

SYSTEMS, METHODS, AND APPARATUS FOR CONVERTING AND COMMISSIONING WIRELESS SENSORS

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BACKGROUND

5 The field of the present invention relates to manufacturing and deployment of RFID (radio frequency identification) and wireless sensors. Large-scale adoption and deployment of RFID depends on low cost transponders (also referred to as tags, inlets, or inlays) and efficient means to commission them for use. Such deployments mark a starting point for widespread adoption of a broader class of devices called wireless tags
10 that include RFID transponders, RFID tags, RFID inlays, and wireless sensors. RFID tags are simple wireless tags that report object identity. Wireless sensors can report identity, or some combination of additional information such as temperature, moisture, sunlight, seismic activity, biological, chemical or nuclear materials, specific molecules, shock, vibration, location, or other environmental details. Wireless sensors and RFID tags are
15 distributed nodes of computing networks that are interconnected by wired and wireless interfaces. Wireless sensors may be made using silicon circuits, polymer circuits, crystals, or Surface Acoustic Wave (SAW) materials to affect radio frequency or other signaling methods.

SUMMARY OF THE INVENTION

20 The present invention is directed to improved systems and methods for converting and commissioning wireless tags, RFID tags, and wireless sensors. The present inventor has recognized that significant benefits can be realized from using wireless sensors that are not directly part of a demand printed label. Among them include elimination of facestock and silicone-based release liner, improved deployment yield and
25 efficiency, and greater mobility for the tag commissioning process.

DRAWING

Fig. 1 is a top view of a UHF RFID inlay with a single dipole antenna structure according to one embodiment of the present invention.

Fig. 2 is a cross-sectional view of a possible arrangement of layers of materials used to create a taped inlay according to one embodiment of the present invention.

Fig. 3 is a cross-sectional view of a possible ESD resistant inlay constructed from adhesive tape according to one embodiment of the present invention.

Fig. 4 is a cross-sectional view of an ESD resistant inlay constructed from adhesive tape according to another embodiment of the present invention.

Fig. 5 is a cross-sectional view of an ESD resistant inlay constructed from adhesive tape according to a possible embodiment of the present invention.

Fig. 6 is a cross-sectional view of an ESD resistant inlay adhered to a conveyance layer according to one embodiment of the present invention.

Fig. 7 is a top view of converted inlays adhered to a conveyance mesh according to one embodiment of the present invention.

Fig. 8 is a flowchart of a method of inlay conversion according to one embodiment of the present invention.

Fig. 9 is flow chart illustrating a method of tagging cartons using a mobile applicator according to one embodiment of the present invention.

Fig. 10 is a top view of a possible adhesive tape and illustrates possible regions of adhesive on the tape according to one embodiment of the present invention.

Fig. 11 is a diagrammatic representation of an inlay attached to encoded adhesive tape according to one embodiment of the present invention.

Fig. 12 is a diagrammatic representation of an automated tag encoding system according to one embodiment of the present invention.

Fig. 13 is a cross-sectional side view of a handheld RFID tag applicator according to one embodiment of the present invention.

Fig. 14 is a diagrammatic representation of a base unit for a mobile applicator and cartridges according to one possible embodiment of the present invention.

5 Fig. 15 is a diagrammatic representation of a machine to selectively attach RFID transponders to adhesive tape according to one embodiment of the present invention.

Fig. 16 is a diagrammatic representation of RFID transponders attached to adhesive tape according to one embodiment of the present invention.

10 Fig. 17 is a diagrammatic representation of a mechanism to attach RFID tags from a roll of RFID Tape according to one embodiment of the present invention.

Fig. 18 is a diagrammatic representation of a mechanism to attach tags from an RFID magazine according to one embodiment of the present invention.

Fig. 19 is a diagrammatic representation of a mechanism to attach RFID tags from a mesh roll according to one embodiment of the present invention.

15 Fig. 20 is a diagrammatic representation of a mechanism to attach RFID tags from a mesh roll according to another embodiment of the present invention.

Fig. 21 is a diagrammatic representation of a mechanism to attach RFID tags from release liner according to an alternate embodiment of the present invention.

DESCRIPTION OF THE INVENTION

20 Possible embodiments will now be described with reference to the drawings and those skilled in the art will understand that alternative configurations and combinations of components may be substituted without subtracting from the invention. Also, in some figures certain components are omitted to more clearly illustrate the invention.

25 Certain preferred embodiments are directed to methods for tagging transportation containers. In most instances, the tagging methods will be described with

reference to containers such as loaded pallets, paperboard boxes, corrugated cartons, pharmaceutical containers, and conveyable cases, but other containers may be used by these methods. Certain preferred embodiments relate to commercial corrugated shipping cartons, RFID or wireless sensors, tagged pallet-loads of shrink-wrapped cases, consumer goods packaging, consumer goods, or to other various methods of tagging objects. Corrugated cases are typically constructed with an inner and an outer linerboard, between which a corrugated medium is glued.

This document refers to transponders interchangeably with the term tags. A transponder is generally fabricated from an inlay and additional materials that may include a substrate material. An inlay is a thin segment of plastic such as PET that carries an antenna structure bonded to at least one RFID chip or other type of wireless sensor device. Though many of the embodiments herein are described with reference to various inlays, transponders and RFID tags, the methods and devices described herein may be applicable to other types of wireless tags, transponders, or wireless sensors. Wireless tags are a broad class of wireless devices that transmit and receive information wirelessly, have a unique identity, and optionally sense one or more attributes within its environment. Wireless tags include RFID transponders, RFID tags, RFID inlays, and wireless sensors. Wireless sensors are devices that report identity, and or some combination of additional information such as temperature, moisture, sunlight, seismic activity, biological, chemical or nuclear materials, specific molecules, shock, vibration, location, or other environmental parameters. Wireless tags are distributed nodes of computing networks that are interconnected by wired and wireless interfaces. Wireless tags may be made using silicon circuits, polymer circuits, optical modulation indicia, an encoded quartz crystal diode, or Surface Acoustic Wave (SAW) materials to affect radio frequency or other signaling methods. Wireless tags preferably communicate wirelessly to an interrogator, and certain preferred embodiments of wireless tags communicate on a peer-to-peer basis. Communication methods may include narrow band, wide band, ultra wide band, or other means of radio or signal propagation methods.

There are certain preferred transponder embodiments that include RFID tags or wireless sensors as a component. Other preferred tag embodiments include RFID inlays as a component.

5 This disclosure refers to objects that are associated with RFID tags and are referred to by the data within RFID tag memories. Such objects may include, but are not limited to: manufactured sub-assemblies, pharmaceuticals, medical supplies, electronic products or components, consumer goods, manufactured goods, waste containers, shipping containers, and industrial equipment.

Preferred categories of tag attachment include:

- 10 1) Conveyor line or other high-speed machinery with automated tag printing, encoding, and attachment.
- 2) Hand attachment of tags (a method that is referred to as "slap and ship").
- 3) And now, a new category of mobile tag applicators.

15 UHF is an acronym for Ultra High Frequency. UHF refers to the band of the electromagnetic spectrum that, for RFID applications, spans from about 860MHz to 960MHz. RFID tags responsive to this frequency band generally have some form of one or more dipoles in their antenna structure.

20 Ultra Wide Band (UWB) is a method of transmitting radio pulses across a very wide spectrum of frequencies that span several gigahertz of bandwidth. Modulation techniques include the use of Orthogonal Frequency Division Multiplexing (OFDM) to derive superior data encoding and data recovery from low power radio signals. OFDM and UWB provide a robust radio link in RF noisy or multi-path environments and improved performance through and around RF absorbing or reflecting materials compared to narrowband, spread spectrum, or frequency-hopping radio systems. UWB wireless sensors

25 are preferably reused according to certain preferred methods disclosed herein. UWB wireless sensors may be combined with narrowband, spread spectrum, or frequency-hopping inlays or wireless sensors as disclosed herein.

Passive RFID refers to tags without batteries. Active tags have batteries and have been historically been considerably more expensive than passive RFID tags. Passive RFID tags backscatter incident RF energy. Active RFID tags often have their own transmitter and generally do not use backscatter for the return link. A battery assist tag is a sort of hybrid that uses a battery to power the RFID chip and a backscatter return link to the interrogator.

The RFID inlays are fundamentally an RFID chip bonded to an antenna, formed on a substrate that is often plastic such as Mylar®, polyester, or PET. Antennae may be formed by etching copper from the substrate, but an alternate method is to print multiple layers of conductive ink onto a substrate.

Particularly highlighted in Figures 1 and 2, inlay 10 and other designs may also be optionally combined with a shield and/or a dielectric spacer behind the antenna to create a tag that performs well over a broad range of packaging conditions. A robust design would preferably also include features to protect the tag from damage.

Inlay 10 may alternatively be replaced by a used or recycled wireless tag. In certain preferred embodiments, RFID tags are recovered from waste streams for reconditioning, reprogramming, and reuse.

Additional transponder layers have been developed by Power Paper Ltd. Power Paper has developed technology that enables the mass production of low-cost, thin and flexible energy cells capable of powering a host of applications. Power Paper's core technology is an innovative process that enables the printing of caseless, thin, flexible and environment-friendly energy cells on a polymer film substrate, by means of a simple mass-printing technology and proprietary inks. Power Paper cells are composed of two non-toxic, widely-available commodities: zinc and manganese dioxide. The cathode and anode layers are fabricated from proprietary ink-like materials that can be printed onto virtually any substrate, including specialty papers. The cathode and anode are produced as different mixes of ink, so that the combination of the two creates a 1.5-volt battery that is thin and flexible. Unlike conventional batteries, the Company's power source does

not require casing. UHF-based battery-assisted backscatter tags can operate at about twice the range of a passive RFID tag. UHF battery-assist RFID tags and battery-powered UWB wireless sensors represent a class of devices that warrant reuse according to preferred methods disclosed herein.

- 5 Paper facestock may be the lowest cost RFID tag structure, but it is the least environmentally resistant. UV-resistant plastic and plastic foam facestocks generally provide the best survivability in outdoor and rough service environments, and also tend to provide the best protection for the tag.

- 10 Materials such as adhesive-backed tape used on or around a wireless tag preferably will not absorb radio frequencies within the range of frequencies used by the transponder, tag, sensor, or inlay. The tape materials must also never cause corrosion of the inlay or in any way hamper its functionality.

- 15 A layer of clear, translucent, or opaque adhesive-backed film or tape is required to attach the panel and the transponder, wireless sensor, or inlay to the box, bottle, jug, transport container, or shrink wrap. The tape may be any thin, low cost, flexible material with a self adhesive backing. A conventional packing tape is representative of the material that may be used for this method of attachment. The tape may be formed into various shapes to achieve the requirements of this method. Certain preferred
20 embodiments may use tape that is preprinted with certain logos, marks, symbols, bar codes, colors, and designs.

- 25 Certain preferred embodiments use the same constituent materials as packing tape and is manufactured specifically for applicators 130, 170, 180, 190, or 200. Packing tape can be single-coated pressure sensitive adhesive tape or alternatively media constructed with multiple layers including a backing layer. Certain preferred backing layers are constructed on a plastic film having one or more layers. Certain preferred backing layers are made from plastic resins such as polypropylene (PP), polyethylene (PE), or copolymers of PP, PE, PVC, polyesters, or vinyl acetates. Certain preferred
 embodiments of PP are monoaxially-oriented polypropylene (MOPP), biaxially-oriented

polypropylene (BOPP), or sequentially biaxially-oriented polypropylene (SBOPP). Certain preferred backing layers are biodegradable. Certain preferred backing layers are coated with a pressure sensitive adhesive on one side and a low adhesion release coating on the other side to reduce the amount of power required for the applicator to unroll the tape for application.

Referring to Fig. 8, a preferred method is disclosed for converting RFID inlays or wireless sensor components into application-ready wireless tags. This process uses adhesive-backed packing tape or some similar material to adhere inlays to transport containers such as corrugated cartons. Certain preferred embodiments of tape include pre-printed text, symbols, graphics, and background. Certain preferred embodiments contain a series of preprinted bar codes.

Certain preferred embodiments of this process use mesh or netting as a transport media for converted tags. In certain preferred embodiments, mesh or netting is made of plastic such as nylon, polypropylene, polyethylene, HDPE, Teflon, or other resins. In certain other preferred embodiments, mesh or netting is fabricated from metal or carbon impregnated plastic to provide a conductive path to bleed electric charge away from points of accumulation. Certain preferred embodiments within all parts of the conversion and tag application process do not allow significant amounts of electric charge to accumulate to voltages in excess of the ESD rating of the tags. In certain preferred embodiments, there are several conductive paths to bleed charge away to a safe location away from ESD-sensitive tags. The first step 81 is to prepare the adhesive tape and mesh for the conversion process.

Certain preferred embodiments for step 81 include machines to cut large rolls of mesh or net into numerous small rolls with the desired width, length, and core diameter. Certain preferred rolls of stock mesh or net are 14 feet wide and 5000 feet long, rolled onto a core. For certain preferred embodiments, including the mobile applicator illustrated in Figs. 18-20, the mesh or net width is about the length of a simple UHF dipole inlay 10 as shown in Fig. 1. For certain preferred embodiments, this is a width of

about 4 inches. The preferred length of mesh or net is dependent on many factors including the target cost per tag of the cartridge and all of its components. This is an important consideration, even if the cartridge is intended to be reconditioned and reused. Other important factors that determine the length of mesh or net is the target size and weight of the cartridge and/or the mobile applicator. As the length of mesh or net increase, so do the diameters of both the empty and the full rolls of converted tags and the housing required to contain them.

The machine that converts large mesh rolls into smaller ones in step 81 is in certain preferred embodiments, a separate stand alone industrial machine. In certain other preferred embodiments, that function is part of an integrated machine.

Preparation of adhesive-backed tape in step 81 for certain preferred embodiments includes cuts along two major axes: length and width. Cuts along the length of tape are performed in certain preferred embodiments for two reasons: ESD hardening and tag size reduction. Referring to Fig. 10, there are preferably four zones across the width of an adhesive-backed tape such as packing tape. In certain preferred embodiments, all four zones are of approximately the same width. In certain preferred embodiments, zone 101 is reserved for an RFID inlay to be adhered preferably according to a construction method illustrated in Fig. 2-5. Zone 100 and zone 102 are preferably reserved for attachment to a transport container such as any wall or flap of a corrugate carton. Zone 103 is preferably removed from the other three zones to create an encapsulation layer 35, 45, or 55 with corresponding adhesive layer 34, 44, or 54. In certain preferred tape conversion machines, zone 103 is cut from adhesive-backed tape as it spools off of a source reel or roll. In certain preferred embodiments, source rolls are 2 inches wide or about 48mm wide, and one quarter of that width is removed to provide material for cap layer 35, 45, or 55 with their corresponding adhesive layers 34, 44, and 54, and inverted 180 degrees in preparation for attachment to create an ESD resistant tag according to certain preferred constructions including those illustrated in Figs. 3-5.

In step 82 each inlay is preferably interrogated. In certain preferred embodiments, an interrogator and an antenna or a near field coupler are used to read the transponder, wireless sensor, tag or inlay, preferably monitoring parameters such as activation energy, backscatter signal strength, sensor performance, and other indications of the quality of the tag. Any tag or sensor that does not meet certain minimum performance criteria is preferably discarded. Good tags or sensors are then preferably programmed with new information relating to the object that it is being associated with. That information is stored in non-volatile memory within the RFID inlay. Tag programming may also occur during, after, or between the second step 82 and third step 83. In certain preferred embodiments inlays that fail to perform to adequate levels of performance are immediately separated from the tag conversion process.

The third step 83 is preferably to apply and encapsulate good inlays preferably in the adhesive tape layer zone 101 shown in Fig 10. Certain preferred packing tapes are constructed from pressure sensitive acrylic adhesive and backed by a substrate layer of bi-axially oriented polypropylene film. Certain preferred packing tapes can provide up to about 25,000 volts of ESD resistance when properly applied in about 0.002-inch thick layers of encapsulation. Certain packing tapes are available in thicknesses less than that, and in certain preferred embodiments are about 0.001-inches thick. In certain preferred embodiments, two layers of tape are layered on top of each other to provide higher ESD voltage resistance ratings. In certain other preferred embodiments, the inlay substrate also contributes additional ESD resistance in certain preferred configurations.

Certain preferred embodiments do not include an encapsulation layer of additional tape; such a construction is illustrated in Fig 2. In such a construction, adhesive layer 21 preferably bonds with antenna layer 22 and integrated circuit 26. Inlay substrate layer 23 and tape substrate layer 20 preferably provide resistance against electrostatic discharge into antenna layer 22 or chip 26.

Certain preferred constructions for converted tags have one or more additional layers of high dielectric material such as packing tape that encapsulate or substantially

cover the inlay. Certain preferred embodiments use material from zone 103 as self-adhesive dielectric material for layers 35, 45, or 55. Certain preferred embodiments for such a construction are illustrated in Figs 3-5. In the preferred embodiment shown in Fig 3, chip 36 and antenna 32 are preferably bonded to adhesive layer 31 and protected from a discharge path through tape substrate 30 by its particular thickness of dielectric material. In general, the thicker the dielectric layer, the higher the voltage must be to initiate a flow of electrons through a dielectric layer, which preferably results in higher ESD voltage ratings for the resulting tag. Second dielectric layer 35 is preferably bonded to inlay substrate 33 by adhesive layer 34, preferably such that a low voltage discharge path is non existent around the layers of tape substrates 30 and 35.

Certain preferred inlay conversion constructions use inlay substrate 43 as a second layer of ESD resistance against a discharge path through outward facing tape layer 40 and adhesive layer 41. Such a preferred construction is illustrated in Fig 4, and preferably protects antenna 42 and chip 46 from electrostatic discharge originating from any direction. Encapsulation tape layer 45 is bonded to antenna 42 and chip 46 by adhesive layer 44. Like substrate 35, tape substrate 45 provides no adhesive bond to the transport container when the tag is commissioned, and therefore depends on zones 100 and 102 for attachment to the desired object to be transported and tracked by the wireless sensor.

Figure 5 illustrates another preferred embodiment for multiple layers of ESD resistance where an outer layer substrate 50 is bonded to an inner substrate 55 by an adhesive layer 51. Adhesive layer 54 then bonds with chip 56 and antenna 52. Inlay substrate 53 is inward facing, preferably pressed against a transport container when the tag is commissioned.

Preferably the adhesives create strong and permanent bonds between tapes and inlay layers over a certain practical range of operating temperatures.

The fourth step 84 is preferably to apply the converted tag to an interposing transport media. Such media preferably have properties that preserve the tackiness of

exposed adhesive in zones 100 and 102. Pressure sensitive adhesives adhere to most surfaces with very slight pressure and they retain their tackiness above their melting point of about -65 to -90 degrees centigrade. Certain prior art uses silicone-based release liner to transport and preserve pressure sensitive adhesive tags and labels.

- 5 Certain preferred embodiments use air pockets bounded by regions having tensile strength such as fibers. Certain preferred fibers are made of plastic or metal. Certain plastic resins have a low surface energy, and preferably prevent strong adhesive bonds from forming with them. In certain preferred embodiments, fibers are bound together to form a mesh or net. Certain preferred mesh or net constructions offer a means of
- 10 handling converted tags without allowing a substantial percentage of the available adhesive to make contact with any other solids until the tag is commissioned.

There are two principal advantages of net or mesh over prior art silicone release liners: less weight and increased recyclability. A comparison of the weight of a net with a higher percentage of open area to a typical sheet of release liner reveals that the netting

15 is lighter for any given section of comparable size. Environmental problems of disposal of release liner are well known, especially in Europe. Mesh or netting that is comprised of recyclable resins is preferably recovered after each use so that the mesh or net can be either reused or recycled for its constituent materials.

Figs. 6 and 7 illustrate preferred embodiments for attachment of converted tags

20 60, 71 and 73 onto a transport layer of mesh or net 67 or 70. Preferred inlay conversion construction of Fig. 4 is shown in Fig. 6 adhered to mesh or net 67. Adhesive zones 100 and 102 of tape 60 make contact with the fibers of mesh or net 67, leaving a substantial percentage of the adhesive not in contact with anything. Within the shelf life of the adhesive, the tackiness preferably remains at or near full potential, ready for

25 commissioning. In certain preferred embodiments, and in step 85, some small percentage of adhesive layers 61 makes contact through the centers of holes in mesh 67 with the backs of layers 60 on the layers below that are rolled onto a spool immediately before the present layer. In certain preferred embodiments, the thickness and hole sizes of mesh

67 are optimized to provide a desired percentage of adhesive 61 in contact with both the fibers of mesh 67 and tape backing 60 for certain bend radii of certain spools. In certain preferred embodiments, only a small amount of energy is required to unroll the spool during tag commissioning, yet there exists a certain amount of adhesion to prevent a converted spool from unraveling.

In step 85, converted tags are preferably wound onto a spool with the interposing media described in step 84. The core diameter, number, of tags, layer thickness, and outer diameter are all preferably optimized for efficient, economical, and convenient deployment in tag commissioning processes disclosed herein. Finished spools are preferably packaged in a manner to prevent ESD damage. Certain preferred enclosures include anti-static bags, foil-lined cartons, metal plated cartridges, and carbon-impregnated plastic enclosures. Certain preferred enclosures are reusable. Certain preferred enclosures of application-ready rolls or Z-folded tags having low energy interposing transport media mate directly with certain tag applicators such as applicator 180, 190, or 200.

Referring to Fig. 9, a novel preferred method is disclosed for applying RFID tags to transport containers such as corrugated cartons or shrink-wrapped cases on a shipping pallet. Prior art does not provide solutions for manually operated automatic encoding and attachment to a carton.

The first step 91 is to select a carton to attach a wireless tag onto. Certain preferred methods include manual selection and verification processes involving manual handling, visual sighting, and scanning bar codes. A tag encoding scheme is preferably ready in advance and preferably synchronized with a pick list, customer purchase order, advanced shipping notice, and other such records to assure that goods are properly moved and accounted for.

In preparation for step 92, an operator is to be holding a preferred embodiment of a mobile tag applicator, such as one illustrated in Figs. 13, 17, 18, 19, 20, or 21. In this step, an operator preferably holds an applicator against the face of a transport container

such as a corrugated carton. The location and orientation of the applicator is preferably matched to the tagging requirements for that particular carton, if any. In certain preferred embodiments, the operator is informed of the proper location and orientation of the tag that is to be applied. In certain preferred embodiments, the preferred location and orientation information is conveyed visually or aurally. In certain preferred
5 embodiments, visual information is received by the operator through a screen or display. In certain preferred embodiments, a display is integrated into the applicator. In certain other preferred embodiments, visual information is conveyed through the use of guides and other physical indicators. In certain preferred embodiments, physical indicators are
10 attached to the applicator and extend from its body in a direction and manner so as to assist the operator in the positioning of the tag onto the carton. In certain preferred embodiments, tags are applied to the interior of a carton, preferably before it is sealed.

Step 92 also preferably performs certain preparations for successful execution of step 93, including the verification of available tags and commissioning data. In certain
15 preferred embodiments, applicator 130, 170, 180, 190, 200, or 210 tests the next tag and determines if it is operating within certain predefined specifications. Certain preferred embodiments read the transponder, wireless sensor, or tag, preferably monitoring parameters such as activation energy, backscatter signal strength, sensor performance, and other indications of the quality of the tag. If the applicator determines that the next
20 tag is not likely to result in a successful tag deployment due to either physical or electronic deficiencies or abnormalities, then the operator is preferably informed. In certain preferred embodiments, a bad tag is discarded when an operator pulls a trigger under an operator-acknowledged tag failure condition and the bad tag is preferably not released into a supply chain or other intended use. Instead, all bad tags are preferably
25 collected in such a manner to allow for subsequent problem diagnosis.

The second step 92 also preferably includes processes to read or determine by dead reckoning the information encoded into certain preprinted optically encoded symbols on the outward facing non-adhesive surface of the adhesive tape. In certain

preferred embodiments the adhesive tape is printed with information. In certain preferred
embodiments the printed information is a machine readable symbol such as a bar code
symbol. In certain preferred embodiments, one or more machine readable symbols are
read when the tape is prepared for use in an automated applicator or alternatively during
5 the inlay conversion process and conveyed to an applicator through other data storage
means, such as an RFID tag. Certain preferred information encoding methods use either
one-dimensional or two-dimensional bar codes. In certain preferred embodiments a linear
imager 368 is used to read either linear 113 or two-dimensional 114 bar codes as the
tape 110 or 367 is being unrolled from a spool. Certain preferred encoding schemes
10 preprint machine-readable symbols at regular intervals along the length of a roll of
adhesive tape. In certain preferred embodiments the spacing of the preprinted symbols is
at an interval of one half of the nominal length of each section of adhesive tape. In
certain preferred embodiments, the encoded information is used as a reference to one or
more data storage locations. In certain preferred embodiments, the data storage
15 locations are accessible through a computer network. In certain preferred embodiments,
the encoded information is a series of sequential numbers. Information relating to data
stored in the RFID tag or inlay is preferably stored in certain data storage locations that
are referenced by one or more of the preprinted symbols. In certain preferred
embodiments, more than one machine readable symbols can be read from the surface of
20 a segment of tape. In certain preferred embodiments, more than one machine readable
symbol is used as a reference to the same or closely related data records of information
stored in the RFID tag or inlay, and either can be successfully used to access stored data.

In step 93, a Trigger Event occurs preferably resulting in the attachment and
verification of an encoded tag to a transport container. In certain preferred
25 embodiments, an operator preferably pulls a trigger to commission a tag. Tag
commissioning preferably involves attachment, encoding, and verification. In certain
preferred modes of preconfigured operation of certain preferred applicator embodiments,
a Trigger Event occurs when certain sensors detect certain preprogrammed conditions

resulting in the commissioning of a tag. Details of certain preferred Trigger Events and sensor functions are described herein, including one or more modes wherein the operator-induced action of step 92 whereby an applicator with sensor suite 178, 188, 198, 208, or 218 is placed against a carton face, causing step 93 to occur immediately after step 5 92 is completed.

Good tags or sensors are preferably programmed with new information relating to the object that it is being associated with. That information is stored in non-volatile memory within the RFID inlay. Tag programming may also occur during, after, or between the second step 92 and third step 93. Wireless sensors, transponders, or wireless tags 10 that are capable of collecting other information such as location, temperature, barometric pressure, humidity, nuclear radiation, biological information, interrogator interactions, or other measurable conditions or events are preferably activated at this time if they require such an action.

Figure 10 is a diagrammatic view of an RFID tag, inlay, transponder, or wireless 15 sensor 111 that is attached to a segment of adhesive tape 110. Inlay 111 is secured under adhesive tape 110 preferably using any of the preferred constructions shown in Figs. 3-5. In certain preferred embodiments, machine readable symbol 113 and/or symbol 114 are printed on the tape. In certain preferred embodiments the machine readable symbols are unique preprinted symbols such as a bar code. In certain preferred 20 embodiments, the bar codes are two-dimensional barcodes. In certain preferred embodiments, more than one unique bar code is applied to the same segment of tape to assure that at least one machine readable symbol can be read regardless of the position of the symbols relative to the ends of the segments. In certain preferred embodiments more than one type of bar code symbol is used. In Fig. 10 symbol 113 is a PDF417 bar 25 code and symbol 114 is a Data Matrix bar code. In certain preferred embodiments, other types of bar code symbols are used in other useful combinations.

Certain preferred embodiments use rolls or z-folded transponders mounted to a continuous web or release liner. Other certain embodiments use transponders that are

stacked and loaded into magazines for transport, handling, and automated dispensing. In certain preferred embodiments, the magazines contain metallic shielding to protect tags and inlays from electrostatic discharges (ESD).

5 Certain preferred magazines are part of a family of interchangeable magazines of similar size, shape, and functionality, preferably capable of housing and dispensing certain types, styles, shapes, and sizes of new or used RFID tags, transponders, or inlays. Certain preferred embodiments of magazines and cartridges have RFID tags permanently attached to them such that they can be automatically interrogated and tracked. In order to minimize interference, certain preferred embodiments use permanently attached RFID tags that operate in a frequency band that is different than the tags or inlays contained within the magazine. Other preferred embodiments selectively interrogate cartridge identification tags that operate in the same band as tags within the cartridge that are to be applied.

Referring now to Fig. 12, certain preferred methods of commissioning transponders 125 having no exposed adhesive use a magazine 122 of new or reprocessed transponders that are transported from another location.

Certain preferred embodiments use a mobile handheld reader 128 to verify transponder functionality after carton attachment. Certain preferred methods use a fixture to align and coordinate a mobile reader 128 and automate the programming of a magazine of transponders 122. Certain preferred handheld readers also read bar codes that either partially or completely specify the data that is to be programmed into a transponder. An optical path 129 from reader 128 to a location for reading bar code labels 120 is preferably used to identify at least certain non-serialized information about the objects or containers that are to be tagged. Additional transponder encoding instructions and data is preferably acquired through an integral network interface or a batch mode memory in reader 128.

Transponders 123 are preferably dispensed one at a time from magazine 122 under the control of a miniature tag singulation system 121. Shield 126 prevents RF

fields from interrogating or reprogramming tag 125. Tag 123 is preferably retained in the interrogation field by material handling roller 124 preferably until a programming transaction is completed.

5 Compared to methods that use stationary readers and conveyors, the handheld reader 128 is a preferred solution for small scale or decentralized RFID deployments. A handheld is preferably able to both program and verify transponders, saving the expense of a Smart Label printer, a stationary reader, and a conveyor.

A preferred embodiment of a handheld RFID tag applicator 130 is shown in Fig. 13. A handheld tag applicator is preferably capable of helping an operator apply and
10 commission RFID transponders or wireless sensors. Certain preferred embodiments use a transponder magazine 134 to handle and dispense tags, transponders, inlays, or wireless sensors that are stacked, ready to be adhered onto a transport container such as a carton or pallet. Certain preferred adhesives are adhesive tape, spray on, or dispensed as a gel or paste. Transponders are preferably read, written, and verified when an operator
15 initiates an action such pulling a trigger 135, pushing a button, or some other command sequence.

In the preferred embodiment shown in Fig 13, a contact image sensor (CIS) 138 or a linear optical array is used to scan along the length of a roll of packing tape 137 or 110 before each segment is applied to a carton. CIS 138 preferably produces a video
20 stream that is decoded and then interpreted and stored by an On-board Computer 131. CIS 138 or a similar linear array sensor is preferably capable of reading both linear and two-dimensional bar codes. In certain preferred embodiments, CIS 138 reads two-dimensional bar code 114 and 116 from adhesive tape 110, preferably before attachment to inlay or tag 111. Preferably symbols 115 and messages 112 and 113 do
25 not adversely affect bar code scanning and decoding functions. In certain preferred embodiments On-board Computer 131 creates a logical association between bar codes 114/ 116 and RFID tag 133. In certain preferred embodiments, the location and number of readable bar codes on tape 110 is not controlled, there may be more than one

readable bar code on some segments of tape 110. Applicator 130 preferably reads and associates all bar code symbols on a single segment of tape 110 with the RFID tag or inlay 133 adhered to it.

5 When an operator pulls trigger 135, RFID tag 133 is preferably pressed against a transport container, a corrugated carton, or a pallet within a fraction of a second. In certain preferred embodiments, mechanisms internal to applicator 130 transfer mechanical force to tag 133 through the use of air, springs, motors, plungers, elastomers, or other energy storing or delivering methods. Reloading of the next tag and readying of the system are preferably performed within a time interval that is acceptable
10 to the operator and preferably enables a high degree of productivity for tagging cartons, pallets, or other transport containers.

Onboard computer 131 preferably controls operation of RFID Interrogator Module 132 to read, write, and verify RFID tags, inlays, transponders, and wireless sensors that are applied or are within range of the interrogation fields produced by antenna 139.
15 Handheld applicator 130 is preferably capable of reading multiple RFID tags near it. In certain preferred embodiments antenna 139 produces a linearly polarized radio field. In Fig. 13, and in certain preferred embodiments antenna 139 produces a horizontally polarized RF field that is preferably aligned with RFID tags 133 that it is capable of applying. Tag 133 can preferably be read both before and after it is applied to a
20 transport container. When multiple tags are within the interrogation field of applicator 130, On-board computer 131 is preferably able to determine which tags have already been applied and which tags have not. In certain preferred embodiments, On-board Computer 131 maintains records of tags recently applied in order to properly determine how to interact with each tag in the field of antenna 139 or other antennae under the
25 control of RFID Interrogator 132.

Certain preferred embodiments of a handheld applicator have a handle grip and trigger to activate the application of a programmed transponder. Certain preferred embodiments have an RFID interrogator to read, write, and verify RFID tags,

transponders, or wireless sensors. Certain preferred embodiments have a magazine or stack of transponders that are ready for programming and application. Certain preferred embodiments have a roll of adhesive-backed tape ready to be dispensed and applied to the transponders in sequence. Certain preferred embodiments have adhesive tape that is

5 pre-printed with certain information. Certain preprinted information preferably includes one or more logos, an EPCglobal Seal, and informative information. Certain preferred embodiments have a motorized tape drive and dispensing system. Certain preferred embodiments contain some or all of the following: a rechargeable battery, an operator display, a wireless interface, a network stack, an IP address, a PCMCIA port, a Compact

10 Flash port, a USB cable, a serial cable, a dock port, a window to allow the operator to view the tag attachment process, or a bar code scanner. A bar code scanner is preferably used to help verify that RFID tag 133 receives encoding that correctly matches the bar coded information that may be attached to the same transport container.

Certain features and methods described and explained with relation to handheld

15 applicators are also relevant to non-mobile RFID tag applicators that use a magazine, cartridge, reel, or roll to handle, transport, and dispense RFID tags, inlays, transponders, or wireless sensors. Magazines, cartridges, reels, and rolls are preferably capable of carrying either new or used tags and are preferably capable of being used in either mobile or non-mobile applicators. Magazines, cartridges, and reels are preferably refilled and

20 reused. Magazines and cartridges preferably protect RFID tags from ESD. Such devices are preferably capable of communicating with other devices or networks using either wired or wireless means, over either long or short distances.

Mobile applicators such as applicator 130, 170, 180, 190, 200, and 210 all require replenishment of a stored energy source such as batteries, fuel cell, or other

25 energy storage technology. Referring now to Fig. 14 certain preferred methods of using mobile applicators involve the use of a base unit 140 that preferably remains in close proximity to one or more applicators 130, 170, 180, 190, 200, and 210. The principal purpose of base unit 140 is to replenish tag magazines and/or cartridges 146a-c,

recharge applicator energy levels, and provide a communications gateway and an optional user interface 142. Spare tag magazines/cartridges 146a-c are preferably retained in cartridge pockets 145a-c where they are preferably protected from damage. Cartridges preferably indicate their empty/full status with a visible indicator such as: an LED, an LCD, a mechanical flag, a window with a view into the source reel, or other such indicators that help an operator choose which cartridge from which to next consume tags. Applicator 144 is preferably retained by pocket 143 to prevent damage and to make any electrical or mechanical connections to base unit 140. Frame 141 provides an overall structure and preferably mounting options for various operating locations including various models of fork lift trucks. Base unit 140 preferably includes a variety of wired and wireless communications options with applicator 144, cartridges 146a-c, a host computer, a vehicle mount terminal, a fork truck computer, or other relevant computing devices. Base unit 140 preferably has a power system that is suitable for the application, including power filtering and energy storage capabilities such as batteries or fuel cells.

Certain preferred applicator embodiments such as applicator 160 use a spool of converted self-adhesive RFID tape 160 to transport to a desired location and replenish mobile applicators. A preferred embodiment for RFID tape is illustrated in Fig. 16. In certain preferred embodiments, the tape is translucent, clear, or opaque. In certain preferred embodiments, RFID tape 160 has certain preferred preprinted symbols as shown in Fig. 11. A spool is preferably constructed on a hollow core 161. Inlays 162, 163a, and 163b are preferably attached to adhesive backed tape 164. Preferred construction methods are shown in Figs. 2-5, and are an improvement over prior art such as "Packaging Tape with Radio Frequency Identification Technology" disclosed in U.S. Patent number 6,478,229 by Harvey Epstein of Newton, MA. Epstein teaches a packing tape construction consisting of two layers of tape bonded to each other along their lengths and encapsulating scrim and a plurality of RFID tags. Epstein furthermore teaches that pressure sensitive adhesive on the bottom layer should be covered by an additional

layer of release liner to maintain its active life and to prevent it from bonding to adjacent portions of the laminated tape. The present invention teaches the opposite as a preferred and improved design for RFID tape by having the pressure sensitive adhesive be intentionally become bonded to selected adjacent portions of the laminated tape,
5 provided that the surface energy of the tape backing is relatively low, allowing for release and reuse of the van der Waals bonds. The present invention has the advantage over Epstein's prior art of having no release liner to dispose of nor any water-activated adhesive to dampen. Both of these advantages are important for preferred embodiments of mobile applicators disclosed herein.

10 Figure 15 illustrates a preferred embodiment of a machine to convert RFID inlays into RFID tape 150b as is also shown in Fig 16 as RFID tape 160. Care must be exercised to prevent damage do to electrostatic discharge when operating the machine illustrated in Fig. 15. In certain preferred embodiments charge is removed using a variety of conduction methods including wiping, air, and humidity controls. A roll of inlays 159a is
15 preferably mounted onto tag source fixture 159b in preparation for use. Inlay 156 is preferably interrogated, tested, and selectively programmed by antenna 157 and interrogator 158. Punch 155b preferably cuts inlay 155a from inlay roll 159a. If the inlay does not perform within required operational parameters it is preferably discarded into reject port 152 and removed from the conversion process. Good inlay 151 is preferably
20 attached to exposed adhesive on tape 153 as it unrolls from tape source fixture 154a.

Certain preferred applicator embodiments such as applicator 210 use wireless tags or RFID tags such as ALL-9338-02 from Alien Technology of Morgan Hill, California that are die cut and adhered to release liner. Preferably wireless tags are manufactured to specifications that are compatible with applicator 210, including such specifications as
25 core diameter, outer diameter, and web width. Alternatively, certain preferred steps are required to prepare a standard roll of ALL-9338-02 tags for use in an automated applicator, including unrolling from a large roll onto several smaller rolls having a smaller core diameter.

Referring now to Figs. 17-21 and within them applicators 170, 180, 190, 200, and 210 there are certain preferred characteristics that are shared among them. Preferred characteristics are described only once while making references to instances within those five Figs 17-21.

- 5 Applicators 170, 180, 190, 200, and 210 preferably include options to physically, electrically, and communicatively integrate with a portable data terminal (PDT) or a mobile computing platform. Figs 20-21 illustrate a preferred configuration for mechanically integrating PDT 209 or 219 which is representative of a wide range of commercially available PDT's or PDA's of various shapes, sizes, types, and capabilities.
- 10 Certain preferred PDT's have a variety of wireless connections including PAN and WLAN. Certain preferred PDT's include a bar code scanner comprised of a laser, an imager, or other means.

- Certain preferred Applicators 170, 180, 190, 200, and 210 preferably exchange information with a host device, including PDT 219, in either a batch mode or through a
- 15 real time connection. Batch mode preferably uses a periodically connected data transfer channel such as a wired connection. Certain preferred wired connections include serial data, infrared, optical, Universal Serial Bus, a parallel port, or other physical data connection. Certain preferred real time connections include wireless data links including Personal Area Network (PAN), Wireless Local Area Network (WLAN), and Wide Area
- 20 Network (WAN). Certain preferred PAN connections include Bluetooth and Zigbee. Certain preferred WLAN connections include IEEE802.11a, IEEE802.11b, and IEEE802.11g.

- Sensor suite 178, 188, 198, 208, and 218 - in certain preferred embodiments - includes a single sensor that is responsive to changes in light, capacitance, pressure, acoustics, or optical path length to a transport container. In certain other preferred
- 25 embodiments, sensor suite 178, 188, 198, 208, and 218 operates as a collection of sensors. Changes in capacitance are detectable using certain preferred QProx charge transfer capacitance sensors available from Quantum Research Group Ltd. of Hamble, England. Ultrasonic range sensors are available from supplier such as muRata

Manufacturing Co., Ltd. of Kyoto Japan under the trade name Piezotite. Optical path length sensors are available from Keyence Corporation of Osaka, Japan. Sharp manufactures a compact distance measuring sensor GP2D02 that is responsive in the range from 5 to 100 cm. When a predetermined set of conditions is realized, sensor suite 5 178, 188, 198, 208, and 218 preferably triggers, enables, or selects a desired action. In certain preferred embodiments, proximity or contact of sensor suite 178, 188, 198, 208, and 218 with the targeted transport container causes a second type of Trigger Event, resulting in the programming and application of a tag.

Certain preferred embodiments of sensor suite 178, 188, 198, 208, and 218 10 measure range of applicator 170, 180, 190, 200, and 210 from other objects. Preferably range information is acquired and processed in real time to determine if the applicator is: in Close Proximity, Near, or Far from a transport container. In certain preferred embodiments controller 203b or 213b are programmable to alter threshold distances between each range category. In certain preferred embodiments, controller 203b or 15 213b are programmed to associate a preferred function with each range. In certain preferred embodiments, range category Close Proximity is associated with tag programming and application functions. In certain preferred embodiments range category Near is reserved for tag verification and/or reading functions; and Far is preferred for bar code scanning functions to verify that bar code information aligns properly with RFID tag 20 data.

Certain preferred embodiments include trigger 135, 205b or 215b that is preferably coupled with an electrical switch having one or more stable positions that are detectable by controller 203b or 213b. In certain preferred modes of operation trigger switch state is coupled with range information from sensor suite 178, 188, 198, 208, 25 and 218 to execute preferred functions at preferred ranges at preferred times. The result is a trigger 135, 205b or 215b whose function is preferably dependent upon detected range from a transport container. The advantage of doing this is operator productivity. One trigger is used to execute several different functions that are typically

involved with RFID tagging including the tagging of bar-coded cartons that have been selected to receive wireless tags.

Certain preferred embodiments of applicator 170, 180, 190, 200, and 210 do not have any means to interrogate RFID tags or read bar codes. Such embodiments are intended to apply tags and inform PDT 219 of certain events, including but not limited to certain Trigger Events. Other events, information, and status such as changes in tag readiness, tags remaining on source roll 217b, remaining charge in battery 213a, changes in range status between certain predefined states such as Close, Near, and Far are preferably communicated to PDT 219. Certain preferred information is communicated from PDT 219 to applicator 170, 180, 190, 200, or 210, including certain power management functions, commands, status, and data that is to be encoded into each readied tag 216f at the appropriate time. Certain preferred embodiments exchange information over a wireless connection to PDT 219, including PAN or WLAN. Such a configuration puts applicator 170, 180, 190, 200, or 210 in the role of a peripheral device to PDT 219, with PDT 219 managing the primary user interface and most computation functions. Certain preferred means of pairing wireless communications nodes includes PDT 219 reading a bar code attached to applicator 170, 180, 190, 200, or 210.

Bar code verification is preferably performed either before or after an RFID tag is applied by merely stepping back away from the marker cartons to at least the point where the sweep angle of a laser beam or field of view of an imager can read a bar code label. In certain preferred embodiments, ranges shorter than that, but not in close proximity are used for sweeping a radio frequency interrogation signal across the faces of multiple cartons to assure that the correct tags, the correct number of tags, and the correct data within that tags were all properly programmed.

In certain preferred embodiments Close Proximity range is reserved exclusively for programming, applying, and verifying one tag, preferably all in a single pull of trigger 135, 205b or 215b.

In certain preferred embodiments, certain programmable conditions are set such that Trigger Events enable interaction with external devices or nearby equipment. In a preferred embodiment trigger 135, 205b or 215b at a certain range as determined by sensor suite 208 or 218 and controller 203b or 213b causes applicator 200 or 210 to transmit a coded signal to an external device as an indication of an operator action. In certain preferred embodiments pulling trigger 135, 205b or 215b at Far range causes a signal to be transmitted from applicator 200 or 210 requesting an external device to read a bar code. In certain preferred embodiments, bar code information is decoded and transmitted back to applicator 200 or 210. In other preferred embodiments, decoded bar code information is processed remotely from applicator 200 or 210. In certain preferred embodiments, decoded bar code information is processed by a portable data terminal (PDT), a vehicle mount terminal, or other computing device. In certain preferred embodiments a PDT is collocated with applicator 200 or 210. In certain preferred embodiments, PDT 209 or 219 is mounted to applicator 200 or 210 as shown in Figs 20 and 21. In certain preferred embodiments, there are no ohmic or electrical connections between applicator 200 or 210 and PDT 209 or 219. In certain preferred embodiments the coded signal is transmitted using a Bluetooth, or a Zigbee, or an IEEE air interface standard.

Certain preferred embodiments of sensor suite 178, 188, 198, 208, and 218 are responsive to certain colors or patterns. Sensor suite 178, 188, 198, 208, and 218 is preferably capable of recognizing certain predefined colors and patterns to initiate certain preprogrammed responses including the detection of the correct locations for applying good tags and separate locations for discharging bad tags.

Certain preferred embodiments of applicators 170, 180, 190, 200, and 210 are capable of using sensor suite 178, 188, 198, 208, and 218 to learn one or more colors and/or patterns and storing information relating to it, and optionally exchanging that information with other applicators 170, 180, 190, 200, and 210.

Certain preferred embodiments of applicators 170, 180, 190, 200, and 210 manage preset conditions that allow an operator to only apply a tag to objects having a predetermined set of surface characteristics. Certain preferred embodiments of applicators 170, 180, 190, 200, and 210 use sensor suite 178, 188, 198, 208, and 218 to detect colors and/or patterns to identify preferred target locations for wireless tags. Certain preferred embodiments of corrugated cartons are preprinted with certain preferred colors and patterns that are detectable by sensor suite 178, 188, 198, 208, and 218.

Certain preferred embodiments of applicators 170, 180, 190, 200, and 210 manage preset conditions that allow an operator to discharge a defective tag from the applicator. Prior art teaches that defective tags are to be rolled up with spent release liner. There are two problems with that, one relating to the lack of proper waste disposal, and the other relating to the lack of failure analysis. Certain preferred embodiments of applicators 170, 180, 190, 200, and 210 enable a mode of operation whereby an operator is informed that the next tag is defective and should be discharged onto a particular object or surface for subsequent failure analysis and disposal. Certain preferred embodiments also prevent an operator from discharging a defective tag onto a surface that does not match a predetermined set of conditions. Such a lock-out condition is preferred as a solution to prevent bad tags from being shipped to a customer or from being improperly discarded before a failure analysis can be performed.

Fig. 17 illustrates a preferred embodiment of mobile applicator 170 using RFID tape roll 171 loaded into cartridge 179. Capstan 173 assures that the minimum bend radius of the tag specifications is not violated. In certain preferred embodiments, capstan 173 is motor-driven and has sufficient surface texture to provide enough friction to help tape 172 move forward. The gateway to the tag attachment zone is marked by cut-and-hold device 174. Sensors preferably monitor the location of each tag on tape 172 to properly register their position and to spatially synchronize all applicator functions with

them. The forward motion of tape 172 is led by strokes from right to left of cut-and-hold device 174.

Trigger 135, 205b or 215b, preferably embedded within trigger handle 136, 176, 186, 196, 205a, or 215a is actuated by an operator, preferably causing a Trigger Event.

5 In certain preferred embodiments, there is more than one kind of Trigger Event. In certain preferred embodiments of applicators 200 and 210 certain types of either mechanical or electromechanical actuators are preferably used to cause hammer mechanism 206a or 216a to trip, being driven toward readied tag 206f or 216f, through opening 206e or 216e for placement on a transport container at the face of bulkhead 201a or 211a.

10 Figure 20 illustrates certain preferred embodiments of a mechanical actuator that can be embodied within applicator 200 or 210, or other similar applicator designs. Proximity probe 205c when pressed against the face of a transport container such as a corrugated carton will preferably slide deeper into applicator 200 along its primary axis, applying pressure to trigger arm 205d preferably causing it to move at least to the point
15 that latch 206b becomes disengaged. Having no means to hold off the torque applied by the energy stored in spring 206c, hammer 206a accelerates toward impact with tag 206f and the face of a carton that tripped probe 205c. In certain preferred embodiments, push rod 206h preferably makes contact with a transport container, exerting force inward through housing wall 201a to load spring 206c preferably locking it
20 into firing position. This closed loop mechanical system preferably achieves a high degree of properly placed wireless tags by ensuring that an applicator such as applicator 200 or 210 is in close contact with a target transport container.

An alternative mechanical actuation system that is embodied within certain preferred embodiments of applicator 200 or 210 is a manually initiated Trigger Event
25 using trigger 205b. When an operator pulls trigger 205b, trigger arm 205d preferably moves away from its point of engagement with latch 206b preferably by sliding along its primary axis. Once disengaged from latch 206b, hammer 206a is free to strike tag 206f and also preferably the target zone of the container.

A means of electromechanical actuation is initiated by solenoid 205e that is preferably embedded within handle 205a and is capable of initiating another type of Trigger Event. In certain preferred embodiments of applicator 130, 200, or 210, trigger 135, 205b or 215b is coupled with an electrical switch mechanism to make or break
5 electrical circuits that are indicative of an operator's intent to perform an action such as applying a tag to a carton. In certain preferred embodiments of applicator 200 or 210, solenoid 205e pulls on trigger arm 205d to disengage latch 206b and the corresponding chain of events.

Another means of electromechanical actuation is initiated by a Trigger Event
10 detected by sensor suite 178, 188, 198, 208, and 218. Such a Trigger Event is preferably processed and controlled by a set of preprogrammed rules and conditions in a controller such as controller 203b or 213b. A positive result of that process preferably causes solenoid 205e to actuate whereby retracting trigger arm 205d and causing latch 206b to disengage.

Another means of electromechanical actuation from a Trigger Event initiated by
15 sensor suite 178, 188, 198, 208, and 218 is illustrated in Fig. 21 whereby DC motor 215c runs in a reverse direction causing ratchet 216b to become disengaged, allowing hammer 216a to accelerate toward tag 216f due to the torque exerted by spring 216c. Hammer 216a passes between holding rollers 216d to press tag 216f against the face of
20 a transport container.

At the moment a Trigger Event occurs a properly programmed tag is preferably applied. A Trigger Event preferably sets into motion a sequence of events to commission a tag by applying a properly programmed tag to a carton, a shrink-wrapped pallet of cases, or other shipping container.

Referring to Fig. 17, immediately following a Trigger Event and the commissioning
25 of a tag, another tag is preferably pulled into position squarely in front of tamp head 175 and cut-and-hold-device 174 preferably severs tape 172.

Referring to Figs. 20 and 21 drive motor 204 or 214 are preferably located inside the center of the source reel 207b or 217b within the circular walls of applicator housing 210b or 211b, around which cartridge 207a or 217a is nested when mated to applicator 200 or 210. Motor 204 or 214 is mounted to the structural frame of applicator 200 or 210 and preferably transfers mechanical power to certain drive points preferably using gears, belts, or drive shafts within applicator housing 201a or 211a. In certain preferred embodiments of applicators 170, 180, 190, 200, and 210 certain preferred drive points include take-up reel 184, 194, 207c or 217c, source reel 207b or 217b, separation roller 183, 193, 207d, hammer arm 206a, roller 181, 191, or spring 206c.

10 Separation roller 183, 193, 207d preferably has nubs that extend in uniformly spaced radial directions from a cylindrical core that preferably extend through mesh or net from source reel 195, 207b or Z-fold stack 185 to break the weak adhesive bonds that have formed between the packing tape primarily in zones 100 and 102, and form a temporary bond with it so that it can be temporarily bonded to holding rollers 182, 192, 15 206d. In certain preferred embodiments separation roller 183, 193, 207d is powered by motor 204, and preferably maintains desired tension and registration of tags, mesh or net transport layer. Take-up reel 207c is diagrammatically shown in both the empty and the full conditions to illustrate the range of possible mechanical relationships among the various parts of the transport system.

20 Edge 217d illustrates a preferred method of removing pressure sensitive adhesive backed tags from release liner from source reel 217b. Unlike removal from mesh or net, there is no need for a separation roller, Instead the smooth surface of the release liner glides easily round the distal end of edge 217d causing the stiffer tag substrate to continue on toward holding roller 216d or other suitable mechanism to temporarily hold a tag until it is struck by hammer 216a as it swings through the tag holding area defined by holding rollers 216d in Fig 21.

Certain preferred embodiments of applicators 170, 180, 190, 200, or 210 do not contain an RFID interrogator or antenna but are collocated in proximity of a device that

does. Certain preferred PDT 219 embodiments contain an RFID interrogator and antenna 219a. Preferred embodiments of PDT 219 have RFID interrogator/antenna 219a built in, while certain others have a card slot manufactured to a standard such as PCMCIA, CompactFlash, or Secure Digital, into which interrogator/antenna 219a is plugged. An
5 example of such a card is the MPR5000 that plugs into a PCMCIA Type II slot and is available from WJ Communications of San Jose, California. The MPR 5000 is compatible with handheld computers such as the Hewlett Packard iPAQ5550, enabling it to read and write EPCglobal compatible UHF RFID tags. Certain preferred embodiments, such as the MPR 5000 use an integrated YAGI antenna to create a large forward-looking main lobe of
10 radio frequency energy for interrogation of RFID tags. Antennae, including a YAGI also produce side lobes of RF energy that although attenuated from the main lobe by several dB, couple enough power into nearby readied tag 216f to interrogate and preferably write to it. Certain preferred embodiments also use reflector 219b to passively reflect RF signals from an upper side lobe downward toward readied tag 216f. Backscatter from tag
15 216f then preferably propagates back to both antenna 219a and reflector 219b for processing by the interrogator. Having an antenna 219a be such an antenna, embedded in PDT 219, mounted to the structure of applicator housing 211a preferably enables PDT 219 to encode and verify readied tag 216f while commanding applicator 200 to apply tag 216f preferably when a Trigger Event or a predetermined range status change
20 occurs.

Antenna 177a, 187, 197, 202b, 212b, 202c, 212c or leaky coax 177b, 202a, 212a are preferably located outside of cartridge 179, 189, 199, 207a, 217a in a location very close to the tag attachment zone in front of tamp head 175 or tag application roller 181 or 191 and holding rollers 182 or 192, or hammer 206a or 216a. In
25 certain preferred embodiments antenna 177a, 187, 197, 202c, 212c is a patch antenna with a radiation pattern toward the tag attachment zone. In certain other preferred embodiments antenna 177a, 187, 197, 202c, 212c is a near field coupler having multiple points of radiation along its length.

Leaky coax 177b, 202a, or 212a is a type of coaxial cable having slits, slots, or perforations that allow radio frequencies to leak in or out. Certain preferred embodiments of leaky coax cables for use in applicators 170, 180, 190, 200, or 210 are coupled-mode cables that do not radiate as well as radiating-mode cable. Coupled-mode cable is
5 preferably constructed with closely spaced slots in a corrugated outer conductor. Radiating-mode cable typically has a foil outer conductor with non-uniformly spaced slots arranged in a periodic pattern. Coupled-mode cable is a slow-wave structure. In free space its external fields are closely bound to the cable and do not radiate, except for minor end effects according to "Prediction of Indoor Wireless Coverage by Leaky Coaxial
10 Cable Using Ray Tracing" by Samuel P. Morgan of Bell Laboratories, Lucent Technologies.

In certain preferred embodiments an interrogator 202d or 212d drives a signal into a leaky coax 202a or 212a that is terminated in a purely resistive load. In certain preferred embodiments the resistive load is about 50 ohms. In certain preferred embodiments there is an RF switch selectable between radiating and non-radiating loads
15 such as antenna 177a or leaky coax 177b. Interrogator 202d or 212d preferably never feeds into a mismatched load impedance.

In certain preferred embodiments antenna 187, 197, 202c or 212c is a patch antenna with its strongest lobes oriented toward the tag holding and placement area in the region of holding rollers 182, 192, 206d or 216d. Antenna 177a, 187, 197, 202b,
20 212b, 202c, 212c or leaky coax 177b, 202a, or 212a preferably work with an interrogator to produce electromagnetic fields to interrogate, program, and verify wireless tags. Shield 207e and 217 e preferably prevent interrogation or programming of tags until they arrive at separation roller 207d or tag peel edge 217d. Reflector 206g is used in certain preferred embodiments to reflect RF radiation back toward readied tag
25 206f. In the event that verification failed, and a preferred number of programming and verification retries also fail, then the operator is preferably informed that the bad tag is to be preferably discharged onto a surface of a third object other than the applicator or the transport container, preferably for post-mortem analysis.

All properly programmed tags are preferably adhered to a wall or flap of a transport container by a single forward stroke of tamp head 175, a single lateral stroke of roller 181 or 191 between holding rollers 182 or 192, or a single forward stroke of hammer 206a or 216a.

5 Certain preferred embodiments of applicators 130, 170, 180, 190, and 200 correlate RFID tag data with data encoded in certain preferred bar codes 113 and/or 114 marked on packing tape 110. In certain preferred embodiments, applicators such as applicator 130 read the bar code preferably using a sensor such as CIS 138 as the tape is unrolled from a spool. In certain other preferred embodiments, an RFID tag is located on
10 cartridge 179, 189, 199, or 207a and contains a numerical value that is directly or indirectly representative of the numerical values optically encoded into bar codes 113 and/or 114, preferably at least indicating the starting numerical values of a number sequence. Other additional information is also encoded in the RFID tag in certain preferred embodiments, including the number of tag positions, the number of good tags,
15 the ending sequence number, the date, time and place of tag conversion or other preferred commercial, logistic, or manufacturing information. In certain preferred embodiments of applicators 130, 170, 180, 190, 200, or 210 certain wireless tags attached to cartridges 179, 189, 199, 207a, or 217a are capable of being read. In certain preferred embodiments the interrogator such as interrogator 202d or 212d is
20 capable of reading an RFID tag mounted to the loaded cartridge, and is also preferably capable of filtering out its response to interrogation or programming of RFID tags.

Interrogator 202d or 212d is a device that is commercially available from several manufacturers, including SAMSys Technologies, Inc. of Durham, NC. Interrogator 202d or 212d is preferably similar to a SAMSys model MP9311. Other RFID or wireless tag
25 interrogator modules with other feature sets are also suitable for use in mobile applicators 130, 170, 180, 190, 200, or 210.

Interrogator 202d or 212d is preferably capable of working with controller 203b or 213b to recognize which tags have been recently programmed or applied so as to

filter out their response to interrogations other tags, especially those tags that are being prepared for attachment. Interrogators such as interrogator 202d or 212d are preferably capable of modulating their transmitted radio power to affect the range and signal to noise ratio of their coupling to wireless tags.

5 In certain preferred embodiments batteries 203a or 213a are used to store electrical energy to operate applicator 130, 170, 180, 190, 200, or 210. In certain other preferred embodiments other devices are used to store electrical energy, including devices such as fuel cells, or devices that convert hydrogen or hydrogen-rich molecules into an electromotive force and a stream of electrons.

10 For certain preferred applicator embodiments 130, 170, 180, 190, 200, or 210 passwords are encoded into tags or wireless sensors when they are programmed. Password generation methods are disclosed below. For certain preferred embodiments, passwords are safeguarded using cryptographic techniques, secure and trusted channels, locked memory, and other methods that are commonly used to protect confidential
15 information. Passwords are generated or retrieved:

1) Data from a tag or transponder is used to generate an index into one or more databases that contain any of the following:

- a. A one dimensional array of passwords; or
- b. A two dimensional array of passwords; or
- 20 c. A multidimensional array of passwords; or
- d. An array of actual or pointers to algorithms used to generate passwords from tag data.

2) Cryptographic algorithms are used generate passwords from tag data.

25 In certain preferred embodiments, the location of wireless sensor such as tag 10, 110, 163b on transport containers is stored in a database. In certain preferred embodiments, templates or certain other descriptive or characteristic information is

stored one or more databases that are preferably referenced or pointed to by information that is stored in the memory a wireless sensor such as tag 10, 110 or 163b.

5 In certain preferred embodiments, replenishment of empty cartridges or magazines is performed as a service at a customer's site such as a warehouse, distribution center, packing plant, 3PL logistics center, or a manufacturing plant. In certain preferred embodiments, all machines that are required to replenish and service applicators 130, 170, 180, 190, 200, and 210 and their cartridges or magazines are preferably contained within a single vehicle.

10 While the invention has been particularly shown and described with reference to certain embodiments, it will be understood by those skilled in the art that various changes in form and detail may be made without departing from the spirit and scope of the invention.