
Recap of the Constraints Governing the Design of Antennas for an NFC Device

In the interest of understanding, let us begin with a few terms of the vocabulary specific to the norms and/or standards of radio frequency identification (RFID), contactless and near-field communication (NFC).

Table 1.1 offers a few examples of jargon applied in different fields of application.

ISO group		Transmitter	Responder
		Base station	Target/transponder
		Reader	Card
		Modem	
		Coupler	Badge
SC 17 WG8	Proximity cards and personal devices	PCD Proximity coupler device	PICC Proximity integrated circuit card
	Vicinity cards and personal devices	VCD Vicinity coupler device	VICC Vicinity integrated circuit card
SC 31 WG 4	Item management/RFID	Interrogator	Tag
SC 06	NFC	Initiator	Target
		etc.	etc.

Table 1.1. *ISO terminology for the main contactless transmitters and responders*

In this book, which deals exclusively with NFC (originally developed by the ECMA in Switzerland, and then taken up again by Sub-Committee SC 06 at the ISO in 2000), we will employ only the official ISO terms: “*initiator*” and “*target*”. Thus, from this point on, having looked briefly at the principle above, all other terms will be proscribed (or almost).

In the context of NFC applications, this chapter recaps the context, numerous constraints, functional and structural problems relating to the intrinsic content of the NFC protocols and those connected to it, and their direct implications in terms of antennas, which must be dealt with in order to be worthy – in the legal sense (to prevent lawsuits for false advertising) – of the label “Complies with NFC ISO 18092 or 21481 or NFC Forum standard” (in active or passive mode, batteryless or battery-assisted, etc.).

As we will see later on, there are various kinds of such issues.

1.1. Normative constraints

When designing an NFC system and the associated antennas, the technical and protocol constraints needing to be respected are, obviously, the legislative and physical constraints pertaining to the “low layers” 1 and 2 of the open systems interconnection (OSI) model (which are, respectively, the physical and data link/medium access layers), without which the whole setup could never work. As the antenna is part of layer 1 – the physical layer – for all intents and purposes, it is the center of the world.

The forms (appearances, amplitudes, etc.) of NFC signals that must be respected are described in detail in the *international standards* ISO 18092 NFC IP1 and ISO 21481 NFC IP2 – the lone true standards – which draw extensively on the contactless proximity chip-card standards ISO 14443 A & B (including numerous classes of antennas – 1-6) and on Japanese standard JIS X6319-4 for the patented product FeliCa, and finally those surrounding ISO 15693. In addition to these, there may be *proprietary-and/or market-sector-specific standards* such as (mainly) NFC Forum, EMVCo and CEN, where the specific operational application characteristics of distances and volumes (in cm³) very frequently involve antennas with different adaptations.

To conclude this introduction, the normative framework of NFC aside, in this book the exchanges taking place between initiators and targets are defined, once and for all, as follows:

- “from the initiator to the target” known as *uplink*;
- “from the target to the initiator” known as *downlink*.

1.1.1. Uplink from initiator to targets

In order to avoid any comprehension problems, note now that, regardless of the intelligence built into the target, it only functions on the basis of “commands” sent by the initiator, which is a *TRANSMITTER*. The initiator also includes a *RECEIVER* to pick up and interpret communication in the other direction.

Therefore, the initiator is a *TRANSMITTER*... *RECEIVER*; a *TRANSCIVER*.

Once again, in order to prevent numerous potential cases of confusion, two potential scenarios are officially defined by the ISO (ISO 19762-3 – Information technology – Automatic identification and data capture (AIDC) techniques – Harmonized vocabulary – Part 3: Radio frequency identification (RFID):

– either the energy transmitted by the radio frequency (RF) wave from the initiator is able to provide the necessary power to the target, and in this case the target is “*remote-powered*” or “*batteryless*”;

– or the energy transmitted by the RF wave emitted from the initiator is unable to remotely power the target (which may be the case because of the desired distances of operation, the technologies used, the regulations in force, hostile environments, etc.), and of course, it is important to do something about that. In this case, the target is “*battery-assisted*”, and we are dealing with other types of antennas.

NOTE.– Very frequently – too often, in fact, and *incorrectly* – remote-powered targets are said to be “passive”, while battery-assisted targets are said to be “active”. This makes absolutely no sense (see the explanations later on for details).

Nevertheless, it is impossible to put the point across more clearly. Here again, it is important to try to choose the right word.

1.1.2. Downlink from targets to initiator

Independently of the type of power supply to the target (remote-powered or battery-assisted), that device must have an electronic means of communication to perform a downlink from the target to the initiator – also known as the “return link”. Downlink can take place in a number of different ways depending on the principles which are used.

It is important not to confuse the power/energy transfer system with the principles of upward and downward communication.

1.1.2.1. “Passive” targets

The adjective “passive” refers to the fact that the downlink – from the target to the initiator – takes place without the use of an RF transmitter.

1.1.2.2. “Active” targets

However, regardless of the way in which the target is powered, if it has a transmitter built in to respond to the initiator, it is said to be “active”.

1.1.2.3. Load modulation

In order to achieve downlink, the initiator provides a physical support in the form of a sustained, non-modulated “carrier” frequency, and allows the target to act however it seems fit depending on its own way of working, in order to communicate with the initiator by modulating its electrical characteristics. For this purpose, there are two very similar modulation techniques, and one of which could be considered a “distant relative”:

– the first, based on a principle of “modulation of impedance (resistance and/or reactance) of the target antenna’s load” – known as *passive load modulation* (PLM) is used by most of the targets available on the market;

– the second, which is more recent, is known as *active load modulation* (ALM), and is still independent of the mode of power supply to the target (whether it is tele-powered or battery-assisted). The target is equipped with a (mini) low-power local transmitter so that just for that period of time, the signals returned to the initiator can be “boosted”..., i.e. sent with a newly adapted antenna.

In view of the physical consequences which arise from these two forms of near-field modulation, we typically speak of “retro-modulation” by “magnetic coupling”.

In certain systems (such as NFC devices in “peer-to-peer” mode), during the downlink phase in a *half-duplex* system, the initiator no longer provides a carrier to serve as a support for the return signals. In this particular case, known as *active-mode NFC*, in order to communicate with the initiator, the target transmits its own wave, calibrated to the same frequency as that of the carrier, and becomes an “active” NFC device.

1.1.2.4. *Retro-modulation voltage*

Once it has sent interrogation commands, the initiator switches to *listen mode*, waiting for responses from the target. To this effect, with the exception of P2P mode, the initiator transmits a pure carrier consistently and waits, in the interests of comprehension, for the target to signal its presence and respond by a particular modulation which represents the variation of its load, whether that modulation is passive PLM or active ALM (see the previous sections 1.1.2.2 and 1.1.2.3).

1.1.2.5. *Retro-modulation voltage in PLM*

In reciprocity of the phenomenon of mutual induction between a secondary party (target) and a primary party (initiator), the value of the variation of voltage induced in the coil of the initiator’s antenna during the return modulation is “ ΔV_1 ”. Evidently, this variation in voltage is all the greater when there is a significant distance between the target and the initiator, because the coupling coefficient and the mutual are less.

When the target is situated very close to the initiator’s antenna (an example is a mobile telephone, held to a point of sale (POS) payment reader), the coupling coefficient “ k ” can be up to 20 or 30%, and we need to take account of the presence of a *shunt* or a *loading effect*.

This voltage “ ΔV_1 ” is added to that which is already present at the edges of the initiator antenna. Hence, the resulting signal is the carrier, slightly modulated by that return signal, and with a consequent modulation index of a few percent. The signal which is present at the edges of the initiator antenna is also radiated, with its specific spectrum, and therefore its own side bands, which must, of course, fit into the Federal Communications Commission (FCC) and European Telecommunications Standards Institute (ETSI) patterns.

In conclusion, Table 1.2 sums up the passive, active, remote-powered, battery-assisted and communication functions.

<i>“Supply” versus “tag to interrogator communication” (Harmonized Vocabulary ISO 19762 part 3)</i>		
	<i>Communication from tag to interrogator</i>	
	<i>Via load modulation</i>	<i>Via transmitter</i>
<i>Supply</i>		
<i>No battery on board</i>	<i>Passive Battery less</i>	<i>Active Battery less</i>
<i>Battery on board</i>	<i>Passive Battery-assisted</i>	<i>Active Battery-assisted</i>

Table 1.2. *Passive, active, remote-powered and battery-assisted functions*

Now that this little review of the vocabulary has been carried out, we can focus on the purely technical aspects, examining how passive and active targets work.

1.1.3. “Contactless” standards versus NFC device antennas

Table 1.3 shows the normative consequences on antenna design of the main significant technical points of proximity contactless chip cards (ISO 14443 and JIS X6319-4) and those for vicinity contactless chip cards (ISO 15693), considered to be a “legacy of the existing technology”, which were then joined by the additional points to create the concept and standards of NFC.

Once again, we need to look at a few key points of vocabulary specific to NFC, which have now emerged from the concatenation of the definitions given by ISO 18092 (NFC communication protocols IP 1 and 2 for the air interface) and the specifications of the NFC Forum and the design of their antennas.

	Chip cards			NFC			Immediate consequences for antenna design
	ISO	EMV	ISO	ISO		NFC Forum	
	proximity		vicinity	IP1	IP2		
	14443	EMVCo L1	15693	18092	21481	Analog/DP	
14443-2	yes	yes		yes	yes	yes	
						106 to 424	Q for proximity
Bit rate in kbps		106 only		106 and 212-424	106 and 212-424		Q for vicinity
							Bp for 106
							Bp for above
Field H in A/m	1.5 to 7.5	not specified	0.5 to 5	1.5 to 7.5	1.5 to 7.5	not specified	EMV & Forum = not specified
Retro-modulation							ISO = EMV & Forum another possibility
14443-3	Yes			yes	yes	yes	Target management, and thus stacks to be managed
Data collisions	yes	without anti-collision	yes	yes	yes	yes	Multi-card prohibited, and thus no stacks
RF collisions	no	No	no	yes	yes	yes	
Active mode	no	No	no	yes	yes	no	Dynamic initiator/target turnover
Tests	10373-6	EMVCo L1	10373-7			not available	
							ISO = field
Field H in A/m	yes	no	yes	yes	yes	no	EMV & Forum another possibility
Antenna class	yes (6)	1	not specified	not specified	not specified	yes (3)	
		3				3	
Volume	no	yes	no	no	no	yes	ISO = no volume imposed EMV & Forum two different volumes
Distance	no	yes	no	no	no	yes	ISO = no distance imposed EMV & Forum two different distances

Table 1.3. Normative consequences for antenna design

1.1.4. Technologies

Beyond the ISO NFC IP2 and IP1 standards, the NFC Forum defined three generic groups of transmission types under the term “technologies”.

1.1.4.1. NFC-A technology

“NFC-A” technology is very similar to ISO 18092 NFC IP 1 and IP 2 which, themselves, were heavily inspired by the contactless chip card standard ISO 14443 type A, parts 2 and 3. In the NFC Forum, NFC-A is used for the tags called T1T, T2T, T4AT and P2P.

1.1.4.2. NFC-B technology

“NFC-B” technology is very similar to ISO 14443 type B, tirets 2-3, which had already been reused solely in ISO NFC IP 2. In the NFC Forum, NFC-B is used for the tags called T4BT and P2P.

1.1.4.3. NFC-F technology

“NFC-F” technology is very similar to ISO 18092 NFC IP 1 and IP 2 which, in large part, were heavily inspired by the Japanese standard JIS X6319-4. In the NFC Forum, NFC-F is used for the tags called T3T and P2P.

1.1.5. “NFC Forum Devices” and “NFC Forum Tags”

Even more new terminology.

1.1.5.1. NFC device

The ISO standards pertaining to NFC use this term to denote a communicative “initiator” or “target”, be it in active mode or in passive mode (see section 1.1.6). For its part, after dividing up different classes of “technologies” (see section 1.1.4), the NFC Forum also decided to define and separate all “NFC devices” (from the ISO) into two classes of elements:

- first, *NFC Forum Devices*;
- second, *NFC Forum Tags*.

1.1.5.2. NFC Forum Devices

Whatever their physical forms (a mobile phone, a PC, a TV, a camera, a photo frame, tablets, etc.), *NFC Forum Devices* are elements which support the different modes and roles of operation described below, for all products and standards supported by the NFC Forum, which implement at least the *mandatory* parts of the protocol *stack* issued by the NFC Forum, and satisfy the demands and necessities of interoperability imposed by the NFC Forum.

No particular form factor is specified for NFC Forum Devices, but they:

- *must (mandatorily)* communicate with one another in accordance with ISO 18092, the protocols attached to the NFC Forum LLCP, “P2P”, read (and write) the different types of NFC Forum Tag and be able to function as an initiator, target and reader/writer;

- *should (optionally)* offer the possibility of emulating a contactless card. Thus, an NFC Forum Device can be used as a contactless chip card of type ISO 14443 A (such as MiFare) or B or FeliCa (via the platforms T3T, T4AT or T4BT).

As we can see, an NFC Forum Device is a technologically complex element (and so is its antenna), because it is mandatory for it to:

- implement multiple technologies (A, B and F) on board;
- be able to switch from listen mode to poll mode;
- be able to discover whether there are other NFC Forum Devices or NFC Forum Tags in its vicinity, and process RF collisions and data collisions;
- communicate with those other devices.

1.1.5.3. NFC Forum Tags

Once again, no form factor is specified for these elements, but often a use case is envisaged: that of a *smart poster*, which essentially means nothing and tells us nothing about its form factor – is it round, square, small, large? It is a mystery. More formally, an NFC Forum Tag is a contactless tag or a (smart) card supporting the protocol *NFC Data Exchange Format* (NDEF) on a passive communication, and consequently, an NFC Forum Tag only

transmits responses and supports at least one legacy communication protocol, defined in the specifications of the NFC Forum.

Let us now briefly look at the definitions of the “modes” and “roles” which NFC devices may take on during their respective operations.

1.1.6. Modes of communication of an NFC Forum Device

By dividing its time, an NFC Forum Device can support different “modes” of operation. There are four such modes which pertain to communication between elements. However, the word “mode” also covers two different, unrelated concepts.

To begin with, two suboptions of *modes of communication* are described in the standards NFC IP-1 (ISO 18092) and IP2 (ISO 21481).

1.1.6.1. Passive communication mode

In this mode, the NFC Device “Initiator” generates an RF field, which it modulates in order to send commands. The NFC devices “Targets” present in the field send their answers by load modulation (see Figure 1.1).

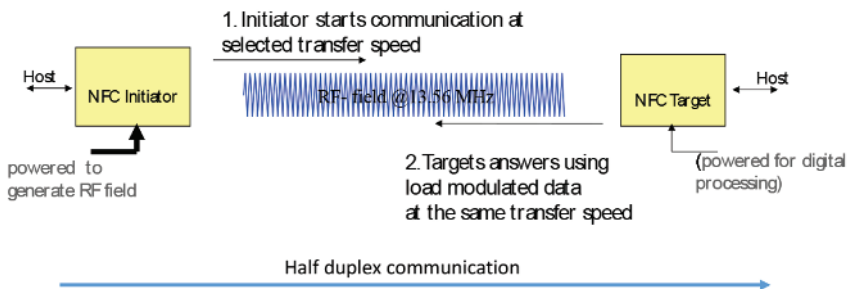


Figure 1.1. Passive communication mode

1.1.6.2. Active communication mode

In this mode, the NFC devices take it in turns to generate an RF field. The initiator begins by generating a field to send commands, and then stops totally. Then, in turn, the target produces its own field and modulates to send its answers (see Figure 1.2).

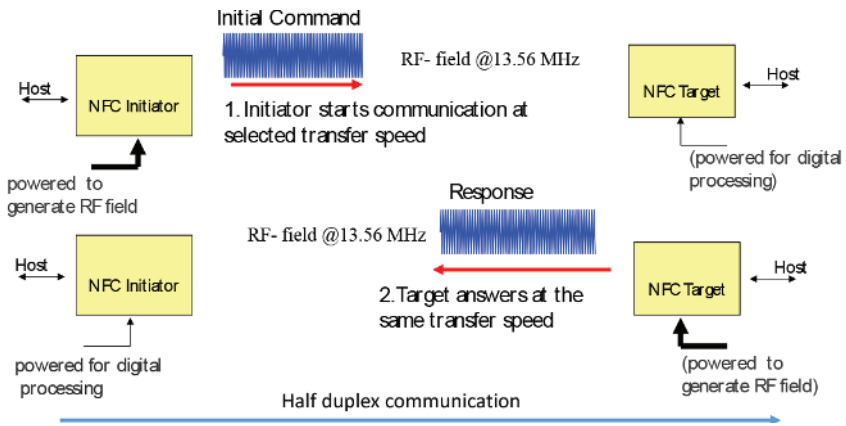


Figure 1.2. Active communication mode

Furthermore, two other modes – *listen mode* and *poll mode* – define how communication is established.

NOTE 1.1.– These communication modes are completely independent of how the NFC devices are powered. There is no relation with the notions of remote power supply (batteryless) or battery-assisted operation of the NFC devices.

NOTE 1.2.– Whether the NFC devices (the initiator or the target) are in active or passive mode, transport of the data in the two directions takes place in an alternating manner, rather than simultaneously. Thus, communication is *always half-duplex*. This remark remains applicable for the whole of this book.

NOTE 1.3.– Although many people use the term *peer-to-peer*, abbreviated as P2P, to speak of “active mode” the term *appears nowhere in the ISO standards*. Indeed, with no pun intended, “active mode” does not, in itself, constitute a true P2P model. A P2P model is a *client-server*-type model, in which each client is also a server, and this is not exactly the case because, in active mode, there is always the same server: the initiator which started off the exchange remains in charge of that exchange for the whole duration of the communication, and the client remains the same: a target.

1.1.7. Role of an NFC Forum Device

The NFC Forum defined four different roles for NFC Forum Devices, depending on the mode and communication protocol used.

1.1.7.1. Initiator

The “initiator” is the NFC device which generates the RF field and which begins the communication. This role is played by an NFC Forum Device in poll mode, having passed through a number of stages (*Activities*). In this role, the NFC Forum Device communicates by using the NFC-DEP Protocol (which is very similar to NFC IP1 – ISO 18092).

1.1.7.2. Reader/writer

This role is played by an NFC Forum Device in poll mode having passed through a certain number of activities. In this role, the NFC Forum Device acts as a “contactless reader” (in read/write mode), using a protocol and commands “inherited” as a legacy from one of the “Technology Subsets” (platform T1T, T2T, T3T or T4T).

The function of an initiator in poll mode, operating as a reader, is that of a device which reads, for example, simple tags to discover their content, but is unable to alter their content – for instance, we might read a poster on the street. However, note that: the term “reader” is always fallacious, because it often carries with it the implied double meaning of reading and writing, rather than that of reading “*only*”. This being the case, the purpose of the NFC device is not only to read content, but also to be able to modify that content – for example, during a stock-take.

1.1.7.3. Target

An “NFC device” becomes a target when it responds to the initiator’s commands, replying by way either of load modulation (with the RF field always being generated by the initiator) or modulating its own generated field. This is a role played by an NFC Forum Device having passed through a number of activities. In this role, the NFC Forum Device communicates by using the NFC-DEP Protocol.

Beware of the term *target*. In terms of functions, a target may be very powerful (a target in active mode – i.e. one which can also transmit), or a

target may be in passive mode (and act as a simple tag), or indeed operate in card-emulation mode.

1.1.7.4. *Card emulator*

The role of a card emulator is achieved when an NFC Forum Device is in listen mode. The NFC Forum Device then behaves like one of the technology subsets and a legacy protocol (T3T or T4T platform). In this role, the NFC Forum Device communicates using the ISO-DEP Protocol.

1.1.8. *Beware of false advertising*

To conclude, and to state it plainly (to call a spade a spade), before proudly branding a product with the NFC label and declaring it “compliant with NFC standard ISO 18092 or 21481 or the NFC Forum standard” (of course, in active or passive mode, batteryless or battery-assisted, etc.) in the legal sense (otherwise, we risk lawsuits for false advertising), it must be at least worthy of that declaration, rather than being merely (though not pejoratively) a simple ISO 14443 system, as is often the case. This is a gross misuse of language.

1.2. Regulatory constraints

1.2.1. *RF regulations*

All the NFC systems described in this book have antennas, capable of transmission, arranged at the initiator and also at the target. There are very numerous regulatory texts which, by way of emitted frequency values, authorized radiation levels and specific patterns (templates), stipulate the constraints and restrictions (radiation, pollution, susceptibility, etc.) to which equipment designed for contactless applications, in the broad sense of the term (contactless chip cards, RFID, NFC, geolocalization, etc.) is subject.

At the frequency of 13.56 MHz used for NFC, the regulations and norms on radiation and pollution are essentially harmonized throughout the world, although there are some minimal variations from one region to another.

In the United States, the FCC – Federal Communications Commission – under the aegis of the ANSI (American National Standards Institute) established the famous reference document “US Code of Federal

Regulations (CFR), Title 47, Chapter I, Part 15, ‘Radio Frequency Devices’”, which is the local bible for regulations.

In Europe, the recommendation in force is the ERC – REC 70 03 “Relating to the use of Short Range Devices (SRD)”, issued by the CEPT/ERO (European Regulation Organization, based in Denmark). Readers are strongly advised to obtain a copy of the latest version (available at www.ero.dk). In addition, the ETSI’s measuring and testing methods follow the ERO recommendations: “Electromagnetic compatibility and Radio spectrum Matters (ERM) – Short range devices”: EN 300 – 330 – frequencies from 9 kHz to 25 MHz, so applicable for 125 kHz and 13.56 MHz.

In Japan, the Association of Radio Industries And Businesses (ARIB) specifications are obeyed.

1.3. Constraints on the NFC market

If we create a product, it is because we hope to sell it. Thus, it needs to be “saleable” (and better yet, “buyable”); its function, usefulness, sale price at entry onto the market, the decrease in that price over time, profitability, etc., need to be known. That is to say, we need to carefully study the famous “Business Model” before beginning.

The NFC market is subdivided, overall, into two main domains: the markets for “niche” applications and the markets for “mass” applications. Often, NFC systems are intended for the general consumer market – i.e. for mass distribution – so the costs are a crucial factor. This, in one line, is the brief description of the techno-economic chain put in place to satisfy users’ wishes and desires:

inexpensive → batteryless → remote-powered → radiated power within the authorized limits.

Inexpensive, and therefore with no battery on board the element. Here, the term “batteryless” means that the system’s local power supply must come from a principle known as “remote power”, using the near-HF field radiated by the initiator;

One of the problems readers may rightly ask is whether remote power supply is possible while respecting the RF regulations in force (bands, frequencies, powers and/or maximum authorized radiated fields H or E,

patterns such as data rates, bit codes, collision management, cyclic usage report, etc.).

1.4. Typical constraints of NFC

No, no and no – the applicational typology of NFC is not linked only to mobile telephony. No, NFC is not merely a contactless payment card (emulator). No, because these views are highly reductives, and there are numerous applicational typologies of NFC, which we will now briefly review, along with the attendant consequences for the design of their antennas.

Table 1.4 summarizes the range of “reader” applications (RFID, P2P, battery-assisted passive card emulation, remote-powered passive card emulation, etc.) engendered by the physical fundamentals of the NFC system.

		NFC device							
		Initiator		Target					
Means of communication		Role		Role					
		Initiator		Tag	Card		Down-link		
Passive Half-duplex Bidirectional	P	Reader/writer	L	T1T, T2T, T3T or T4T poster			PLM <i>ALM</i>	Batteryless	Poster, label
	P	Reader/writer	L		T3T or T4T chip card		PLM <i>ALM</i>	Batteryless	Ordinary chipcard. Bank card, loyalty card
		Reader/writer	L			T3T or T4T cardemul.	PLM <i>ALM</i>	Batteryless	Phone with flat battery, loading effect
						T3T or T4T card emul.	PLM <i>ALM</i>	Battery-assisted	Normal phone, loading effect
							ALM not described in NFC transmits	Battery-assisted	
Active Half-duplex Bidirectional	P	Initiator NFC- DEP Protocol NFC IP1 – ISO 18092			Other device			Battery-assisted	

Table 1.4. Range of NFC applications

1.4.1. Application consequences and their direct constraints

From these generic possibilities derive applicational services, which are generally grouped into the following for main marketing terms: “*Touch & Go*”, “*Touch & Confirm*”, “*Touch & Connect*” and “*Touch & Explore*”. In parallel, the applicational diversity in terms of the architectures and electronic functions of NFC devices is very great, and the “ecosystem” associated with NFC is very difficult to establish, as the tie-ins, overlaps and interapplications are so numerous, both at economic level and at the level of technical solutions to be put in place and resolved.

Table 1.5 gives numerous examples of the applicational technical diversity of NFC and the forms, dimensions and form factors of antennas toward which we are advancing (... with no attempt at publicity).

		Architectures			Non-exhaustive examples	
		Initiator	Target			
Markets	Functions	Writer/ reader	Tag	Chip-card emulation	Dimensions of the antennas (order of magnitude)	Non-exhaustive examples of manufacturers
Loyalty card	Badge chip cards		x x		5 × 6 cm	
Mobile telephony	Smart phones All applications	x		x	6 × 6 cm to 3 × 3 cm	Google, Apple, Samsung, etc.
	Add-on cards			x	2.5 × 2.5 cm	Mercury
Banking payment	Smart card			x	5 × 7 cm 2.5 × 7 cm	Gemalto, G&D Oberthur, etc.
	MPOS – <i>Mobile Point of Sales</i>	x			5 × 4 cm screen circumference	Ingenico, Wincor Nixdorf, etc.
	Tablets, wallets	x	X	x	above and below	
	DAB player	x			Φ = 7 cm EMVCo	Thales, etc.
Industrial	Badges		X		Any shape and size!	Dag System etc.
	Tags		X			
	Smart poster		X			
	Racing numbers		X			
Medical	Identification, monitoring	x	X		4 × 1 cm	Trixiell, Maquet
	Decontamination bin	x			30 × 30 cm	IMS
	Monitoring of babies, mice, ants, bees	x	X		Very small 4 × 1 mm	Lutronic, Arelis, Nonatec, etc.
Consumer	Photo frames		X		30 × 20 cm Screen circumference	Parrot, etc.
	Acoustic chambers		X			Parrot, etc.
	TVs	x		x	Secure access	Philips, etc.
	PCs	x		x		Dell, etc.
	Advertising items	x	X		All formats	Strapmedia
	Museum guides		X		Φ = 2.5 cm	Strapmedia
	Wireless chargers, libraries	x			10 × 8 cm	Tagsys, etc.
Computer technology	USB dongles	x	X	x	1 × 1.5 cm	Mercury, Neowave
	USB keys		X		2.5 × 2.5 cm	Neowave

	Terminals	x				Taztag
Automobile	Car dashboards					Herman
	Contact keys		X	x	3 × 5 cm	Conti, Valeo
	NFC accu. charger.	x			10 × 8 cm	Delphi Conti
Public transport	Access validator				Φ = 10 cm	Xerox, Parkeon Thales, etc.
	Control device				5 × 3 cm	
IoT Connected “things”	Watches, keys				2.5 × 2.5 cm	Apple Mercury
	Bracelets				1.5 × 3 cm	Apple, Mercury
	Phone booths					
	Social networks Community					Zèbre
Luxury items, jewelry	UHF and NFC in HF					
	Lingerie, glasses, shoes, etc.		X		Combating counterfeiting All formats	Louboutin, Lise Charmel, Ray-Ban, etc.
	Wines, spirits, LCD labels, corks		X			
			X			
Jewelry store windows				Security		

Table 1.5. *Examples of the diverse technical applications of NFC*

As readers may realize, the mechanical ingenuity of the marketing department, designers and developers of all these markets is limitless. However, in terms of magnetic fields and communication in the surrounding environment (passive or active communication, reader/writer mode, P2P, emulation card, loading effect, etc.), let us simply say, diplomatically, that it is a different story.

In addition, to serve the needs of applications in banking, transport, etc., we often need to bring the initiators and targets operating in contactless chip card emulation mode and the performances of the magnetic fields generated by their antennas back within the limitations of the technical specifications of “EMVCo Contactless”, which are particular implementation specifications reviewed and adapted from ISO 14443 A & B, which are encapsulated by the NFC IP2 standard. Thereafter, of course, we need to run all the infamous tests on common criteria, and obtain all the labels such as EAL 5+, 6+ and even better.

1.5. Applicational constraints on antenna design

Whether an NFC device is an initiator or a target, in active or passive mode, batteryless or battery-assisted, the very numerous applicational constraints and their direct relations with the design of an antenna arise

primarily at seven or eight major levels, presented in the form of three distinct domains to clearly define each one's role.

To begin with, the *structural problems* linked to the direct and indirect consequences of the intrinsic content of the NFC norms and standards (ISO, NFC Forum, EMV, etc.). These include:

- “*form factors*” of the antennas;
- the variations in operational distance, and therefore of magnetic couplings;
- the values of coupling coefficients and indicators;
- the values of retro-modulation voltages;
- the values of quality coefficients;
- the various modes of operation per slice of time.

Then, the *functional applicational problems* pertaining to the different types and the variability of applications (loading effects on the targets, stack effects, etc.) dealing with:

- initiators and targets that are deliberately not synchronized and/or have accidentally become desynchronized;
- problems relating to “stacks” of NFC devices.

Finally, we face the *environmental problems* arising directly from the antenna and how to get around them either partly or completely. These include:

- environments hostile to wave propagation;
- the effects of boxes, metal parts, the presence of the battery;
- electromagnetic compatibility (EMC) pollution.

Readers can also refer to an entire book devoted to the constraints involved in the design of an NFC device: [PAR 16], from the same publisher.