

Dual-contact chipcard module and smart card with a dual-contact chipcard module

The present application generally relates to a smart card.

A smart card is preferably a portable device equipped with embedded integrated circuits that can
5 process and store data securely. These cards utilize contact or contactless methods to
communicate with readers, performing functions such as authentication, data storage, and
application processing. Commonly used in financial transactions, identity verification, access
control, and public transport systems, smart cards provide enhanced security over traditional
magnetic stripe cards. Synonyms for a smart card may include terms such as chipcard, integrated
10 circuit card (ICC), microchip card, and electronic card, among others. This list is merely a
representative selection of the various alternative names used.

To enable data exchange between an external reader or an external system and a smart card,
the external reader or system generates a high frequency magnetic field. This magnetic field
induces a current in an antenna system of the smart card comprising at least one antenna coil.
15 The antenna system may be connected to a microchip, possibly by inductive coupling. This
coupling provides the necessary power to operate the microchip and facilitates the transmission
of data.

Designing an antenna system for a smart card that achieves optimal performance while adhering
to the strict requirements of EMV standards (a global benchmark for secure payment systems) is
20 a complex technical challenge. This complexity is further increased when the antenna system
must reliably meet EMV standards while optimizing performance across different chip types, such
as NXP and STM. Many configurations encounter failures due to issues like analog field
interference, assessed using the CA111 test for electromagnetic compatibility, or digital timing
errors, evaluated through the CA144 test for communication stability.

25 Additionally, achieving compactness and manufacturability without compromising functionality
adds another layer of difficulty.

US 20130075477 A1 discloses a booster antenna system for smart cards, including components
such as a card antenna, coupler coil, and optional extension antenna to enhance coupling. It
focuses on arrangements of these components and methods for embedding wire into card bodies
30 DE 19632115 C1 discloses a combination chip module for the transmission of electrical signals
or data with or without contact to an external read-write station, with an insulated substrate on

which an integrated semiconductor circuit is arranged. The circuits connected via connecting terminals to one or more couplers of an interface circuit. This interface circuit enables contactless bidirectional data communication between the chipcard module and the external read-write station. Additionally, the circuits are connected to electrically conducting contact surfaces provided
5 on one side of the substrate, enabling bidirectional data communication with contact between the chipcard module and the external read-write station. The couplers are formed on the side of the substrate facing the contact surfaces.

The object of the application is to provide a smart card with an antenna system configuration that improves performance and functionality during communication with external readers. Specifically,
10 the invention aims to achieve robust and reliable operation by addressing challenges related to electromagnetic coupling, compliance with EMV standards, and compatibility with multiple chip types, while maintaining a compact and manufacturable design.

This and other objects are solved by the subject matter of the independent claims. Further improvements are given by the dependent claims.

15 The application provides solutions for enhancing the matching between the smart card's antenna system and the external reader antenna, thus enabling efficient communication.

In this context, the proposed smart card comprises in particular a unique antenna system configuration which allows and optimized inductive coupling with external readers or external systems. In particular, this configuration provides an antenna system in the smart card with three
20 coils, wherein a second coil may be part of an LC network, which may be arranged in an interior space of an antenna coil and improves the matching of the antenna coil to the resonant frequency of the external reader. In addition, the antenna coil can be connected to a first coil which can be coupled to a microchip. Through this design, the smart card achieves a higher sensitivity and more reliable data exchange, making it ideal for various applications requiring secure and rapid
25 communication.

The structural design of the smart card according to the application not only enhances communication capabilities, but also ensures that the card is robust, maintaining high structural integrity. The arrangement of the coils and the use of durable materials help to ensure that the smart card retains its functionality when subjected to physical stresses such as bending or
30 pressure. In addition, this design allows for efficient use of space within the card, facilitating the integration of additional features such as security elements or personalization options, without compromising performance or size.

The application further provides solutions for enhancing the electrical connectivity and structural integrity of the chipcard module by incorporating conductive antenna traces, ISO contact pads, and a conductive material in the via hole. Additionally, the application addresses the need for encapsulation material to protect the chip and bond wires, ensuring reliable performance of the module.

Embodiments of the invention are associated with various advantages and/or technical effects.

In a first aspect the application refers to elements of a first configuration for the antenna system within a smart card, various advantageous effects can be seen. These elements can be combined with the other elements in the present application as described below.

10 The smart card may comprise a substrate supporting a dual-interface antenna system and a chipcard module that includes an IC chip and an IC module coil. The chipcard module may be integrated into the antenna system, which may include a first coil, an antenna coil, and a second coil. The antenna system is preferably configured to interface with external systems for contactless and contact-based operations and may be optimized for coupling efficiency and compliance with EMV standards.

The antenna coil, the first coil, and the second coil may have turns defining a perimeter enclosing a surface area, with the surface area of the antenna coil preferably corresponding to $\frac{2}{3}$ of the total surface area of the smart card, within a tolerance of $\pm 10\%$.

20 The wire diameter of the antenna coil, the first coil, and the second coil may be within the range of 0.08 mm to 0.15 mm.

The wire pitch may be generally uniform, with the second coil preferably having a pitch of 0.34 mm $\pm 10\%$.

The number of turns may range from 8 to 11 in the first coil, 2 to 6 in the antenna coil, and 6 to 12 in the second coil.

25 The unique configuration of the antenna system, characterized by carefully selected parameters including the surface area of the antenna coil, the wire diameter of the first coil, the second coil and the antenna coil, as well as the pitch of the second coil, and the number of turns in the first, second, and antenna coils, plays a critical contribute significantly to achieving optimized performance. These parameters ensure effective electromagnetic coupling, compliance with standards such as EMV, and reliable operation in both contactless and contact-based modes.

In this regard, the wire diameter, wire pitch, and the number of turns in each of the antenna coil, the first coil, and the second coil may be variably adjusted within the selected parameter ranges to achieve specific performance goals. These adjustments may tune the resonant frequency of the entire smart card to approximately 13.77 MHz, preferably within a tolerance of ± 0.1 MHz, thereby enhancing coupling efficiency with minimal delay. Additionally, these parameters can ensure that the Quality Factor is maintained at or below 40, which helps to limit resonance efficiency and prevent potential chip overload.

The Quality Factor (Q) is a measure of the damping or energy loss in a resonant system. It represents the ratio of the energy stored in the system to the energy lost as heat or other forms of dissipation during one oscillation period. A high quality factor indicates that the system loses only a small amount of energy and maintains its oscillation with minimal attenuation. In electrical engineering, the Q-factor also describes the ratio of the resonant frequency to the bandwidth over which the power decreases to half its maximum value. Systems with a high Q-factor are efficient and exhibit sharp resonance, which is particularly important in applications like filters, oscillators, and antennas

Particularly, the proposed refinements resulted in an antenna system configuration that successfully balances compactness, performance, and near-compliance with EMV standards, setting it apart from prior attempts and challenging conventional expectations in the field.

For example, the smart card developed according to the application demonstrates that the smart card achieves superior coupling and energy efficiency with minimal tuning, in a compact 2/3-size antenna format, outperforming larger designs such as ID1-sized antennas. This format specifically refers to the area enclosed by the antenna coil, which corresponds to approximately 2/3 of the total surface area of the smart card. In contrast, an ID1-sized antenna coil typically encloses an area that corresponds to the full surface area of the smart card, as the coil is positioned along the card's edges.

Moreover, the use of a uniform pitch particularly 0.2 mm, 0.4 mm, or 0.34 mm simplifies manufacturing processes while maintaining high performance.

The wire diameter of the first coil, the second coil and the antenna coil may for example be configured as $0.13 \text{ mm} \pm 10\%$. This precise diameter enhances resonance stability and improves coupling efficiency.

In a further preferred embodiment, the number of turns in the first coil is preferably 9 or 10, with 10 being particularly preferred. For the antenna coil, the preferred number of turns is between 3 and 5, with 5 being especially advantageous. In the second coil, the number of turns is ideally between 6 and 12, with 7 being particularly favorable. These configurations are optimized to achieve the desired resonance frequency and Quality Factor.

Generally, a substrate may refer to the base material or structural layer that supports the integration of components such as the semiconductor chip, contact pads, and/or antenna system. The substrate may provide mechanical support to ensure the structural integrity of the chipcard module and/or the antenna system, allowing it to withstand bending, pressure, and other physical stresses during everyday use. It also may serve as an electrical insulator, preventing short circuits by separating conductive elements, while simultaneously acting as a platform for assembling conductive pathways and integrating various components.

The substrate can be divided into different layers or types, such as an antenna substrate and/or a card substrate. The substrate may comprise a plurality of card substrates and/or antenna substrates.

An antenna substrate can be a layer within a smart card that houses or accommodates the antenna coil as well as the first and second coil i.e. the antenna, first and second coils are embedded or integrated into the antenna substrate. This substrate forms the base and is specifically designed for seamless integration into the smart card. After embedding the the antenna, first and second coils, it can establish a strong, durable connection that remains intact over time. Preferably, the antenna substrate contains no metallic materials.

The antenna substrate may comprise of materials such as PVC (Polyvinyl Chloride), PC (Polycarbonate), PET (Polyethylene Terephthalate), or PETG (Polyethylene Terephthalate Glycol-modified). Utilizing a substrate made from materials such as PVC, PC, PET, or PETG provides flexibility in the manufacturing process, as these materials are widely available and can be selected based on cost, mechanical properties, or other application-specific requirements. These materials can in particular provide the necessary mechanical support for the embedded wires while maintaining the electronic card's overall thin profile. These materials have also good durability and environmental resistance properties which can enhance the longevity and robustness of the antenna substrate in various operating conditions.

The antenna substrate can be formed by lamination of layers into a monoblock substrate without use of adhesives. Forming the antenna substrate by lamination of layers into a monoblock

substrate without the use of adhesives eliminates potential points of failure associated with adhesive degradation over time, thereby increasing the structural integrity of the substrate. The absence of adhesives in the lamination process can reduce the overall manufacturing costs and complexity.

- 5 The card substrate may comprise a printed layer, a PVC layer or an overlay layer, wherein the card substrate can also comprise a combination of a printed layer, PVC layer and/or an overlay layer. The ability to combine different layers such as printed, PVC and overlay layers in the card substrate provides flexibility in tailoring the physical properties of the card, such as stiffness, transparency and surface finish, to specific application requirements.

- 10 A printed layer can refer to a layer that is directly applied to the antenna substrate or to the inlay by printing technology. A printed layer can also refer to a layer that is first printed (to a sheet or layer) and then placed and laminated on the antenna substrate or inlay. The printed layer may have a thickness of 15 microns to 190 microns, preferably of 100 microns.

- The PVC layer of the card substrate may also have a thickness of 15 microns to 190 microns,
15 preferably of 100 microns.

An overlay layer in a smart card can act as a protective coating. It can be designed as a clear, durable material applied directly over the printed layer and any intermediate layers, such as PVC, to protect them from physical wear, moisture and environmental elements. The overlay layer may have a thickness of 5 microns to 100 microns, preferably of 50 microns.

- 20 Furthermore, an engagement hole for a chipcard module can be formed in the card substrate indented for each smart card by way of milling. The formation of an engagement hole in the card substrate by milling provides a precise and clean recess for accommodating a chipcard module, ensuring a snug fit and reducing the likelihood of misalignment or movement of the module within the smart card. Milling the engagement hole allows for the customization of the hole's dimensions
25 to match various chipcard module sizes, enhancing the versatility of the smart card manufacturing process to accommodate different module specifications. The milled engagement hole also allows for low profile of the smart card, as the chipcard module can be fully integrated into the substrate.

- The antenna substrate can be collated with at least one card substrate by means of lamination, using heat and pressure. The lamination of the antenna substrate with one or more card
30 substrates using heat and pressure ensures a durable bond, enhancing the structural integrity and longevity of the smart card. The use of lamination in the manufacturing process allows for the

integration of various functional layers, potentially improving the card's resistance to environmental factors such as moisture and temperature variations.

As described above, a dual-interface antenna system is provided for the smart card. A dual-interface antenna system is generally a configuration within a smart card or similar device that
5 enables seamless communication through both contact-based and contactless methods. It may include one or more antennas designed to interface with external readers for data transmission and reception. Contact-based communication is preferably facilitated through physical contact pads on the card, which provide direct electrical connections to a reader for reliable data exchange and power transfer. The contact-based communication can be supported by the chipcard module,
10 which may include electrodes and an IC module coil. By coupling the IC module coil with the first coil of the antenna system, the chipcard module becomes an integral part of the antenna system. At the same time, the electrodes enable the smart card to facilitate contact-based communication with external systems.

One of the key advantages of the disclosed embodiments in the present application is that they
15 meet the EMV standards with the aforementioned configurations. EMV standards are a globally recognized set of specifications designed to ensure the security and interoperability of payment transactions made using chip-based payment cards and terminals. Unlike magnetic stripe cards, which store static data, EMV cards generate unique transaction data, significantly reducing the risk of fraud. The standards support both contact-based transactions, where the card is inserted
20 into a terminal, and contactless transactions using near-field communication (NFC). EMV technology employs advanced cryptographic methods to authenticate transactions, verify the cardholder, and securely authorize payments.

Preferably, the antenna coil, the first coil, and the second coil have turns defining a perimeter each enclosing a surface area. This surface area may refer to the two-dimensional region
25 bounded by the path of the coil's turns. The design of these perimeters, including their size and shape, directly impacts the electromagnetic properties of the coils, such as their ability to couple effectively with external systems or resonate at specific frequencies.

In other words, these coils may be arranged in a flat, planar configuration on the smart card, such that the turns of each coil encompass an internal area. This configuration can include both the
30 physical space occupied by each coil on the card and the inner area circumscribed by the turns of the coils.

In the proposed smart card, the antenna coil may be designed to occupy approximately 2/3 of the total card surface area, with a tolerance of $\pm 10\%$, corresponding to a range between 60% (0.6) and 73.33% (0.7333) of the total surface area. This ensures a balance between compactness and performance, allowing sufficient space for other components while optimizing the antenna's ability to achieve effective electromagnetic coupling. The $\pm 10\%$ tolerance indicates that this proportion can vary slightly, accommodating manufacturing variations or specific performance tuning, while still maintaining the desired balance and functionality.

The surface area of the antenna coil, corresponding to approximately 2/3 of the total surface area of the smart card, may also relate to 2/3 of the surface area of an ID1 antenna coil, where the ID1 antenna coil essentially matches the size of an ID1 card, as it is positioned near the edges of the smart card.

For example, the antenna coil may be formed in the dimensions 80 mm * 35 mm with a tolerance of $\pm 10\%$. This means the length of the antenna coil could vary between 72 mm and 88 mm, while the width could range from 31.5 mm to 38.5 mm. Consequently, the surface area of the antenna coil may range from a minimum of 2,268 mm² (72 mm × 31.5 mm) to a maximum of 3,388 mm² (88 mm × 38.5 mm). In this context, the antenna coil preferably has a substantially rectangular configuration.

In a preferred embodiment, the surface area enclosed by the antenna coil may encompass the surface areas enclosed by the first coil and the second coil, wherein the surface areas enclosed by the first coil and the second coil are non-overlapping. This configuration offers several advantages.

The non-overlapping arrangement reduces electromagnetic interference, thereby enhancing the performance and reliability of the antenna system. Furthermore, by enclosing the smaller coil areas within the larger area of the antenna coil, the available space within the smart card is utilized more efficiently, enabling a compact form factor without compromising functionality. In addition, the absence of crossings between the coils may simplify the manufacturing process, as it reduces the complexity of coil placement and minimizes alignment errors.

In the context of this application, the wire diameter refers preferably to the measurement of the outer diameter of the wire used in the smart card's antenna system. This measurement may include the insulating layer that surrounds the conductive core.

For instance, the nominal diameter may be specified as 0.13 mm, the actual diameter could vary within a tolerance range, such as 0.117 mm to 0.143 mm. The wire used may be enamel-coated copper wire, also known as magnet wire, which features a conductive copper core for efficient signal and power transmission and a thin, durable insulating layer to prevent electrical shorts
5 between adjacent turns of the coil. This insulation can be included in the diameter measurement, and wherein the insulation is important for maintaining the integrity of the tightly wound coils in the antenna system.

Larger wire diameters improve coupling and reduce resonant frequency variability but may increase energy dissipation (Q factor). Smaller diameters allow tighter turns and compact designs
10 but can introduce performance challenges.

Preferably, the wire pitch may refer to the distance between the centers of adjacent turns of wire in a coil. A generally uniform wire pitch means that this spacing remains consistent throughout the coil.

In a preferred embodiment of the second coil, the pitch is preferably set at 0.34 mm, with an
15 allowable variation of $\pm 10\%$. This means the pitch can range between 0.306 mm and 0.374 mm to accommodate manufacturing tolerances while ensuring the coil's performance remains within the desired parameters. Maintaining a uniform pitch and adhering to the specified tolerance helps optimize the coil's electromagnetic coupling and resonant behavior. Tighter pitch increases coupling and resonant frequency tuning precision but may affect energy dissipation.

20 The first coil may comprise a pitch of 0.2 mm $\pm 10\%$ and the antenna coil may comprises a pitch of 0.4 mm $\pm 10\%$. The specified tolerances ensure that the first coil's pitch can range from 0.18 mm to 0.22 mm, while the antenna coil's pitch may vary between 0.36 mm and 0.44 mm.

Surprisingly, the second coil, with the specified pitch values, has the most significant impact on the electromagnetic coupling and resonance behavior. However, the carefully chosen pitch values
25 for the first coil and the antenna coil also contribute to achieving favorable electromagnetic coupling and resonance characteristics, enhancing the overall system performance.

The number of turns in a coil preferably refers to the total count of complete windings or loops of wire in a coil. In the context of a smart card antenna system, the number of turns is an important design parameter that directly influences the coil's inductance, electromagnetic coupling, and
30 resonant frequency. A higher number of turns generally increases the inductance, improving the coil's ability to store magnetic energy and enabling better coupling with external readers.

However, the number of turns must be carefully optimized to balance performance with physical constraints, such as available space within the smart card, compliance with design standards, and the intended operating frequency.

5 The proposed smart card preferably includes a chipcard module with a IC chip and a IC module coil. Specific module types, such as the NXP P71 and STM ST31, can be integrated into the smart card, with antenna system designs meticulously tailored to ensure optimal interaction with these modules.

10 In this regard, the first coil may be operatively coupled to the IC module coil which is connected to the IC chip. The first coil can serve as an inductive coupling between the antenna coil and the IC module coil.

15 The first coil can be used to ensure that the signal or energy received from the antenna coil is transmitted to the chipcard module, which includes the IC chip, via inductive coupling. Therefore, the first coil can be electrically connected to the antenna coil. When a current is induced in the antenna coil, it simultaneously induces a current in the first coil, which in turn generates a magnetic field. This first coil is positioned in relation to an IC module coil such that the magnetic field it generates can induce a current in the IC module coil. The IC module coil, located on the chipcard module, then supplies current to the chip. Thus, the first coil also functions as a first coupler coil and the IC module coil as a second coupler coil. Insofar, the first coil may be configured to couple to a IC module coil. By configuring the first coil to couple specifically to a IC module coil, the design ensures a dedicated and efficient energy transfer pathway for powering the smart card's microchip.

The first coil is further designed so that it does not match with the external reader or system and, as a result, does not effectively absorb any energy from it.

25 The chipcard module can comprise an IC module coil, a microchip or a IC chip, a module substrate and electrodes. In this respect the module substrate is preferably cladded with a copper foil. The electrodes and the IC module coil are formed on different surfaces of the substrate module by etching the copper cladded module substrate. The IC chip is connected to the IC module coil by wire bonding, and the substrate module comprises through holes filled with conductive material which serve as a connection between the microchip and the electrodes. Cladding the module substrate with copper foil before etching to form the electrodes and IC module coil allows for a high degree of precision in the chipcard module layout, which can improve the electrical performance and reliability of the chipcard module. Further, the etching of electrodes and an IC

module coil on different surfaces can lead to a reduction in the size of the chipcard module. The use of wire bonding to connect the microchip to the IC module coil ensures a robust and stable electrical connection. The inclusion of through holes filled with conductive material in the substrate module creates a secure and efficient pathway for electrical signals between the microchip and the electrodes.

The term module substrate cladded with a copper foil can refer to a process in manufacturing where a module substrate is bonded with a thin layer of copper foil. This cladding technique enhances the substrate's electrical conductivity and allows for the creation of precise and complex circuit pathways.

In this context, cladding may involve applying a layer of copper foil directly onto a module substrate, which can be a non-conductive or less conductive substrate such as fiberglass, epoxy resin, or a polymer like Polyimide. The copper serves as the conductive surface upon which electronic circuits can be etched or printed.

Various etching processes can be used, such as wet chemical etching, dry etching and laser etching.

Further, the chipcard module may be attached to the engagement hole of a card substrate. Attaching the chipcard module to the engagement hole integrates the electronic components with the card substrate, creating a unified structure. The attachment of the chipcard module within the engagement hole can provide a flush surface on the smart card, which not only improves the aesthetic appeal but also minimizes the risk of snagging or catching on wallets, card readers, or other objects. This method of attachment can also facilitate easier replacement or upgrading of the chipcard module, as it is clearly defined and accessible within the structure of the electronic card.

In particular, the module substrate may be glued into the engagement hole by a laminating method and a hot-melt adhesive filling method. The use of a laminating method to glue the module substrate into the engagement hole ensures a strong bond that can withstand the stresses of daily use, including bending and torsion, which contributes to the structural integrity of the smart card. Employing a hot-melt adhesive filling method provides a quick and secure means of fixing the module substrate in place, which can streamline the manufacturing process and reduce production times. The combination of laminating and hot-melt adhesive methods can seal the

engagement hole, protecting the chipcard module from environmental factors such as moisture and dust.

Further, the second coil can be configured as a passive, non-radiating component of an LC network for matching the antenna coil with an external system.

- 5 The second coil can be particularly configured to match the antenna coil with an external reader (or system) antenna. In this context, the second coil functions as a passive, non-radiating component of an LC network, which is a synonym for a resonant circuit, resonance circuit or inductor capacitor circuit. In order for the second coil to act as a component of an LC network, it can be connected to a capacitive element. This connection can be either in parallel or in series
10 with the capacitive element. The second coil does not radiate energy (being passive) nor does it absorb substantial radiation from the external reader. This is because the second coil is not effectively matched with the external reader antenna. Instead, the energy from the reader antenna is primarily absorbed by the antenna coil, which is specifically designed to be matched with the external reader's antenna. Furthermore, the second coil is neither configured as a dipole nor as
15 a quasi-dipole.

- The antenna coil can act as an antenna for the smart card. In order to absorb as much energy as possible from the external reader or system, the antenna coil must match the resonant frequency. This can be achieved by the design of the coil and can also be influenced by an additional LC network. Since the antenna coil is tuned to the resonant frequency and the first and second coils
20 are not close to the resonant frequency due to their design, the amount of induced current in the first and second coils is an order of magnitude lower than the current induced in the antenna coil. Accordingly, the sensitivity of reception depends greatly on characteristics of the third coil.

- This allows for a compact design of the coils, particularly of the antenna coil, which maintains effective bidirectional communication capabilities. Since the antenna coil is matched to an
25 external reader antenna by the second coil, the matching of the antenna coil to the external reader is not determined solely by the geometric design of the antenna coil. A small antenna coil can therefore be used which is still matched to the external reader by the second coil. This leads to more space on the card for personalization, e.g. by laser engraving.

- The design approach ensures that the smart card can operate effectively within transmission
30 protocols such as AM (Amplitude Modulation) and SSB (Single Side Band), maintaining clear and reliable communication.

Amplitude Modulation (AM) is generally a modulation technique used in wireless communication to transmit information through waves. In this method, the amplitude of a carrier wave, typically a sine wave, is varied in direct proportion to the amplitude of the signal being transmitted.

5 Single Side Band (SSB) is generally a refinement of amplitude modulation that reduces bandwidth and power usage by eliminating one of the sidebands and the carrier frequency in an AM signal. SSB transmits only one of the sidebands (either upper or lower) which contains the actual information, making it more efficient than AM.

Using the high-frequency magnetic field, information can be transmitted. In this setup, the smart card can send information back to the reader. The external reader or system emits an
10 electromagnetic field through its antenna, which the smart card captures. Through induction, a current is generated in the smart card's antenna coil, powering the microchip. This activated microchip may decode commands from the external reader. Subsequently, the smart card can encode and modulate the response into the emitted field. This allows the smart card to transmit its serial number or other requested information. The smart card itself does not produce a field
15 but modifies the electromagnetic transmission field of the reader. By changing the impedance via integrated switching circuits, a distinct signal can be created. This alteration in the field can be detected by the external reader and utilized for digital communication. The smart card can modulate the carrier signal, which is then received by the reader for communication.

Furthermore, the second coil can be separate from the antenna coil, the antenna coil being larger
20 in diameter than the first and second coils. The larger diameter of the third coil compared to the first and second coils can increase the effective inductive coupling area, which may enhance the range and strength of communication with external reader antennas. The separation of the second coil from the antenna coil allows for the antenna coil to be specifically optimized for interactions with reader antennas. Additionally, the increased diameter of the third coil permits
25 the accommodation of the other two coils within its structure, thereby supporting a compact and integrated design.

In this context, "separate" particularly refers to a spatial separation, in particular enabling each coil to generate its own magnetic field independently. However, the coils can still be interconnected, possibly configured in serial or parallel arrangements. This refers in particular to
30 the separation of the second coil from the third coil, as well as the separation of the second coil from the first coil. However, the first coil can also be separated from the antenna coil.

Preferably, the second coil and a capacitive element form the LC network. As already indicated in the passages above, the integration of a resonance circuit comprising a second coil and a capacitive element enhances the efficiency of energy transfer between the smart card and an external reader or system, thereby improving the reliability of data transmission. Since the IC chip receives its energy from the IC module coil, which is generated by the inductive coupling with the first coil, a modular structure is possible, leading to simplified assembly. This means that the IC chip and the IC module coil can be assembled as a module in any smart card without having to be wired. In addition, the microchip can be better protected against interference from the antenna coil, as it is not directly connected to it. In the same way, the IC chip does not affect the antenna coil. The IC chip can further comprise a memory or other relevant components for data processing and transmitting.

The capacitive element and the second coil can be a structural unit, wherein the capacitive element is formed by two wire ends of the second coil. Combining the capacitive element and the second coil into a single structural unit simplifies the card's design, which can lead to a reduction in manufacturing complexity and associated costs. The capacitive element being formed by two wire ends of the second coil can provide a self-contained LC network with minimal components, which can improve the card's durability by reducing the number of potential failure points.

Furthermore, it is possible that the capacitive element and the second coil are separate elements. In this regard, the capacitive element may be connected to both wire ends of the second coil to constitute a parallel resonance circuit. A parallel resonance circuit configuration can contribute to a more stable tuning of the resonance frequency.

In a preferred embodiment, the IC chip comprises a NXP P71 EMV 6-pin icoM chip, enabling reduced timing delays and enhanced coupling for payment applications. The NXP P71 EMV 6-pin icoM chip is a secure microcontroller developed by NXP Semiconductors, designed for use in smart card applications such as payment systems, secure identity verification, and access control. This chip is based on the advanced NXP P71 platform, which integrates robust cryptographic capabilities and high-performance processing to meet the stringent requirements of sensitive applications.

In further aspects that refer to elements of a second configuration for the antenna system within a smart card, various advantageous effects can be seen. These elements can be combined with the other elements in the present application as described above and below.

In this context, a smart card may comprise a substrate that supports a dual-interface antenna system and a chipcard module with an IC chip and an IC module coil. The chipcard module can be integrated into the antenna system, which may include a first coil, an antenna coil, and a second coil.

- 5 The antenna system is preferably configured to interface with external systems for both contactless and contact-based operations and may be optimized for integration with an STM ST31P45054APB1 icoM PAY 6-pin module.

The antenna system may be further characterized by a wire diameter within the range of 0.06 mm to 0.1 mm. The wire pitch can vary, with the first coil preferably having a pitch of 0.17 mm $\pm 10\%$,
10 the second coil a pitch of 0.5 mm $\pm 10\%$, and the antenna coil a pitch of 0.3 mm $\pm 10\%$. The number of turns in the first coil may range from 8 to 10, in the antenna coil from 2 to 5, and in the second coil from 10 to 13.

The advantage of the smart card described in this context lies in its highly optimized dual-interface antenna system, which supports both contactless and contact-based communication with external
15 systems. The integration of the chipcard module, which includes a chip and an IC module coil, into the antenna system enables seamless communication in diverse use cases. By incorporating a first coil, an antenna coil, and a second coil, the system achieves efficient electromagnetic coupling and reliable data exchange.

The system's design is specifically optimized for integration with advanced chip modules, such as
20 the STM ST31P45054APB1 icoM PAY 6-pin module. The carefully defined parameters of the antenna system - such as the wire diameter, wire pitch, and the number of turns in each coil - enhance its performance. For example, the wire diameter, ranging from 0.06 mm to 0.1 mm, ensures precise electromagnetic behavior, while the varying wire pitches for each coil allow for efficient energy transfer and coupling. The number of turns in each coil is tailored to balance
25 inductance and resonant frequency, optimizing the system for high-speed and reliable communication.

Overall, this configuration provides a compact, high-performance solution that ensures interoperability, energy efficiency, and precision in communication, while maintaining flexibility for integration with cutting-edge chip technologies.

- 30 The functionality and interaction of the first, second, and antenna coils, as well as the chipcard module, can be understood analogously to the preceding aspect and can therefore be applied

here. The second configuration differs from the previous aspect primarily in the selection of parameters, including the wire diameter, the pitch for each coil, and the number of turns in each coil.

5 The STM ST31P45054APB1 icoM PAY 6-pin module is a chip card module developed by STMicroelectronics, designed for use in dual-interface smart cards. It is based on a secure microcontroller from the ST31 family, and is optimized for both contact-based and contactless applications. The module supports various security features and delivers high performance for payment applications.

10 Variable pitch preferably refers to the intentional variation in the spacing between wire turns within a coil, also known as wire pitch. This design approach enables segment-specific tuning of the coil, allowing different parts of the coils to achieve optimal electromagnetic properties tailored to specific functional requirements. By varying the pitch across the coil, the design can enhance inductance, coupling efficiency, and resonance characteristics in critical sections, while maintaining overall performance stability. The specified values for variable pitch indicate that at
15 least one section of the coil conforms to these values. For example, a second coil with a pitch of $0.5\text{ mm} \pm 10\%$ means that at least a portion of the coil adheres to this specified range.

This technique is particularly valuable in applications where smaller wire diameters or fewer turns are used, as it compensates for these limitations by strategically improving electromagnetic behavior in key areas. For instance, sections with tighter wire pitch can increase inductance and
20 improve coupling near critical components, such as the chip module, ensuring reliable energy transfer. Conversely, wider pitch in less critical areas helps reduce energy dissipation and accommodates space or structural constraints.

The wire diameter, wire pitch, and number of turns in the antenna coil, the first coil, and the second coil may preferably be variably adjusted within the selected ranges to achieve specific
25 performance goals. These adjustments can tune the resonant frequency of the smart card to approximately 13.8 MHz within a tolerance of $\pm 0.5\text{ MHz}$, improving coupling efficiency while minimizing delay. Additionally, such modifications may help stabilize the Quality Factor to around 34, which enhances compliance with EMV standards and ensures reliable operation in relevant applications.

30 By maintaining a Quality Factor of approximately 34, the smart card achieves a balance between resonance efficiency and power stability, preventing chip overload while ensuring effective data exchange. The compact design of the antenna system, occupying $2/3$ of the total card area,

provides additional space for features like security elements or personalization options, enhancing the card's versatility without compromising performance.

The antenna system is preferably designed to minimize response timing errors, ensuring compliance with CA144 digital timing standards. Response timing errors refer to delays or inconsistencies in the smart card's ability to process and respond to signals from an external reader. Such errors can lead to failed transactions, slower processing times, or unreliable data exchange, especially in high-speed environments like payment terminals. Compliance with CA144 digital timing standards, a benchmark for evaluating the stability and precision of digital communication between the smart card and external systems, ensures the card's ability to synchronize reliably with external readers.

This is achieved through the optimized antenna design, which includes carefully calibrated parameters such as wire diameter, pitch, and the number of turns, along with tuned resonant frequencies. These design features enhance electromagnetic coupling with the external reader, improving signal strength and stability. By minimizing delays and preventing jitter, or variations in signal timing, the antenna system ensures smooth and reliable communication. Furthermore, it enhances signal integrity by reducing interference and noise, preventing mismatched timing between transmitted and received signals.

In further aspects that refer to elements of a method for manufacturing a smart card, various advantageous effects can be seen. These elements can be combined with the other elements in the present application as described above and below.

The proposed method for manufacturing a smart card involves several steps to ensure optimal performance and compliance with industry standards. The process can preferably begin with the design of a dual-interface antenna system, which may be tailored to facilitate both contact-based and contactless communication. This antenna system might incorporate advanced features to enhance electromagnetic coupling and signal transmission. Once designed, the antenna system can be integrated with a chip selected from high-performance options such as the NXP P71 EMV 6-pin or the STM ST31P45054APB1 icoM PAY 6-pin, both of which are known for their security and reliability in smart card applications.

Following integration, the antenna system may preferably be tuned to achieve a resonant frequency of approximately 13.8 MHz with a tolerance of ± 0.5 MHz, supporting efficient operation and compatibility with external readers. The tuning process can also include stabilizing the quality factor, or Q, to fall within a range of approximately 34 to 40. This balance between resonance

efficiency and stability might minimize energy loss while maintaining reliable performance. Additionally, the wire diameter, pitch, and the number of turns in the antenna coils may be adjusted as needed to optimize coupling efficiency with external systems and reduce energy dissipation during data transmission.

- 5 Finally, the smart card can undergo rigorous testing to confirm compliance with EMV standards. This may include evaluations for analog interference using the CAB111 test and assessments of digital timing precision through the CA144 standard. These tests preferably ensure that the smart card meets the stringent requirements for secure, reliable, and efficient operation in payment and related applications.
- 10 This method for manufacturing a smart card provides several significant advantages, making it highly effective for modern applications. First, the tuning of the antenna system to a resonant frequency of $13.8 \text{ MHz} \pm 0.5 \text{ MHz}$, combined with optimizing the quality factor to fall within a range of 34 to 40, ensures highly efficient electromagnetic coupling. This results in enhanced performance and reliability during both contact-based and contactless operations, allowing for
- 15 consistent communication with external readers in a variety of environments. Additionally, the method incorporates rigorous testing to ensure compliance with EMV standards, including evaluations for analog interference through the CAB111 test and digital timing precision via the CA144 standard. Meeting these global benchmarks guarantees universal compatibility with a wide range of devices and systems, reducing operational issues and improving the user experience.
- 20 Furthermore, the precise adjustment of wire diameter, pitch, and turns in the antenna system optimizes energy efficiency and coupling performance, minimizing energy dissipation. This approach also supports a more compact design, leaving space for additional features such as security elements or personalization options without compromising functionality.

- The skilled person will recognize that the advantages, technical effects, and preferred
- 25 embodiments discussed in connection with the smart card may analogously apply to the method for manufacturing a smart card. Similarly, all advantages, technical effects, and preferred embodiments described in connection with the method may be transferable to the smart card.

- In further aspects that refer to elements of a method for manufacturing a dual-contact chipcard module and the dual-contact chipcard module itself, various advantageous effects can be seen.
- 30 These elements can be combined with the other elements in the present application as described above and below.

The method of manufacturing a dual-contact chipcard module with an RFID transmission antenna coil involves several steps. This module comprises a number of conductive antenna traces and ISO contact pads. The process includes the following

5 First, a module substrate with an antenna side and a contact side is provided. Next, a bonding side conductive foil layer is provided and attached to the bonding side of an insulating substrate layer. This attachment may optionally involve laminating the foil layer, and an adhesive may be used during this process.

Following this, a pre-determined pattern of conductive traces and contact pads is created in the bonding side conductive foil layer. This pattern may optionally be etched into the foil layer.

10 A via hole is then created in the bonding side conductive foil layer and the insulating substrate layer. This step may optionally involve creating one or more via holes.

Afterward, a contact side conductive foil layer is provided and attached to the contact side of the insulating substrate layer. This step may optionally include laminating the foil layer using adhesive.

15 The next step involves etching a pre-determined pattern of conductive traces and contact pads into the contact side conductive foil layer. This etching process may optionally remove parts of the bonding side conductive foil layer and the adhesive beneath those parts. Additionally, this step may involve etching six or eight ISO contact pads into the contact side copper foil layer.

20 Optionally, a Ni/Au plating may be applied onto both the contact side conductive foil layer and the bonding side conductive foil layer.

Conductive material is then provided in the via hole to electrically connect a section of the conductive traces with a section of the contact side conductive foil layer.

Further steps in the method include mounting a chip on the antenna side of the module substrate, which may optionally involve the use of adhesive.

25 A first pre-determined contact pad of the chip, which may optionally be referred to as a first antenna chip pad, is connected with an antenna contact pad surface area, optionally referred to as a second antenna contact pad, on the bonding side conductive foil layer by providing a first antenna bonding wire.

30 A second pre-determined contact pad of the chip, which may optionally be referred to as a second antenna chip pad, is connected with a bonding side surface of the ISO contact pads by providing

a bond wire through the bonding hole. This step may optionally involve connecting the second antenna chip pad with a contact pad area on the contact side conductive foil layer by providing a second bond wire.

5 The method ultimately provides a dual-contact chipcard module in which the conductive material in the via hole electrically connects a section of the conductive traces with one of the ISO standard contact pads C6, C4, or C8. Additionally, the first pre-determined contact pad of the chip, optionally referred to as a first antenna chip pad, is connected with a bonding side surface of the same ISO standard contact pads C6, C4, or C8.

10 The dual-contact chipcard module includes an RFID transmission antenna coil that comprises a number of conductive antenna traces and an ISO contact set with several ISO contact pads. The module comprises the following elements

A module substrate is provided, which has an antenna side and a contact side. A bonding side conductive foil layer is attached to the bonding side of an insulating substrate layer. Optionally, adhesive may be placed between these layers.

15 Conductive traces and contact pads are provided within the bonding side conductive foil layer. A via hole is created in both the bonding side conductive foil layer and the insulating substrate layer. This may optionally include one or more via holes.

20 A contact side conductive foil layer is attached to the contact side of the insulating substrate layer. Optionally, adhesive may be placed between these layers. Conductive traces and contact pads are then provided within the contact side conductive foil layer. The etching process may optionally remove parts of the bonding side conductive foil layer and the adhesive beneath those parts.

25 Additionally, a Ni/Au plating may optionally be applied to both the contact side conductive foil layer and the bonding side conductive foil layer. Conductive material is placed within the via hole to electrically connect a section of the conductive traces to a section of the contact side conductive foil layer.

30 The module may further include a chip placed on the antenna side of the module substrate, with adhesive optionally placed between them. A first pre-determined contact pad of the chip, which may optionally be referred to as a first antenna chip pad, is connected to an antenna contact pad surface area, optionally referred to as a second antenna contact pad, on the bonding side conductive foil layer by a first antenna bonding wire.

A second pre-determined contact pad of the chip, which may optionally be referred to as a second antenna chip pad, is connected to a bonding side surface of the ISO contact pads by a bond wire within the bonding hole. Optionally, this bond wire may electrically connect the second antenna chip pad to a contact pad area on the contact side conductive foil layer.

- 5 The conductive material in the via hole ensures an electrical connection between a section of the conductive traces and one of the ISO standard contact pads C6, C4, or C8. Furthermore, the second pre-determined contact pad of the chip, which may optionally be referred to as a second antenna chip pad, is connected to a bonding side surface of the same ISO standard contact pads C6, C4, or C8.

- 10 In a development, the method further provides a number of conductive antenna traces and with a number of ISO contact pads. The inclusion of conductive antenna traces and ISO contact pads enhances the functionality of the chipcard module by enabling dual-interface capabilities, allowing for both contact and contactless communication.

- The method offers the advantage of improved bonding strength by utilizing a conductive material, such as conductive glue, which is cured after filling the via hole. The manufacturing process of the dual-contact chipcard module provides increased protection and durability through the encapsulation step, which covers the chip and bond wires with encapsulation material.

- The module offers the advantage of efficient electrical connection between conductive traces and ISO standard contact pads through the use of a conductive material in the via hole. The invention provides a simplified and reliable connection of the second pre-determined contact pad of the chip to the bonding side surface of the ISO standard contact pads.

By using one of those unused ISO contacts C6, C4, or C8 for providing an electric loop between pre-determined antenna chip pads, a simple and durable loop antenna can be provided.

- In a development, the method further comprises a conductive material in one of the via holes, comprising conductive glue, and there is a step of curing the conductive glue after filling the via hole. Utilizing conductive glue as the conductive material for via hole filling provides a cost-effective solution compared to traditional metal plating or soldering techniques, potentially reducing manufacturing costs. The curing step of the conductive glue ensures a robust and durable electrical connection within the via hole, enhancing the mechanical stability and longevity of the chipcard module.

In a method of manufacturing a dual-contact chipcard module with an encapsulating step of providing encapsulation material over the chip and the bond wires at the antenna side of the module substrate, the encapsulation of the chip and bond wires on the antenna side of the module substrate protects the delicate components from environmental factors such as moisture and dust, thereby improving the durability and reliability of the module. Encapsulation can also provide mechanical support to the bond wires and chip, reducing the risk of damage due to physical stress or handling, which is critical for maintaining the integrity of the electrical connections.

In a development, the module further comprises a conductive material in the via hole electrically connecting a section of the conductive traces and one of the ISO standard contact pads C6, C4 or C8, and wherein the second pre-determined contact pad of the chip is connected above a bonding side surface of the same ISO standard contact pads C6, C4 or C8. The conductive material in the via hole creates a direct electrical connection between the conductive traces and specific ISO standard contact pads, which can simplify the module design by reducing the number of required interconnects. By connecting the second pre-determined contact pad of the chip above the bonding side surface of the same ISO standard contact pads, the design allows for a more compact module layout, potentially enabling the creation of thinner chipcard modules.

In the present invention, the term "number of conductive antenna traces" refers to a plurality of conductive antenna traces and the term "a number of ISO contact pads" refers to a plurality of ISO contact pads.

The term "conductive material comprising conductive glue" refers to a material which is capable of providing an electrically conductive connection.

The term "dual-contact chipcard module" refers to a card module that provides a contactless data connection and a contact pads data connection.

The term "encapsulating step" refers to a step of providing encapsulation material over the chip and the bond wires at the antenna side of the module substrate.

The term "bond wires" is used herein to refer to electrically conductive wires that are connected at the antenna side of the module substrate.

The term "antenna side" is used herein to refer to the side of the module that directly receives signals from an external RFID transmission antenna, which is usually but not always the same side as the "bonding side" of the module substrate.

The term "contact side" is used herein to refer to a side of the module substrate that carries the ISO contact pads of the module.

A "LA first antenna chip pad" designates a first pre-determined contact pad of the chip, which is usually connected with the antenna contact pad surface area above the bonding side conductive foil layer by providing a first antenna bonding wire. The label "LA" can be seen in Fig. 1.

A "LB second antenna chip pad" designates a pad of the chip which is connected to the antenna coil, via the ISO contact pad and the conductive material in the via hole. The label "LB" can be seen in Fig. 1.

An "insulating substrate layer" designates a layer of insulating material which is used to provide a substrate for the module.

An "adhesive" designates a material that is used to bond two surfaces together.

The term "bonding side conductive foil layer" is used herein to refer to a layer that is provided at the bonding side of the module.

A "Ni layer" designates a layer of nickel.

An "Au layer" designates a layer of gold.

A "contact side Cu layer" or "contact side conductive foil layer" designates a conductive foil layer that is provided at the contact side of the module.

A "bonding hole" designates a hole in the bonding side conductive foil layer and the insulating substrate layer.

The term "via hole" refers to a hole in the bonding side conductive foil layer and the insulating substrate layer that allows to connect a section of the conductive traces and the contact side conductive foil layer by filling the via hole with conductive material.

A "conductive paste" designates conductive material, such as conductive glue.

The term "conductive material" is used herein to refer to a material which can be electrically conductive.

The term "chip" is used herein to refer both to a single chip and to a plurality of chips.

A "first antenna bonding wire" designates a wire that is used to connect a first pre-determined contact pad of the chip with an antenna contact pad surface area at the bonding side of the binding side conductive foil layer.

5 A "second antenna bonding wire" designates a wire that is used to connect a second pre-determined contact pad of the chip with the upper side or bonding side surface of one of the ISO contact pads C4, C6, or C8.

A "first antenna chip pad" and a "second antenna chip pad" designate those contact pads of the chip that provide a wireless data connection via a loop antenna that is connected to these chip pads-

10 A "first antenna end" designates the end of the antenna coil that is connected to the first pre-determined contact pad of the chip and a "second antenna contact pad" designates the contact pads C6, C4 or C8 that is connected to the second pre-determined contact pad of the chip.

An "upper via end" designates the end of the via hole that is located above the bonding side surface of the ISO standard contact pads C6, C4 or C8.

15 A "bridge" designates a section or an area that electrically connects a "lower bridge bonding contact area", an area of one of the ISO standard contact pads C6, C4 or C8 where the second bonding wire is provided, and the area of that same ISO standard contact pads C6, C4 or C8 near the lower via end, where the conductive material is provided.

20 The term "conductive traces" is used herein to refer to the antenna traces and also to the contact pads, while the term "conductive antenna traces" is used herein to refer to conductive traces that form the module antenna at the bonding side of the module.

An "ISO contact pad" designates contact pads according to the ISO 7816 standard.

25 The term "encapsulation material" is used herein to refer to a material that can be provided over the chip and the bond wires at the antenna side of the module substrate. One example is Glob tops that are usually epoxies that are dispensed to cover a chip, for example in chip-on-board (COB) applications.

30 Fig. 1 shows that on the contact side of the insulating substrate, a contact side Cu foil layer is laminated using adhesive. Similar to the bonding side, a pre-determined pattern of conductive traces and contact pads is etched into the contact side Cu foil layer. The outlines of the contact pads are provided with thin lines in Fig. 2, although they cannot be seen from the top side of the

chipcard module because they are hidden behind the other components and elements of the chipcard module.

Whenever the application mentions a conductive foil, this may be provided in the form of a Cu (Copper) foil or an Ag (Silver) foil or an Al (Aluminum) foil. In the following, the term "Cu foil" is used to explain this by way of using one possible synonym of materials that can be used interchangeably.

The outer surfaces of both the contact side Cu foil layer and the bonding side Cu foil layer are plated with Ni/Au. The figures further depict the chip on the antenna side of the module substrate, using adhesive. The chip contact pads are connected to the contact side surfaces of the ISO contact pads through bond wires passing through the via holes, as can be seen in Fig. 2. Additionally, a first antenna chip pad is connected to an antenna contact pad 51 the bonding side Cu foil layer using a bond wire, while a second antenna chip pad is connected to an antenna contact pad surface on the contact side Cu foil layer, by way of a bond wire passing through the via hole, thereby forming a bridge for a loop antenna-

The closed-loop antenna of the device in Fig. 1 and 2 comprises a first antenna chip pad LA, a first bonding wire 40, antenna conductive traces going counterclock-wise in circular direction, a first antenna end pad, an upper via end, a conductive paste, a lower via end, a bridge, a lower bridge bonding contact area, a second antenna bonding wire, and a second antenna chip pad LB.

Fig. 2 shows a top view of the chipcard module of Fig. 1. As one can see in Fig. 2, a pre-determined pattern of conductive traces forming the closed-loop antenna and contact pads 51 for contacting one end of the antenna loop is etched into the bonding side Cu foil layer. The figure also shows the presence of one via hole and six bonding holes in the bonding side Cu foil layer, the insulating substrate, and the adhesive. The via hole is filled with conductive material.

Figures 1 and 2 illustrate the result of the following measures:

- Laminating a bonding side Cu foil layer to the bonding side of an insulating substrate layer, using an adhesive,
- Etching a pre-determined pattern of conductive antenna traces, a first antenna end and a second antenna contact pad into the bonding side Cu foil layer,
- Providing at least one via hole and a bonding hole in the bonding side Cu foil layer, insulating substrate 10, and adhesive,

- Laminating a contact side Cu foil layer to the contact side of the insulating substrate, using adhesive,
- etching six or 8 ISO contact pads into contact side Cu foil layer,
- Providing a Ni/Au plating onto the contact side Cu foil layer and the bonding side Cu foil layer,
- 5 - Filling the via hole with conductive material, thereby contacting the first antenna end with a first section of the contact side surface of the contact side Cu foil layer, and especially with one of the ISO contact pads,
- Mounting a chip onto the antenna side of the module substrate, using an adhesive,
- Contacting a first pre-determined chip contact pad with a second section of the contact side surface of the contact side Cu foil layer, and especially with the same one of the ISO contact pads,
- 10 by providing a bond wire through the bonding hole,
- Connecting a pre-determined chip contact pad with a first antenna contact pad on the bonding side Cu foil layer, by providing a bond wire,
- Connecting a second antenna chip contact pad with an antenna contact pad surface on the contact side Cu foil layer by providing a bond wire into the via hole,
- 15 - contacting one or more chip contact pads with further sections of the contact side surface of the contact side Cu foil layer, and especially with one of the ISO contact pads, by providing bond wires into further via holes.

The above order of the measures does not necessarily mean that this is a preferred order of steps, other sequences also work. Providing a Ni/Au plating and/or adhesive is optional, other methods can be applied to achieve the same function.

While Fig. 2 shows a bridge area in the ISO contact pad C6 that is structured with gaps between conductive traces, the Fig. 3 shows the same ISO contact pad C6 without that structure, providing the same bridge function.

Fig. 4 shows an example of the external connecting terminals of the card chip. The eight external connecting terminals shown in Fig. 4 conform to ISO/IEC7816-2.

ISO/IEC 7816-2 pinout:

Pin #	Name	Description
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	Pin #1	VCC	+5 V or 3.3 V DC
	Pin #2	Reset Card Reset	(Optional)
	Pin #3	CLOCK	Card Clock
	Pin #4	AS	Application Specific
5	Pin #5	GND	Ground
	Pin #6	VPP	+21 V DC [Programming], or NC
	Pin #7	I/O	In/out [Data]
	Pin #8	AS	Application Specific

10 While the figures 1 to 7 do not show an encapsulating step that follows in a further step, the encapsulation material covering the bond wires with the corresponding via holes, and the chip is seen in Fig. 8.

In the coordinate system in the figures, “y” is pointing into the card, the “x” represents the feather of the arrow. The dot “.” represents the point of the arrow.

15 The “x” is often the longer side directed from the Ground pad to the rest of the contact set. The “z” is directed from the Ground pad to outside of the set.

For locating the Ground pad, this one is often provided integral with the center pad or contacted with it, and it is often as large as possible. After one turns the contact set such that one looks on the face of it and such that it is on the top right of the contact set, then the contact pad C6 is the
20 one immediately under the Ground contact pad.

Providing one or more via holes and one or more, preferably five bonding holes in the bonding side conductive foil layer, in the insulating substrate, and in the adhesive can be provided by punching through from the contact side to the bonding side.

Conductive material can be provided in the form of conductive paste, solder, Ag, carbon, etc., for
25 example by using a dispensing system from the bonding side.

A further embodiment combines one or more elements of the aspect relating to a first configuration for the antenna system within a smart card described above with one or more elements of the

aspect relating to a second configuration for the antenna system within a smart card described above.

A further embodiment combines one or more elements of the aspect relating to a first configuration for the antenna system within a smart card described above with one or more elements of the aspect relating to a method for manufacturing a smart card described above.

A further embodiment combines one or more elements of the aspect relating to a first configuration for the antenna system within a smart card described above with one or more elements of the aspect relating to a method for manufacturing a dual-contact chipcard module and the dual-contact chipcard module itself described above.

10 A further embodiment combines one or more elements of the aspect relating to a second configuration for the antenna system within a smart card described above with one or more elements of the aspect relating to a method for manufacturing a smart card described above.

A further embodiment combines one or more elements of the aspect relating to a second configuration for the antenna system within a smart card described above with one or more elements of the aspect relating to a method for manufacturing a dual-contact chipcard module and the dual-contact chipcard module itself described above.

15 A further embodiment combines one or more elements of the aspect relating to a method for manufacturing a smart card described above with one or more elements of the aspect relating to a method for manufacturing a dual-contact chipcard module and the dual-contact chipcard module itself described above.

20 A further embodiment combines one or more elements of the aspect relating to a first configuration for the antenna system within a smart card described above with one or more elements of the aspect relating to a second configuration for the antenna system within a smart card described above.

25 The present disclosure is illustrated by way of example and not limited in the accompanying figures in which like reference numerals indicate similar elements. Embodiments of the application will now be described with reference to the attached drawings

Figure 1 shows a cross-section through a chipcard module according to the application,

Figure 2 shows a top view of the chipcard module of Fig. 1,

30 Figure 3 shows a top view of a further chipcard module according to the disclosure, and;

Figure 4 shows external connecting terminals of a further chipcard module according to the disclosure,

Figure 5 shows external connecting terminals of a further chipcard module according to the disclosure,

- 5 Figure 6 shows external connecting terminals of a further chipcard module according to the disclosure,

Figure 7 shows external connecting terminals of a further chipcard module according to the disclosure,

- 10 Figure 8 shows external connecting terminals of a further chipcard module according to the disclosure,

Figure 9 shows external connecting terminals of a further chipcard module according to the disclosure,

Figure 10 shows 16 examples of external connecting terminals of further chipcard modules according to the disclosure.

- 15 Figure 11 shows an exploded perspective view of a smart card.

Figure 12 shows a cross-section through a chipcard module according to the application.

Figure 13 shows a bottom view of the chipcard module.

Figure 14 shows an antenna configuration for a smart card.

Figure 15 shows a further antenna configuration for a smart card.

- 20 Figure 16 shows a further antenna configuration for a smart card.

Figure 17 shows a cross-sectional view of a smart card, illustrating the arrangement and thickness of its various layers.

Fig. 1 shows a cross-section through a chipcard module according to the application.

- 25 The depicted Fig. 1 is a detailed cross-sectional view of a dual-contact chipcard module, where one can see the arrangement and connection of the different components. At the bottom, there is a module substrate 1 characterized by an antenna side 2 and a contact side 4, visible on the right

and left sides of the image, respectively. The figure is oriented by coordinate axes, where the z-axis points out of the page, the y-axis points upwards, and the X-axis extends horizontally to the right, indicating the depth and layering of the module.

The module substrate 1 comprises an insulating substrate layer 10 sandwiched between two conductive foil layers the bonding side conductive foil layer 12. Above the insulating substrate layer 10, there is provided an adhesive 11 layers that attaches the conductive foil layer 12 to the insulating substrate 10. The figure 1 shows out a via hole 21 filled with conductive material 25, creating an electrical connection between the conductive traces 60 on the bonding side 3 and the contact side conductive foil layer 15.

The chip 31, located at the antenna side 2 of the module substrate 1, is attached by a chip adhesive 30. Two bonding wires are shown, the first antenna bonding wire 40 extends upwards from the first antenna chip pad 42, while the second antenna bonding wire 41 is provided at the second antenna chip pad 43, creating electrical connections from the chip 31 to their respective contact pads. At the contact side 4, there are provided ISO contact pads 70 which are connected to the internal circuitry and would interface with an external reader or device that is not shown here. An encapsulation material 80, which would cover the chip 31 and bond wires, is there but it is not illustrated in Fig. 1. Furthermore, the RFID antenna and its connections are not explicitly shown in Fig. 1 but they are part of the conductive traces 60 at the antenna side 2.

Elements such as the first antenna end 50, second antenna end 51, upper via end 55, lower via end 56, bridge 57, and lower bridge bonding contact area 58 are also labeled, helping to understand the assembly and routing of electrical connectivity within the chipcard module. The first antenna end 50 is the terminal end of the antenna coil located on the bonding side conductive foil layer 12. This end connects to the first pre-determined contact pad of the chip 31 through the antenna structure and through the first antenna bonding wire 40. The connection provided by the first antenna end 50 enables the transmission of signals within the module by linking the antenna and the chip.

The second antenna end 51 is another terminal end of the antenna coil, which connects to the second pre-determined contact pad 43 of the chip 31, through the antenna structure and through the second antenna bonding wire 41 which passes through the bonding hole 20. The second antenna end 51 completes the antenna loop, facilitating RFID transmission.

The upper via end 55 is located at the upper end of the via hole 21, where the conductive material 25 begins to fill the hole. This end is situated above the bonding side surface of the ISO standard

contact pads 70 and serves as the entry point for the conductive material, which forms an electrical connection between the bonding side conductive foil layer 12 and the contact side conductive foil layer 15.

5 The lower via end 56 is found at the lower end of the via hole 21, where the conductive material 25 forms an electrical connection with the contact side conductive foil layer 15. The lower via end 56 provides electrical connectivity from the bonding side 3 to the contact side 4 through the via hole 21.

10 The bridge 57 is a section that creates an electrical connection between the lower bridge bonding contact area 58 and another area on the same ISO standard contact pad 70. The bridge 57 plays a role in conducting electrical signals between the first antenna chip pad 42 and the second antenna chip pad 43 of the chip 31, supporting the operation of the antenna.

The lower bridge bonding contact area 58 is a contact point on the ISO standard contact pad 70 that provides the bridge 57, contributing to the proper functioning of the antenna and the chip 31.

15 Fig. 2 shows a top view of the chipcard module of Fig. 1 that depicts the bottom view of a chipcard module 1. As one can see here, the antenna side 2 or bonding side 3 of the module 1 comprises various conductive antenna traces 60 forming part of an RFID antenna coil around the module substrate 1. The chip 31 is centrally mounted on the module with bonding wires 40 and 41 connecting to one antenna contact pad 51 and one ISO contact pad 70. The antenna side 2 comprises a primary antenna end 50 and a secondary end 51, both of which are connected to
20 individual contact pads on the chip 31. The via hole 21, filled with conductive material 25, provides electrical connectivity between the bonding side conductive foil layer 12 and the contact side conductive foil layer 15 through the insulating substrate layer 10. This via hole 21 links the conductive antenna traces 60 to a specific ISO standard contact pad C4. Additionally, there is a bonding hole 20, which is used for connecting the bonding wire 40 to that ISO contact pad C4.
25 The other ISO contact pads 70 themselves are labeled according to their standard designations, such as C1/VCC, C2/RST, C3/CLK, C5/GND, and C7/IO. The conductive traces 60 are laid out to form the RFID antenna, and both the traces 60 and contact pads 70 are integral to the dual-contact functionality of the chipcard module 1.

30 Fig. 3 shows a top view of a further chipcard module according to the disclosure. The chipcard module of Fig. 3 is in large parts identical to the chipcard module of Fig. 2, except for the shape of the Pin #6 ISO contact pad VPP/NC/Not Connected 76. Fig. 1 shows the cross-section view of the line A-A in Fig. 3.

The module substrate 1, which is the base of the chipcard module, is visible from the antenna side 2. Conductive antenna traces 60 form an RFID transmission loop antenna patterned on the bonding side conductive foil layer 12 of the insulating substrate layer 10. Conductive material 25 fills via hole 21 providing electrical connection through the insulating substrate layer 10 to the contact side conductive foil layer 15. This connection is shown with reference to Pin #6 ISO contact pad VPP/NC/Not Connected 76, which is one of the ISO contact pads 70. The chip 31 is mounted at the antenna side 2 and connected to the RF antenna and the contact pads. The first antenna bonding wire 40 connects a first predetermined contact pad of the chip 31 with an antenna contact pad surface area above the bonding side conductive foil layer 12. The view also includes a ground indication GND and a coordinate system, showing the orientation of the x, y, and z-axes. Fig. 3 also shows the paths for the first antenna bonding wire 40 and the second antenna bonding wire 41, highlighting their connection points to the chip 31 and conductive traces 60.

Fig. 4 shows external connecting terminals of a further chipcard module according to the disclosure, illustrating the layout of the ISO contact pads 70 in a standard configuration on a contact side 4 of a chipcard module substrate 1, which is part of the overall dual-contact chipcard module design. The ISO contact set 81 comprises several distinct pads labeled for their respective purposes. Pin #1 72 labeled as "VCC" indicates the power supply voltage contact. Pin #2 72 labeled as "RST" is for reset. Pin #3 73 labeled as "CLK" is the clock input. Pin #4 74 and Pin #8 78 are labeled as "AS", indicating application-specific use. Pin #5 75 labeled as "GND" is the ground contact. Pin #6 76 labeled as "VPP" is typically for programming voltage and is not connected to anything in some applications so that it can be used as a bridge 57 in the modules of the disclosure. Alternatively, Pin #4 74 and Pin #8 78 can be used as a bridge 57 in the modules of the disclosure. Pin #7 is labeled as "I/O" is the input/output contact. A large center pad 79 is not connected to anything and serves as a mechanical re-inforcement element of the module. The layout is enclosed within the boundaries of the module substrate 1, and spacing between the contact pads is consistent with ISO standards for chipcard modules. The figure is annotated with "Top View" and includes a coordinate system indicating the orientation with axes labeled x, y, and z.

Fig. 5 shows external connecting terminals of a further chipcard module according to the disclosure. The ISO contact set 81 of Fig. 5 is in large parts identical to the the ISO contact set 81 of Fig. 5, except that the GND contact pad 75 is integral with the center pad 79. Pin #6 labeled as "VPP" is typically for programming voltage and is not connected to anything in some

applications so that it can be used as a bridge 57 in the modules of the disclosure. Alternatively, Pin #4 74 and Pin #8 78 can be used as a bridge 57 in the modules of the disclosure. The orientation of the diagram is indicated by the "Top View" label and the axes designation, meaning that one is looking down at the contact side 4 of the card module substrate 1.

- 5 Fig. 6 shows external connecting terminals of a further chipcard module according to the disclosure,

The figure illustrates a series of eight ISO contact pads 70 arranged in two columns on a module substrate 1. Each pad is assigned a label indicating its function "C1 VCC" for power supply, "C2 RST" for reset, "C3 CLK" for clock, "C4 RFU" reserved for future use, "GND C5" for ground, "VPP C6" for programming voltage or not connected, "I/O C7" for input/output communication, and "RFU C8" also reserved for future use. The layout is symmetric with a central area 79 potentially for the chip 31 or antenna placement. The contact pads are part of the external interface of a smart card, allowing it to connect to a card reader. The GND contact pad 75 is integral with the center pad 79. Pin #6 labeled as "VPP" is typically for programming voltage and is not connected to anything in some applications so that it can be used as a bridge 57 in the modules of the disclosure. Alternatively, Pin #4 74 and Pin #8 78 can be used as a bridge 57 in the modules of the disclosure. The figure also includes a coordinate system indicating the x, y, and z-axes, which suggests that the view is from above the contact side 4 of the chipcard module, looking directly down onto the contact pads.

- 20 Fig. 7 shows external connecting terminals of four further chipcard modules according to the disclosure that are arranged as a transport tape. The components include the module substrates 1 which underlie all the visible elements but are not directly labeled in this view. One can see the ISO contact pads 70 that are labeled with numbers corresponding to their function as per ISO standards, such as 71 for the Pin #1 VCC contact pad and 72 for the Pin #2 Reset contact pad, and so on. The image marks the individual ISO contact pads 70 with their respective reference numerals, including 71, 72, 73, 74 and 78, 75, 76, and 77. The conductive material 25 that would fill the via hole 21 is not visible in this view but is there for linking the conductive traces 60 with the contact pads. The directional axes are shown to provide orientation to the viewer. The bonding side 3, chip adhesive 30, and chip 31, as well as the bonding wires and encapsulation material 80, are not seen in this top view but are part of the encapsulated modules. Pin #6 76 is typically for programming voltage and is not connected to anything in some applications so that it can be used as a bridge 57 in the modules of the disclosure.

Fig. 8 shows the bottom view of the chipcard modules of Fig. 7.

Each module includes a module substrate 1, though not labeled in this view, which forms the base for the various elements depicted. The conductive antenna traces 60 are shown as spiraling patterns around the periphery of each module and are part of the RFID transmission antenna coil.

5 At the center of each trace arrangement is a chip 31 mounted at the antenna side 2 of the module substrate 1. The encapsulation material 80 is visible as a transparent or translucent dome-shaped covering over the chips, serving to protect the chips and associated components from environmental factors. The conductive material 25 is filled in the via holes to provide electrical connections between the conductive traces 60 and the contact side conductive foil layer 15 —not
10 marked here but is part of the structure that would be on the opposite side of the substrate. These connections provide the functionality of the chip 31 and its ability to communicate with other devices. The first antenna end 50, which corresponds to one end of the conductive traces 60, and the second antenna end 51 can be seen at opposite ends of the conductive trace loops. These serve as the start and termination points of the antenna coil.

15 Fig. 9 shows external connecting terminals of a further chipcard module according to the disclosure.

The figure presents a top view of the ISO contact set 81 of a dual-contact chipcard module. The ISO contact set 81 comprises several ISO contact pads 70 labeled as follows Pin #1 ISO contact pad VCC 71, Pin #2 ISO contact pad Reset 72, Pin #3 ISO contact pad CLOCK 73, Pin #5 ISO
20 contact pad GND/Ground 75, Pin #6 ISO contact pad VPP/NC/Not Connected 76, Pin #7 ISO contact pad I/O, In/out 77. The GND contact pad 75 is integral with the center pad 79. Pin #6 labeled as "VPP" is typically for programming voltage and is not connected to anything in some applications so that it can be used as a bridge 57 in the modules of the disclosure. These pads are situated in a standard layout for chipcards, where they are positioned to interface with external
25 card readers. The axes are shown to indicate the orientation of the top view relative to the chipcard module. The figure provides a visual representation of the ISO contact pad 70 configuration, which ensures proper electrical contact between the chipcard and card readers or other interface devices.

Fig. 10 shows external connecting terminals of 16 further chipcard modules according to the
30 disclosure. Fig. 10 provides a top view of different configurations of conductive antenna traces 60 and the array of ISO contact pads 70 for the dual-contact chipcard module. Each of the depicted modules showcases a unique arrangement of these elements, illustrating the versatility in the

design and how various chip 31 configurations can be accommodated without altering the fundamental structure. The contact pads are discernible within each illustration and are designated by the number 76, referring to "Pin #6 ISO contact pad VPP/NC/Not Connected 76" in the provided list of reference numerals. Each variant still maintains compatibility with ISO standards, as the contact positions are consistent with the requirements for contact-based chipcard communication. The different designs align with the scope of the disclosure by demonstrating possible variations in module structuring while preserving the electrical functionality required for dual-contact interoperability. Pin #6 labeled as "VPP" is typically for programming voltage and is not connected to anything in some applications so that it can be used as a bridge 57 in the modules of the disclosure.

Fig. 11 illustrates an exploded perspective view of a smart card 100. The smart card 100 comprises multiple integrated components and layers to facilitate data transfer and energy efficiency in communication with external devices.

The smart card 100 comprises a chipcard module 102 with a module substrate 1, an IC chip 31, and an IC module coil 108. The module substrate 1 serves for structural support for the IC chip 31, and the IC module coil 108 is electrically connected to the IC chip 31 and is designed to interact with the first coil 103 by utilizing magnetic field induction.

The antenna coil 104, first coil 103, and second coil 112 are arranged to create an efficient resonance circuit for signal transfer and energy matching with external readers 200. The antenna coil 104 is electrically connected to the first coil 103 and the second coil 112, with the second coil 112 further integrating a capacitive element 115. This resonance circuit is designed to optimize the antenna coil's 104 performance by matching it with the external reader's antenna for improved signal reception and transmission.

The capacitive element 115 is an integral part of the second coil 112, formed by extending the wire ends of the coil itself. Together, the second coil 112 and capacitive element 115 enable tuning of the antenna coil 104 to the resonant frequency of the external reader's antenna.

The design incorporates a multi-layer structure. The antenna substrate 105, which houses the first coil 103, second coil 112, third coil 104, and capacitive element 115, is laminated between card substrates 110 to create a durable sandwich structure. Engagement holes 111 and 120 are milled into the card substrates 110 to facilitate alignment and assembly of the IC module 102 with the smart card layers.

The antenna coil 104 is designed with a larger diameter compared to the first coil 103 and second coil 112, resulting in a larger third surface area. This allows the first coil 103 and second coil 112 to be arranged entirely within the interior space defined by the turns of the antenna coil 104, without overlapping their respective surface areas.

- 5 The IC module coil 108, positioned on a separate layer from the antenna substrate 105, is configured to couple magnetically with the first coil 103. This ensures efficient signal transmission from the antenna coil 104 to the IC chip 31. The magnetic field generated by the first coil 103 induces a current in the IC module coil 108, which is then transmitted to the IC chip 31 for processing.
- 10 During operation, a high-frequency magnetic field generated by an external reader 200 induces a current in the antenna coil 104. The antenna coil 104, tuned to the external reader's frequency, transfers this energy efficiently to the first coil 103. The first coil 103 then closely couples with the IC module coil 108 to transmit the signal to the IC chip 31.

- This configuration ensures optimal energy transfer and signal sensitivity. The third coil 104
15 primarily absorbs energy from the external reader 200, while the second coil 112, as a passive component, enhances the efficiency of the resonance circuit without actively radiating or absorbing significant radiation.

The close coupling of the coils and the strategic placement of components enables the smart card 100 to demonstrate high performance in contactless communication with external devices.

- 20 Fig. 12 shows a cross-section through a chipcard module according to the application.

The depicted Fig. 12 is a detailed cross-sectional view of a dual-contact chipcard module, illustrating the arrangement and connection of its components. At the bottom, there is a module substrate 1 characterized by an antenna side 2 and a bonding side 3, visible on the left and right sides of the image, respectively.

- 25 Fig. 12 shows a cross-section of a chipcard module 102 designed with dual-contact functionality and a closed-loop antenna. The module substrate 1 consists of an insulating substrate layer 10 that is positioned between a bonding side conductive foil layer 12 and a contact side conductive foil layer 15. The bonding side conductive foil layer 12 is adhered to the insulating substrate layer 10 using an adhesive layer 11. Conductive traces 60 are formed on the bonding side 3 and are
30 covered by the insulating substrate layer 10, which has a thickness of 3 to 5 micrometers. The insulating material is applied in such a way that it does not cover or it partially covers the areas

around the antenna side 2 and bonding side 3, ensuring that these areas are not completely covered to maintain electrical connectivity via the bridge 57.

A via hole 21 is filled with conductive material 25 to establish an electrical connection between the conductive traces 60 on the bonding side 3 and the contact side 4 conductive foil layer 15. On top of the insulating substrate layer 10 covering the conductive antenna traces 60, a conductive material layer, which can be in the form of ink, solder, or copper, is applied over the insulator material. This conductive material layer forms the bridge 57, electrically connecting the antenna side 2 to the bonding side 3. The thickness of this conductive material layer is between 10 to 15 micrometers to ensure robust connectivity while maintaining structural stability.

The chip 31 is attached to the bond pad located on the bonding side 3 using chip adhesive 30. The chip 31 is connected to the internal circuitry through bonding wires. The first antenna bonding wire 40 connects the first antenna chip pad 42 of the chip 31 to the bonding side conductive foil layer 12. The second antenna bonding wire 41 connects the second antenna chip pad 43 of the chip 31 to the ISO contact pads 70 located on the contact side 4, passing through a bonding hole 20. The ISO contact pads 70 are designed to interface with external readers 200 and are part of the electrical system for communication and power transfer.

The chip 31 and the bonding wires are encapsulated using epoxy material to protect the components from environmental and mechanical stress. This encapsulation step ensures durability and reliability of the module. After encapsulation, the module undergoes electrical testing to verify the integrity of the connections and functionality of the system.

This detailed cross-section highlights the precise layering and interconnections in the chipcard module, which ensure efficient performance, robust signal transmission, and reliable dual-contact functionality.

Fig. 13 illustrates a bottom view of the chipcard module 102, showing the arrangement of the conductive traces 60, ISO contact pads 70, and the bridge 57 that connects the antenna side 2 to the bonding side 3. The bonding side conductive foil layer 12 contains a pre-determined pattern of conductive antenna traces 60, which form a closed-loop antenna system. These traces are partially covered by an insulating substrate layer 10, applied with a thickness of 3 to 5 micrometers. The insulating material is carefully applied to the antenna side 2 and bonding side 3 to ensure that these areas are not completely covered, allowing for electrical connectivity through the bridge 57.

The bridge 57 is formed by applying a conductive material layer over the insulating layer. This conductive material, which can take the form of ink, solder, or copper, has a thickness of 10 to 15 micrometers and electrically connects the antenna side 2 to the bonding side 3. The bridge ensures robust signal transmission by linking these areas without disrupting the integrity of the loop antenna design.

The ISO contact pads 70, including C1/VCC 71, C2/RST 72, C3/CLK 73, C5/GND 75, and C7/I/O 77, are etched into the contact side conductive foil layer 15. These pads are visible as dotted outlines in Fig. 13 because they are located on the contact side 4 and are hidden from direct view by the insulating substrate layer 10. The dotted outlines highlight the precise alignment of the pads with the bonding side 3, ensuring reliable electrical connectivity through the via hole 21, which is filled with conductive material 25.

The chip 31 is mounted on the bonding side 3 of the module substrate 1 and is connected to the internal circuitry through bonding wires. These wires extend from the chip 31 and pass through bonding holes 20 to connect with the contact side conductive foil layer 15. The closed-loop antenna system includes the first antenna end 50, second antenna end 51, upper via end 55, lower via end 56, and lower bridge bonding contact area 58, which collectively ensure efficient energy transfer and signal transmission between the chip 31 and the external reader 200.

The conductive traces 60 are laid out in a counterclockwise pattern, forming the RFID antenna coil that operates as the primary communication medium between the module and an external reader 200. The bridge 57 plays a crucial role in connecting the two main antenna areas while maintaining the structural and functional integrity of the antenna system.

This bottom view of the chipcard module highlights the integration of the chip 31, the conductive traces 60, and the bridge 57, demonstrating the advanced design and manufacturing processes that ensure reliable operation and efficient data transfer.

Figs. 14, 15, and 16 illustrate different antenna configurations for a smart card 100, demonstrating variations in antenna size and structure to optimize reliability in data transmission with an external reader 200.

These three antenna configurations, shown in Figs. 14, 15, and 16, illustrate the adaptability of the smart card 100 design. Each configuration is optimized for specific operational requirements, ensuring reliable data transmission and compatibility with external reader 200 systems. The

integration of coils into the antenna substrate 105 through ultrasonic embedding simplifies the manufacturing process while maintaining structural integrity and performance.

In Fig. 14, the antenna substrate 105 is shown in a top view, incorporating a first coil 103, an antenna coil 104, a second coil 112, and a capacitive element 115. This type of antenna is commonly noted as ID1 size antenna wherein the coils occupy the full area of the substrate. The antenna coil 104, which has the largest diameter among the coils, encloses the second coil 112, the first coil 103, and the capacitive element 115. The capacitive element 115 is formed by the extended wire ends of the second coil 112, creating an integral resonance circuit with the coil. All components, including the first coil 103, the antenna coil 104, the second coil 112, and the capacitive element 115, are embedded into the antenna substrate 105 using a constant downward force. This embedding process involves ultrasonic vibration, which securely lays the wire within the substrate without the need for additional conductive foil, laser ablation, or etching.

The antenna coil 104, the first coil 103, and the second coil 112 are formed from a single continuous wire, ensuring uniform winding direction and eliminating the need for welding or soldering between wire sections. The uniformity of the wire simplifies manufacturing and ensures reliable electrical connections.

Fig. 15 presents a smart card 100 with a half-size antenna coil 104. This configuration is depicted in a top view, showing the antenna coil 104 along with the first coil 103, the second coil 112, and the capacitive element 115 embedded in the antenna substrate 105. The half-size antenna coil 104 has dimensions of approximately 80 mm by 26 mm. In this design, the second coil 112 is enclosed within the third interior space defined by the antenna coil 104, while the first coil 103 is located outside the area enclosed by the antenna coil 104. The antenna coil 104 is electrically connected to both the second coil 112 and the first coil 103.

To achieve a specific resonant frequency for reliable data transmission, the second coil 112 provides a resonance circuit by forming an LC network. The capacitive element 115, integrated into the second coil 112, enhances the tuning of the antenna coil 104. The reduced size of the antenna coil 104 requires precise adjustments to the number of wire turns in the first coil 103 and the second coil 112 to maintain efficient communication with the external reader 200.

Fig. 16 illustrates a smart card 100 with a two-thirds (2/3) size antenna coil 104 in a top view. This antenna coil 104 has dimensions of approximately 80 mm by 35 mm, striking a balance between the ID1 size and half-size configurations. Testing with different chip types revealed optimized configurations for coupling the antenna coil 104 with the external reader 200. For a chip card with

STM chip, the ideal configuration includes 9 turns for the first coil 103, 11 turns for the second coil 112, and 3 turns for the antenna coil 104. For a chip card with NXP chip, the first coil 103 comprises 10 turns, the second coil 112 has 7 turns, and the antenna coil 104 has 5 turns.

The two-thirds size antenna coil 104 enhances the coupling efficiency with the external reader 200's antenna. This design can reduce the number of wire turns in the antenna coil 104 to accommodate features such as embossing on banking cards. Reducing the number of turns decreases the capacitance of the antenna coil 104, necessitating adjustments to the inner coils to achieve a target resonant frequency, such as 13.77 MHz for the NXP chip. Both the first coil 103 and the second coil 112 are located within the third interior space defined by the antenna coil 104, with the first and second surface areas remaining distinct from one another.

Fig. 17 shows a cross-sectional view of a smart card 100, illustrating the arrangement and thickness of its various layers. The smart card 100 comprises multiple layers, including PVC sheets and an antenna sheet, which are bonded together to form a compact and functional structure. The layers are arranged symmetrically around an inlay, ensuring consistent thickness and alignment.

The inlay contains the antenna sheet, which incorporates the antenna coil 104 and the second coil 112. These coils are embedded directly into the antenna substrate 105 during manufacturing. The embedding process involves laying the coils within the antenna substrate 105 using constant downward force and ultrasonic vibration. This method eliminates the need for conductive foil, laser ablation, or etching. The antenna coil 104 and the second coil 112 are designed to form part of a closed-loop antenna system, facilitating reliable signal transmission with the external reader 200.

The layers of the smart card 100 include the antenna sheet with a thickness of 0.15 mm and multiple PVC sheets that provide structural support and protection. The PVC sheets are layered above and below the antenna sheet, with each PVC sheet having specific thicknesses. The layers include two outermost PVC sheets with a thickness of 0.05 mm each, two inner PVC sheets with a thickness of 0.15 mm each, and two additional inner PVC sheets with a thickness of 0.10 mm each. Together, these layers form the card substrates 110, which enclose the antenna substrate 105.

The smart card 100 does not contain any layer made entirely of metal, and the total metal composition does not exceed 40% of the card's overall weight. This ensures compatibility with external readers 200 and maintains the flexibility and durability of the card. All layers are permanently bonded through lamination, creating a unified structure that ensures reliability during

usage. The dimensions and materials used in the construction of the smart card 100 contribute to its robustness and functionality while meeting industry standards for contactless communication.

5 The above embodiments in the application can also be described using the following Itemized lists.

The first itemized list refers to the aspect relating to the method for manufacturing a dual-contact chipcard module and the dual-contact chipcard module itself. The items of the first itemized list can be combined with one or more items of all other itemized lists in this document as well as with one or more features of the claims.

10 First itemized list:

1. Method of manufacturing a dual-contact chipcard module with an RFID transmission antenna coil comprising a number of conductive antenna traces 60 and with a number of ISO contact pads 70, comprising

- 15 - providing a module substrate 1 with an antenna side 2 and a contact side 4,
- providing a bonding side conductive foil layer 12 to a bonding side 3 of an insulating substrate layer 10,
- providing a pre-determined pattern of conductive traces 60 and contact pads in the bonding side conductive foil layer 12,
- 20 - providing a via hole 21 in the bonding side conductive foil layer 12 and the insulating substrate layer 10,
- providing a contact side conductive foil layer 15 to a contact side 4 of the insulating substrate layer 10,
- 25 - etching a pre-determined pattern of conductive traces 60 and contact pads into the contact side conductive foil layer 15,
- providing conductive material 25 in the via hole 21, electrically connecting a section of the conductive traces 60 and a section of the contact side conductive foil layer 15,

further comprising

- mounting a chip 31 above [on] the antenna side 2 of the module substrate 1,
- connecting a first pre-determined contact pad of the chip 31 with an antenna contact pad surface area above the bonding side conductive foil layer 12 by providing a first antenna bonding wire 40,
- 5 - contacting a second pre-determined contact pad of the chip 31 above a bonding side 3 surface of the ISO contact pads 70, by providing a bond wire through the bonding hole 20, and

wherein the method provides the dual-contact chipcard module such that the conductive material 25 in the via hole 21 electrically connects a section of the conductive traces 60 and one of the ISO standard contact pads C6, C4 or C8, and wherein the first pre-determined contact pad of the chip 31 is connected above a bonding side 3 surface of the same ISO standard contact pads C6, C4 or C8.

2. Method of manufacturing a dual-contact chipcard module according to item 1, wherein the conductive material 25 comprises conductive glue and wherein there is a step of curing the conductive glue after filling the via hole 21.

3. Method of manufacturing a dual-contact chipcard module according to item 1 or item 2, with an encapsulating step of providing encapsulation material 80 over the chip 31 and the bond wires at the antenna side 2 of the module substrate 1.

4. Dual-contact chipcard module with an RFID transmission antenna coil that comprises a number of conductive antenna traces 60 and with an ISO contact set 81 with a number of ISO contact pads 70,

with

- a module substrate 1 with an antenna side 2 and a contact side 4,
- a bonding side conductive foil layer 12 at a bonding side 3 of an insulating substrate layer 10,
- 25 - conductive traces 60 and contact pads provided in the bonding side conductive foil layer 12,
- a via hole 21 in the bonding side conductive foil layer 12 and in the insulating substrate layer 10,

- a contact side conductive foil layer 15 at a contact side 4 of the insulating substrate layer 10,
 - conductive traces 60 and contact pads in the contact side conductive foil layer 15,
 - conductive material 25 in the via hole 21, electrically connecting a section of the
- 5 conductive traces 60 and a section of the contact side conductive foil layer 15,

further comprising

- a chip 31 above the antenna side 2 of the module substrate 1,
 - a first pre-determined contact pad of the chip 31 [a first antenna chip pad 42] being
- 10 connected with an antenna contact pad surface area above the bonding side conductive foil layer 12 by a first antenna bonding wire 40,
- a second pre-determined contact pad of the chip 31 above a bonding side 3 surface of the ISO contact pads 70, with a bond wire in the bonding hole 20, and

wherein the conductive material 25 in the via hole 21 electrically connects a section of the conductive traces 60 and one of the ISO standard contact pads C6, C4 or C8, and wherein the

15 second pre-determined contact pad of the chip 31 is connected above a bonding side 3 surface of the same ISO standard contact pads C6, C4 or C8.

The second itemized list refers to the structural, functional, and manufacturing features of the smart card as depicted in Figs. 11 to 17. The items of the second itemized list can be combined

20 with one or more items of all other itemized lists in this document as well as with one or more features of the claims and any other embodiments described in the application.

Second itemized list:

- 25 1. A smart card comprising:
- A module substrate 1 having an antenna side 2 and a bonding side 3;
 - An insulating substrate layer 10 disposed between a bonding side conductive foil layer 12 and a contact side conductive foil layer 15, the bonding side conductive foil layer 12

and the contact side conductive foil layer 15 being adhered to the insulating substrate layer 10 using an adhesive layer 11;

- A chip 31 mounted on the bonding side 3 of the module substrate 1 using chip adhesive 30;
- 5 - A first coil 103, a second coil 112, and an antenna coil 104 embedded within an antenna substrate 105, the antenna coil 104 surrounding the first coil 103 and the second coil 112;
- A capacitive element 115 formed by wire ends of the second coil 112, the capacitive element 115 being integrated into a resonance circuit with the second coil 112;
- 10 - Conductive traces 60 electrically connecting the antenna coil 104 to the first coil 103 and the second coil 112;
- A bridge 57 formed from a conductive material layer that connects the antenna side 2 to the bonding side 3, the bridge 57 being applied over an insulating layer partially covering the antenna coil 104; and
- 15 - ISO contact pads 70 formed on the contact side 4, wherein the ISO contact pads 70 are electrically connected to the chip 31 through bonding wires passing through bonding holes 20.

2. The smart card of item 1, wherein:

- 20 - The conductive material layer of the bridge 57 has a thickness between 10 and 15 micrometers;
- The insulating substrate layer 10 has a thickness between 3 and 5 micrometers and partially covers the antenna side 2 and the bonding side 3 to ensure connectivity through the bridge 57.

25

3. The smart card of item 1, further comprising:

- A closed-loop antenna system comprising:

- A first antenna end 50 electrically connected to a first antenna chip pad 42 on the chip 31 through a first antenna bonding wire 40;
- A second antenna end 51 electrically connected to a second antenna chip pad 43 on the chip 31 through a second antenna bonding wire 41;
- 5 - A via hole 21 filled with conductive material 25, electrically connecting the bonding side conductive foil layer 12 to the contact side conductive foil layer 15.

4. A method of manufacturing the smart card of item 1, comprising:

- 10 - Embedding the first coil 103, the second coil 112, the antenna coil 104, and the capacitive element 115 into the antenna substrate 105 using constant downward force and ultrasonic vibration;
- Laminating the bonding side conductive foil layer 12 to the insulating substrate layer 10 using adhesive 11;
- 15 - Etching a pre-determined pattern of conductive traces 60, including the antenna coil 104 and ISO contact pads 70, into the bonding side conductive foil layer 12;
- Filling the via hole 21 with conductive material 25 to connect the bonding side conductive foil layer 12 to the contact side conductive foil layer 15;
- Applying an insulating material layer with a thickness of 3 to 5 micrometers over the antenna coil 104 and partially covering the antenna side 2 and the bonding side 3;
- 20 - Applying a conductive material layer with a thickness of 10 to 15 micrometers over the insulating material layer to form the bridge 57;
- Mounting the chip 31 onto the bonding side 3 using chip adhesive 30;
- Connecting bonding wires between the chip 31 and the ISO contact pads 70; and
- Encapsulating the chip 31 and bonding wires with an encapsulation material 80.

25

5. The smart card of item 1, wherein the antenna coil 104, the first coil 103, and the second coil 112 are formed from a single continuous wire, and no welding or soldering is required to connect sections of the wire.

6. The smart card of item 1, wherein the antenna coil 104 is configured in three size variations:
- An ID1 size antenna as shown in Fig. 14, wherein the antenna coil 104 surrounds the first coil 103 and the second coil 112 completely;
 - 5 - A half-size antenna as shown in Fig. 15, wherein the antenna coil 104 partially surrounds the second coil 112 while the first coil 103 remains outside the perimeter of the antenna coil 104; and
 - A two-thirds size antenna as shown in Fig. 16, wherein the antenna coil 104 surrounds both the first coil 103 and the second coil 112 within its interior space.
7. The smart card of item 6, wherein the size of the antenna coil 104 is adjusted to optimize
10 coupling efficiency with an external reader 200, and the number of wire turns in the antenna coil 104, first coil 103, and second coil 112 are modified to achieve a desired resonant frequency.
8. A multi-layer structure of a smart card comprising:
- An inlay formed by an antenna sheet containing the antenna coil 104 and the second coil 112;
 - 15 - PVC sheets layered above and below the antenna sheet to form card substrates 110;
 - The antenna sheet having a thickness of 0.15 mm, and the PVC sheets including two outer layers of 0.05 mm thickness each, two inner layers of 0.15 mm thickness each, and two additional inner layers of 0.10 mm thickness each;
 - 20 - All layers being permanently bonded together through lamination to form a unified smart card 100.
9. The smart card of item 8, wherein the overall metal composition of the card does not exceed 40% of the smart card's total weight.

REFERENCE NUMERA LIST

- 1 Module substrate
- 2 Antenna side
- 3 Bonding side
- 5 4 Contact side
- 5 LA first antenna chip pad
- 6 LB second antenna chip pad
- 10 Insulating substrate layer
- 11 Adhesive
- 10 12 Bonding side Cu foil
- 12 Bonding side conductive foil layer
- 12 Side conductive foil layer
- 13 Ni layer
- 14 Au layer
- 15 15 Contact side Cu layer
- 15 Contact side conductive foil layer
- 15 Side conductive foil layer
- 20 Bonding holes
- 20 Bonding hole
- 20 21 Via hole
- 25 Conductive paste
- 25 Conductive material
- 30 Chip adhesive
- 31 IC chip

- 40 First antenna bonding wire
- 41 Second antenna bonding wire
- 42 First antenna chip pad
- 43 Second antenna chip pad
- 5 50 First antenna end
- 51 Second antenna contact pad
- 51 Second antenna end
- 55 Upper via end
- 56 Lower via end
- 10 57 Bridge
- 58 Lower bridge bonding contact area
- 60 Conductive traces
- 60 Conductive antenna traces
- 60 Traces
- 15 70 ISO contact pads
- 70 ISO contact pad
- 71 Pin #1 ISO contact pad VCC
- 72 Pin #2 ISO contact pad Reset
- 73 Pin #3 ISO contact pad CLOCK
- 20 74 Pin #4 ISO contact pad AS/Application Specific
- 75 Pin #5 ISO contact pad GND/Ground
- 76 Pin #6 ISO contact pad VPP/NC/Not Connected
- 77 Pin #7 ISO contact pad I/O, In/out
- 78 Pin #8 ISO contact pad AS/Application Specific

- 80 Encapsulation material
- 80 Providing encapsulation material
- 81 ISO contact set
- 100 Smart card
- 5 102 chipcard module
- 103 First coil
- 104 Antenna coil
- 105 Antenna substrate
- 108 IC module coil
- 10 110 Card substrates
- 111 Engagement hole
- 112 Second coil
- 115 Capacitive element
- 120 Engagement holes
- 15 200 External reader

CLAIMS

1. A smart card (100) comprising:

- a. a substrate (105, 110) supporting a dual-interface antenna system and a chipcard module (102) with an IC chip (31) and an IC module coil (108),
- 5 b. the chipcard module (102) integrated into the antenna system, the antenna system comprising a first coil (103), an antenna coil (104) and a second coil (112), wherein the antenna system is configured to interface with external systems (200) for contactless and contact-based operations, wherein the antenna system is optimized for coupling efficiency and compliance with EMV standards,
- 10 **characterized in that**
- c. the antenna coil (104), the first coil (103), and the second coil (112) have turns defining a perimeter enclosing a surface area, the surface area of the antenna coil (104) corresponding to $\frac{2}{3}$ of the total surface area of the smart card (100), with a tolerance of $\pm 10\%$,
- 15 d. the wire diameter of the antenna coil (104), the first coil (103), and the second coil (112) is within the range of 0.08 mm to 0.15 mm,
- e. the wire pitch is generally uniform, with the second coil (112) having a pitch of $0.34 \text{ mm} \pm 10\%$,
- f. the number of turns is 8 to 11 in the first coil (103), 2 to 6 in the antenna coil (104), and 6
20 to 12 in the second coil (112).

2. The smart card (100) according to claim 1, wherein the wire diameter, wire pitch, and number of turns in each of the antenna coil (104), the first coil (103), and the second coil (112) are variably adjusted to:

- 25 - tune the resonant frequency of the entire smart card (100) to $13.77 \text{ MHz} \pm 0.1 \text{ MHz}$, thereby improving coupling efficiency with minimal delay, and
- ensure the Quality Factor is less than or equal to 40, limiting resonance efficiency to prevent chip overload.

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3. The smart card (100) according to claim 1 or claim 2, wherein the surface area of the antenna coil (104) is formed in the dimensions 80 mm * 35 mm with a tolerance of $\pm 10\%$.
4. The smart card (100) according to any of the preceding claims, wherein
- 5 the first coil (103) comprises a pitch of 0.2 mm $\pm 10\%$ and the antenna coil (104) comprises a pitch of 0.4 mm $\pm 10\%$
5. The smart card (100) according to any of the preceding claims, wherein the surface area enclosed by the antenna coil (104) encompasses the surface areas enclosed by the first coil
- 10 (103) and the second coil (112), wherein the surface areas enclosed by the first coil (103) and the second coil (112) are non-overlapping.
6. The smart card (100) according to any of the preceding claims, wherein the first coil (103) is operatively coupled to the IC module coil (108) which is connected to the chip (31).
- 15
7. The smart card (100) according to any of the preceding claims, wherein the second coil (112) is configured as a passive, non-radiating component of an LC network for matching the antenna coil (104) with an external system (200).
- 20
8. The smart card (1) according to claim 7, comprising a capacitive element (115), wherein the second coil (142) and the capacitive element (145) form the LC network.
9. The smart card (1) according to claim 6, wherein the chip (31) comprises a NXP P71 EMV 6-pin icoM chip, enabling reduced timing delays and enhanced coupling for payment applications.
- 25
10. A smart card (100) comprising:
- a. a substrate (105, 110) supporting a dual-interface antenna system and a chipcard module (102) with an IC chip (31) and an IC module coil (108),

- b. the chipcard module (102) integrated into the antenna system, the antenna system comprising a first coil (103), an antenna coil (104) and a second coil (112),
- c. wherein the antenna system is configured to interface with external systems (200) for contactless and contact-based operations, optimized for integration with an STM
5 ST31P45054APB1 icoM PAY 6-pin module,
- d. wherein the antenna system is characterized by:
- o the wire diameter of the antenna coil (104), the first coil (103), and the second coil (112) is within the range of 0.06mm – 0.1mm,
 - o the wire pitch is variable, with the first coil (103) having a pitch of 0.17 mm +/-
10 10%, the second coil (112) having a pitch of 0.5 mm +/-10%, and the antenna coil 104 having a pitch of 0.3 mm +/-10%
 - o the number of turns is 8 to 10 in the first coil (103), 2 to 5 in the antenna coil (104), and 10 to 13 in the second coil (112).
- 15 11. The smart card (100) according to claim 10, wherein the wire diameter, wire pitch, and number of turns in each of the antenna coil (104), the first coil (103), and the second coil (112) are variably adjusted to:
- tune the resonant frequency of the entire smart card (100) to 13.8 MHz $\pm$ 0.5 MHz, thereby improving coupling efficiency with minimal delay, and
 - 20 - ensure the Quality Factor is stabilized to 34 to enhance compliance with EMV standards.
12. The smart card (100) according to claim 10 or claim 11, wherein the antenna system reduces response timing errors and ensures compliance with CA144 digital timing standards.
- 25 13. The smart card (100) according to any of the preceding claims 10 - 12, wherein the antenna coil (104), the first coil (103), and the second coil (112) have turns defining a perimeter enclosing a surface area, and wherein the surface area enclosed by the antenna coil (104) encompasses the surface areas enclosed by the first coil (103) and the second coil (112),
- 30 wherein the surface areas enclosed by the first coil (103) and the second coil (112) are non-overlapping.

14. The smart card (100) according to claim 13, wherein the surface area of the antenna coil (104) corresponding to 2/3 of the total surface area of the smart card (100), with a tolerance of $\pm 10\%$,

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15. A method for manufacturing a smart card (100), comprising:

- a. designing a dual-interface antenna system as described in any of the preceding claims;
- b. Integrating the antenna system with a chip (31) selected from NXP P71 EMV 6-pin or
10 STM ST31P45054APB1 icoM PAY 6-pin;
- c. tuning the antenna system to achieve a resonant frequency of $13.8 \text{ MHz} \pm 0.5 \text{ MHz}$ and a quality factor (Q) between 34 and 40;
- 15 d. adjusting the wire diameter, pitch, and turns to optimize coupling and reduce energy dissipation;
- e. testing the smart card (100) for compliance with EMV standards, including CAB111 analog interference and CA144 digital timing.