SPACECODE

INTELLIGENT ASSET MANAGEMENT

Core Technology Overview

2011

Contents

1. Introduction

SpaceCode – Who we are and what do we do?

SpaceCode is a specialist award winning RFID technology company that provides Total Business Solutions comprising advanced software, innovative hardware, and comprehensive wireless workflow automation technologies.

Our PLEXUS™ and VORTEX™ product suite uses sophisticated powerful software with advanced RFID hardware to provide the leading system of its kind in the diamond and healthcare industries. The system constantly lets the client know where stock is and what the stock is doing. It provides accurate stock records and audits, and adds another layer of security which is always running in the background 24/7.

Since 2005 the PLEXUS™ and VORTEX™ RFID based concepts have been developed to a complete product solution. Physics have been optimized, IC techniques finalized, communications protocol advanced, system tested, and market needs established and confirmed. We have focused on, and developed extensive expertise in, tracking high value items in the healthcare & diamond industries where total reliability is required. Our customers include leading global companies in their fields including a Fortune Top 20 company in healthcare, and major players in the diamond industry including sightholders and laboratories.

2. SpaceCode Core Technology

This section provides an overview of the SPACECODE RFID core technology components that ensure differentiation of the solution. These include:

- **RFID Algorithm:**
  Novel deterministic algorithm ensuring 100% reliability
- **Chip Technology:**
  Original chip and tag technology achieving superior performance
- **RFID Frequency:**
  Optimal harnessing and selection of radio wave physics and frequencies

RFID systems are classified according to the *frequency* of the radio waves (keeping in mind that waves are sent by the station to the tags and that waves are sent by the tags to the station). In some parts of the world, some frequencies are not available for use for RFID systems because they are already allocated for other uses. The *range* (the typical maximum distance between the station and the tag beyond which effective communication between them no longer occurs) varies with a number of factors including the frequency, power, antenna type, and antenna orientation for each of the station and the tag, the type of coupling used, and governmental regulations concerning allowable signal strength. The *data transmission* rate also varies with the distance between the station and the tags, governmental regulations concerning allowable signal strength, amount of information on the tag etc. The *environment* in which the RFID system is to be used plays a key role in determining which, if any, type of RFID system can be used including if there is metal or organic material in the vicinity which may significantly interfere with the radio waves.

3.1 RFID Algorithm

Introduction

In RFID systems, the algorithm dictates how the reader interacts or interfaces with tags to be identified in a field.

Typically, there are a number of tags in a field each with a unique identification number or code. For example, if there are one thousand tags, for convenience the first tag could be assigned the number 1, the second tag could be assigned the number 2, the six hundredth tag could be assigned the number 600, … and the thousandth tag could be assigned the number 1000. In a computer, each such number or code may be thought of as actually requiring four digits or character, and the thousand tag numbers would be represented in decimal (base 10) notations as 0001, 0002, …0600 … 1000. A byte may be thought of as the amount of computer memory needed when using the normal storage protocol to store a single character. Thus, four bytes are needed for the decimal character string 0001 of the tags code. Each of the four positions of that string has a different rank, the position of highest rank corresponding to the leftmost of the four characters (and to the byte in which it is stored) and the position of lowest rank corresponding to the rightmost of the four characters (and to the byte in which it is stored). For example, in the character string 0001 (which in the example represents the decimal number 1) the character or digit is a 0 at the position of highest rank and the character or digit 1 is at the position of lowest rank. In modern computers, each byte typically comprises eight bits. Each bit is binary i.e. it can be turned *on* (equivalent to a '1' or 'yes') of *off* (equivalent to a '0' or 'no'). Those are the only two possible states of a bit. In other words, a bit holds, stores, indicates etc one of the two binary or base values 2 values (i.e. either '0' or '1'). There are 256 possible combinations of the eight binary bits of a byte (i.e. 0000000, 00000001, …….. 11111111). The number 256 is equal to the eighth power i.e. 2^8. Two bytes (each of eight bits) together provide sixteen bits, so two such bytes together can provide 2^{64} or 65,536 combination. There are various code systems for representing characters in the character set of interest. Computer memory is measure in kilobytes (1,024 bytes) megabytes (1,024 kilobytes) or gigabytes (1,024 megabytes)

A station typically repeatedly sends out a question to determine if any tag of interest to it is in range, which question in essence is "Is anyone there?" (i.e. "does any tag that can hear me have a code in which I am interested"). As soon as the station receives a "yes", it usually needs to determine who is there (i.e. what the code is). The station might as "Are you number 1" and if it received a "no" then "Are you number 3?" etc. In asking each question, characters or digits at all four positions or ranks of the code must be transmitted by the station to the tag. With that interrogation scheme, if the tag were number 125, the station would have to ask one hundred twenty five questions until it received a "yes". If the tag were number 1000, a thousand questions would be required to receive a "yes". Asking each tag the same set of one thousand questions is the brute force method and it is time consuming, requiring many messages to be sent and received. Furthermore, that method will fail to determine the identity of any tag that moves out of range before it sends a "yes" to the station. One way to speed up identification is to keep track of which tags have said "yes" and not ask any as yet unidentified tag if it has the same number as a tag already identified. There are numerous identification schemes.

An interrogation scheme could of course have the station merely ask "Who are you" and the tag reply with "I am number …). In this case, characters of all four positions or ranks of the code are transmitted by the station to the tag or by the tag to the station, and transmission of all four characters or digits (32 binary bits) takes time. Furthermore, an error in even a single bit in the number string (e.g. failing to send or detect a bit value or sending the wrong bit value) causes the code in the question sent by the station or in the answer sent by the tag to be wrong. There are schemes for trying to prevent, detect, and correct such errors.

Performance:

SPACECODE pioneered the development of octal/binary tree search methodology applied in the SPACECODE solutions, which is used for communication between the tag and reader in a deterministic algorithm.

The algorithm is formulated to achieve essential performance parameters including:

- guaranteed ability to ensure that all tags in the interrogation volume will be detected with 100% accuracy
- significantly reduced time needed to recognize (determine) the value in a given field e.g. an identification number

Together with phase alignment (described below) and other design features, the algorithm ensures that the RIFD system is able to increase its effective data transmission rate and at the same time guarantee complete accuracy throughout the reading volume.

The RFID system is a Reader Talk First. Tags are slaved to the base station; where data exchanges are first synchronized. This means all tags work on a particular clock or synchronization to assure that the complete tags answer is the sum of all individual answers.

Data is launched in AM modulation (Amplitude Shift Keying ASK 50%) of the magnetic field amplitude. The base station sequentially transmits the following commands to the tags:

- synchronization signal => tag selects the right phase on clock
- activation of all tags supplied by the antenna
- identify whether there are any tags present
- obtain tag UID information of all tags supplied
- lock individual tag after detection of its complete UID

Identification process:

Down stream communication between base station and tags

- base station antenna using magnetic field energy supplies all tags in the reading volume
- first command is sent to activate tags
- base station determines if any tags are present
- the algorithm uses binary tree search to manages sequential interrogation between the base station and tag UID's.
- according to the algorithm, the base station sends a specific request which is understood by tags with the corresponding UID.
- identified tags are informed that their answer was detected and received, and the process continues with unidentified tags. Tags not answering to the UID request enter an inhibited state

- once a complete UID is detected the base station sends a lock signal to block this tag. The process then continues until all tags are identified and locked.

Tag answer

- the tag answer is obtained from backscattering on the tag antenna using a transistor to switch frequency. This corresponds to a tag frequency response half that of the base station frequency emitted. The answering signal is sent in a precise time slot without any collision thus avoiding any kind of collision.

Deterministic algorithm

- the algorithm is described above. It is a tree branch approach digit after digit.

Synchronization and phase detection

classical anti-collision systems are not synchronized. Due to the multi and dual frequency SPACECODE technology, it is necessary to synchronize and to phase all tags. This approach guarantees 100% identification of all items present.

Technology:

The SPACECODE PLEXUS and VORTEX system achieves this as follows:

Messaging format:

The response from the tags have the advantage of only needing one single bit, rather than many bits which is required in many other systems to achieve the same performance as that of this system. Using messages of minimal length as well as a very small number of messages, the technology is able in a reduced period of time to recognize a number of tags (that can be as many as necessary)

Anti-collision format:

SPACECODE digital coding comprises the following key attributes:

- digits are decimal digits divided into groups, where the response of the tag occurs within a time window that is a function of the digits that the tag code carries
- determination of whether or not tags in the field have one of possible digits at a certain digit position or rank in their code
- prior to reaching a last digit position, determination of whether or not tags exist for a given digit, storing this digit, and then temporarily blocking all other tags, and returning for the next digit position
- at a last digit position, determining whether or not a tag exists for a given digit, storing this digit and reconstructing a tag code using said stored digits
- tags whose code has been reconstrued is permanently blocked, and the system then goes back to the first digit position or to a previous digit position that is not necessarily the first digit position

Thus the system has the advantage of not needing to detect and manage response collisions, which simplifies transmission constraints, reduces response time, and makes for simpler evaluation: there is no need to evaluate any CRC (cyclic redundant check) code or similar in the station (although these are part of the coding). The station and the tags thus have very simple logic circuits and are highly robust.

Response duration:
Compared to known systems using random periods between responses, and for which increasing the number of tags can lead to total polling time increasing exponentially, the SPACECODE system has the advantage that the total duration of evaluation is always substantially proportional to a number of tags; resulting in reduced identification duration required.

3.2 Chip Technology

Introduction:
The chip imparts the intelligence to an otherwise innate tag. Included in this intelligence is knowing when to respond to a reader command, what information to send to the reader, and how to behave during the identification process.

An important attribute of the tag is the power it requires to operate. Tags can either be tuned or detuned/non-tuned. A tuned (parallel resonance) circuit is used in receive mode to extract energy from the station's signal to power the tag. Maximum power is extracted by such a tag when the tags circuit operates at its preselected tuned (resonant) frequency (i.e. the circuit is designed to operate at that specific frequency; and the specific frequency is the only frequency that the tag is able to absorb its power from); however the ability to extract power falls off as the actual resonant frequency of the tag circuit varies from the preselected tuned frequency. Such variations can occur if inductive bodies are near the tag (metal cans, persons hands, other tags etc) rendering the respective tag useless, and is particularly important when items are in close proximity. To overcome this problem tags can be detuned.

A further important attribute of tags is the ability to identify many items within a particular field, as is the case with most applications. These responses coming from a plurality of tags within a distribution may interfere with each other. More precisely, it is possible for several tags to simultaneously reply to an interrogation or for them to send reply signals together over a given period. This is normal and has no effect on the operation of the system if the responses sent from the tags are identical and add together, or if the responses sent by the tags are in phase opposition and undergo subtractions; however it can and does happen that tags having symmetrical positions within the inductive field deliver identical responses in phase opposition, or separate responses having relative phases, whereby the resulting signal in the receive loop is not detectable. Canceling of responses from various tags can be partial or complete, and simultaneous responses originating from the tags lying end-to-end in the inductive field of the station may completely cancel each other out.

Performance:

Original chip technology employed by SPACECODE enables superior performance:

- effective, co-ordinated and 100% reliable identification of tags
- avoidance of collisions between signals from different tags
- increased speed of identification
- full function in close proximity, without interference by other tags or metal in the environment
- tags can function with minimal energy requirements

Technology:

A number of proprietary techniques are employed to achieve this:

Phasing

SPACECODE PLEXUS and VORTEX technology solves this problem and also allows faster polling of a large number of tags. In addition the system solves the problem of spatial orientation of tags making it possible to remotely and simultaneously poll tags, independent of their polling position in the polling field. Rather than detecting and avoiding collisions, the solution manages collisions by making it possible to provoke, and control, collisions; and also reduce total polling time.

The system achieves this by putting the tags into phases by sending from the station a phasing command to the tag. This phasing command enables the tags present in the area covered by the station to be brought into 'order' by supplying a time reference. This command can be of any desired type provided there is no danger of it being confused with another command or polling signal by the tag, and provided it does effectively provide a time reference able to be recognized by the tags. In all such circumstances, the step consisting in putting the tags into phase decreases the possibility of errors of interpretation by the station as follows:

- sending at least one polling signal from the station to the electronic tags
- receiving reply signals from the electronic tags in response to the polling signal, and bringing the tags into phase alignment before the reply signals are transmitted
- other: bringing tags into alignment involving the tags counting half waves of the phasing command and determining the polarity of a half wave of a predetermined rank, and the tags response being sent at a frequency that is a sub multiple of the stations send frequency

Non tuned tags

RIFD tags do not rely on a single 'resonant' or 'tuned' frequency to obtain their power. Rather, the tags use capacitance that can draw power from any available frequency, and not only the tuned frequency. Since RIFD tags do not use this parallel resonant circuit in receive mode (i.e. when receiving a signal from the station), they cannot be detuned and thus do not lose power when the resonant frequency is interfered with by RFID hostile environments such as can occur near metal cans, a persons hand, other tags, etc). The result is that the tags remain fully operational irrespective of the challenging conditions

Power efficiencies

- dual frequency: the tag's use a transmission frequency equal to exactly half the receiving frequency, thus allowing the tag to use less power; so less needs to be captured from the station waves received by the tag
- tag sensitivity: the tags use an inductor coil having more turns in combination with a voltage doubler. Because the inductor has more turns, the field from a station will induce a higher voltage across the inductor. The doubler then takes that induced voltage and increases it before being provided to the rest of the tag circuitry. That circuitry requires a minimum voltage for operation. Thus, the higher turn inductor and doubler allow the tag to operate farther from the station, that is, even if the tag is farther from the station and the field 'seen' by the tag is therefore weaker, the higher turn inductor and the doubler increase the possibility that the tag will still be able to operate; the sensitivity of the tag increased.
- other chip and tag design features are employed to reduce the amount of energy needed to power the system

Load modulation:

Strictly speaking, a signal in the classic sense is not transmitted by the RIFD tag to the station end thus there is no classic transmission circuitry in the tag. Rather, the SPACECODE system uses *load modulation.* When information is to be imparted by the RIFD tag to the station (e.g. when answering a question such as 'is anyone there?'), the operating characteristics of the tag circuitry are temporarily modified, which in turn changes the properties of the coupling between the tag and station, which change the station interprets as the information the tag is trying to impart to the station.

Messaging format

As described above, the tags interact via the algorithm in such a way as to require the tags sending back only a single beep (a bit) for a 'yes' rather than a string of bits to answer a query. It is easier and more efficient to accurately detect the presence or absence of a single beep than to accurately detect a string of beeps (bits) particularly in a difficult environment. This factor contributes to both a reduced power supply, as well as augmenting the ability to operate in close proximity.

3.3 Frequency

Introduction:

SPACECODE technology is applicable to all frequencies, and not restricted to any particular frequency. Our focus of activities however has been on development of i) low frequency (125kHz) - due to the reliability and advantage of the physics in dealing with challenging environments such as metallic products and environments; organic materials/products/environments (liquids, drugs, food), ability to deal with close proximity tags; uniform and reliable reading field; well defined fields; as well as other non physics rationale such as global availability.

Performance:

Given this frequency independent platform, the SPACECODE PLEXUS and VORTEX portfolio thus allows selection of the most appropriate frequency for applications, depending on the respective requirements.

Our low frequency dependant attributes are tabulated below:

Power	**Inductive coupling**
Global Availability	**Yes**
Interface algorithm	**Deterministic**
Reading distance	**0 – 2m, well defined (according to customer needs)**
Typical data rates	**100 kbps**
Detection rates	**20 - 50 tags/s,**
Interference by metal	**Minimal**
Absorption by organic materials	**None**
Susceptibility to item orientation	**None**
Susceptibility to item proximity	**None**
Field nature	**Intense, well defined, uniform**
Antenna size	**Customized**

Technology:

Even though our technology is applicable across all frequency ranges, SPACECODE has focussed on Low Frequency due to our ability to deliver a reliable, secure, and superior performance that achieves desired customer performance levels irrespective of the environment, proximity or unique challenges. The solution is provided to achieve 100% performance in challenging environments, achieve high identification speeds and read ranges, and be implemented seamlessly, company wide.

Frequency considerations are important for both reader to tag transmission, as well as tag to reader transmission. For SPACECODE, the frequencies selected can be different for each route depending on the respective customer requirements. Such permutations include receiving frequency (tag to station) being equal to half the transmitting frequency (station to tag); transmitting in HF and receiving in LF, etc. For example in the low frequency product line, transmission from the station to the tags is at 125 kHz range, and transmission from the tags to the station is at half that frequency, namely 62.5 khz. As a result the system has all the advantages of lower frequencies as compared to other higher frequencies and other solutions e.g. the ability to be used in the presence of water and other organic materials, metal etc.

A further example of the optimal use of frequencies is the stations antenna operating at a higher voltage resulting in the station sending a higher energy wave, something that is broadly speaking possible at lower frequencies but may not be possible at higher frequencies due to governmental regulations limiting the amount of energy that can be sent at higher frequencies.

3.4 Unique Advantages

The USP achieved as a result of the SPACECODE core technology includes:

- *100% reliability and accuracy*
  The use of a deterministic anti-collision algorithm, phasing, detuned tags, and the optimal radio waves providing a uniform field, guarantees that all powered tags are also detected tags.
- *Excellent performance in metal environments*
  The use of non resonant tags, correct frequency of radio waves, and phasing ensures optimal performance in metallic environments (e.g. other tags, metal, etc)
- *Outstanding ability to read tags in close proximity*
  Due to advanced phasing methodologies, absence of a resonant requirement, combined with customized tag-to-reader coding and modulation, and low frequency SpaceCode RIFD technology has full ability to read tags in close proximity
- *Excellent ability to read tags in multiple orientations*
  Proprietary and customised reader design allows SpaceCode RIFD products to read products in multiple and/or random orientations
- *Not affected by organic material such as liquids and food*
  The physics of appropriately selected RFID frequencies, combined with phasing and power efficiencies results in full functioning and minimal absorption by metal and organic materials including liquids.
- *Well defined read range*
  RFID field can be very precisely defined so as not to pick up any RFID tags present close to the read range and thus generating false positive reads and inaccuracy
- *Total ability to identify items inside large volumes*
  The correct use of RFID frequencies together with anti-collision, phasing, and messaging formats ensures identification of items inside large volumes
- *Mixed and multi item reading*
  The combination of the SPACECODE algorithm, antenna design and non resonant tags allows the relatively unique ability to identify all items in heterogeneous stacking and storage

3.5 Summary

To summarise, the combination of the three core technology components i.e. algorithm, chip, and frequency results in specific advantages for the RFID system including: collision of signals from the tag are obviated; tags cannot be detuned because they do not have tuned circuits; metal (e.g. a millimeter in thickness, which is thicker than the thickness of a typical metal product container) has little or no effect whether from detuning, absorption, reflection, or other field distortion ; there is little or no absorption by liquids, drugs and other organic materials; the field is uniform regardless of presence in the field of tagged objects with different absorption characteristics and orientations, and the close proximity of other tags has no adverse effects.

The advanced approaches include:

- messaging format
- anti-collision format
- response duration
- phasing
- non tuned tags
- power efficiencies
- load modulation
- frequency selection
- etc, …

The invention is broadly applicable and can be used at any frequency, with active or passive tags, with various types of coupling (e.g. near field, far field etc), resulting in significant advantages compared to a solution not using the invention.

As described above, the RFID system has been developed for multi-item identification in challenging environments such as those for diamonds, healthcare etc. The combination of the algorithm and the tags warrant a very high level of accuracy. A key challenge is the level of disturbance created by numerous tags - up to 10,000 - that may need to be detected at any one time (major limitation of other anti-collision systems), the detuning created by tags in very close proximity, and the detuning caused by the presence of substantial metal (stent material as well as aluminium packaging) in the environment. Standard systems are usually limited in terms of the total tag population, interference by metal, and tag proximity.

Requirements unique to the diamond and healthcare industries include numerous variables able to change tag characteristics including:

- items are very close to each other

- metal products and environments
- organic products and environments
- unknown number of tags
- tags may be in random orientation

The first challenge is solved using a deterministic algorithm and protocol ensuring 100% exchange of data between the base station and tags. The second and third challenges are solved using non-tuned RFID chips with customized tag antenna. Random orientation of tags in either "head" or "tail" placement may result in additive tag answers in opposite phases or orientations canceling out each other leading to 'no response vector' - thus no signal being detected. Synchronization and phase control solves this aspect.

3. Products

PLEXUS™ SmartDevices

Our PLEXUS SmartDevices continuously and automatically scan thousands of diamond parcels or jewellery items with complete reliability and with no manual intervention. Stock is counted, identified, and located automatically up to 240 times per day or more. This significantly increases the level of accuracy, control, monitoring, and security in real time. Delays, inefficiencies, bottlenecks, and errors associated with physical counts and manual locating processes are eliminated.

Plexus SmartDevices

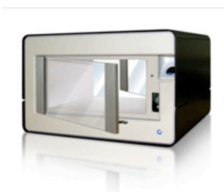
SmartBox

The **SmartBox** is finger print accessed and can be placed on desk tops or inside safes. It can store about 600 parcel papers and can automatically read its content every six minutes.

SmartPrinter

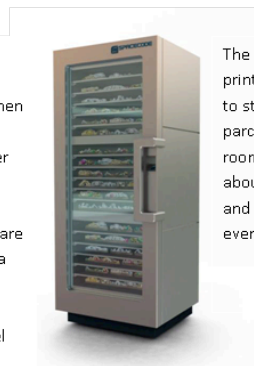
The **SmartPrinter** is ideally used to read, print and link RFID code into customer database and can print the Parcel Tag.

SmartSAS



The **SmartSAS** has finger print access on both sides. This is extremely useful when handing over stones, from one department to another or from a manager to a worker. This will eliminate the memo process. There are two versions; ***Large***, with a capacity of 1500 parcel papers & ***Small*** with a capacity of about 50 parcel papers.

SmartCabinet



The **SmartCabinet** is finger print accessed and is used to store large quantities of parcel papers inside strong rooms or safes. It can store about 9000 parcel papers and can read its content every six minutes.

SmartBoard

The **SmartBoard** is a quick stock reader and can handle up to 1000 parcel papers at one time. Can also be used at a station for inventory control for larger number of parcel papers

SmartStation

The **SmartStation** is a customised smaller version of the **SmartBoard** that can be used to monitor small quantities of about 20 parcel papers and can be utilised at a workers station.

PLEXUS™ is unique in its ability to deal with the very specific and demands of the diamond industry, incl:

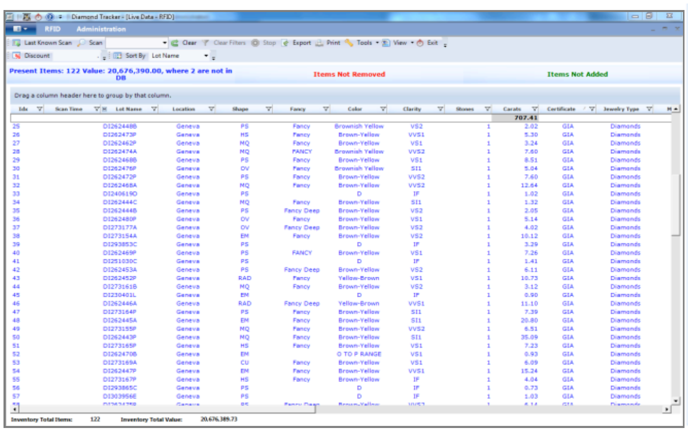
- ‘000’s of diamond parcels need to be read simultaneously
- Parcels can be stacked in close proximity AND in any orientation
- Total accuracy is essential
- Metal safes are commonplace
- Utmost security mandatory
- Sophisticated software to make the data meaningful

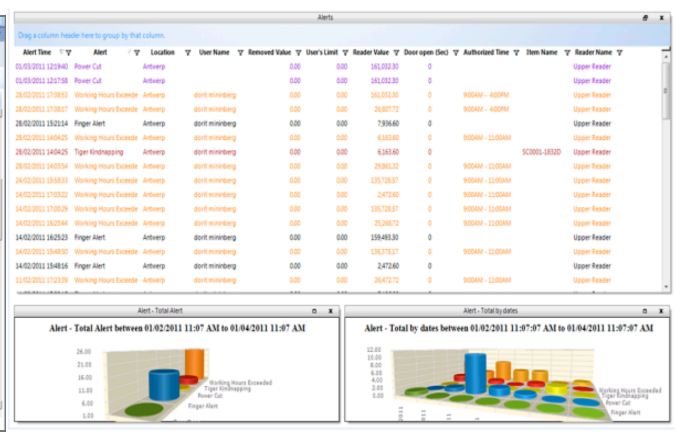
PLEXUS™ Diamond SmartTracker Software

The Diamond SmartTracker software developed specifically for the diamond industry links and analyses all the data in real time, offering incredible visibility, traceability, control and analytics. Stones, movements, and transactions are monitored and analysed in real time. Alerts are triggered when unusual or prohibited activity occurs such as when a door is left open too long, removal of exceptionally valuable items and removal of goods beyond the permitted value limit of a user. The software can generate real time activity reports and data in regard to any stock movement.

The software automatically and simultaneously acquires rich data sets from all SmartDevices thus tracking the asset movement and generating business intelligence and reports such as:

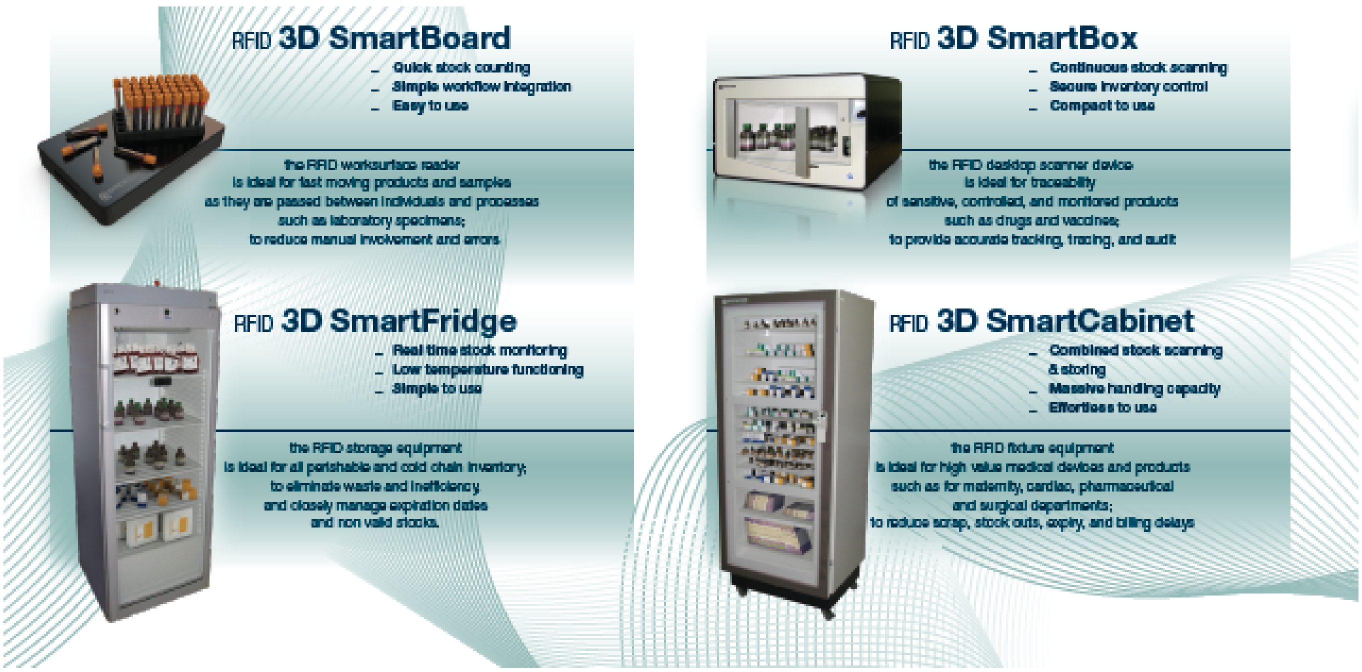
- total inventory and its value
- stock location and movements anywhere in the world in real time, who accessed it, and when
- key employees' activity and transactions on demand
- stock situation in a particular global office
- movements of a particular stone
- security alerts for any breach of rules





VORTEX™ SmartDevices

As a revolutionary automation and tracking platform, VORTEX™ supports and enhances the unique and often complex workflows used within healthcare settings. Capabilities embedded into the platform include the visibility, control, tracking, monitoring, security and management of clinical, logistical, and commercial processes for utilization of pharmaceuticals, supplies, devices, instruments, equipment, and more.



VORTEX™ is unique in its ability to deal with the very specific and demanding challenges of the healthcare industry, including:

- Total reliability mandatory
- High metallic content of products and environments
- High organic content of products and environments
- Large amounts of items, stored in any orientation
- Well defined read ranges
- No interference with hospital systems
- Advanced software to provide global business intelligence

VORTEX™ Healthcare Software

SpaceCode's VORTEX™ software, the engine behind our Total Business Solution, is implemented together with any and all of our smartcabinets. Together, our hardware and software combine to provide a system that offers the highest level of automation, visibility, and secure stock management while at the same time helping to reduce time-consuming, labour intensive, error-prone manual processes and inefficiencies. The system helps…

- clinicians and administrators to improve workflow efficiency
- hospitals to improve inventory control and tracking
- suppliers to improve availability of supplies and reduce scrap and stock outs
- patients to enjoy better quality of care
- supply chain to manage high worth inventory automatically and with minimum manual input
- regulators to have comprehensive audit trials, reports, and alerts related to product movement
- clinical staff to increase productivity and eliminate burdensome and inefficient manual processes
- logistics staff to better manage expiration dates and recalls, and reduce high-value inventory diversion