling Device to Listening Device – NFC-B

This section lists the requirements for the reception capabilities of a Listening Device of NFC-B.

When using analog levels to derive digital timing characteristics, the rise time should be considered to be part of the not modulated section and excluded from the period when the modulation is applied. Conversely, the fall time should be considered to be part of the modulated section and excluded from the period when the modulation is not applied.

5.4.1 Specification Purpose

The purpose of these requirements is to ensure that a Listening Device functions properly with the NFC Forum – Reference Polling Device that applies NFC-B modulation characteristics at the border of the tolerance interval.

5.4.2 Specification Context

- The NFC Forum – Reference Polling Device is set for nominal power as specified in Appendix B.6.

- The NFC Forum – Reference Listening Device is configured with fixed resistive load (see $R_{S,L}$ for "Modulation Poller→Listener (NFC-B)" in Appendix B.3) and no modulation transmit signal is applied to J_2.
- Polling Device configured to send an ALLB_REQ or SENSB_REQ command.
- With the NFC Forum – Reference Listening Device placed in the Operating Volume of the NFC Forum – Reference Polling Device, the modulation characteristics of the ALLB_REQ or SENSB_REQ signal transmitted by the Polling Device are adjusted to obtain modulation characteristics $m_{S,i,B}$, $t_{S,f,B}$, $t_{S,r,B}$, and $V_{S,OU,B}$. The modulation characteristics are monitored at the sense coil J_4 output of the NFC Forum – Reference Listening Device or 8-shaped coil. Refer to Appendix B.3 for the set-up values of $m_{S,i,B}$, $t_{S,f,B}$, $t_{S,r,B}$, and $V_{S,OU,B}$.
- The Listening Device is placed in Operating Volume of the NFC Forum – Reference Polling Device.

Specification Requirements

Requirements 5.4 — Modulation Polling Device to Listening Device – NFC-B (Listening Device Reception)

Listening Device	
5.4.2.1	When placed in the Operating Volume of the NFC Forum – Reference Polling Device, a Listening Device of NFC-B SHALL function properly when the NFC Forum – Reference Polling Device has been set up as described in the specification context above.

5.5 Polling Device Requirements for Modulation Polling Device to Listening Device – NFC-F

NFC-F communication from Polling Device to Listening Device uses the modulation principle of ASK nominally 10%.

The amplitude of the carrier is reduced to create a lower level with a modulation index $\mathbf{m_i}$. The requirements on the lower level, as well as on the envelope of the carrier, are defined below.

When using analog levels to derive digital timing characteristics, the rise time should be considered to be part of the not modulated section and excluded from the period when the modulation is applied. Conversely, the fall time should be considered to be part of the modulated section and excluded from the period when the modulation is not applied.

5.5.1 Specification Purpose

The purpose of these requirements is to ensure that a Polling Device produces NFC-F modulation characteristics that are within a Listening Device's receiver capability so that the Polling Device's transmission can be reliably received by the Listening Device.

It is not the purpose of this section to define requirements on bit boundaries; this is defined in [DIGITAL].

5.5.2 Specification Context

- The NFC Forum – Reference Listening Device is configured with two independent values for the fixed resistive load (see $\mathbf{R_L}$ for "Modulation Poller→Listener (NFC-F)" in Appendix B.2) and no modulation transmit signal is applied to $\mathbf{J_2}$.
- Polling Device configured to send a SENSF_REQ command.
- NFC Forum – Reference Listening Device placed in Operating Volume of the Polling Device.
- SENSF_REQ signal transmitted by the Polling Device is received and characterized at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D.

For this section, V represents the envelope of the signal measured at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D, with the NFC Forum – Reference Listening Device placed in the Operating Volume of the Polling Device. $\mathbf{V_a}$ is the initial value measured immediately before any modulation is applied by the Polling Device. $\mathbf{V_b}$ is the lower level. The modulation index ($\mathbf{m_i}$), $\mathbf{V_3}$, and $\mathbf{V_4}$ are defined as follows:

$$\mathbf{m_i} = \frac{V_a - V_b}{V_a + V_b}$$

$$\mathbf{V_3} = \mathbf{V_a} - 0.1(\mathbf{V_a}-\mathbf{V_b})$$

$$\mathbf{V_4} = \mathbf{V_b} + 0.1(\mathbf{V_a}-\mathbf{V_b})$$

A representation of the wave shape and position of parameters is shown in Figure 8.

Specification Requirements

Requirements 5.5 — Modulation Polling Device to Listening Device – NFC-F (Polling Device Transmission)

Polling Device	
	When measured as described in the specification context above, the Polling Device SHALL modulate the Operating Field in the Operating Volume in such a way that the signal measured at the output $\mathbf{J_4}$ of the sense coil of the NFC Forum – Reference Listening Device or by means of an 8-shaped sensing coil as described in Appendix D has the following characteristics:
5.5.2.1	The modulation index ($\mathbf{m_i}$) of the signal SHALL be $\mathbf{mod_{i,F}}$.
5.5.2.2	V SHALL decrease from $\mathbf{V_3}$ to $\mathbf{V_4}$ (i.e., the falling edge) in a time $\mathbf{t_{f,F}}$.
5.5.2.3	V SHALL increase from $\mathbf{V_4}$ to $\mathbf{V_3}$ (i.e., the rising edge) in a time $\mathbf{t_{r,F}}$.
5.5.2.4	The rising and falling edges of the modulation SHALL be monotonic with time.
5.5.2.5	Overshoots and undershoots following the falling edge ($\mathbf{h_f}$) SHALL be less than $\mathbf{V_{OU,F}}$ x ($\mathbf{V_a}$-$\mathbf{V_b}$).
5.5.2.6	Overshoots and undershoots following the rising edge ($\mathbf{h_r}$) SHALL be less than $\mathbf{V_{OU,F}}$ x ($\mathbf{V_a}$-$\mathbf{V_b}$).
	Refer to Appendix B.2 for the values of $\mathbf{mod_{i,F}}$, $\mathbf{t_{f,F}}$, $\mathbf{t_{r,F}}$ and $\mathbf{V_{OU,F}}$.

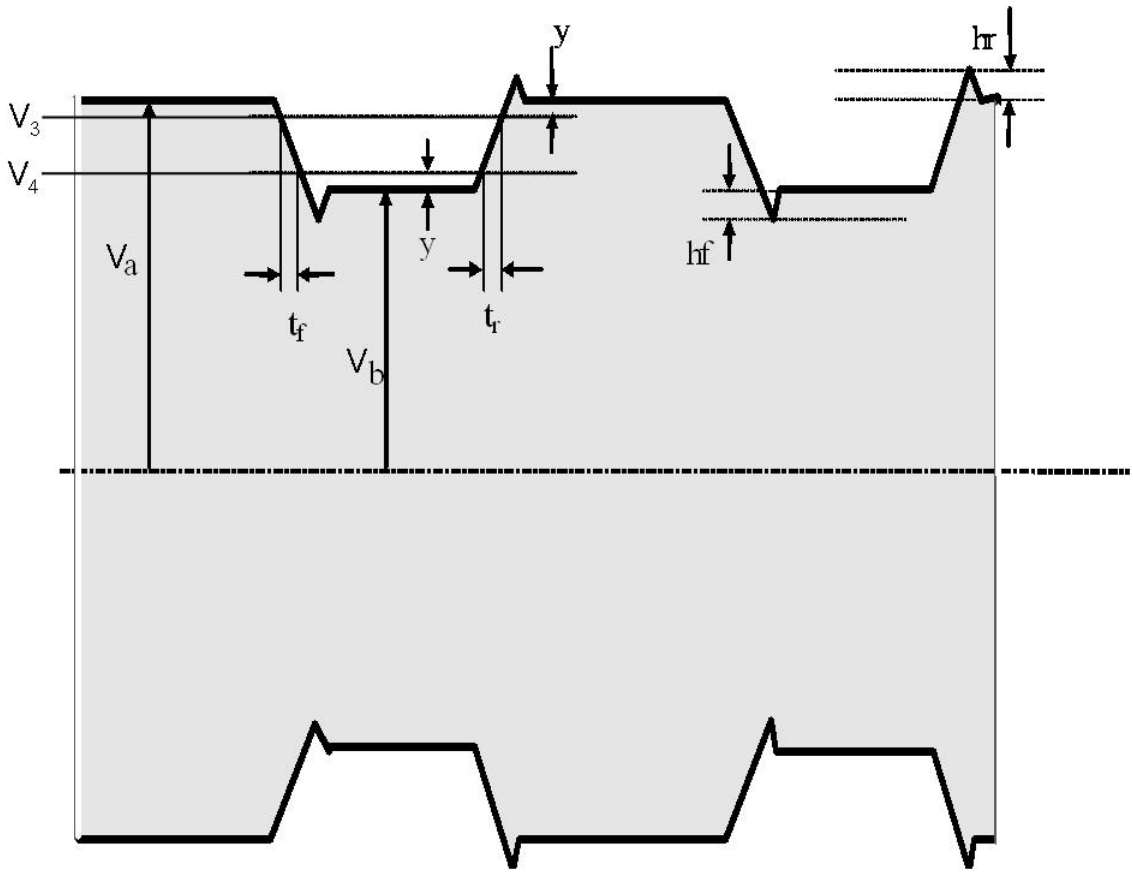


Figure 8: Modulation Polling Device to Listening Device for NFC-F

5.6 Listening Device Requirements for Modulation Polling Device to Listening Device – NFC-F

This section lists the requirements for the reception capabilities of a Listening Device of NFC-F.

5.6.1 Specification Purpose

The purpose of these requirements is to ensure that a Listening Device functions properly with an NFC Forum – Reference Polling Device that applies NFC-F modulation characteristics at the border of the tolerance interval.

When using analog levels to derive digital timing characteristics, the rise time should be considered to be part of the not modulated section and excluded from the period when the modulation is applied. Conversely the fall time should be considered to be part of the modulated section and excluded from the period when the modulation is not applied.

5.6.2 Specification Context

- The NFC Forum – Reference Polling Device is set for nominal power as specified in Appendix B.6.

- The NFC Forum – Reference Listening Device is configured with fixed resistive load (see $R_{S,L}$ for "Modulation Poller→Listener (NFC-F)" in Appendix B.3) and no modulation transmit signal is applied to J_2.
- Polling Device configured to send an SENSF_REQ command.
- With the NFC Forum – Reference Listening Device placed in the Operating Volume of the NFC Forum – Reference Polling Device, the modulation characteristics of the SENSF_REQ signal transmitted by the Polling Device are adjusted to obtain modulation characteristics $m_{S,i,F}$, $t_{S,f,F}$, $t_{S,r,F}$, and $V_{S,OU,F}$. The modulation characteristics are monitored at the sense coil J_4 output of the NFC Forum – Reference Listening Device or 8-shaped coil. Refer to Appendix B.3 for the set-up values of $m_{S,i,F}$, $t_{S,f,F}$, $t_{S,r,F}$, and $V_{S,OU,F}$.
- The Listening Device is placed in Operating Volume of the NFC Forum – Reference Polling Device.

Specification Requirements

Requirements 5.6 — Modulation Polling Device to Listening Device – NFC-F (Listening Device Reception)

Listening Device	
5.6.2.1	When placed in the Operating Volume of the NFC Forum – Reference Polling Device, a Listening Device of NFC-F SHALL function properly for each bit rate supported by the device when the NFC Forum – Reference Polling Device has been set up as described in the specification context above.

6 Signal Interface Listening Device to Polling Device

This section specifies the modulation methods used by NFC-A, NFC-B, and NFC-F for the communication from Listening Device to Polling Device. It deals with:

- The data transmission characteristics of the Listening Device are given as requirements listed in sections 6.1, 6.2, 6.3 and 6.4.
- The reception capabilities of the Polling Device to interpret the data transmission of the Listening Device are given as requirements listed in section 6.5.

For the communication from Listening Device to Polling Device, NFC-A, NFC-B and NFC-F use load modulation as shown in Figure 9. The NFC Forum device generates the Load Modulation signal for NFC-A, NFC-B, and NFC-F either by switching a load, or any other mean that generates the Load Modulation signal over the air interface according to this specification.

For NFC-A and NFC-B, the carrier frequency $\mathbf{f_c}$ is used to derive a subcarrier with frequency $\mathbf{f_S}$ equal to $\mathbf{f_c}/16$ (~847 kHz). Applying the load modulation at this frequency creates the subcarrier.

For NFC-F, the load modulation is applied with 50% duty-cycle. When the Listening Device is in the loaded state, a higher current will flow through the antenna of the Listening Device than in the case where the load modulation is not switched on.

This difference in current in the Listening Device antenna is sensed by the Polling Device.

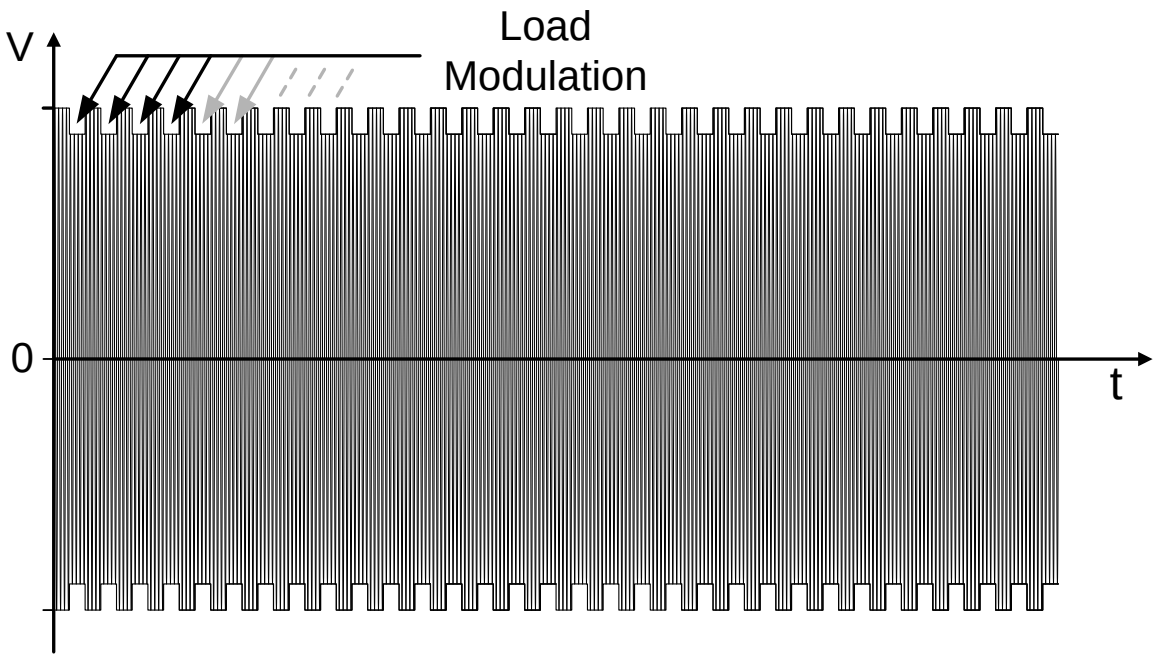


Figure 9: Load Modulation Listening Device to Polling Device

NFC-A modulates a subcarrier using On-Off Keying (OOK). Symbols are described in [DIGITAL].

NFC-B modulates a subcarrier using Binary Phase Shift Keying (BPSK). Symbols are described in [DIGITAL].

For NFC-F, the load modulation scheme is the same as the one used from polling device to listening device. Refer to Section 5.5 for details. Symbols are described in [DIGITAL].

All requirements described in this section must be evaluated with the NFC Forum – Reference Polling Device and the NFC Forum – Reference Listening Device calibrated as specified in the specification context of the requirement.

6.1 Listening Device Requirements for Load Modulation Generic

This section lists the load modulation generation requirements for the Listening Device that are the same for all NFC-A, NFC-B, and NFC-F.

6.1.1 Specification Purpose

The purpose of these requirements is to ensure that the Listening Device produces load modulation that is compatible with the modulation expected by the Polling Device's receiver and has sufficient amplitude to ensure that it can be received successfully.

6.1.2 Specification Context

- NFC Forum – Reference Polling Device setup for nominal power as specified in Appendix B.6.
- NFC Forum – Reference Polling Device setup for nominal modulation characteristics as specified in Appendix B.6.
- NFC Forum – Reference Polling Device sending an ALL_REQ or SENS_REQ command to the Listening Device for NFC-A or an ALLB_REQ or SENSB_REQ command to the Listening Device for NFC-B or an SENSF_REQ command to the Listening Device for NFC-F.
- Listening Device is put in the Operating Volume of the NFC Forum – Reference Polling Device.

Specification Requirements

Requirements 6.1 — Load Modulation Characteristics - Generic (Listening Device Transmission)

Listening Device	
	When put in the Operating Volume of the NFC Forum – Reference Polling Device that has been set up as described in the specification context above, the Listening Device SHALL modulate the Operating Field in such a way that the signal monitored at $\mathbf{J_2}$ of the NFC Forum – Reference Polling Device has the following characteristics:
6.1.2.1	The subcarrier frequency $\mathbf{f_s}$ of the modulation signal SHALL be $\mathbf{f_c}$/16 for NFC-A and NFC-B.
6.1.2.2	For NFC-F, the frequency $\mathbf{f_s}$ of the modulation signal during the preamble SHALL be $\mathbf{f_c}$/32 or $\mathbf{f_c}$/64 and SHALL be $\mathbf{f_c}$/32, $\mathbf{f_c}$/64 or $\mathbf{f_c}$/128 (see note 1) at other times.
6.1.2.3	The amplitude ($\mathbf{V_{pp}}$) of the modulation signal at $\mathbf{J_2}$ of the NFC Forum – Reference Polling Device SHALL be $\mathbf{V_{pp}}$ (peak to peak). (Choosing a measurement position avoiding all transient effects, e.g., the first change from 0 to 1 for NFC-A, the TR1 zone for NFC-B and the zero coding preamble before the Sync code for NFC-F). Refer to Appendix B.2 for the value of $\mathbf{V_{pp}}$.

NOTE 1: $\mathbf{f_c}$/128 can occur when transmission sequence is 010101.....

6.2 Listening Device Requirements for Subcarrier Load Modulation NFC-A

This section lists the Listening Device requirements for the modulation of the subcarrier for the communication from Listening Device to Polling Device for NFC-A.

6.2.1 Specification Purpose

The purpose of these requirements is to ensure that the Listening Device produces load modulation that will be compatible with the modulation expected by the Polling Device's receiver.

Specification Requirements

Requirements 6.2 — Load Modulation Characteristics – NFC-A (Listening Device Transmission)

Listening Device	
6.2.1.1	A Listening Device of NFC-A SHALL modulate the subcarrier using On-Off Keying (OOK).
6.2.1.2	When modulating the subcarrier, a Listening Device of NFC-A SHALL only start the bit period on the rising or falling edge of the subcarrier so that the modulation starts with a defined phase relationship to the subcarrier.

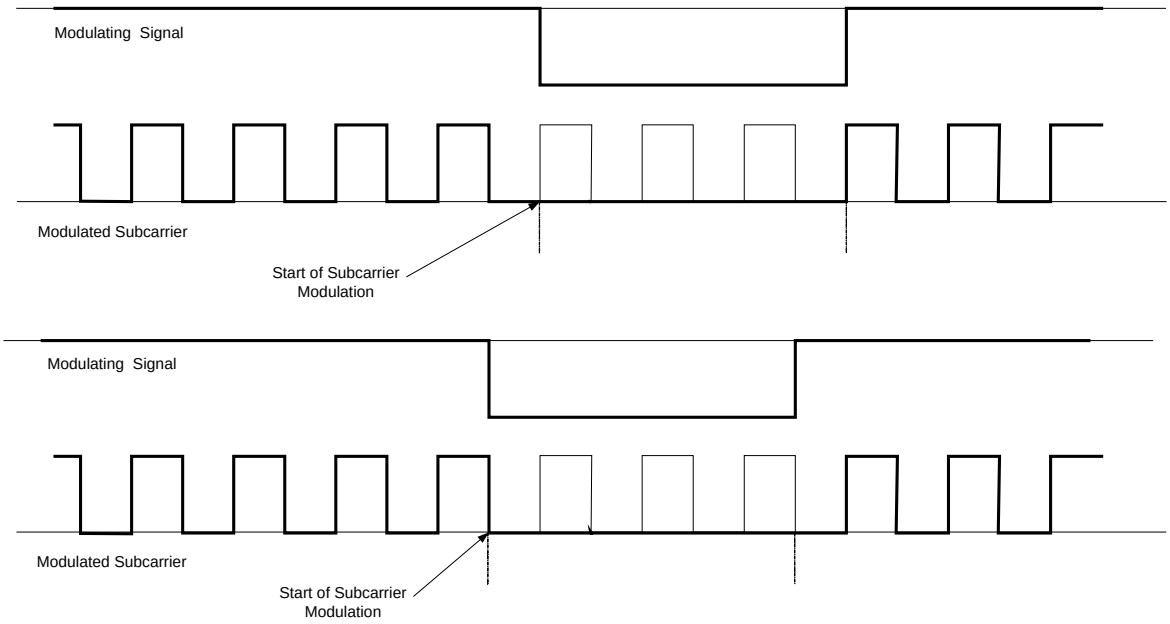


Figure 10: Start of Subcarrier Modulation – NFC-A

6.3 Listening Device Requirements for Subcarrier Load Modulation NFC-B

A Listening Device of NFC-B modulates the subcarrier using BPSK. Before the Listening Device sends information to the Polling Device by means of phase shifts, the Listening Device and Polling Device first establish a reference phase Ø0. Then the Listening Device can start modulating the subcarrier: a change of logic level is denoted by a phase shift of 180° of the subcarrier.

6.3.1 Specification Purpose

The purpose of these requirements is to ensure that the Listening Device produces load modulation that will be compatible with the modulation expected by the Polling Device's receiver.

Specification Requirements

Requirements 6.3 — Load Modulation Characteristics – NFC-B (Listening Device Transmission)

Listening Device	
6.3.1.1	A Listening Device of NFC-B SHALL modulate the subcarrier using BPSK.
6.3.1.2	A Listening Device of NFC-B SHALL generate a subcarrier only when data is to be transmitted.
6.3.1.3	Phase shifts SHALL only occur at nominal positions of rising or falling edges of the subcarrier.

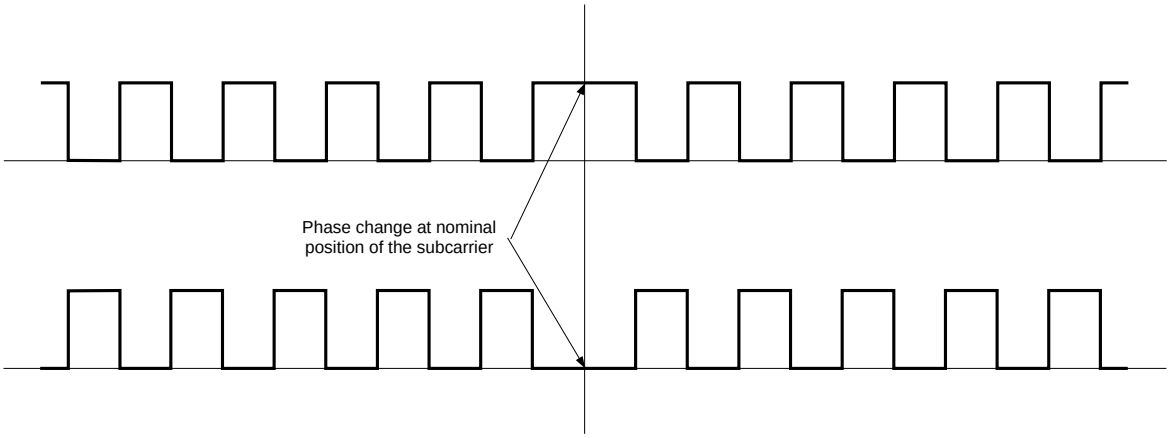


Figure 11: Allowed Phase Shifts – NFC-B

6.4 Listening Device Requirements for Load Modulation NFC-F

A Listening Device of NFC-F modulates the carrier using ASK.

6.4.1 Specification Purpose

The purpose of these requirements is to ensure that the Listening Device produces load modulation that will be compatible with the modulation expected by the Polling Device's receiver.

It is not the purpose of this section to define requirements on bit boundaries; this is defined in [DIGITAL].

Specification Requirements

Requirements 6.4 — Load Modulation Characteristics – NFC-F (Listening Device Transmission)

Listening Device	
6.4.1.1	A Listening Device of NFC-F SHALL load modulate the carrier using Amplitude Shift Keying (ASK).

6.5 Polling Device Requirements for Load Modulation Listening Device to Polling Device

This section lists the requirements for the reception capabilities of a Polling Device to interpret the modulation applied by the Listening Device at the border of the tolerance interval.

6.5.1 Specification Purpose

The purpose of these requirements is to ensure that the receiver of the Polling Device is sufficiently sensitive to be able to receive the load modulation produced by a Listening Device.

6.5.2 Specification Context

- NFC Forum – Reference Polling Device setup for nominal power as specified in Appendix B.6.
- NFC Forum – Reference Listening Device configured with fixed resistive load (see $\mathbf{R_{S,L}}$ for "Load Modulation (NFC-A, NFC-B, NFC-F)" in Appendix B.3).
- NFC Forum – Reference Listening Device set to produce an appropriate response with load modulation of an amplitude $\mathbf{V_{S,pp}}$ (peak to peak) measured at $\mathbf{J_2}$ of the NFC Forum – Reference Polling Device when it is placed in the position (r=0, φ=0, z=$\mathbf{Z_{S,LM}}$, θ=0) of the Operating Volume of the NFC Forum – Reference Polling Device. Refer to Appendix B.3 for the values of $\mathbf{Z_{S,LM}}$ and $\mathbf{V_{S,pp}}$.
- Polling Device set to send a valid command to the NFC Forum – Reference Listening Device.

Specification Requirements

Requirements 6.5 — Modulation Listening Device to Polling Device (Polling Device Reception)

Polling Device	
6.5.2.1	For NFC-A, NFC-B, and NFC-F, the Polling Device SHALL function properly with the NFC Forum – Reference Listening Device placed in its Operating Volume, provided the NFC Forum – Reference Listening Device has been set up as described in the specification context above.

A. Exhibit A

No items have been included in Exhibit A.

B. Appendix Values

Throughout the document, symbols are used to identify the values of parameters. The actual values of the parameters are listed in these appendixes.

B.1 Operating Volume

This appendix lists the values of the parameters to define the Operating Volume.

Table 4: Parameters for Operating Volume

Topic	Parameter	Value	Units
Operating Volume	D1	10	mm
	D2	20	mm
	D3	20	mm
	S1	5	mm
	S2	0	mm
	S3	0	mm

B.2 RF Power and Signal Interface

This appendix lists the values of the parameters to define the RF power and signal interface requirements. For each of the parameters, a minimum and maximum value is defined.

Unless stated otherwise, the NFC Forum - Reference Listening Device is tuned to 13.56 MHz. Figures in gray below represent values that, while valid, are not expected to be subject to testing. For example, although $\mathbf{V_{ov}}$ figures are given for all listeners, the worst case is Listener-1.

Table 5: Parameters for RF Power and Modulation

Topic	Parameter	Coil	Value		R_L Ω	Units
			Min	Max		
Power transfer: Poller→Listener	V_{OV} 0≤z≤(S1+S2+S3)	Listener-1	4.10		820	V
		Listener-3	3.14			V
		Listener-6	3.79			V
	V_{OV} 0≤z≤(S1+S2+S3)	Listener-1		2.85	82	V
		Listener-3		2.30		V
		Listener-6		2.23		V
Influence of Listening Device	ΔV_{OV}	Poller-0	0	0.56	820	V_{pp}
		Poller-3	0	0.30		V_{pp}
		Poller-6	0	0.51		V_{pp}
Power Off/On	$V_{OV, RESET}$		0	3.5	820	mV rms
Carrier Frequency	f_c		13.553	13.567	820	MHz
Modulation Poller→Listener (NFC-A)	t_1 (106kbps)		2.06	2.99	330 & 820	µs
	t_2 (106kbps)		0.52	t_1		µs
	t_3 (106kbps)		1.5 x t_4	1.18		µs
	t_4 (106kbps)		0	0.44		µs
	t_5 (106kbps)		0	0.50		µs

Topic	Parameter	Coil	Value		R_L Ω	Units
			Min	Max		
	$V_{OU,A}$ (106kbps)		0	$0 \le t_3 \le \frac{3}{f_c}$ $\Rightarrow \left(1 - \frac{t_3}{2 \cdot t_{3\_max}}\right) \cdot 0.39$ $\frac{3}{f_c} \le t_3 \le \frac{6}{f_c}$ $\Rightarrow \frac{-y_1 + y_2}{3/f_C} \cdot t_3 + 2y_1 - y_2$ $\frac{6}{f_c} \le t_3 \le t_{3\_max}$ $\Rightarrow \left(1 - \frac{t_3}{2 \cdot t_{3\_max}}\right) \cdot 0.1$ with $y_1 = \left(1 - \frac{3/f_C}{2 \cdot t_{3\_max}}\right) \cdot 0.39$ $y_2 = \left(1 - \frac{6/f_C}{2 \cdot t_{3\_max}}\right) \cdot 0.1$	330 & 820	-
Modulation Poller→Listener (NFC-B)	**$mod_{i,B}$** (106kbps)		8	15	330 & 820	%
	$t_{f,B}$ (106kbps)		0	1.18		µs
	$t_{r,B}$ (106kbps)		Maximum of 0 and **$t_{f,B}$**-0.59	Minimum of 1.18 and 0.59+**$t_{f,B}$**		µs
	$V_{OU,B}$ (106kbps)		0	$0 \le t_{r,B} \le \frac{3}{f_c}$ $\Rightarrow \left(1 - \frac{t_{r,B}}{2 \cdot t_{r,B\_max}}\right) \cdot 0.39$ $\frac{3}{f_c} \le t_{r,B} \le \frac{6}{f_c}$ $\Rightarrow \frac{-y_1 + y_2}{3/f_C} \cdot t_{r,B} + 2y_1 - y_2$ $\frac{6}{f_c} \le t_{r,B} \le t_{r,B\_max}$ $\Rightarrow \left(1 - \frac{t_{r,B}}{2 \cdot t_{r,B\_max}}\right) \cdot 0.1$	330 & 820	-

Topic	Parameter	Coil	Value		R_L Ω	Units
			Min	Max		
				or $\left\lvert \begin{array}{l} 0 \le t_{f,B} \le \frac{3}{f_c} \\ \Rightarrow \left(1 - \frac{t_{f,B}}{2 \cdot t_{f,B\_\max}}\right) \cdot 0.39 \\ \frac{3}{f_c} \le t_{f,B} \le \frac{6}{f_c} \\ \Rightarrow \frac{-y_1 + y_2}{3/f_C} \cdot t_{f,B} + 2y_1 - y_2 \\ \frac{6}{f_c} \le t_{f,B} \le t_{f,B\_\max} \\ \Rightarrow \left(1 - \frac{t_{f,B}}{2 \cdot t_{f,B\_\max}}\right) \cdot 0.1 \end{array} \right.$ with $y_1 = \left(1 - \frac{3/f_C}{2 \cdot t_{r/f,B\_\max}}\right) \cdot 0.39$ $y_2 = \left(1 - \frac{6/f_C}{2 \cdot t_{r/f,B\_\max}}\right) \cdot 0.1$		

Topic	Parameter	Coil	Value		R_L Ω	Units
			Min	Max		
Modulation Poller→Listener (NFC-F)	$\mathbf{mod_{i,F}}$		8	15	330 & 820	%
	$\mathbf{t_{f,F}}$ (212kbps)		0	1.18		µs
	$\mathbf{t_{f,F}}$ (424kbps)		0	0.8		µs
	$\mathbf{t_{r,F}}$ (212kbps)		Maximum of 0 and $\mathbf{t_{f,F}}$-0.59	Minimum of 1.18 and 0.59+$\mathbf{t_{f,F}}$		µs
	$\mathbf{t_{r,F}}$ (424kbps)		Maximum of 0 and $\mathbf{t_{f,F}}$-0.4	Minimum of 0.8 and 0.4+$\mathbf{t_{f,F}}$		µs
	$\mathbf{V_{OU,F}}$		0	$\left\lvert \begin{array}{l} 0 \le t_{r,F} \le \frac{3}{f_c} \\ \Rightarrow \left(1 - \frac{t_{r,F}}{2 \cdot t_{r,F\_\max}}\right) \cdot 0.39 \\ \frac{3}{f_c} \le t_{r,F} \le \frac{6}{f_c} \\ \Rightarrow \frac{-y_1 + y_2}{3/f_C} \cdot t_{r,F} + 2y_1 - y_2 \\ \frac{6}{f_c} \le t_{r,F} \le t_{r,F\_\max} \\ \Rightarrow \left(1 - \frac{t_{r,F}}{2 \cdot t_{r,F\_\max}}\right) \cdot 0.1 \end{array} \right.$ or $\left\lvert \begin{array}{l} 0 \le t_{f,F} \le \frac{3}{f_c} \\ \Rightarrow \left(1 - \frac{t_{f,F}}{2 \cdot t_{f,F\_\max}}\right) \cdot 0.39 \\ \frac{3}{f_c} \le t_{f,F} \le \frac{6}{f_c} \\ \Rightarrow \frac{-y_1 + y_2}{3/f_C} \cdot t_{f,F} + 2y_1 - y_2 \\ \frac{6}{f_c} \le t_{f,F} \le t_{f,F\_\max} \\ \Rightarrow \left(1 - \frac{t_{f,F}}{2 \cdot t_{f,F\_\max}}\right) \cdot 0.1 \end{array} \right.$ with	330 & 820	-

Topic	Parameter	Coil	Value		R_L Ω	Units
			Min	Max		
				$y_1 = \left(1 - \frac{3/f_C}{2 \cdot t_{r/f,F\_max}}\right) \cdot 0.39$ $y_2 = \left(1 - \frac{6/f_C}{2 \cdot t_{r/f,F\_max}}\right) \cdot 0.1$		
Load Modulation Poller←Listener	**V_{pp}**	**Poller-0**	20	110		mV_{pp}
		Poller-3	9.5	53		mV_{pp}
		Poller-6	7	90		mV_{pp}

NOTE In the above table, t_{r,B_max}, t_{r,F_max}, and t_{f,F_max} refer to the absolute maximum value according to the max column of the associated rise/fall time definition without t_r versus t_f symmetry limitations.

B.3 Set-up Values for NFC Forum Reference Equipment

This appendix lists the set-up parameters for the NFC Forum Reference Equipment. For each of the parameters, a minimum and maximum value is defined. When applicable, a nominal value is also defined.

Table 6: Parameters for Setting-up of Reference Equipment

Topic	Parameter	Coil	Setup Values to establish….			$R_{S,L}$ Ω	Units
			Min	Nominal	Max		
Carrier Frequency	**$f_{S,C}$**		13.55	13.56	13.57		MHz
Power transfer: Poller→Listener	**$Z_{S,ov}$**		5	5	5		mm
	$V_{S,ov}$ **Set up using Listener-1**	**Poller-0**	4.70	5.22		820	V
		Poller-3	4.24	4.72			
		Poller-6	3.73	4.15			
	$V_{S,ov}$	**Poller-0 with Listener-1**			2.84	82	V

Topic	Parameter	Coil	Setup Values to establish….			$R_{S,L}$	Units
			Min	Nominal	Max	Ω	
		Poller-3 with Listener-3			2.22		
		Poller-6 with Listener-6			1.82		
	$V_{S,0V,RESET}$ using Listener-1 (PICC-1)	**Any Poller**		5.3		820	mV rms
Polling device RF Collision Avoidance	**Z_S**		5	5	5		mm
	$V_{s,thresh\ RF\ Collision\ Avoidance}$ using Listener-1 (PICC-1) Based on 0.1875 A/m on ID-1	**Any Poller**	0.573			820	V
Modulation Poller→Listener (NFC-A)	**Z_S**		5	5	5		mm
	$t_{S,1}$ (106kbps)		2.03	2.85	3.02	330 & 820	µs
	$t_{S,2}$ (106kbps)		0.44		**$t_{S,1}$**		µs
	$t_{S,3}$ (106kbps)		Greater of 1.5 x **$t_{S,4}$** or Minimum achievable		1.25		µs

Topic	Parameter	Coil	Setup Values to establish….			$R_{S,L}$	Units
			Min	Nominal	Max	Ω	
			value				
	$t_{S,4}$ (106kbps)		Minimum achievable value		0.52		µs
	$V_{S,OU,A}$ (106kbps)		0		$0 \le t_3 \le \frac{3}{f_c}$ $\Rightarrow \left(1-\frac{t_3}{2\cdot t_{3\_max}}\right)$ $\frac{3}{f_c} \le t_3 \le \frac{6}{f_c}$ $\Rightarrow \frac{-y_1+y_2}{3/f_C}\cdot t_3$ $\frac{6}{f_c} \le t_3 \le t_{3\_max}$ $\Rightarrow \left(1-\frac{t_3}{2\cdot t_{3\_max}}\right)$ with $y_1 = \left(1-\frac{3/f_c}{2\cdot t_{3\_}}\right.$ $y_2 = \left(1-\frac{6/f_c}{2\cdot t_{3\_}}\right.$	330 & 820	-
Modulation Poller→Listener (NFC-B)	$m_{S,i,B}$ (106kbps)		8	11	19	330 & 820	%
	$t_{S,f,B}$ (106kbps)		Minimum achievable value		1.25		µs
	$t_{S,r,B}$ (106kbps)		Maximum of Minimum achievable value and $t_{S,f,B}$-0.66		Minimum of 1.25 and 0.66+$t_{S,f,B}$		µs

Topic	Parameter	Coil	Setup Values to establish….			$R_{S,L}$	Units
			Min	Nominal	Max	Ω	
	$V_{S,OU,B}$ (106kbps)		0		$0 \le t_{r,B} \le \frac{3}{f_c}$ $\Rightarrow \left(1-\frac{t_{r,B}}{2\cdot t_{r,B\_max}}\right.$ $\frac{3}{f_c} \le t_{r,B} \le \frac{6}{f_c}$ $\Rightarrow \frac{-y_1+y_2}{3/f_C}\cdot t_{r,B}$ $\frac{6}{f_c} \le t_{r,B} \le t_{r,B\_ma}$ $\Rightarrow \left(1-\frac{t_{r,B}}{2\cdot t_{r,B\_max}}\right.$ or $0 \le t_{f,B} \le \frac{3}{f_c}$ $\Rightarrow \left(1-\frac{t_{f,B}}{2\cdot t_{f,B\_max}}\right.$ $\frac{3}{f_c} \le t_{f,B} \le \frac{6}{f_c}$ $\Rightarrow \frac{-y_1+y_2}{3/f_C}\cdot t_{f,B}$ $\frac{6}{f_c} \le t_{f,B} \le t_{f,B\_m}$ $\Rightarrow \left(1-\frac{t_{f,B}}{2\cdot t_{f,B\_max}}\right.$ with $y_1 = \left(1-\frac{3/f_C}{2\cdot t_{r/f,B}}\right.$ $y_2 = \left(1-\frac{6/f_C}{2\cdot t_{r/f,B}}\right.$	330 & 820	-
Modulation Poller→Listener (NFC-F)	$m_{S,i,F}$		8	11	19	330 & 820	%
	$t_{S,f,F}$ (212kbps)		Minimum achievable value		1.25		µs
	$t_{S,f,F}$ (424kbps)		Minimum achievable value		0.9		µs
	$t_{S,r,F}$ (212kbps)		Maximum of Minimum achievable		Minimum of 1.25 and 0.66+$t_{S,f,F}$		µs

Topic	Parameter	Coil	Setup Values to establish….			$R_{S,L}$	Units
			Min	Nominal	Max	Ω	
			value and $t_{S,f,F}$-0.66				
	$t_{S,r,F}$ (424kbps)		Maximum of Minimum achievable value and $t_{S,f,F}$-0.44		Minimum of 0.9 and 0.44+$t_{S,f,F}$		µs
	$V_{S,OU,F}$		0		$0 \le t_{r,F} \le \frac{3}{f_c} \Rightarrow \left(1-\frac{t_{r,F}}{2\cdot t_{r,F\_max}}\right)$ $\frac{3}{f_c} \le t_{r,F} \le \frac{6}{f_c} \Rightarrow \frac{-y_1+y_2}{3/f_C}\cdot t_{r,F}$ $\frac{6}{f_c} \le t_{r,F} \le t_{r,F\_ma} \Rightarrow \left(1-\frac{t_{r,F}}{2\cdot t_{r,F\_max}}\right)$ or $0 \le t_{f,F} \le \frac{3}{f_c} \Rightarrow \left(1-\frac{t_{f,F}}{2\cdot t_{f,F\_max}}\right)$ $\frac{3}{f_c} \le t_{f,F} \le \frac{6}{f_c} \Rightarrow \frac{-y_1+y_2}{3/f_C}\cdot t_{f,F}$ $\frac{6}{f_c} \le t_{f,F} \le t_{f,F\_m} \Rightarrow \left(1-\frac{t_{f,F}}{2\cdot t_{f,F\_max}}\right)$ with $y_1=\left(1-\frac{3/f_C}{2\cdot t_{r/f,F}}\right)$ $y_2=\left(1-\frac{6/f_C}{2\cdot t_{r/f,F}}\right)$	330 & 820	-
Load Modulation (NFC-A, NFC-	$Z_{S,LM}$		5	5	5		mm
	$V_{S,pp}$	**Listener-1**	18	25		330	**mV_{pp}**
		Listener-3	26	30			

Topic	Parameter	Coil	Setup Values to establish….			$R_{S,L}$	Units
			Min	Nominal	Max	Ω	
B, NFC-F)	with Poller-0	**Listener-6**	26	30			
Load Modulation (NFC-A, NFC-B, NFC-F)	$V_{S,pp}$	**Poller-0 with Listener-1**			114	330	mV_{pp}
		Poller-3 with Listener-3			54		
		Poller-6 with Listener-6			90		

B.4 Calibration Procedure for NFC Forum Reference Pollers

The preferred method for calibration or verification is by using a Vector Network Analyzer (VNA).

The Reference Poller must be positioned in free air. A short length of semi-rigid RG-402 cable is ideal for this purpose.

The analyzer is used to perform a reflection measurement (S11) after calibrating the VNA using Open, Short, Load (OSL) 1 port calibration. The calibration plane for this corresponds to the mating surface of the SMA plug on the cable from the VNA that will be connected to the SMA socket of the Reference Equipment. See Figure 12.

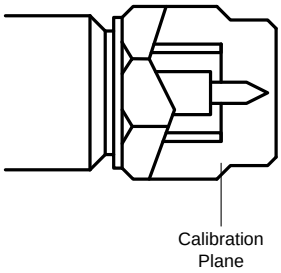


Figure 12: Calibration Plane of SMA Plug and Socket

The VNA is connected to $\mathbf{J_1}$, the socket that accepts the carrier from the power amplifier. The socket that connects to the Sense Resistor ($\mathbf{J_2}$) must be terminated with a 50 ohm load during calibration and use.

The VNA must be set to a drive level of 0dBm and the scan and steps adjusted to ensure adequate resolution and accuracy for the measurement (for example, scanning from 13 to 14 MHz with 1000 points in the scan). Set up the VNA in S11 measurement mode, and display return loss.

Use a non-metallic tuning tool appropriate for the trimmer capacitors VC1 and VC2, and tune it in order to achieve maximum return loss at 13.56 MHz and 50Ω matching. A Reference Poller is correctly tuned when the return loss is greater than 45dB at 13.56 MHz. Note that VC2 affects matching and tuning, whereas VC1 affects primarily tuning.

An example of a typical VNA display when tuning a Reference Poller is shown in Figure 13.

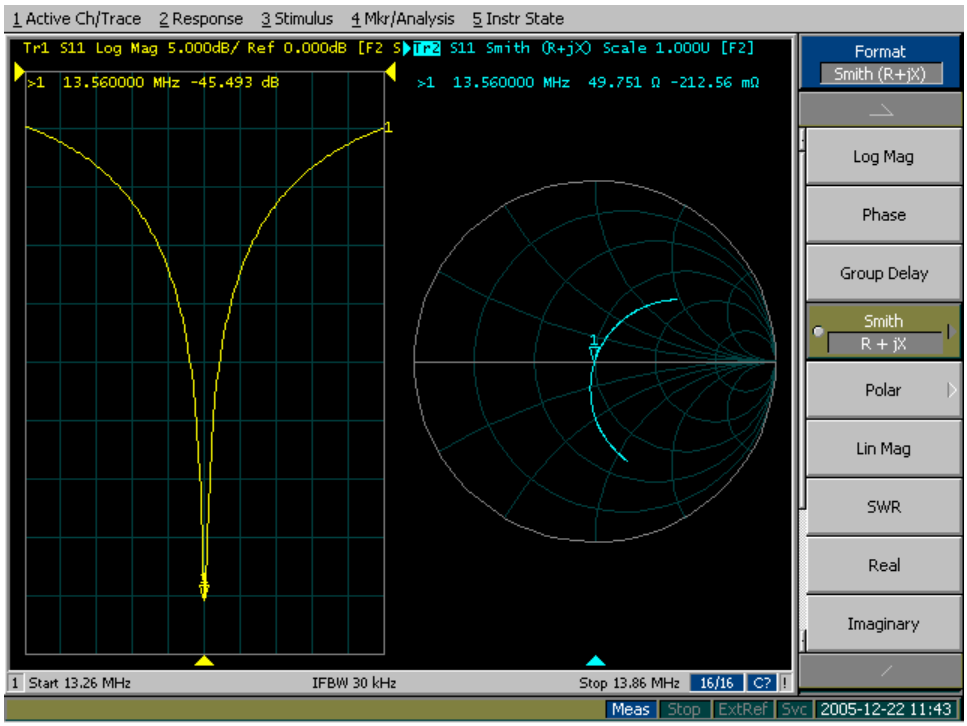


Figure 13: Example of VNA Display When Tuning a Reference Poller

B.5 Calibration Procedure for NFC Forum Reference Listeners

The preferred method for calibration or verification is by using a Vector Network Analyzer (VNA).

The Reference Listener must be positioned in free air. A short length of semi-rigid RG-402 cable is ideal for this purpose.

The 820Ω fixed load shall be selected.

The analyzer is used to perform a reflection measurement (S11) after calibrating the VNA using Open, Short, Load (OSL) calibration. The calibration plane for this corresponds to the mating surface of the SMA plug on the cable from the VNA that will be connected to the SMA socket of the Reference Equipment. See Figure 12.

The VNA is connected to $\mathbf{J_5}$, the SMA socket in parallel with the antenna coil. When calibrating the Reference Listener, no connection must be made to any of the other connectors of the device.

The VNA must be set to a drive level of +10dBm and the scan and steps adjusted to ensure adequate resolution and accuracy for the measurement (for example, scanning from 10 to 20 MHz with 1000 points in the scan).

Set up the VNA in S11 measurement mode and display impedance as modulus and phase. At the resonant frequency of the Reference Listener antenna, note the peak of the impedance and zero degrees phase shift.

Use a non-metallic tuning tool appropriate for the trimmer capacitor VC1, and tune it in order to achieve close to zero degrees phase shift (which should correspond approximately to the peak |Z|) at 13.56MHz. A Reference Listener is correctly tuned when its resonance is within 50 kHz of the intended frequency.

An example of a typical VNA display when tuning a Reference Listener is shown in Figure 14.

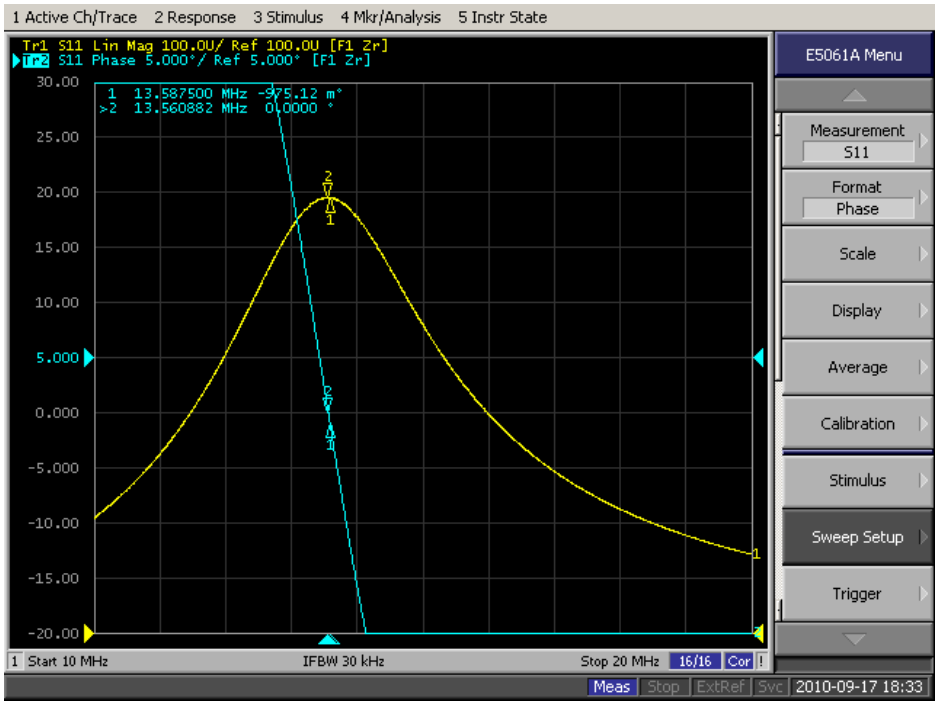


Figure 14: Example of VNA Display When Tuning a Reference Listener

B.6 Nominal Settings for NFC Forum Reference Equipment

Table 7: Setup for Nominal Field Strength

Step	Action
1	Place the NFC Forum – Reference Listening Device in position (r=0, φ=0, z= $\mathbf{Z_{S,OV}}$, θ=0) of the Operating Volume of the NFC Forum – Reference Polling Device. Apply no modulation transmit signal to $\mathbf{J_2}$ of the NFC Forum – Reference Listening Device. Configure the NFC Forum – Reference Listening Device with resistive load $\mathbf{R_{S,L}}$ for $\mathbf{V_{S,OV}}$ (Nominal value). Refer to Appendix B.3 for the values of $\mathbf{Z_{S,OV}}$ and $\mathbf{R_{S,L}}$.
2	Connect input $\mathbf{J_1}$ of the NFC Forum – Reference Polling Device with a signal generator V generating a carrier signal with frequency $\mathbf{f_{S,c}}$ (nominal value). Regulate the signal generator V in such a way that it generates an average voltage $\mathbf{V_{S,OV}}$ (nominal value) at $\mathbf{J_1}$ of the NFC Forum – Reference Listening Device. Refer to Appendix B.3 for the values of $\mathbf{V_{S,OV}}$ and $\mathbf{f_{S,c}}$.
3	Remove the NFC Forum – Reference Listening Device from the Operating Volume of the NFC Forum – Reference Polling Device.

Table 8: Setup for Nominal Modulation

Step	Action
1	Place the NFC Forum – Reference Listening Device (r=0, φ=0, z= $\mathbf{Z_{S,OV}}$, θ= 0) of the Operating Volume of the NFC Forum – Reference Polling Device. Apply no modulation transmit signal to J_2 of the NFC Forum – Reference Listening Device. Configure the NFC Forum – Reference Listening Device with resistive load $\mathbf{R_{S,L}}$ for "Modulation Poller→Listener" for NFC-A, NFC-B or NFC-F as appropriate. Refer to Appendix B.3 for the values of $\mathbf{Z_{S,OV}}$ and $\mathbf{R_{S,L}}$.
2	Modulate the carrier to obtain the following modulation characteristics: For NFC-A • Nominal value of $\mathbf{t_{S,1}}$ • $\mathbf{t_{S,2}}$, $\mathbf{t_{S,3}}$, $\mathbf{t_{S,4}}$, and $\mathbf{V_{S,OU,A}}$ are within Min-Max range For NFC-B • Nominal value of mS,i,B • $\mathbf{t_{S,f,B}}$, $\mathbf{t_{S,r,B}}$, and $\mathbf{V_{S,OU,B}}$ are within Min-Max range For NFC-F • Nominal value of $\mathbf{m_{S,i,F}}$

	• $t_{S,f,F}$, $t_{S,r,F}$, and $V_{S,OU,F}$ are within Min-Max range The modulation characteristics are measured at the sense coil J_4 output of the NFC Forum – Reference Listening Device. Refer to Appendix B.3 for the nominal values of $t_{S,1}$, $m_{S,i,B}$, and $m_{S,i,F}$ and for the ranges for $t_{S,2}$, $t_{S,3}$, $t_{S,4}$, $V_{S,OU,A}$, $t_{S,f,B}$, $t_{S,r,B}$, $V_{S,OU,B}$, $t_{S,f,F}$, $t_{S,r,F}$, and $V_{S,OU,F}$.
3	Remove the NFC Forum – Reference Listening Device from the Operating Volume of the NFC Forum – Reference Polling Device.

B.7 Orientation and Alignment of NFC Forum Reference Equipment

The NFC Forum – Reference Poller Devices have an alignment legend on the silk screen which consists of an arrow and a cross mark that are centered on the geometrical center of the antenna. The arrow points away from the components.

The NFC Forum – Reference Listener Devices have an alignment legend on the silk screen which consists of an arrow and a cross mark that are centered on the geometrical center of the antenna. The arrow points towards the components.

Both devices are intended to be presented to the Poller or Listener device to be characterized in an orientation whereby the components are upper-most. In this orientation, the thickness of the PCB, and stack-up of layers is used to generate a consistent z=0 separation. Therefore, it is important that the construction details given in Appendix C.8 are adopted.

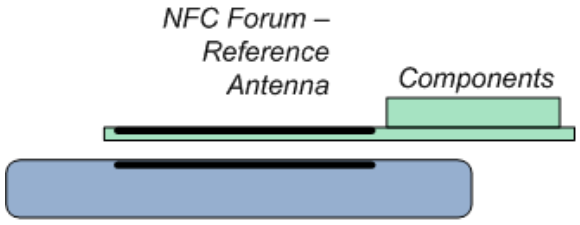


Figure 15: Orientation of NFC Forum Reference Equipment Used To Characterise a Polling or Listening Device

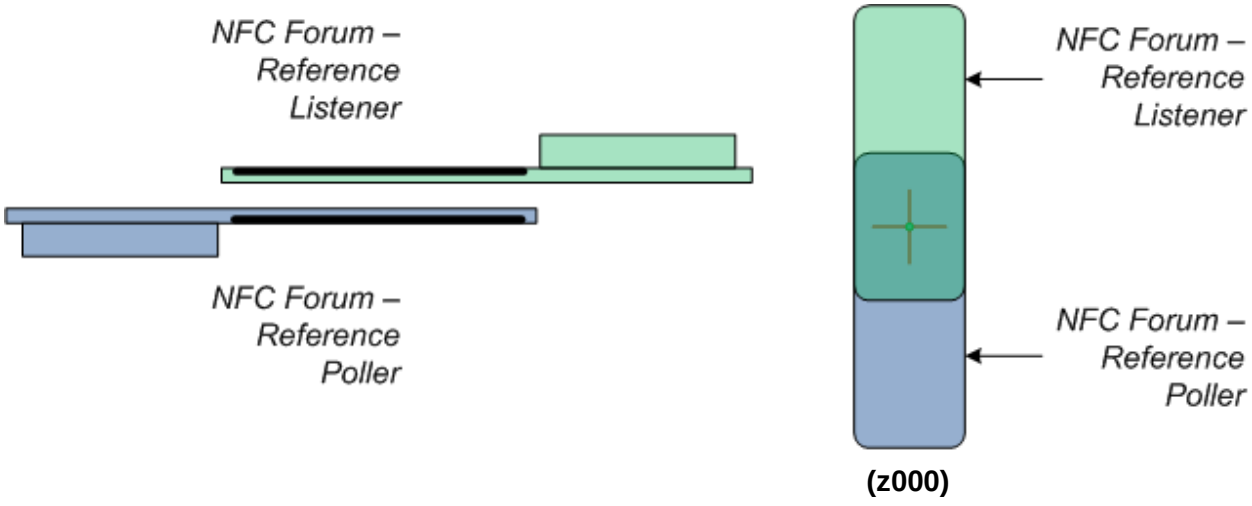


Figure 16: Relative Orientation of NFC Forum Reference Equipment During Set-up

C. Design Information for NFC Forum Reference Equipment

This appendix provides design information essential for defining the NFC Forum - Reference Polling Devices and the NFC Forum - Reference Listening Devices.

Fixed components used in these circuits must have tolerance ≤2%. It is advisable to use high stability capacitors; e.g., NPO/COG.

C.1 NFC Forum - Reference Polling Device Poller-0

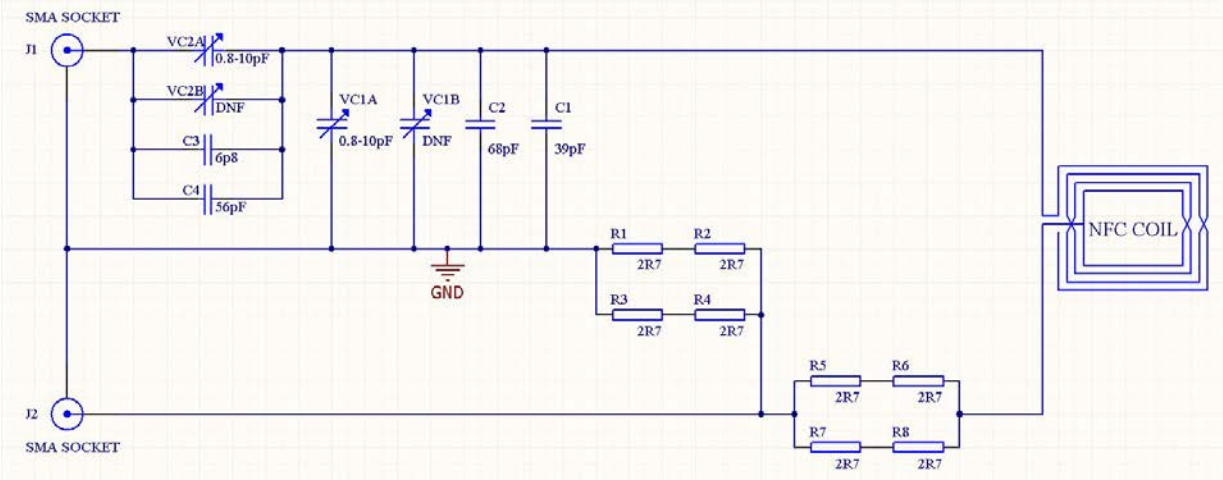


Figure 17: Circuit for NFC Forum - Reference Device Poller-0

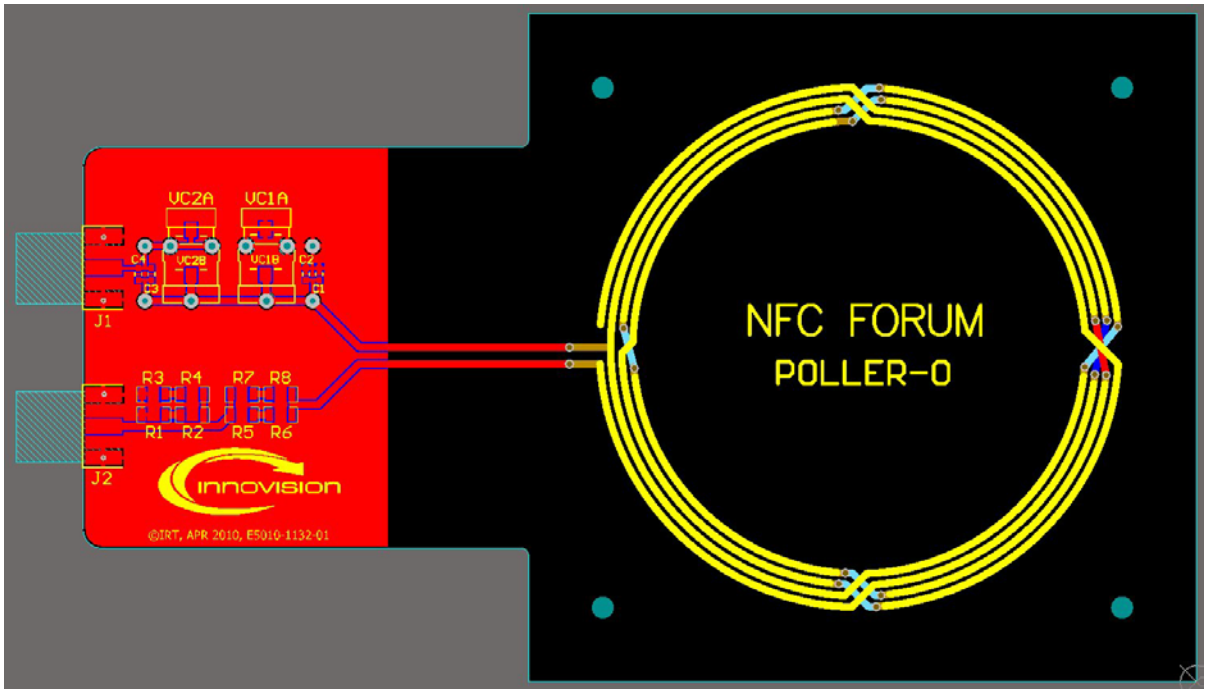


Figure 18: PCB Layout for Poller-0

C.2 NFC Forum - Reference Polling Device Poller-3

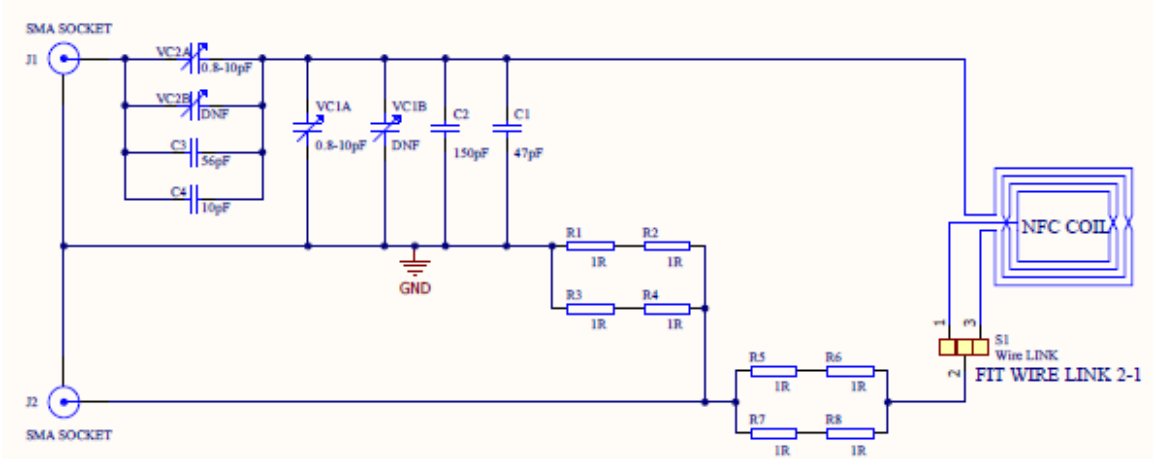


Figure 19: Circuit for NFC Forum - Reference Device Poller-3

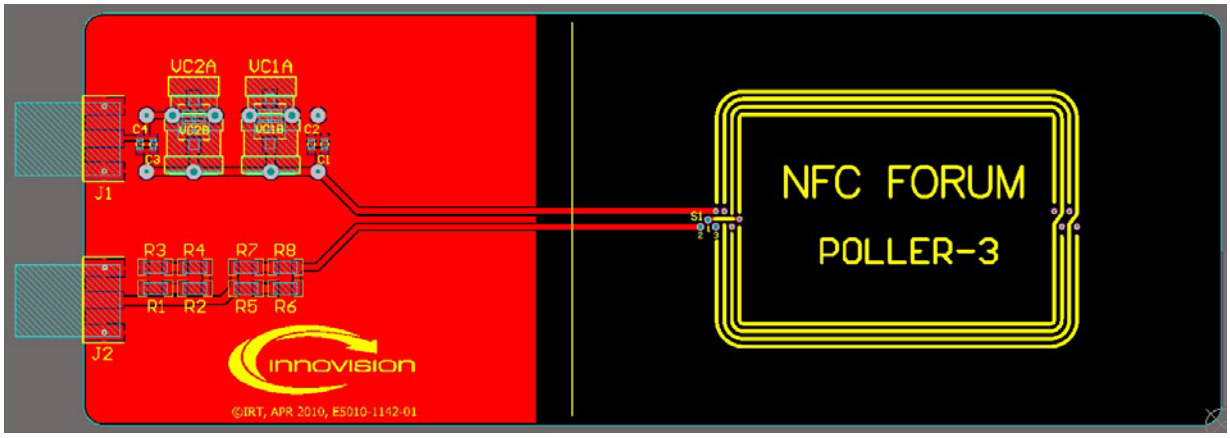


Figure 20: PCB Layout for Poller-3

C.3 NFC Forum - Reference Polling Device Poller-6

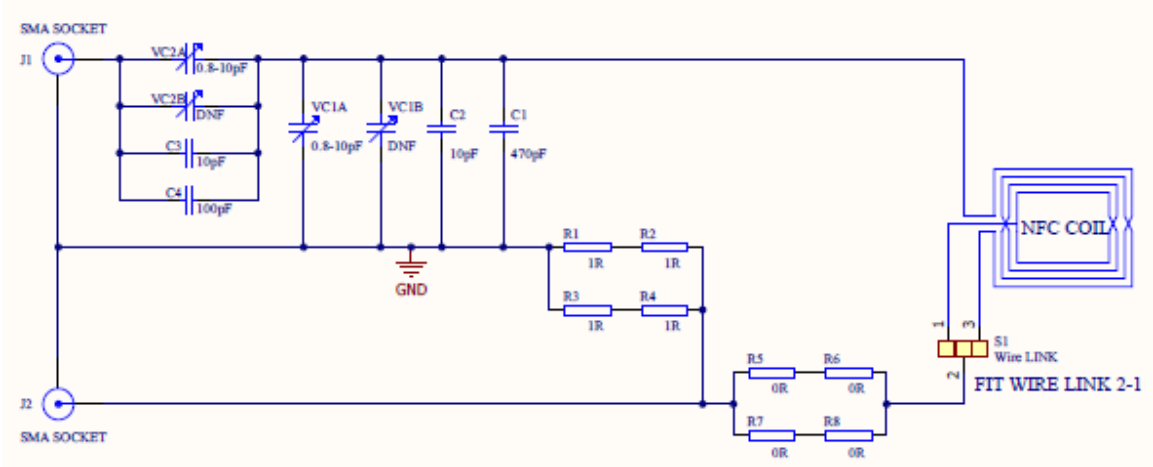


Figure 21: Circuit for NFC Forum - Reference Device Poller-6

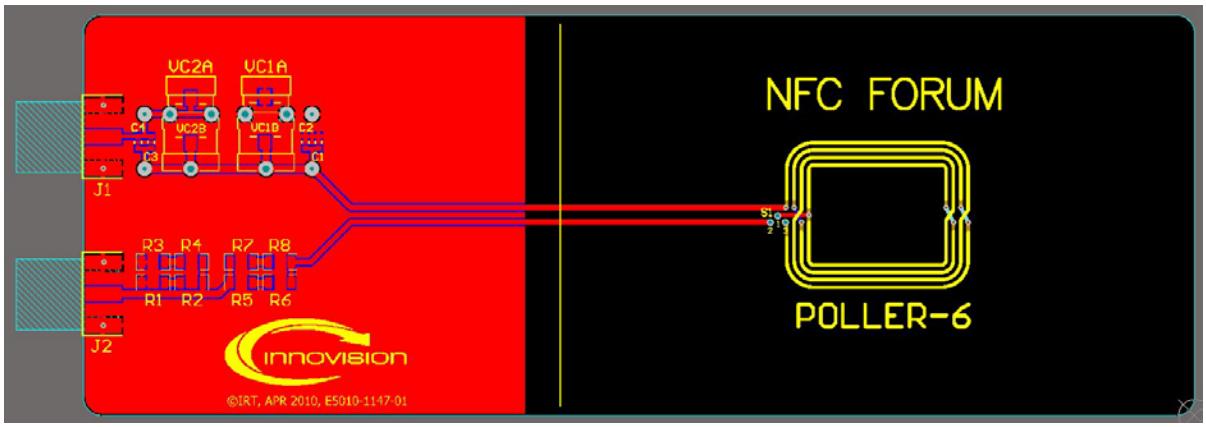
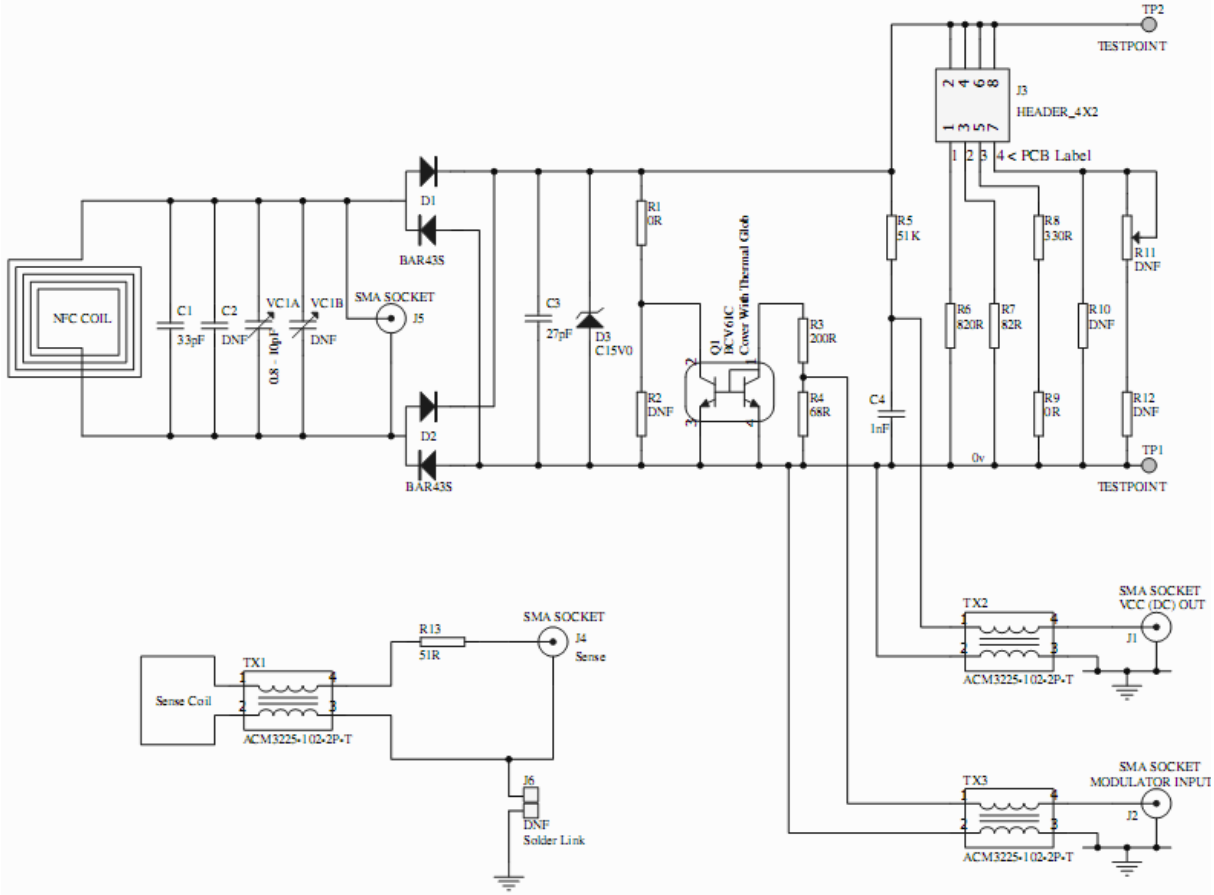


Figure 22: PCB Layout for Poller-6

C.4 NFC Forum - Reference Listening Device Listener-1



NOTE D3 is BZV55-C15,135

Figure 23: Circuit for NFC Forum - Reference Device Listener-1

NOTE During assembly, be sure to crop legs of **J_5** and VC1A flush with underside of PCB prior to soldering so that z=0 can be reliably achieved in operation.

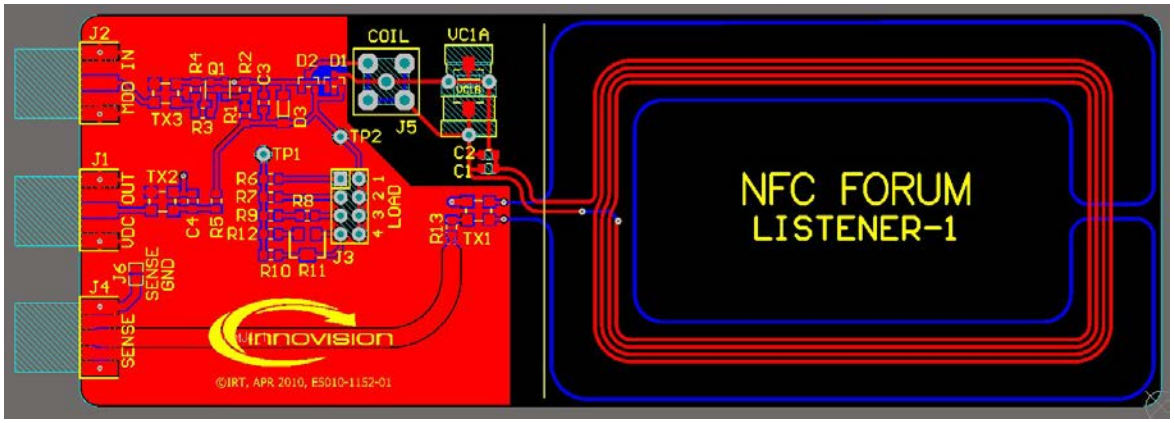
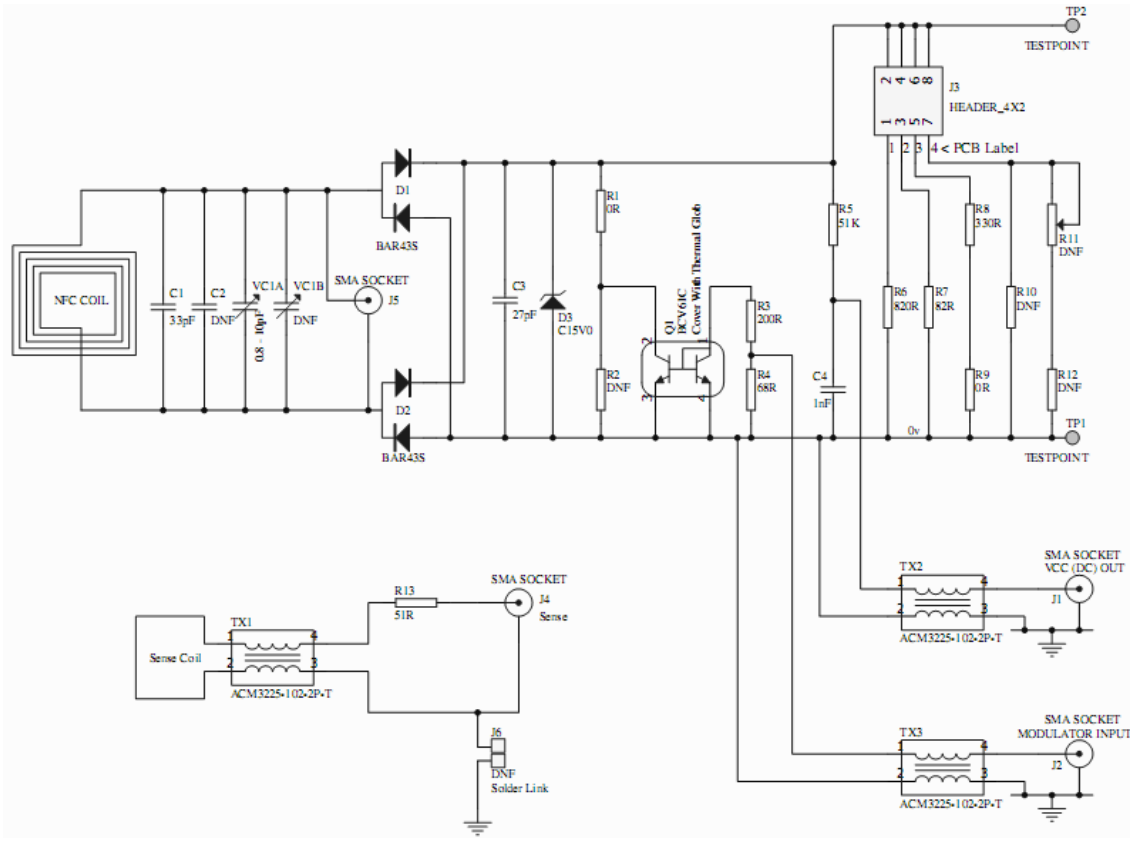


Figure 24: PCB Layout for Listener-1

C.5 NFC Forum - Reference Listening Device Listener-3



NOTE D3 is BZV55-C15,135

Figure 25: Circuit for NFC Forum - Reference Device Listener-3

NOTE During assembly, be sure to crop legs of **J_5** and VC1A flush with underside of PCB prior to soldering so that z=0 can be reliably achieved in operation.

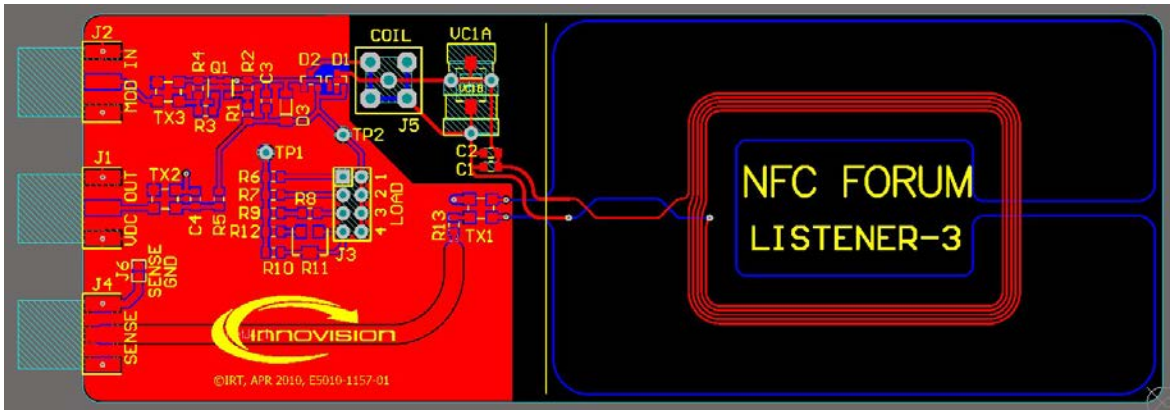
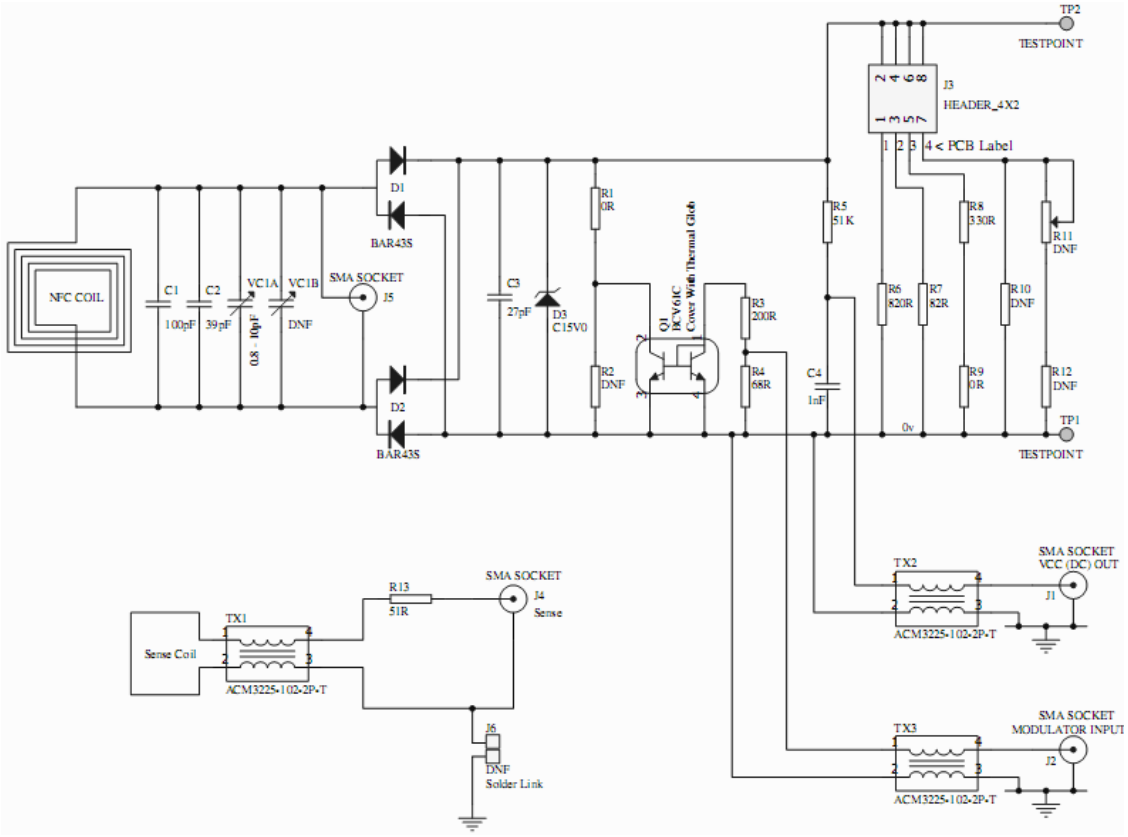


Figure 26: PCB Layout for Listener-3

C.6 NFC Forum - Reference Listening Device Listener-6



NOTE D3 is BZV55-C15,135

Figure 27: Circuit for NFC Forum - Reference Device Listener-6

NOTE During assembly, be sure to crop legs of **J_5** and VC1A flush with underside of PCB prior to soldering so that z=0 can be reliably achieved in operation.

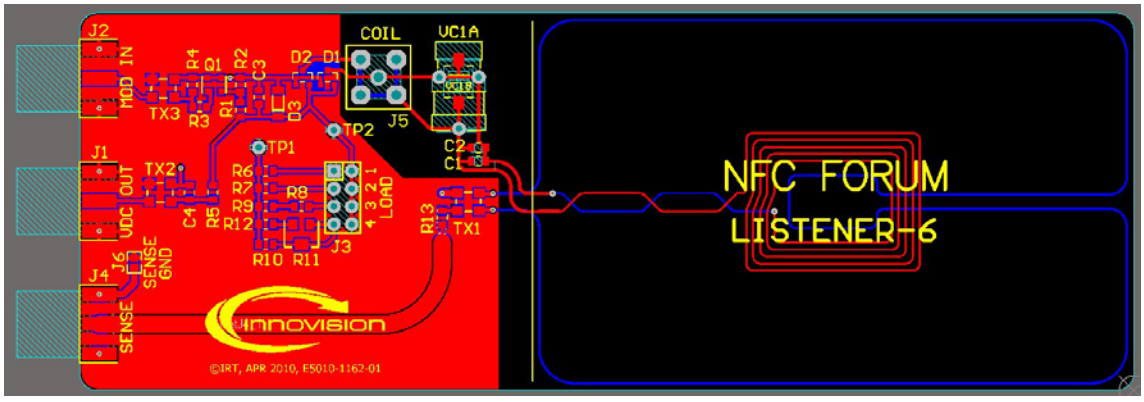


Figure 28: PCB Layout for Listener-6

C.7 Mechanical Dimensions

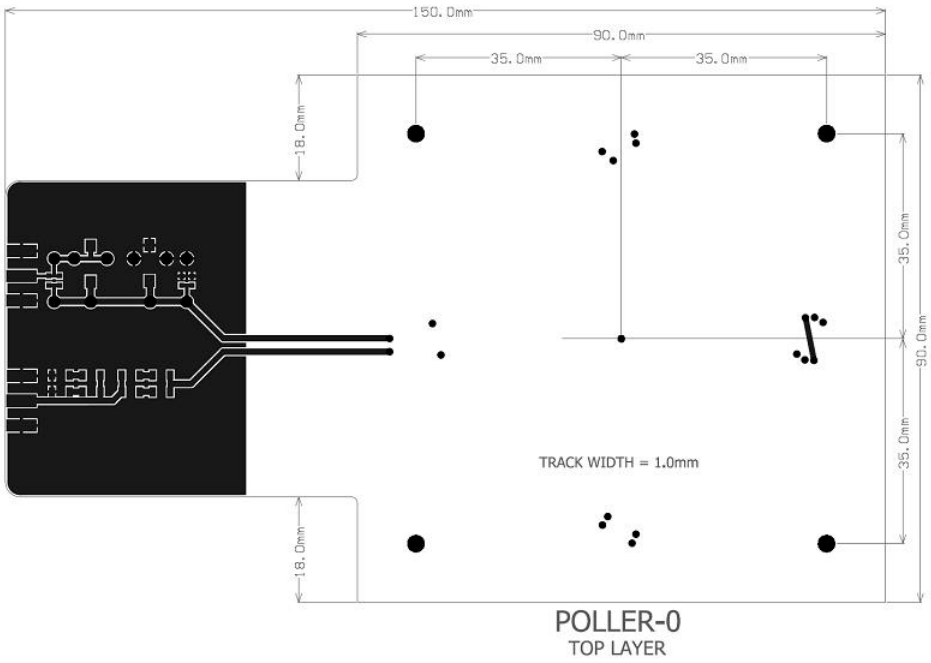


Figure 29: Poller-0 Top Layer

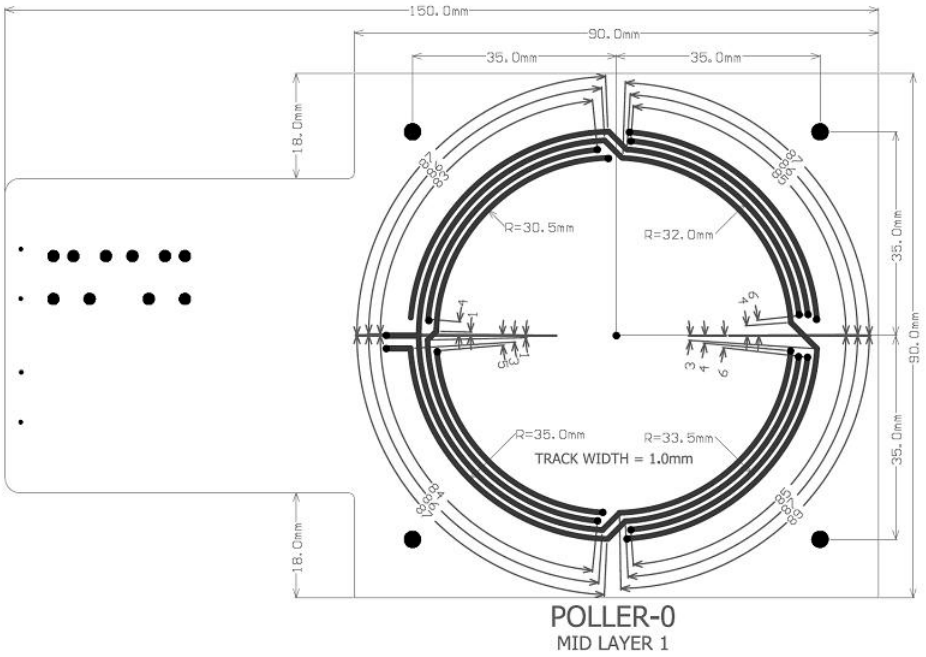


Figure 30: Poller-0 Mid Layer 1

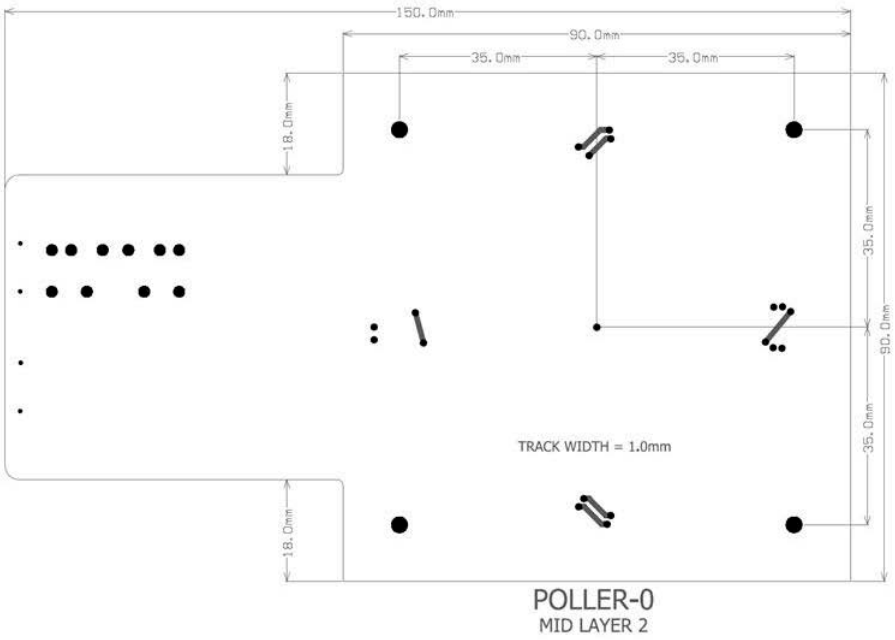


Figure 31: Poller-0 Mid Layer 2

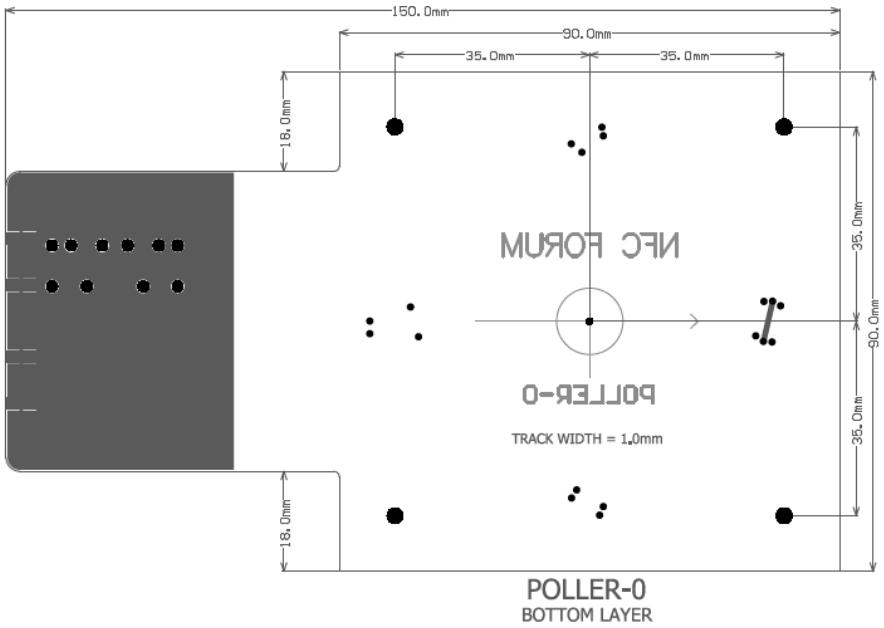


Figure 32: Poller-0 Bottom Layer

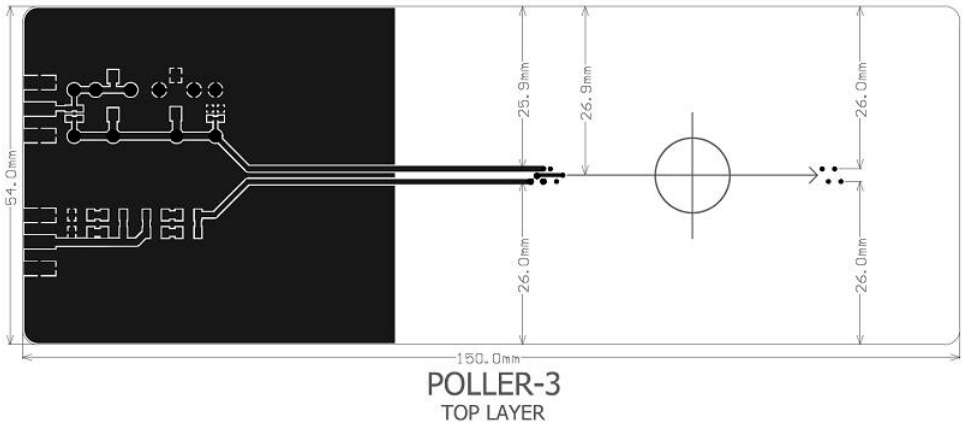


Figure 33: Poller-3 Top Layer

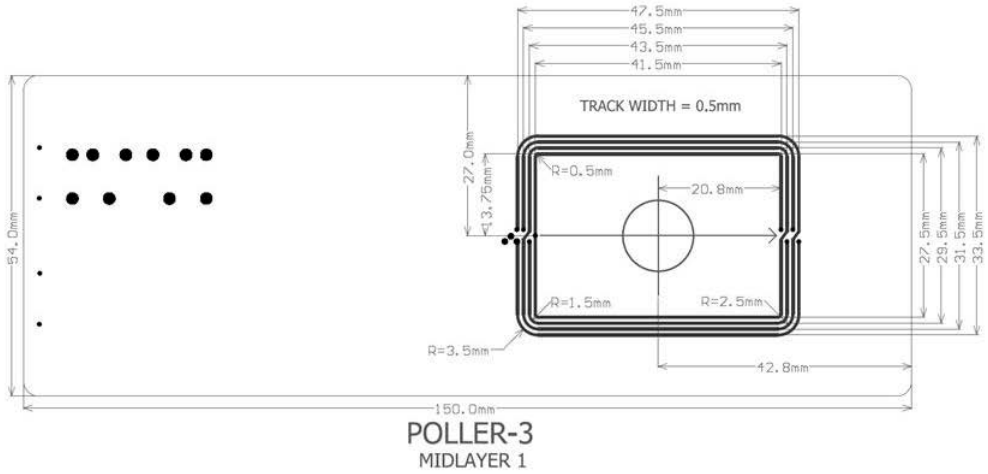


Figure 34: Poller-3 Mid Layer 1

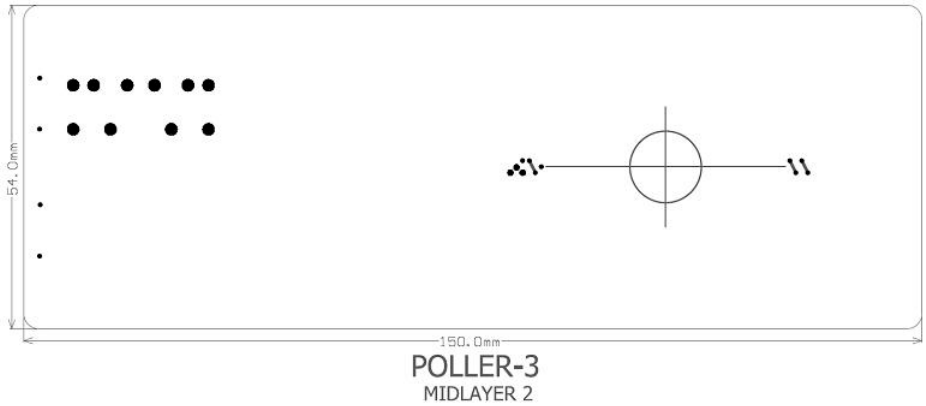


Figure 35: Poller-3 Mid Layer 2

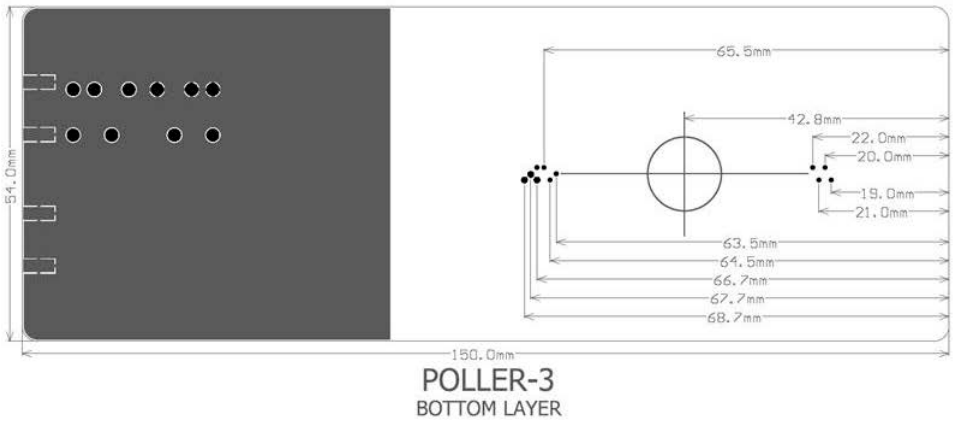


Figure 36: Poller-3 Bottom Layer

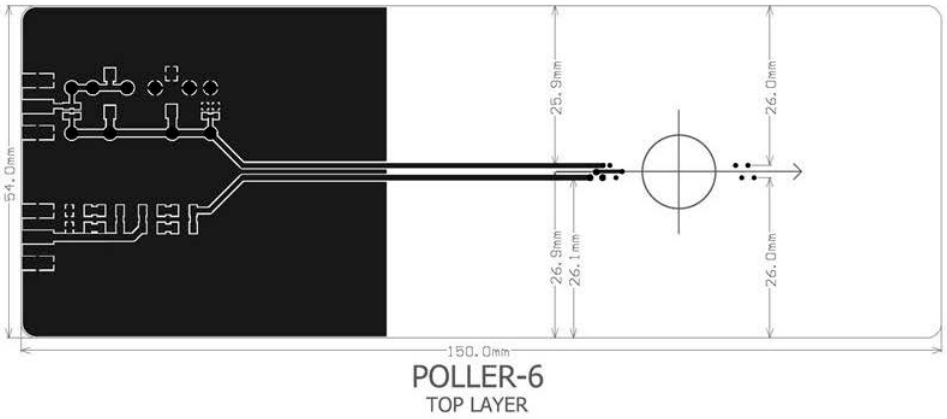


Figure 37: Poller-6 Top Layer

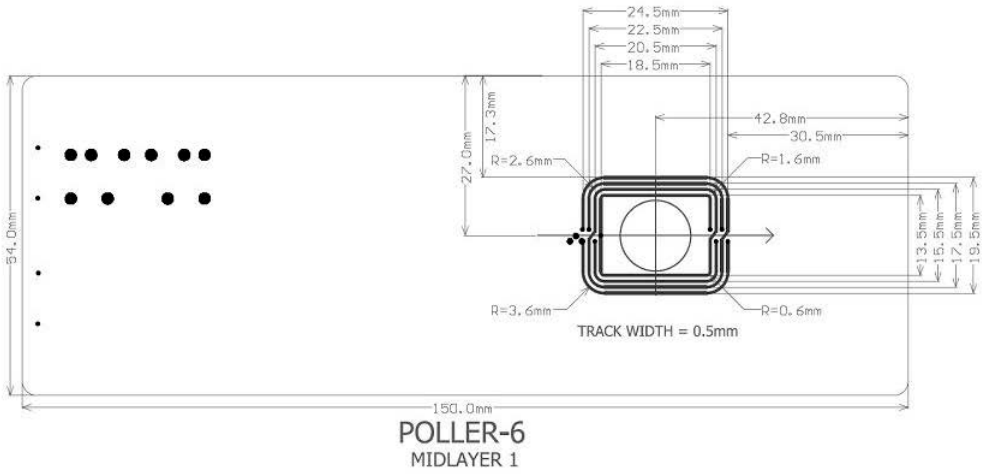


Figure 38: Poller-6 Mid Layer 1

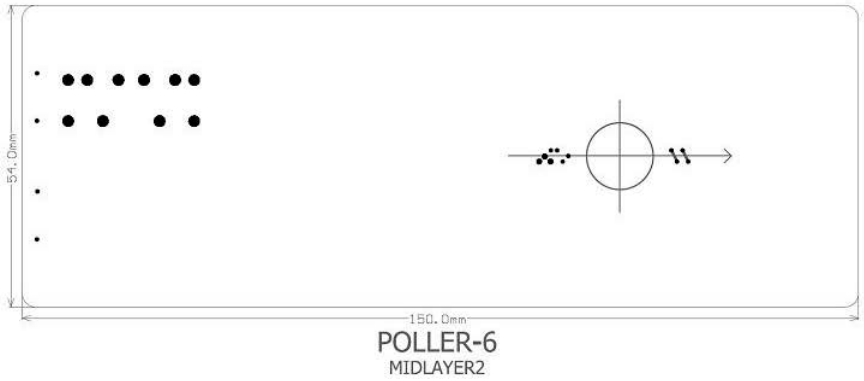


Figure 39: Poller-6 Mid Layer 2

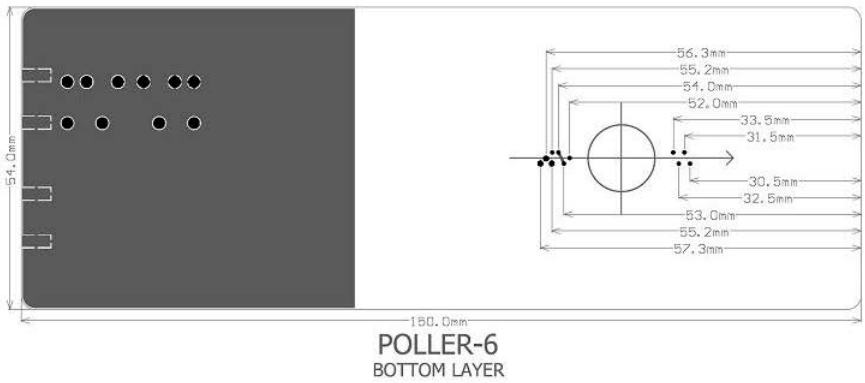


Figure 40: Poller-6 Bottom Layer

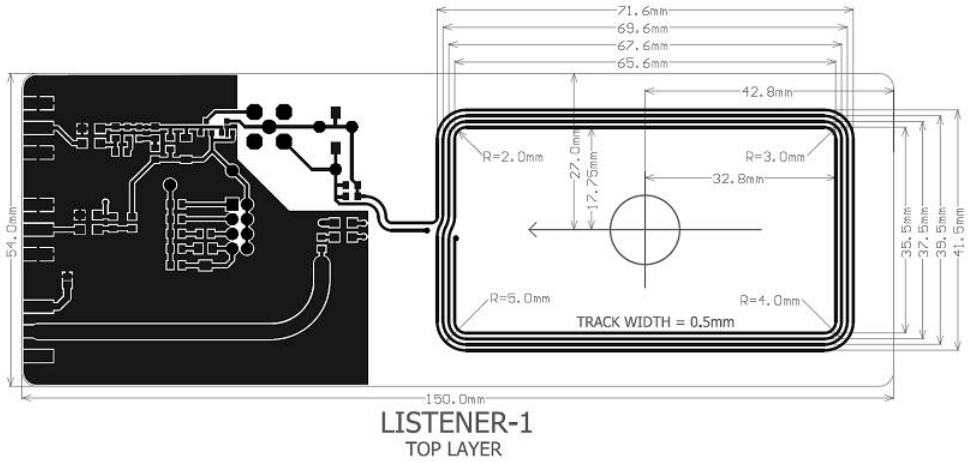


Figure 41: Listener-1 Top Layer

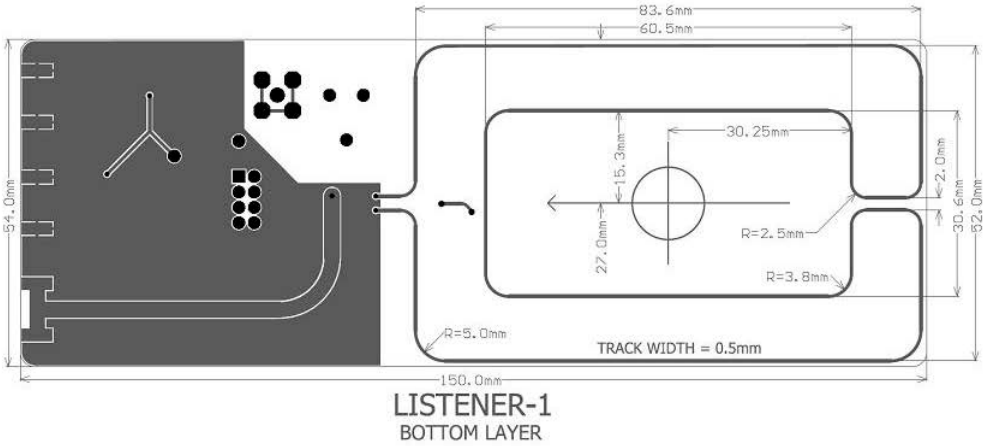


Figure 42: Listener-1 Bottom Layer

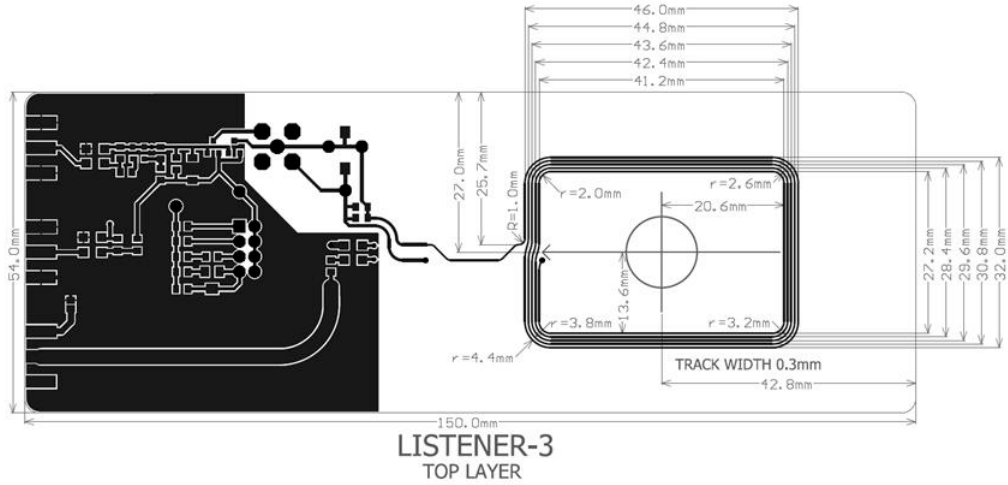


Figure 43: Listener-3 Top Layer

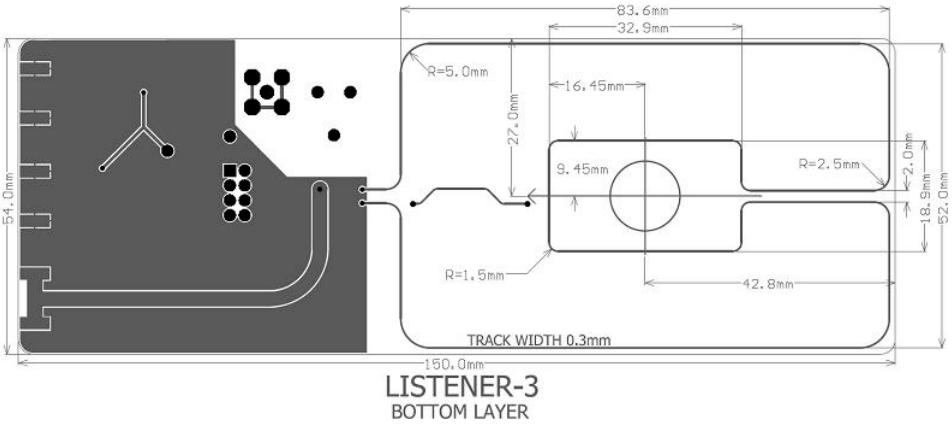


Figure 44: Listener-3 Bottom Layer

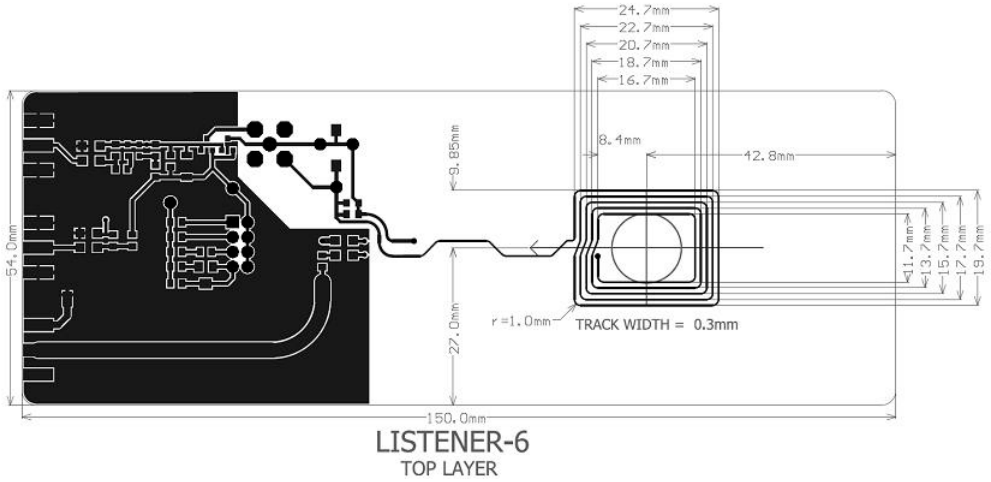


Figure 45: Listener-6 Top Layer

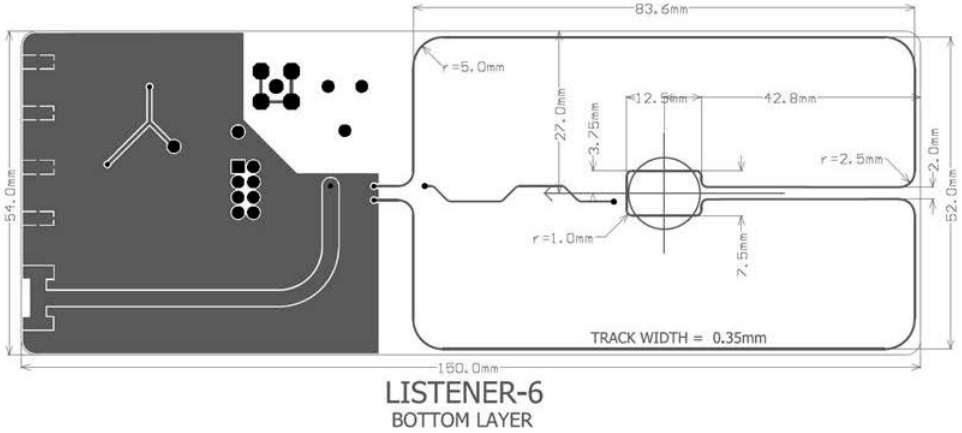


Figure 46: Listener-6 Bottom Layer

C.8 PCB Construction

To maintain consistency, all NFC Forum – Reference Poller Devices should be constructed as nominally 1.6 mm thick, 4-layer PCBs in order to maintain uniform characteristics as specified in Appendix B.4.

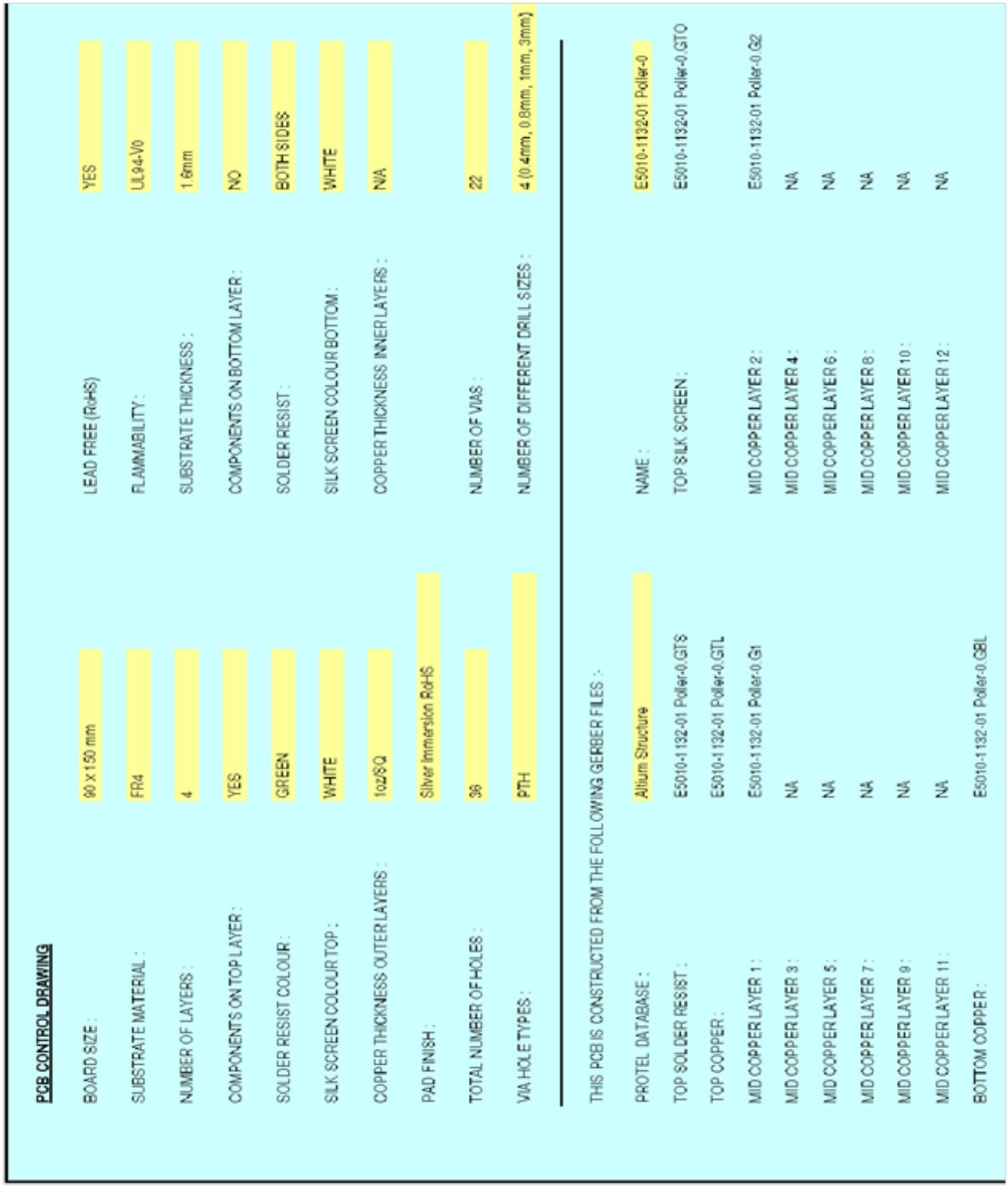
- Overall thickness tolerance +/-10%.
- Dielectric constant (Dk) of FR4 cores: 4.55
- Dielectric constant (Dk) of FR4 prepregs: 4.2
- Outer Layer (1 oz Cu weight): 18 microns (before plating) and 35 microns (after plating)
- Layer 1-2 spacing of copper layer: 0.22mm
- Inner Layer copper weight: 35 microns
- Layer 2-3 spacing of copper layer: 0.99mm
- Inner Layer copper weight: 35 microns
- Layer 3-4 spacing of copper layer: 0.22mm
- Outer Layer (1 oz Cu weight): 18 microns (before plating) and 35 microns (after plating)

All NFC Forum – Reference Listener Devices should be constructed as nominally 0.8 mm thick, 2-layer PCBs in order to maintain uniform characteristics as specified in Appendix B.5.

- Overall thickness tolerance: +/-10%.
- Dielectric constant (Dk) of FR4 cores: 4.55
- Dielectric constant (Dk) of FR4 prepregs: 4.2
- Outer Layers (1 oz Cu weight): 18 microns (before plating) and 35 microns (after plating)

Example PCB Control Drawings for the NFC Forum – Reference Poller-0 and the NFC Forum – Reference Listener-1 are given in Figure 47 and Figure 48.

The other Pollers and Listeners are consistent.

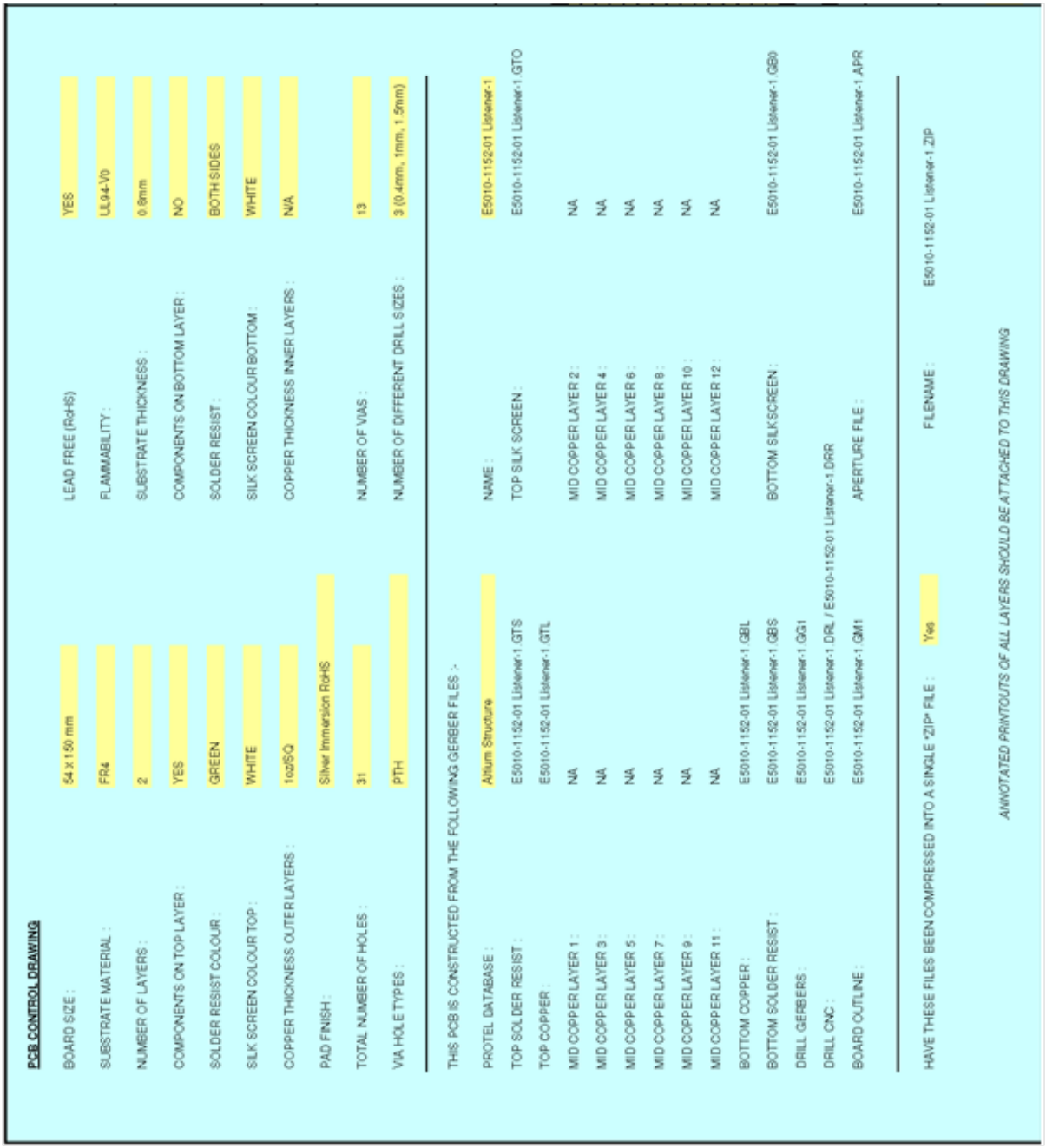


PCB CONTROL DRAWING			
BOARD SIZE :	90 x 150 mm	LEAD FREE (RoHS)	YES
SUBSTRATE MATERIAL :	FR4	FLAMMABILITY :	UL94-V0
NUMBER OF LAYERS :	4	SUBSTRATE THICKNESS :	1.6mm
COMPONENTS ON TOP LAYER :	YES	COMPONENTS ON BOTTOM LAYER :	NO
SOLDER RESIST COLOUR :	GREEN	SOLDER RESIST :	BOTH SIDES
SILK SCREEN COLOUR TOP :	WHITE	SILK SCREEN COLOUR BOTTOM :	WHITE
COPPER THICKNESS OUTER LAYERS :	1oz/SQ	COPPER THICKNESS INNER LAYERS :	N/A
PAD FINISH :	Silver Immersion RoHS		
TOTAL NUMBER OF HOLES :	36	NUMBER OF VIAS :	22
VIA HOLE TYPES :	PTH	NUMBER OF DIFFERENT DRILL SIZES :	4 (0.4mm, 0.8mm, 1mm, 3mm)

THIS PCB IS CONSTRUCTED FROM THE FOLLOWING GERBER FILES :-

PROTEL DATABASE :	Altium Structure	NAME :	E5010-1132-01 Poller-0
TOP SOLDER RESIST :	E5010-1132-01 Poller-0.GTS	TOP SILK SCREEN :	E5010-1132-01 Poller-0.GTO
TOP COPPER :	E5010-1132-01 Poller-0.GTL		
MID COPPER LAYER 1 :	E5010-1132-01 Poller-0.G1	MID COPPER LAYER 2 :	E5010-1132-01 Poller-0.G2
MID COPPER LAYER 3 :	NA	MID COPPER LAYER 4 :	NA
MID COPPER LAYER 5 :	NA	MID COPPER LAYER 6 :	NA
MID COPPER LAYER 7 :	NA	MID COPPER LAYER 8 :	NA
MID COPPER LAYER 9 :	NA	MID COPPER LAYER 10 :	NA
MID COPPER LAYER 11 :	NA	MID COPPER LAYER 12 :	NA
BOTTOM COPPER :	E5010-1132-01 Poller-0.GBL		

Figure 47: PCB Control Drawing for NFC Forum – Reference Poller-0



PCB CONTROL DRAWING

BOARD SIZE :	54 x 150 mm	LEAD FREE (RoHS)	YES
SUBSTRATE MATERIAL :	FR4	FLAMMABILITY :	UL94-V0
NUMBER OF LAYERS :	2	SUBSTRATE THICKNESS :	0.8mm
COMPONENTS ON TOP LAYER :	YES	COMPONENTS ON BOTTOM LAYER :	NO
SOLDER RESIST COLOUR :	GREEN	SOLDER RESIST :	BOTH SIDES
SILK SCREEN COLOUR TOP :	WHITE	SILK SCREEN COLOUR BOTTOM :	WHITE
COPPER THICKNESS OUTER LAYERS :	1oz/SQ	COPPER THICKNESS INNER LAYERS :	N/A
PAD FINISH :	Silver Immersion RoHS		
TOTAL NUMBER OF HOLES :	31	NUMBER OF VIAS :	13
VIA HOLE TYPES :	PTH	NUMBER OF DIFFERENT DRILL SIZES :	3 (0.4mm, 1mm, 1.5mm)

THIS PCB IS CONSTRUCTED FROM THE FOLLOWING GERBER FILES :-

PROTEL DATABASE :	Altium Structure	NAME :	E5010-1152-01 Listener-1
TOP SOLDER RESIST :	E5010-1152-01 Listener-1.GTS	TOP SILK SCREEN :	E5010-1152-01 Listener-1.GTO
TOP COPPER :	E5010-1152-01 Listener-1.GTL		
MID COPPER LAYER 1 :	NA	MID COPPER LAYER 2 :	NA
MID COPPER LAYER 3 :	NA	MID COPPER LAYER 4 :	NA
MID COPPER LAYER 5 :	NA	MID COPPER LAYER 6 :	NA
MID COPPER LAYER 7 :	NA	MID COPPER LAYER 8 :	NA
MID COPPER LAYER 9 :	NA	MID COPPER LAYER 10 :	NA
MID COPPER LAYER 11 :	NA	MID COPPER LAYER 12 :	NA
BOTTOM COPPER :	E5010-1152-01 Listener-1.GBL		
BOTTOM SOLDER RESIST :	E5010-1152-01 Listener-1.GBS	BOTTOM SILKSCREEN :	E5010-1152-01 Listener-1.GBO
DRILL GERBERS :	E5010-1152-01 Listener-1.GG1		
DRILL CNC :	E5010-1152-01 Listener-1.DRL / E5010-1152-01 Listener-1.DRR		
BOARD OUTLINE :	E5010-1152-01 Listener-1.GM1	APERTURE FILE :	E5010-1152-01 Listener-1.APR

HAVE THESE FILES BEEN COMPRESSED INTO A SINGLE "ZIP" FILE : Yes FILENAME : E5010-1152-01 Listener-1.ZIP

ANNOTATED PRINTOUTS OF ALL LAYERS SHOULD BE ATTACHED TO THIS DRAWING

Figure 48: PCB Control Drawing for NFC Forum – Reference Listener-1

D. 8-Shaped Coil

In the case of strong coupling between a Poller device being characterized and the NFC Forum - Reference Listener device, the signal captured with the integrated sense coil (connected to $\mathbf{J_4}$) is very weak and, in the extreme case, zero. This results in the fact that the signal cannot be reliably evaluated in terms of waveshape characteristics (rise/fall-time, overshoot, modulation index).

The recommended alternative approach is to make use of an 8-shaped coil to capture the signal from the Poller device. The 8-shaped coil is constructed of two turns, one is arranged to be clockwise and the other is counter-clockwise. The diameter of each turn should be approximately 15mm (see Figure 49). The thickness of the turns and substrate should be less than or equal to 0.4mm; its actual construction is not important.

The signal across the two ends is measured by means of an oscilloscope probe that has a capacitive loading ≤12 pF so as to make the self-resonant frequency ≥80 MHz.

Figure 49: 8-Shaped Coil

This 8-shaped coil is positioned on the outside surface of the Poller device where the maximum field is induced (the most likely position will be above the actual turns of antenna or coupler coil of the Polling device; see Figure 50). The 8-shaped coil is able to sum up the field on both sides and the amplitude of the 13.56MHz carrier frequency observed must be >250 mV for accurate measurements to proceed.

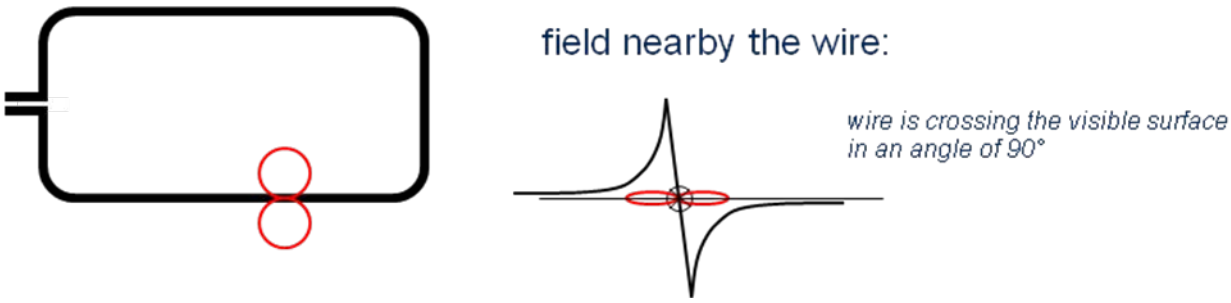


Figure 50: Principle of Operation of 8-Shaped Coil

E. Information About Alternative Method for Measuring V_{OV} levels for Use During Large Ambient Temperature Variations

This appendix is purely Informative and only intended to give advice on the use of this specification during testing under large ambient temperature conditions.

The NFC Forum – Reference Listener Device as specified in this document has many useful functions for NFC characterization including $\mathbf{V_{OV}}$. It has been designed to be used in a Lab environment within the temperature range of 23 ± 3 ºC.

Chip manufacturers will need to characterize their NFC components for adequate drive level and the best way is with a NFC Forum – Reference Listener Device; however, the temperature range over which the components need to be operated is much wider than this, typically -40 to +120 ºC (usual design aim for all chips) during evaluation in an environmental chamber.

There are many components on the NFC Forum – Reference Listener device board that have not been chosen for operation over this wide temperature range. If, for example, the NFC Forum – Reference Listener Device is subjected to temperature variation, then the forward voltages across the rectifying diodes will vary by about 1mV/ºC so that the observed $\mathbf{V_{OV}}$ that is developed across two diodes will vary by about 2 $\mathbf{m_V}$/ºC. Over a narrow temperature variation, this change can be ignored, but over a range of 160 ºC, it will produce a variation of about 320 mV, which is an unacceptably large variation.

An additional circuit block is therefore proposed to the present NFC Forum – Reference Listener Device that will switch out all the temperature sensitive components during a $\mathbf{V_{OV}}$ evaluation and will switch in a less temperature sensitive potential divider that, in conjunction with an oscilloscope, will allow $\mathbf{V_{OV}}$ to be measured more accurately.

E.1 New V_{OV} Monitor Circuit Description

The aim of the suggested circuit is to allow a calibrated test instrument to measure the voltage developed across the defined load while harvesting power from a local magnetic field using as few components as possible. In any design, the addition of a large number of components in any circuit affects the nodal voltages due to component tolerance. If the component tolerance is also temperature sensitive, then large variations in level are possible. The new monitor circuit with the aid of links allows the standard functionality of the NFC Forum – Reference Listener Device to be temporarily disconnected and a potential divider to be inserted.

The parallel resistance of the divider is aimed to produce a load resistance of 820 Ohms when a 50 Ohm load is connected to the new SMA SK1 connector as shown in Figure 51.

A 50 Ohm RF cable is connected from the SK1 to the 50 Ohm input of an oscilloscope that can then be used to measure the peak voltage across the 820 Ohm load. The benefit of this type of connection is that the normal capacitance associated with a cable is effectively neutralized and does not affect the tuning of the resonant circuit. This enables the $\mathbf{V_{OV}}$ level to be measured at a remote location using a long (enough) 50 Ohm cable so that measurements within a temperature chamber can be made.

The variable capacitor used in the NFC Forum – Reference Listener Device is reasonably temperature stable for it to have a negligible effect on accuracy. This is similarly true of the printed 2.4 µH inductor that is resident on the NFC Forum – Reference Listener-1 and NFC Forum – Reference Listener-3.

The NFC Forum – Reference Listener-6 has a different valued inductor, but the required load resistance for a $\mathbf{V_{OV}}$ measurement is still 820 Ohm so that the new monitor circuit is still applicable.

Figure 51 also shows the waveforms that would be expected to be seen in the new circuit. Although the drawn waveforms do not look sinusoidal, they are intended to be so. The present $\mathbf{V_{OV}}$ value is approximately the full wave rectified version (lower trace) of the Tag harvested voltage (upper trace). The forward diode drop of two diodes in the full-wave rectifier will be 0.6V so that for a specified $\mathbf{V_{OV}}$ level of 4.1V the required specified peak voltage level is 4.7V.

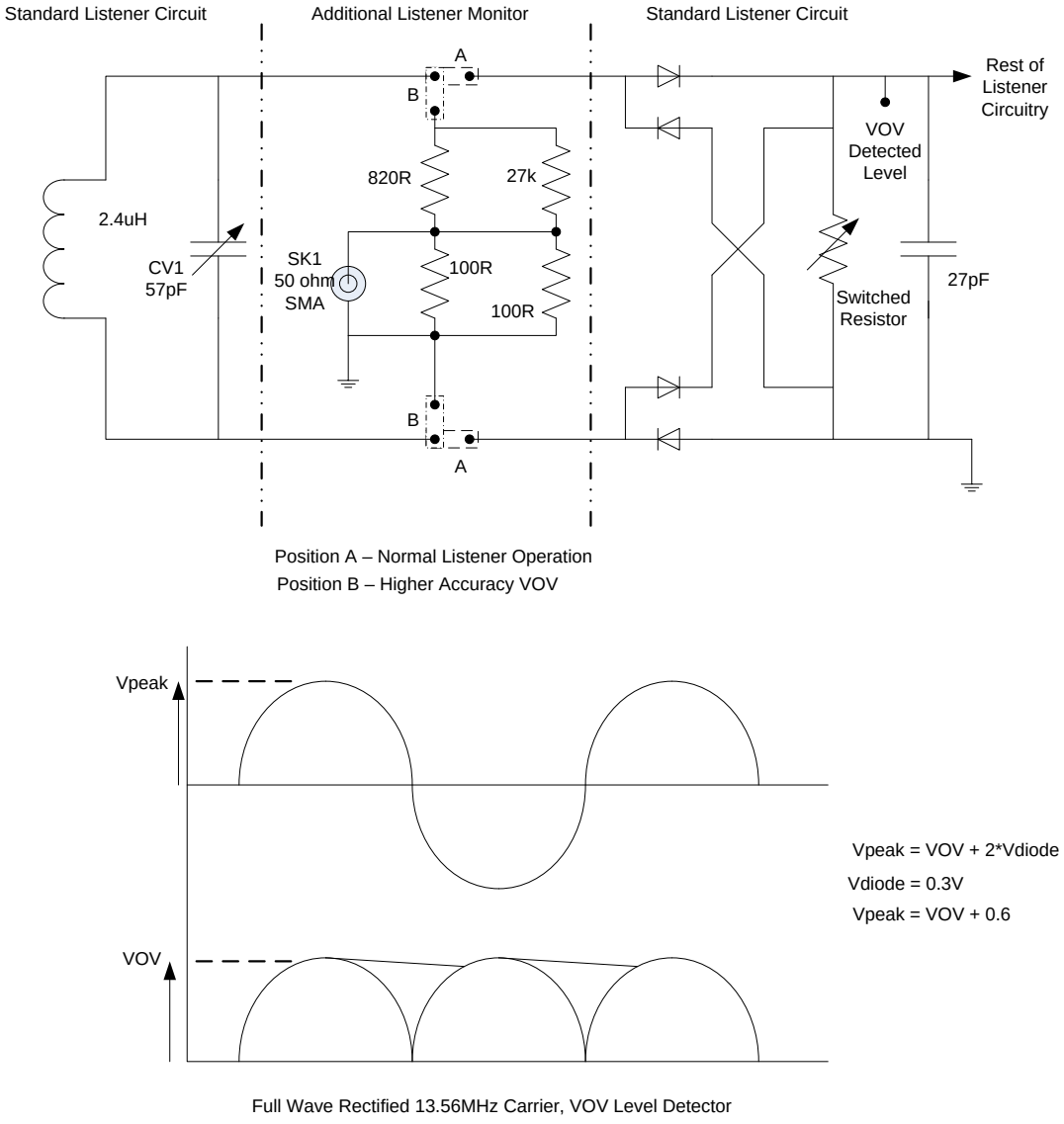


Figure 51: Suggested Additional Circuit Arrangement

The value of the voltage reduction due to the potential divider is (25/820) or an attenuation of 30.3dB. This will need to be measured for each device due to the tolerance of the resistors used. It is recommended that a calibration sticker is attached to the PCB with the attenuation value.

For levels of voltage around 4 V peak, this produces measured voltages at an oscilloscope of 122 $\mathbf{m_V}$ peak.

The following procedure can be used to implement the alternative $\mathbf{V_{OV}}$ measurement procedure that will prevent temperature variations from generating excessive measurement error. Due also to the reduction in the number of components between the input antenna and the $\mathbf{V_{OV}}$ measurement node the accuracy of a basic $\mathbf{V_{OV}}$ measurement will also be improved. The fundamental usefulness of the NFC Forum – Reference Listener Device is not affected by the presence of the additional monitor as it is switched out when not required.

E.2 Alternative V_{OV} Measurement Procedure

1. Reconnect the links at position A/B from position A position to B.
2. Connect a 50 Ohm oscilloscope using a 50 Ohm cable to SK1.
3. Refer to the standard Listener documentation and follow the procedure to adjust the variable capacitor CV1.
4. Place the device into the magnetic field to be characterized and monitor the peak voltage detected on the oscilloscope.
5. To comply with the specifications of the NFC Forum as detailed in the specification shown in Table 5, the measured peak voltage shall be ($\mathbf{V_{OV}}$ + 0.6) V.
6. After the $\mathbf{V_{OV}}$ measurements have been completed, ensure the link positions are moved from position B to position A.
7. It may be necessary to readjust CV1 in accordance with the NFC Forum – Reference Listener Device documentation.

F. Revision History

The following table outlines the revision history of NFC Analog Specification.

Table 9: Revision History

Document Name	Revision and Release Date	Status	Change Notice	Supersedes
NFC Analog Specification	Version 1.0, July 2012	Final		