Abstract: A system determines the entry or exit lane of vehicles passing through a vehicle gate that has a plurality of vehicle lanes through which vehicles enter or exit. A tag interrogator is positioned at a predetermined location of the vehicle gate and emits a signal containing a tag interrogator ID. A plurality of the vehicle lanes are within range to receive that signal. A tag transmitter is mounted on a vehicle that enters or exits the gate and receives the signal emitted from the tag interrogator, which determines the Received Signal Strength Indication (RSSI) and in response, transmits an RF signal containing the tag interrogator ID and the RSSI for determining which vehicle lane the vehicle is located based on the tag interrogator ID and RSSI.
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SYSTEM AND METHOD FOR DETERMINING THE ENTRY
OR EXIT LANE OF VEHICLES PASSING INTO OR FROM A
VEHICLE LOT USING TAG INTERROGATOR AND RSSI

Related Application

[0001] This application is based upon prior filed copending provisional application Serial No. 60/868,430 filed December 4, 2006, the disclosure which is hereby incorporated by reference in its entirety.

Field of the Invention

[0002] This invention relates to the field of sensors and real-time location systems (RTLS), and more particularly, this invention relates to determining the entry or exit lane of vehicles passing into or from a vehicle lot.

Background of the Invention

[0003] Many rental car lots and similar vehicle lots contain hundreds of cars and real-time data regarding the vehicles is often difficult to collect and maintain. Real-time data is necessary for validating a vehicle with a customer, and is especially important for controlling the exit of the vehicle from the rental car lot. Validation is also important when a vehicle car is returned.

[0004] Prior art rental car systems require excessive manual labor during the car rental process. More modern systems, however, are now using some type of automatic data collection system and user interface to aid in automated check-out and check-in at the rental car lots. For example, a customer could swipe a credit card at an exit kiosk having the user interface and validate the car rental. An
exit gate could open automatically after validation. Still, many of these prior art systems require more manual labor than desired and add errors and time delays for a customer during the check-in and check-out process of the rental car.

[0005] Commonly assigned U.S. Patent application Serial No. 11/414,940, published as 2007/0252728 on November 1, 2007, the disclosure which is hereby incorporated by reference in its entirety, addresses the problem with sensing and controlling the entry or exit of vehicles into or from a vehicle lot. At least one vehicle lane is at the vehicle lot through which vehicles pass to at least one of enter or exit the vehicle lot. A tag transmitter is adapted to be mounted on a vehicle and transmits a wireless RF signal that includes vehicle data relating to the vehicle to which the tag transmitter is mounted. A lane sensor is associated at the vehicle lane and configured to receive wireless RF signals from the tag transmitter as the vehicle enters the vehicle lane, while substantially rejecting wireless RF signals from other tag transmitters mounted on other vehicles within the vehicle lot or in any adjacent vehicle lane. A processor is operatively connected to the lane sensor for receiving and processing the vehicle data to validate and control the vehicle’s entry or exit to or from the vehicle lot.

[0006] The processor is operative for validating a customer by pairing a customer renting a vehicle with a vehicle identification as part of the vehicle data. A user interface can be positioned at the vehicle lane at which a vehicle operator interfaces for validating the vehicle as it enters or exits the vehicle lot. A reference tag transmitter can be positioned to emit wireless RF signals that are received at the lane sensor except when a vehicle has entered the vehicle lane indicative of a vehicle presence. The lane sensor could include a directional receiving antenna positioned at the vehicle lane that receives the wireless RF signals from a vehicle as it enters the vehicle lane. This directional receiving antenna can be configured to substantially reject any wireless RF signals from vehicles within any adjacent vehicle lanes and vehicles within the vehicle lot.

[0007] A plurality of vehicle lanes are adjacent to each other through which the vehicles pass. A lane sensor is associated with each vehicle lane and includes a directional receiving antenna positioned at each vehicle lane that receives the wireless RF signals from the vehicle as it enters a respective lane and substantially
rejects any wireless RF signals from vehicles within any other adjacent vehicle lanes and vehicles within the vehicle lot.

[0008] It is desirable at times to know the distance of a tag transmitter to aid in discriminating an exact lane a tag transmitter as an asset is in as it passes various interrogators or other devices. This would allow more accurate information regarding the location of the asset to which the tag transmitter is attached.

Summary of the Invention

[0009] A system determines the entry or exit lane of vehicles passing through a vehicle gate that has a plurality of vehicle lanes through which vehicles enter or exit. A tag interrogator is positioned at a predetermined location of the vehicle gate and emits a signal containing a tag interrogator ID. A plurality of the vehicles lanes are within range to receive that signal. A tag transmitter is mounted on a vehicle that enters or exits the gate and receives the signal emitted from the tag interrogator, which determines the Received Signal Strength Indication (RSSI) and in response, transmits an RF signal containing the tag interrogator ID and the RSSI for determining which vehicle lane the vehicle is located based on the tag interrogator ID and RSSI.

[0010] One or more access points can receive the RF signal transmitted from the tag transmitter. A processor can be operative to receive data from the access point for receiving and processing the data and determining which vehicle lane the vehicle is in based on the tag interrogator ID and RSSI. The processor can geolocate the tag transmitter and correlate signals as first-to-arrive signals for locating the tag transmitter. The processor can conduct differentiation of time of arrival signals received from the tag transmitter.

[0011] In another aspect, the vehicle lanes are parallel and contiguous to each other and the range of the signal emitted from the tag interrogator is limited to about the vehicle lanes. A plurality of tag interrogators are positioned at the vehicle gate at different locations and emit signals having a range covering different vehicle lanes such that a first tag interrogator emits a signal that covers a first plurality of vehicle lanes and a second tag interrogator emits a signal that
covers a second plurality of vehicle lanes. The first and second plurality of vehicle lanes can be different vehicle lanes.

[0012] In another aspect, the tag interrogator is operative for transmitting a magnetic signal carrying the tag identifier ID that activates a tag transmitter in proximity to the magnetic signal for initiating transmission of the RF signals from the tag transmitter. This RF signal could be formed as a spread spectrum wireless signal. A vehicle lot at the vehicle gate can control entry and exit to and from the vehicle lot. The vehicle lot is formed as a rental car agency lot in one non-limiting example.

[0013] A method aspect is also set forth.

Brief Description of the Drawings

[0014] Other objects, features and advantages of the present invention will become apparent from the detailed description of the invention, which follows when considered in light of the accompanying drawings in which:

[0015] FIG. 1 is a plan view of a portion of a vehicle lot and showing two vehicle lanes through which vehicles exit, and lane sensors positioned at each vehicle lane.

[0016] FIG. 2 a top plan view of two vehicle lanes at a vehicle lot and showing a user interface and lane sensor at each vehicle lane.

[0017] FIG. 3 is an environmental view in perspective showing a vehicle and an elevated directional receiving antenna of a lane sensor positioned for sensing vehicles passing in that vehicle lane.

[0018] FIG. 4 is another top plan view similar to that view of FIG. 2 and showing a vehicle, the possible locations of vehicle tags, a lane sensor, user interface, and tag interrogators.

[0019] FIG. 5 a block diagram showing a layout of detailed events that could occur for different vehicles located at a vehicle lot.

[0020] FIG. 6A is a general functional diagram of a tag transceiver that can be adapted for use in the system shown in FIGS. 1-5.

[0021] FIG. 6B is a circuit diagram showing a magnetic field receiver that can be used in accordance with a non-limiting example of the present invention.
FIG. 6C is a schematic circuit diagram of an example of the circuit architecture of a tag transceiver as shown in FIG. 6A that is modified to incorporate a magnetic field receiver.

FIG. 7 is a high-level schematic circuit diagram showing basic components of an example of a circuit architecture that can be adapted for use as a receiver or access points operative with the tag transmitter and configured for use as a lane sensor.

FIG. 8 is a schematic circuit diagram of an example of a circuit architecture that can be modified for use as a processor and operative with a lane sensor and tag transmitter.

FIG. 9 is a plan view of three vehicle lanes and a tag interrogator positioned over the center vehicle lane for ascertaining the exact lane for the vehicle in accordance with a non-limiting example of the present invention.

FIG. 10 is a top plan view of three traffic lanes and two tag interrogators with different identification numbers, "1234" and "1235" to determine an exact lane in which a vehicle is positioned.

FIG. 11 is a high-level flowchart showing an example of a process for a rule-based matching algorithm that can be used in accordance with a non-limiting aspect of the present invention.

**Detailed Description of the Preferred Embodiments**

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

In a non-limiting example of the present invention, a location system determines an approximate distance that a tag transmitter is located from a tag interrogator such as a WherePort device manufactured by Wherenet Corporation of Santa Clara, California. The system is useful to discriminate the
exact lane a tag transmitter (as a transceiver) as an asset is located as it passes the
tag interrogator. The system can be used with multiple tag interrogator
configurations and provide accurate information regarding the location of the tag transmitter as an asset. The tag transmitter is operative as a Radio Frequency
Identification (RPID) tag transmitter and can report the Received Signal Strength
Indication (RSSI) of a received magnetic message as a "ping" along with the
identification (ID) of the tag interrogator received from the combination of the tag
interrogator ID and the RSSI to determine the location of the tag transmitter with
better accuracy then when the tag interrogator is used alone. Throughout the
description, tag transmitter can also be termed a tag transceiver or tag.

[0030] There now follows a description of a system and method for sensing
and controlling the entry and exit of vehicles to and from a vehicle lot with
reference to FIGS. 1-8, followed by details of the use of a tag interrogator and
RSSI for determining the lane for a vehicle passing through an entry or exit gate
relative to FIGS. 9-11.

[0031] FIG. 1 is a plan view of a vehicle lot 10 as a rental car lot with two
vehicle lanes 11,12 forming right and left exit lanes and a hiker exit 13. Each exit
lane 11,12 and the hiker exit 13 include a booth 11a, 12a, 13a as is sometimes
typical in similar commercial and private establishments. The vehicle lot 10
includes a lot office 14 and a help booth 15, and a customer walkway and two
vehicle paths to the exit lanes as illustrated.

[0032] FIG. 2 is a top plan view of the vehicle lot and vehicle lanes 11,12,
showing a user interface 16,17 at each lane. Each user interface includes a
respective lane sensor 18,19, although the lane sensors could be positioned in other
locations besides at the user interface. An antenna 20 associated with each lane
sensor is co-located vertically and aligned with the driver's shoulder, as best shown
in FIG. 3. The antenna footprint for the lane sensor is about 9 feet by about 8 feet
in one non-limiting example. A vehicle is shown in a front adjacent lane of FIG. 4
corresponding to the second vehicle lane 12. The antenna 20 could be connected
by a coaxial cable 21 to the main portion of the lane sensor containing various
sensor circuits, which could be remote from the vehicle lane. The antenna could be
integral with the overall lane sensor, however, and the coaxial cable 21 could be
used to connect to a processor, as illustrated. The user interfaces 16,17 can interact with a vehicle operator for validating and controlling a vehicle as it enters or exits the vehicle lot.

[0033] FIG. 3 shows an antenna 20 configured as a directional receiving antenna and mounted on a pole 22 at a vehicle lane. In this one non-limiting example, the antenna is formed as a 60-degree beam circular polarized (CP) antenna aimed at a 45-degree downward angle. It connects with a double-shielded 50-ohm coaxial cable 21 to appropriate circuits, for example, the processor or to other portions of the lane sensor circuit, which could be adjacent or remote. The antenna can be mounted about five feet above ground level on a post as illustrated and adjacent the vehicle lane.

[0034] FIG. 4 is an enlarged plan view of a vehicle lane showing a vehicle tag transmitter 24 mounted on the vehicle body and inside the vehicle, for example, connected to the on-board diagnostic (OBD) II system. Various tag interrogators 26, for example, WherePort devices, can be mounted at the vehicle lane 11 at an exit near the "kiosk" or user interface 16 and interrogate the vehicle tags as explained in greater detail below. The lane sensor 18 is shown at the user interface. It should be understood that the term tag transmitter includes the transceiver functions of tags as explained relative to commonly assigned U.S. Patent No. 6,853,687, the disclosure which is hereby incorporated by reference in its entirety.

[0035] A tag transmitter 24 can be attached to the vehicle and transmit a continuous and repetitive, data packet stream of vehicle ID information via a RF signal when it detects vehicle motion, either from speedometer data on a vehicle data bus or by direct connection to vehicle motion sensors or the OBD system. The directional receiving antenna 20 detects the RF signals from the vehicle tag as it enters the user interface terminal 16 positioned for check-in or check-out. The directional receiving antenna 20 can be configured to reject signals from adjacent lanes and other vehicle occupied areas.

[0036] In accordance with another non-limiting example, a continuously transmitting RF reference tag 27 (FIG. 2) can be used as an enhancement feature and placed on an opposite side of the vehicle lane from the user interface. This reference tag is detectable at all times except when a vehicle is in the user interface.
position of the vehicle lane. The vehicle effectively blocks the RF signal from the reference tag to the lane sensor. This reference tag acts as a "vehicle in user interface terminal position" detector.

[0037] The processor 28 (FIG. 2) is operative as a computer-based information system and can process the RF tag data and validate a rental process and control the exit from and/or entry to a controlled area containing the vehicle, i.e., the vehicle lot. A customer could select either an assigned vehicle or any vehicle from an eligible pool depending on the type of rental process. At an automated exit gate 29, the vehicle identification and customer validation can be paired together to allow vehicle exit. At an entry gate (not shown), a similar process could be used. The processor 28 could control gate motors 30 as shown in FIG. 2 to permit a vehicle to exit the vehicle lot after validation.

[0038] Information data filters can also be incorporated with the processor 28 functions. For example, any vehicle, after being properly validated, can be blocked from a repeat lane detection for a predetermined time period. Each vehicle lane sensor, after a valid transaction, can reset and respond to the next vehicle tag transmitter it detects with a first-to-detect system. If two or more lane sensors detect a vehicle tag, all would then be reset to respond to a valid customer verification. Whichever lane has a valid transaction will generate a first-detect reset for all lanes currently holding that tag transmitter as valid. If there is more than one lane detection from the same tag transmitter, the lane whose tag transmitter is blocked, which indicates a vehicle presence on the tag transmitter, will be assigned a validation process if the other lane sensors that simultaneously detect the tag transmitter still are detecting their "beacon" or signal.

[0039] The lane sensor can detect ISO 24730 compliant vehicle tags at a 2.4 GHz RF transmit interface in one non-limiting example. The location sensor can have an RF receiver sensitivity that can be decreased by internal firmware change and external attenuator/cable loss by about 40 dB. This reduces the effective range of the lane sensor from a normal 1000 feet to about 9 feet. This allows detection discrimination of near capture lane over an adjacent far lane.

[0040] A vehicle tag transmitter can be configured to blink in a fast 4-second period, 8 sub-blink mode, when the vehicle is moving slowly, such as
through the vehicle lot. These sub-blinks can be treated individually and separately for each of the lane sensor RF input channels. This allows independently tracking of separate vehicle lanes.

[0041] The lane sensor can use data available to it at the direct sensor level to produce two output results:

[0042] (1) a vehicle has been positively identified in a specific vehicle lane, i.e., the Output=ID and vehicle lane; and

[0043] (2) a vehicle has been positively identified but there is an ambiguity between possible vehicle lane locations which does not allow a specific vehicle lane to be assigned, i.e., the Output=ID and possible vehicle lanes (with weighting scores).

[0044] The following is an example of a performance specification in one non-limiting example:

[0045] Lateral capture range = 6 feet;

[0046] Maximum vehicle window to antenna lateral range = 2.5 feet (human reach); and

[0047] Data output accuracy.

[0048] It should be understood that the processor 28 is operative for validating a customer by pairing a customer renting a vehicle with a vehicle identification as part of the vehicle data. The RF signals can be formed as spread spectrum wireless signals.

[0049] It should also be understood that the system as described can be used in other environments besides a vehicle lot. The system can compare any type of asset and a person for entry or exit from a physical space. For example, an asset lane could be a conveyor or other transportation system that has at least one asset lane through which an asset passes for entering or exiting the physical space.

[0050] FIG. 3 shows an example elevation height of dimension X of about five feet in one non-limiting example. FIG. 4 shows dimensions Y and Z for positioning the interrogators 26, for example, about eight feet and four feet in non-limiting examples. The interrogators could be used to interrogate the tags to blink at a different rate such that the processor could identify even better a vehicle, since the interrogators would be limited in range and would only interrogate a tag.
transmitter that is in the vehicle lane near the interrogators. The interrogators could cause other functions to occur with a tag. When many different vehicles are operating within a vehicle lot and passing into and out of the vehicle lot through a plurality of different vehicle lanes, and with the appearance of many noise signals in the environment, the use of the reference tag and the use of interrogators would be advantageous. The interrogators can be designed as Whereport devices such as sold by the assignee, WhereNet, as described below. It is possible to have a dual lane sensor to cover one or more vehicle lanes.

An example of a single vehicle tag lane selection criteria is illustrated in the chart below:

<table>
<thead>
<tr>
<th>Step #</th>
<th>Description</th>
<th>Criteria</th>
<th>Output</th>
<th>Fail Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Progress Trigger</td>
<td>1 sub-blink</td>
<td>Start algorithm &amp; assign vehicle tag #</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Select Primary Lane</td>
<td>6 sub-blinks from same lane</td>
<td>Pass, go to step #3</td>
<td>1. 10 second timeout</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fail, go to step #3</td>
<td>2. &gt;3 sub-blink detects from other lane(s)</td>
</tr>
<tr>
<td>3</td>
<td>Accumulate Data</td>
<td>5 second time window</td>
<td>Pass, go to step #4a</td>
<td>Not &gt;2:1 total ratio of primary to secondary detects</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fail, go to step #4b</td>
<td></td>
</tr>
<tr>
<td>4a</td>
<td>Declare Checkout</td>
<td>Pass #2 &amp; #3</td>
<td>Validate Rental Process</td>
<td></td>
</tr>
<tr>
<td>4b</td>
<td>Declare Conflict</td>
<td>Fail #2 or #3 or both</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Resolve Conflict</td>
<td>1. Eliminate conflicted lanes if other vehicle checkout process is in progress</td>
<td>Pass, Validate rental Process</td>
<td>No alternate conflicted checkouts found</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Wait 10 seconds for alternate valid checkouts in conflicted lanes</td>
<td>Fail, Send &quot;Lane Conflict&quot; message</td>
<td></td>
</tr>
</tbody>
</table>
FIG. 5 shows an example that uses an exit road with two cars and tags positioned on the cars. The drawing also shows three adjacent vehicle lanes as a front adjacent lane, a capture lane and a back adjacent lane. An exit gate, and exit kiosk, and lane sensor are as illustrated.

The chart below indicates the event description and the automatic identification of a rental vehicle at a vehicle lot with the example of FIG. 5.

<table>
<thead>
<tr>
<th>EVENT DESCRIPTION</th>
<th>AUTOMATIC IDENTIFICATION OF RENTAL CARS AT LOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVENT DATA REQUIREMENT</td>
<td>REAL-TIME ID OF CAR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DETAIL EVENT LAYOUT DESCRIPTION (FIG. 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELEMENT</strong></td>
</tr>
<tr>
<td>PRIMARY ASSET</td>
</tr>
<tr>
<td>DEPENDANT ASSET</td>
</tr>
<tr>
<td>AUXILLARY ASSET</td>
</tr>
<tr>
<td>PRIMARY SENSOR</td>
</tr>
<tr>
<td>ASSOCIATE CANDIDATES</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASSOCIATE CANDIDATE SELECTION RULES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RULE TYPE</strong></td>
</tr>
<tr>
<td>EVENT TRIGGER (PREFERRED)</td>
</tr>
<tr>
<td>EVENT TRIGGER (NO-TOUCH)</td>
</tr>
<tr>
<td>PROXIMITY</td>
</tr>
<tr>
<td>BEARING</td>
</tr>
<tr>
<td>DATA INCLUSION</td>
</tr>
<tr>
<td>DATA EXCLUSION</td>
</tr>
<tr>
<td>ASSET TYPE</td>
</tr>
</tbody>
</table>
For the proximity category with the associate candidate selection rules, there can be about a 10 foot detect capture range to about a 30 foot release (ducting) range.

The vehicle tag 24 can incorporate standard technology found in a WhereNet tag transmitters manufactured by WhereNet Corporation in Santa Clara, California. Examples are disclosed in the commonly assigned and incorporated by reference U.S. Patent Nos. or U.S. published applications: 5,920,287; 5,995,046; 6,121,926; 6,127,976; 6,268,723; 6,317,082; 6,380,894; 6,434,194; 6,476,719; 6,502,005; 6,593,885; 6,853,687; 2002/0094012; 2002/0104879; and 2002/0135479, the disclosures which are hereby incorporated by reference in their entirety.

The vehicle tag transmitter 24 can be operative similar to the tag as described in the above-identified issued patents and published patent applications. It can include a state machine to make the tag operative at different states, such as when the vehicle is moving or not moving. Throughout this description, it should be understood that the terms tag transmitter and tag are used interchangeably. The vehicle tag 24 can transmit or "blink" a short duration, wideband (spread spectrum) pulse of RF energy encoded with information received from an on-board diagnostic (OBD) system, and more particularly, a second generation system known as OBD-II. The vehicle tag can be operative at a rental car agency or similar vehicle lot, for example, fleet applications. The vehicle tag can include an oscillator, whose output is fed to a first "slow" pseudorandom pulse generator and to a strobe pulse generator or other circuitry as described in the incorporated by reference patents. It can include a timer and delay circuit and receiver circuitry. A high speed PN spreading sequence generator can be included with a crystal oscillator that provides a reference frequency for a phase locked loop (PLL) to establish a prescribed output frequency, for example, at 2.4 GHz. A mixer and output can be included with a vehicle tag memory that can include a database containing vehicle bus parameters as described in greater detail below.

The vehicle tag could include a microcontroller, an on-board diagnostic connector (tag connector), and at least one transceiver operative with the
various vehicle protocols. A more simple tag transmitter could be used, of course. Basic components of a vehicle tag 24 that could be used are shown in commonly assigned U.S. Patent Publication No. 2004/0249557, the disclosure which is hereby incorporated by reference in its entirety.

[0058] The tag could include a housing base, a tag connector soldered to a printed circuit board and contained within the housing base, and a housing cover. The tag connector could be a J1962OBD-II compatible connector for connection to OBD-II systems, but other tag connectors could be used depending on vehicle and/or OBD designs in use. An LED could be indicative of vehicle tag and visible through an LED opening in the cover operation and is mounted to the printed circuit board. The printed circuit board could include a microcontroller and any necessary transceivers and associated components. The microcontroller could communicate to the vehicle through the connector into the vehicle OBD-II system to gather telemetry information such as the mileage, fuel, speed, engine state and other parameters that make up the telemetry data. The system could transmit this information directly to a CMOS application specific integrated circuit (ASIC) of the vehicle tag, which causes the vehicle tag to blink out the telemetry in a manner similar to the blinking described in the above-identified patents.

[0059] The vehicle tag 24 could be derivative of the current WhereNet Wheretag III architecture as manufactured by WhereNet Corporation in Santa Clara, California. The vehicle tag could be a single assembly that contains the electronic components required for operation, including a vehicle bus interface, as a connector, the controller and transceiver as described before. In this configuration, the vehicle tag 24 could support the querying of a vehicle data bus for identification and diagnostic information. The vehicle tag could be used for buses conforming to the J1850 specification, but also could be compatible with the newly evolving CAN or other vehicle bus specifications.

[0060] The tag connector is compatible preferably with the J-1962 vehicle diagnostic jack that is typically located under a vehicle dash. The software used for the vehicle tag 24 can also be compatible with the Visibility Server Software Suite manufactured and sold by WhereNet Corporation, which is operable to accept, process, and forward data packets. A programming module can attach to a portable
data terminal (PDT) to load vehicle parameters and firmware upgrades into the vehicle tag.

[0061] The vehicle tag 24 could include all functions of a current Wheretag III architecture and can interface to the vehicle bus, including J-1850, ISO-K, CAN and all variants, through the OBD diagnostic jack. It can read the vehicle identification number (VIN), odometer, fuel level, engine running, and/or diagnostic codes (DTC), but many of the functions may not be necessary. It can detect a disconnect to notify the system, even if it is disconnected while out of range. It can detect vehicle motion to the odometer or other circuits operating in a fast transmit mode. The vehicle tag is preferably powered by the vehicle electrical system through the diagnostic jack and into the OBD-II. It would typically be shipped from a factory in a non-blinking state to be triggered by a "connect" to a vehicle. A wired or wireless method and circuit can reprogram a flash memory for the microcontroller, using a handheld terminal with a programming module. The vehicle number, such as in the hardware and firmware, can be transmitted in a message at a reasonable rate. It is possible to detect key ON and motion to change state or being RF signals or "beacon" transmission.

[0062] The vehicle tag can be a single assembly that includes the tag connector and tag housing base and cover as one modular unit. Additional cable extensions could be used to connect to vehicles having an odd placement of jack. The vehicle tag could connect to the J-1962 connector. Input voltage can be a pass-through to provide power to the vehicle tag. Nominal voltage, for example, the SAE J121 1, is 14.2 volts, running with 24-volt jump starts, and 4.5 volts during cold cranking. The vehicle tag can be a direct connect to a battery using fuses.

SAEJ 121 1, Section 14.1 I defines the transience to which the tag can be designed. It can be sealed against dust and rain (IP 54) and operative at humidity levels of 5% to 99%. It can be designed for vibration specifications to SAE. It has 15 kilovolts through a 2.0K resistor from 300 of and allows "operating anomalies." It preferably is designed for an operating temperature range of -30 degrees C. to +70 degrees C., and includes a storage temperature range of about -35 degrees C. to about +85 degrees C. It is compliant with requirements for CE certifications and
"e" marked for use in EU counties. In one aspect of the present invention, the housing base and cover, in one example, is about 2.410 by 1.64 by 0.720 inches. [0063] As to functionality, the RF components of the vehicle tag 24 have the same functionality as a WhereTag III device that is part of the WhereNet Real-Time Locating System (RTLS) as explained in the incorporated by reference patents. The vehicle tag 24 can operate in the globally accepted 2.4 GHz frequency band and transmit spread spectrum signals in excess of 300 meters outdoors, at less that 2mW. It is operable with the Visibility Service Software that could be part of processor 28 software modules, such as offered by WhereNet Corporation, as an integrated software package, that allows management of assets and resources as well as the WhereNet Real-Time Locating System. [0064] The Visibility Service Software is a distributed Windows service that can include configuration tools, diagnostics, system alerts, an interface manager, and installation tools. This software package allows for e-mail and paging notifications. SNMP MIB definition extensions can be included, allowing the RTLS system to be managed as part of an enterprise standard IT infrastructure. A software launcher can provide single point of entry and software modules for operation, administration, diagnostics, installation and documentation. Any administration modules can provide tools to allow configuration of the RTLS system to meet testing requirements. The vehicle tag 24, of course, is operable without any RTLS system and can be used at rental car agencies and close proximity and similar applications. [0065] A user can configure who was notified by specific alerts and how they are notified. Diagnostic modules can contain the tools to allow monitoring of the health and status of any RTLS and monitor operation of any data acquisition module and tools to monitor the health and status of the physical hardware. Any installation and documentation modules are tools to be used during the installation and initial configuration of the system. Installation, operation and troubleshooting are included. [0066] A proximity communication device or tag "interrogator" can be used in association with a vehicle tag of the present invention, and can be a WherePort device, such as manufactured by WhereNet Corporation. This device is
used to trigger vehicle tags and transmit different "blink" patterns or originate other functions as described before.

[0067] The vehicle tag can be operative with the On-Board Diagnostic System, Generation II (OBD-II), which determines if a problem exists. OBD-II can have corresponding "diagnostic trouble codes" stored in the vehicle computer's memory, and a special lamp on the dashboard (called a malfunction indicator lamp (MIL)), which is illuminated when a problem is detected. Engines in newer vehicles are electronically controlled and sensors and actuators sense the operation of specific components, such as the oxygen sensor, and actuate others, such as fuel injectors, to maintain optimal engine control. A "power train control module" (PCM) or "engine control module" (ECM) controls the systems as an on-board computer, which monitors the sensors and actuators and determines if they are working as intended. The on-board computer detects malfunction or deterioration of the various sensors and actuators and can be addressed through the jack in which the vehicle tag of the present invention is connected.

[0068] The vehicle tag 24 can be operative with different vehicle tag electronics and OBD-II systems. The On-Board Diagnostics Phase II (OBD-II) has increased processing power, enhanced algorithms and improved control as compared to earlier generation systems. Different network standards are used. These include the J1850VPW used by GM (Class II) and Chrysler (J1 850). The VPW (variable pulse width) mode is sometimes used with Toyota and Honda and is operative at 10.4 Kbps over a single wire. The J1850PWM has been used by Ford (Standard Corporate Protocol, SCP) and sometimes used by Mazda and Mitsubishi. SCP is 41.6 Kbps over a two wire balanced signal. ISO 9141 and ISO 9141-2 (ISO 9141 CARB) is sometimes used in Chrysler and Mazda products and more commonly used in Europe. It is operative at 10.4 Kbps over a single wire.

[0069] The network protocols are incompatible and describe physical and data link layers with the application layer used for specific messages. The vehicle tag 24 could include the requisite microcontroller and vehicle database and algorithms stored in vehicle tag memory to be operative with the different protocols. A controller area network (CAN) can address data link and application layers, but would not address physical layer or speed parameters. It is operative at
high-speed (ISO 1898) and low speed (ISO 11519). A Class II GM implementation using the J1850VPW implementation and a single wire CAN and SCP have been used. The vehicle tag can be adapted for use with device net, J1939, J1708, a time triggered protocol (TTP), an ITS data bus, and PC type networks. The J1850VPW (variable pulse width) mode has symbols found in the J1850 specification, and operates at a nominal 10.4 Kbps. It uses a single wire with a ground reference and bus idle "low" as ground potential. The bus "high" is +7 volts and operative at +3.5 volts as a decision threshold, in one example. The bus "high" is dominant and has zero bits. Typically messages are limited to 12 bytes, including cyclical redundancy checks (CRC) and IFR bytes. It can use carrier sense multiple access with non-destructive arbitration (CSMA/NDA). A J1850 Pulse Width Modulation (PWM) has symbols defined in the J1850 specification and uses 41.6 Kbps. It can use a two wire differential signal that is ground referenced and a bus "high" as +5 volts, as a dominant state.

[0070] The vehicle tag 24 can also be operative with the ISO 9141-2 standard, which is UART based and operative at 10.4 Kbps. The K-line can be required as ground reference, and used for normal communications. An L-line can be ground referenced.

[0071] The vehicle tag can be designed to be easy to install and de-install, and can use 802.11 telemetry and location applications for fuel cost recovery and odometer verification, by transmitting data regarding the vehicle identification, the fuel and mileage. In rental car applications, it would improve customer experience for faster check-in and reduce labor costs and improve asset use. The vehicle tags 24 can be web-enabled.

[0072] As noted in the '586 patent, GPS can be used, and in the lane sensor system as described, GPS could be part of the lane sensors as a tag signal reader, and could also be operative as locating access points. Also, a port device as an interrogator (either separate or as part of a locating access point) can include circuitry operative to generate a rotating magnetic or similar electromagnetic or other field such that the port device is operative as a proximity communication device that can trigger a tag transmitter to transmit an alternate (blink) pattern. The port device acts as an interrogator, such as in the example of FIG. 4, and can be
term such. Such an interrogator is described in commonly assigned U.S. Patent No. 6,812,839, the disclosure which is incorporated by reference in its entirety. When a tag transmitter passes through a port device field as a tag interrogator, the tag can initiate a pre-programmed and typically faster blink rate to allow the lane sensor and processor to know which vehicle or asset is present and in some location systems working with the system, allow more location points for tracking a tagged asset. Such tags, port devices, and Access Points are commonly sold under the trade designation WhereTag, WherePort and WhereLan by Wherenet USA headquartered in Santa Clara, California.

[0073] The tag interrogator as a WherePort device can generate an AC magnetic field that rotates over a region of increased sensitivity in which an object, such as the tag, may enter. The tag interrogator is operative as a magnetic signal source and its emitted signals can carry identification data. Some data could be representative of information intended for the object entering the region. Of course the described embodiment of the object is a tag transmitter. The tag transmitter enters the region of increased sensitivity detecting the rotating AC magnetic field. The AC magnetic field can be generated as a plurality of respectively spatially and phase offset AC magnetic fields that form within the region a composite AC magnetic field that rotates over the region.

[0074] A distribution of spatially offset magnetic field generators can be proximate to the region and cause a distribution of spatially offset magnetic field generators to generate the phase offset AC magnetic fields and form within the region the composite AC magnetic field that rotates over the region. It can spatially provide complete magnetic field coverage for the region irrespective of the orientation of the tag transmitter. Frequency shift key and coding can be used for the rotating AC magnetic field. It can also be a non-modulated AC magnetic field.

[0075] A plurality of AC magnetic field generators can have a multi-dimensional arrangement of output field coils, axes which are non-parallel with one another and adapted to be driven with phase offset AC drive signals and produce the composite AC magnetic field that rotates over the region at the frequency of the AC drive signals.
The tag interrogator is a proximity communication device that is used to trigger a tag transmitter to transmit an alternate "blink" pattern. When a tag transmitter passes through the interrogator's field, the tag can initiate a pre-programmed and (typically) faster blink rate to allow more location points as a tagged asset passes through a critical threshold, such as a shipping/receiving dock door or from one zone to another. When the tag transmitter is sending interrogator-initiated blinks, the tag transmitter could include the identification number of the tag interrogator. More than 36,000 unique identification numbers are available in one non-limiting example.

The tag interrogator's field is nearly spherical and its range is adjustable from approximately 1m (3 feet) to 6m (20 feet) in some non-limiting examples. For especially large thresholds (such as very large dock doors) or areas where there may be signal blockage, multiple interrogators can be interconnected to provide a larger coverage area.

Designed for fixed indoor and outdoor applications, the interrogator is sealed against dust and water. Each interrogator typically includes an adjustable mounting bracket and requires only AC and DC power. There are no data cables to install. Another device, such as a portable wand, sold under the designation Where Wand, can be used for programming the interrogator and data entry.

The tag interrogator can have the following non-limiting specifications.

**ELECTRICAL**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage</td>
<td>24 VAC or 36 VDC</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>4.2w (max)</td>
</tr>
<tr>
<td>Operating Current</td>
<td>250 mA (max)</td>
</tr>
<tr>
<td>Field Intensity Limits</td>
<td>125 A/m at housing (ANSI/IEEE C 95.1)</td>
</tr>
<tr>
<td></td>
<td>51.5 dBuA/m at 10m (ETSI)</td>
</tr>
<tr>
<td>Propagation Limits</td>
<td>18.9 uV/m at 300m (FCC)</td>
</tr>
</tbody>
</table>

**TRIGGER RANGE**

The interrogator's effective range for a tag transmitter is configurable to one of eight levels. The following values assume voltage inputs of either 24 VAC or 36 VDC.
Level | Effective Range
---|---
8 | 4.5 to 6m (15 to 20ft)
7 | 4 to 5m (13 to 16ft)
6 | 2.5 to 3m (8 to 10ft)
5 | 2.1 to 2.7m (7 to 9ft)
4 | 1.8 to 2.5m (6 to 8ft)
3 | 1.7 to 2.1m (5.5 to 7ft)
2 | 1.5 to 1.8m (5 to 6ft)
1 (low) | 1.1 to 1.2m (3.5 to 4ft)

**ENVIRONMENTAL / PHYSICAL**

- **Operating Temperature Range**: -30°C to +60°C (-22°F to +140°F)
- **Storage Temperature Range**: -40°C to +70°C (-40°F to +158°F)
- **Humidity**: 0-100% (non-condensing)
- **Diameter**: 22.9cm (9in)
- **Depth**: 12.7cm (5in)
- **Weight**: 1kg (2.25lbs)
- **Environmental Sealing**: IP65 (dust tight, water jets)
- **Case Material**: Food-grade polyester blend

[0080] The system as described can also provide a wireless infrastructure for locating a particular vehicle on which the tag mounting device is temporarily mounted. A real-time location system provides real-time ID and location of tags, and provides reliable telemetry to record transactions, and provides mobile communications to work instruction and data entry terminals. Any terminal operating (management) software (TOS) can be optimized by real-time location and telemetry data to provide real-time, exact-slot accuracy of container ID and location, and real-time location and automatic telemetry of container transactions and container handling equipment and other mobile assets. The real-time location system is applicable for basic vehicle or asset inventory control.

[0081] The circuitry of a respective tag may be housed in a relatively compact, sealed transceiver module, which is sized to accommodate installation of a transceiver chip and one or more relatively long-life, flat-pack batteries and
sensor devices. As a non-limiting example, the module may be rectangularly shaped, having a volume on the order of slightly more than one cubic inch, which allows the tag to be readily affixed to the temporary tag mounting device.

[0082] The general functional architecture of a tag can be formed as a transceiver (transmitter-transponder) unit, and used in the lane sensor system as described, and also used in any radio location and tracking system, which is either separate or a part of the lane sensor system. An example circuit is diagrammatically illustrated in FIG. 6A and the circuit components thereof are shown in detail in FIGS. 6B and 6C, such as disclosed in the incorporated by reference ’687 patent.

[0083] FIG. 6A is a general functional diagram of a tag transmitter as a tag transceiver that can be adapted for use in the system shown in FIGS. 1-5 and incorporated into the system shown in FIGS. 9-11 as explained below. The tag transceiver (transmitter) includes an RF transmitter 40 that is operable with a non-volatile memory 110, internal sensor 108, and magnetic receiver as a short range magnetic receiver 50, which requires a very insubstantial amount of power compared to other components of the tag. Because the receiver enabled pulse is very low power, it does not effectively effect the tag’s battery life. As a relatively non-complex, low power device, the magnetic receiver is responsive to queries when the tag interrogator unit is relatively close to the tag (e.g., on the order of 10 to about 15 feet). This prevents an interrogator from stimulating responses from a large number of tags. Signal strength measurement circuitry within the tag interrogator or the tag may be used to provide an indication of the proximity of the query tag relative to the location of the interrogator, such as using RSSI circuitry within the interrogator and preferably within the tag as noted below. The tag includes an appropriate antenna 60.

[0084] FIGS. 6B and 6C show circuits for a tag transmitter as described and using reference numerals in the 700 and 800 series.

[0085] FIG. 6B diagrammatically illustrates the configuration of a magnetic field sensing unit 700a for a respective tag and comprising a resonant (LC tank) detector circuit 700b having a magnetic field-sensing coil 701 coupled in parallel with a capacitor 702. The parameters of the tank circuit components are such that
the tank circuit 700b resonates at a frequency between the two FSK frequencies employed by a FSK-modulating magnetic field generator of the tag interrogator. For the non-limiting example of using frequencies of F1=14.7 kHz and F2=147.5 kHz, referenced above, the tank circuit 700b may have a resonant frequency of 131 kHz.

[0086] The resonant tank circuit 700b is coupled to a sense amplifier 705, which amplifies the voltage produced by the tank sensor circuit for the desired receiver sensitivity and buffers the detected voltage to the appropriate logic level for use by a digital receiver-demodulator 706. The digital receiver—demodulator 706 includes a digital receiver 710, that is referenced to a crystal clock 712. For the present example, the receiver clock is set to a frequency that corresponds to the difference between the FSK frequencies of the selected modulation pair F1/F2. Thus, for the current example of employing transmitter frequencies of 114.7 kHz and 147.5 kHz, the receiver clock may be set at 32.8 kHz. This reduced clock frequency serves maintains very low power consumption at low cost. The use of such a relatively low reference frequency in the receiver requires a slower data rate, since one clock cycle of the receiver clock represents only 3.4-3.8 FSK clock cycles.

[0087] As described in the incorporated by reference '719 patent, the digital receiver 712 may employ complementary buffer paths A/B that operate on alternate sample periods one-half the period of the received data spread code. This ensures that at least one of the two buffer paths will not be sampling data during transitions in the received FSK frequency. The receiver integration time is sufficiently long to count the number of rising edges in a received FSK signal, and readily differentiate between the two valid FSK frequencies (here, Fl=I 14.7 kHz and F2=147.5 kHz), to determine when a frequency change occurs, and to reject other FSK signals and/or noise.

[0088] The digital demodulator 720 contains a state machine that demodulates the data by comparing a received sequence of FSK tones with a predefined start-of-message sequence (corresponding to a start synchronization code). As a non-limiting example, the start-of-message sequence may comprise a plurality of successive samples at one FSK frequency or tone (such as three symbol
periods at the higher of the two FSK tones), followed by a plurality of successive samples at the second FSK frequency (e.g., three symbol periods at the lower of the two FSK tones). Upon detecting this sequence, the state machine initializes the data demodulation circuitry, so that the data may be clocked out as it is detected and demodulated.

[0089] As is customary in FSK-based modulation systems, data values of T and '0' are represented by respectively difference sequences of the two FSK tones. As a non-limiting example, a logical 'one' may correspond to one symbol period at the higher FSK tone (147.5 KhZ) followed by one spreading chip period at the lower FSK tone (114.7 kHz); a logical 'zero' may correspond to one symbol period at the lower FSK tone (114.7 kHz), followed by one symbol period at the higher FSK tone (147.5 KhZ). Similar to detecting the start of a message, the demodulator's state machine may detect the end of a message by comparing a received sequence of FSK tones with a predefined end-of-message sequence. As a non-limiting example, the end-of-message sequence may be complementary to the start-of-message sequence, described above.

[0090] In an alternative embodiment the receiver may employ a phase detector a quadrature phase shift circuit resonant at the center of the two FSK tones. This alternative embodiment eliminates the requirement for a large spectral separation between the tones, so as to allow a narrower receiver bandwidth with better sensitivity and reduced susceptibility to interference. For example, the higher FSK tone may be reduced to 127 KHz, while still using the efficient 32.8 KHz system clock.

[0091] FIG. 6C shows the manner in which the circuit architecture of a tag transceiver (transmitter-transponder) unit employed in the radio location and tracking system of the type detailed in the above-referenced '719 patent (such as that shown in FIG. 4 of U.S. Patent No. 5,920,287) may be modified to incorporate an encoded magnetic field receiver, such as that disclosed in the '719 patent and described above with reference to FIG. 6C. As shown in FIG. 6C, the augmented tag transceiver comprises an oscillator 801, the output of which is coupled to a variable pseudo random (PN) pulse generator 802.
The PN generator 802 is normally operative to generate series of relatively low repetition rate (for example, from tens of seconds to several hours), randomly occurring 'blink' pulses that are coupled through an OR gate 804 to a high speed PN spreading sequence generator 806. These blink pulses define when the tag randomly transmits or 'blinks' bursts of wideband (spread spectrum) RF energy to be detected by the tag transmission readers, in order to locate and identify the tag using time-of-arrival geometry processing of the identified first-to-arrive signals, as described above. The PN generator 802 is also coupled to receive a control signal on line 803 from magnetic field sensing circuitry of the type shown in FIG. 6B, and depicted generally in broken lines 810.

In response to the tag's magnetic field sensing circuitry demodulating a blink rate reprogramming message, FSK-modulated onto the magnetic field generated by the magnetic field generator (pinger), it couples a blink rate change signal (e.g., changes the binary state of line 803 from its default, low blink rate representative level to a high blink rate logic level) to the variable PN generator 802. This increases the pulse rate at which 'blink' pulses are produced by generator and coupled through OR gate 804 to the high speed PN spreading sequence generator 806. As a consequence the tag blinks at an increased rate and thereby alert the tracking system of the proximity of the tagged object to an 'increased sensitivity' region where the magnetic field generator is installed.

In response to an enabling 'blink' pulse, the high speed PN spreading sequence generator 806 generates a prescribed spreading sequence of PN chips. The PN spreading sequence generator 806 is driven at the RF frequency output of a crystal oscillator 808. This crystal oscillator provides a reference frequency for a phase locked loop (PLL) 812, which establishes a prescribed output frequency (for example, a frequency of 2.4 GHz, to comply with FCC licensing rules). The RF output of PLL 812 is coupled to a first input 821 of a mixer 823, the output 424 of which is coupled to an RF power amplifier 826. Mixer 823 has a second input 825 coupled to the output 831 of a spreading sequence modulation exclusive-OR gate 833. A first input 835 of the exclusive-OR gate 831 is coupled to receive the PN spreading chip sequence generated by PN generator 806. A second input 837 of exclusive-OR gate 831 is coupled to receive the respective bits
of data stored in a tag data storage memory 840, which are clocked out by the PN spreading sequence generator 806.

[0095] The tag memory 840 may comprise a relatively low power, electrically alterable CMOS memory circuit, which stores a multibit word or code representative of the identification of the tag. The tag memory 840 may also store additional parameter data, such as that provided by an associated sensor (e.g., a temperature sensor) 842 installed on or external to the tag, and coupled thereto by way of a data select logic circuit 844. The data select logic circuit 844 is further coupled to receive data transmitted to the tag by the FSK-modulated magnetic field generator, described above, and demodulated by the magnetic field sensing circuit 810. For this purpose the demodulated data is decoded by a command and data decoder 846. The data select logic circuit 844 may implemented in gate array logic and is operative to append any data it receives to that already stored in the tag memory 840. It may also selectively couple sensor data to memory, so that the tag will send only previously stored data. It may also selectively filter or modify data output by the command and data decoder 846.

[0096] When a magnetic field-modulated message from the magnetic field generator is detected by the receiver 810, the data in the decoded message is written into the tag memory 840, via the data select logic circuit 844. The command and data decoder 846 also couples a signal through OR gate 804 to the enable input of the PN generator 806, so that the tag's transmitter will immediately generate a response RF burst, in the same manner as it randomly and repeatedly 'blinks,' a PN spreading sequence transmission containing its identification code and any parameter data stored in memory 840, as described above. A RSSI circuit 850 is operative with the receiver as a magnetic field sensing circuit 810 to measure the received signal strength.

[0097] As will be appreciated from the foregoing description, the desire to communicate with or controllably modify the operation of a tag whose object comes within a prescribed region (e.g., passes through a passageway) of a monitored environment, is readily accomplished in accordance with the present invention, by placing an arrangement of one or more relatively short range, magnetic field proximity-based, tag-programming 'pingers' at a respective location.
of the monitored environment that is proximate to the region through which a tag may pass. The pinger may be readily implemented and the tag transceiver augmented in accordance with the respective magnetic field generator and tag-installed magnetic field sensor architectures described in the above referenced '719 patent.

[0098] As a non-limiting example, the magnetic field generator may be installed on a forklift, so that a tagged item being moved by the forklift will receive the increased blink rate command. This will allow continuous tracking of a tagged item, as it is being moved by the forklift. After the forklift has transported and deposited the tagged item, and then leaves the proximity of the tagged item, the tag will again resume its previous slow blink rate, thus conserving battery life.

[0099] The tag transmitter can be mounted to different tag support members and can comply with ANSI 371.1 RTLS standard and can use a globally accepted 2.4 GHz frequency band, transmitting spread spectrum signals in accordance with the standard. The use of the spread spectrum technology can provide long-range communications in excess of 100 meters for read and a 300 meter locate range for outdoors. In the lane sensor application, that range is not as important as described before. This can be accomplished with less than two milliwatts of power. Battery life can be as long as seven years depending upon the blink rate, which could be user configurable from as little as five seconds to as much as one hour. Any type of activation from an interrogator can be up to six meters. The power could be a battery such as an AA lithium thionyl chloride cell. In one aspect, the height is about 0.9 inches and a length of about 2.6 inches or with mounting tags such as used for mounting the tag transmitter on the tag support member about four inches. The width is about 1.7 to about 2 inches.

[00100] FIGS. 7 and 8 represent examples of the type of circuits that can be used with modifications as suggested by those skilled in the art for receiver circuitry as a lane sensor, also operative as an access point and processor circuitry as part of a server or separate unit to determine any timing matters, validate rentals or returns, set up a correlation algorithm responsive to any timing matters, determine which tag signals are first-to-arrive signals and conduct differentiation of
first-to-arrive signals to locate a tag or other transmitter generating a tag or comparable signal.

Naturally, a more simple processor design could be used if only vehicle identification for validation and controlling entry and exit from a vehicle lot is desired.

Referring now to FIGS. 7 and 8, a representative circuit and algorithm as described in the above mentioned and incorporated by reference patents are disclosed and set forth in the description below to aid in understanding the type of receiver or access point and location processor circuitry that can be used for determining which signals are first-to-arrive signals and how a processor conducts differentiation of the first-to-arrive signals to locate a tag transmitter. These circuits would be beneficial if a location system is used in addition to the lane sensor system, but would not be necessary when only a lane sensor system is used.

FIG. 7 diagrammatically illustrates one type of circuitry configuration of a respective architecture for "reading" associated signals or a pulse (a "blink") used for location determination signals, such as signals emitted from a tag transmitter to a receiver as a locating access point. An antenna 210 senses appended transmission bursts or other signals from the object and tag transmitter to be located. The antenna in this aspect of the invention could be omnidirectional and circularly polarized, and coupled to a power amplifier 212, whose output is filtered by a bandpass filter 214. Naturally, dual diversity antennae could be used or a single antenna. Respective I and Q channels of a bandpass filtered signal are processed in associated circuits corresponding to that coupled downstream of filter 214. To simplify the drawing only a single channel is shown.

A respective bandpass filtered I/Q channel is applied to a first input 221 of a down-converting mixer 223. Mixer 223 has a second input 225 coupled to receive the output of a phase-locked local IF oscillator 227. IF oscillator 227 is driven by a highly stable reference frequency signal (e.g., 175 MHz) coupled over a (75 ohm) communication cable 231 from a control processor. The reference frequency applied to phase-locked oscillator 227 is coupled through an LC filter 233 and limited via limiter 235.
[00105] The IF output of mixer 223, which may be on the order of 70 MHz, is coupled to a controlled equalizer 236, the output of which is applied through a controlled current amplifier 237 and preferably applied to communication cable 231 through a communication signal processor, which could be an associated processor. The communication cable 231 also supplies DC power for the various components of the access point by way of an RF choke 241 to a voltage regulator 242, which supplies the requisite DC voltage for powering an oscillator, power amplifier and analog-to-digital units of the receiver.

[00106] A 175 MHz reference frequency can be supplied by a communications control processor to the phase locked local oscillator 227 and its amplitude could imply the length of any communication cable 231 (if used). This magnitude information can be used as control inputs to equalizer 236 and current amplifier 237, so as to set gain and/or a desired value of equalization, that may be required to accommodate any length of any communication cables (if used). For this purpose, the magnitude of the reference frequency may be detected by a simple diode detector 245 and applied to respective inputs of a set of gain and equalization comparators shown at 247. The outputs of comparators are quantized to set the gain and/or equalization parameters.

[00107] It is possible that sometimes signals could be generated through the clocks used with the global positioning system receivers and/or other wireless signals. Such timing reference signals can be used as suggested by known skilled in the art.

[00108] FIG. 8 diagrammatically illustrates an example architecture of a correlation-based, RF signal processor circuit as part of a location processor to which the output of a respective RF/IF conversion circuit can be coupled such as by wireless communication (or wired in some instances) for processing the output and determining location based on the GPS receiver location information for various tag signal readers. The correlation-based RF signal processor correlates spread spectrum signals detected by an associated tag signal reader with successively delayed or offset in time (by a fraction of a chip) spread spectrum reference signal patterns, and determines which spread spectrum signal is the first-to-arrive corresponding to a location pulse.
Because each access point can be expected to receive multiple signals from the tag transmitter due to multipath effects caused by the signal transmitted by the tag transmitter being reflected off various objects/surfaces, the correlation scheme ensures identification of the first observable transmission, which is the only signal containing valid timing information from which a true determination can be made of the distance.

For this purpose, as shown in FIG. 8, the RF processor employs a front end, multichannel digitizer 300, such as a quadrature IF-baseband down-converter for each of an N number of receivers. The quadrature baseband signals are digitized by associated analog-to-digital converters (ADCs) 2721 and 272Q. Digitizing (sampling) the outputs at baseband serves to minimize the sampling rate required for an individual channel, while also allowing a matched filter section 305, to which the respective channels (reader outputs) of the digitizer 300 are coupled to be implemented as a single, dedicated functionality ASIC, that is readily cascadable with other identical components to maximize performance and minimize cost.

This provides an advantage over bandpass filtering schemes, which require either higher sampling rates or more expensive analog-to-digital converters that are capable of directly sampling very high IF frequencies and large bandwidths. Implementing a bandpass filtering approach typically requires a second ASIC to provide an interface between the analog-to-digital converters and the correlators. In addition, baseband sampling requires only half the sampling rate per channel of bandpass filtering schemes.

The matched filter section 305 may contain a plurality of matched filter banks 307, each of which is comprised of a set of parallel correlators, such as described in the above identified, incorporated by reference '926 patent. A PN spreading code generator could produce a PN spreading code (identical to that produced by a PN spreading sequence generator of a tag transmitter). The PN spreading code produced by PN code generator is supplied to a first correlator unit and a series of delay units, outputs of which are coupled to respective ones of the remaining correlators. Each delay unit provides a delay equivalent to one-half a
chip. Further details of the parallel correlation are found in the incorporated by reference '926 patent.

[00113] As a non-limiting example, the matched filter correlators may be sized and clocked to provide on the order of $4 \times 10^6$ correlations per epoch. By continuously correlating all possible phases of the PN spreading code with an incoming signal, the correlation processing architecture effectively functions as a matched filter, continuously looking for a match between the reference spreading code sequence and the contents of the incoming signal. Each correlation output port 328 is compared with a prescribed threshold that is adaptively established by a set of "on-demand" or "as needed" digital processing units 340-1, 340-2, ... 340-K.

One of the correlator outputs 328 has a summation value exceeding the threshold in which the delayed version of the PN spreading sequence is effectively aligned (to within half a chip time) with the incoming signal.

[00114] This signal is applied to a switching matrix 330, which is operative to couple a "snapshot" of the data on the selected channel to a selected digital signal processing unit 340-1 of the set of digital signal processing units 340. The units can "blink" or transmit location pulses randomly, and can be statistically quantified, and thus, the number of potential simultaneous signals over a processor revisit time could determine the number of such "on-demand" digital signal processors required.

[00115] A processor would scan the raw data supplied to the matched filter and the initial time tag. The raw data is scanned at fractions of a chip rate using a separate matched filter as a co-processor to produce an auto-correlation in both the forward (in time) and backwards (in time) directions around the initial detection output for both the earliest (first observable path) detection and other buried signals. The output of the digital processor is the first path detection time, threshold information, and the amount of energy in the signal produced at each receiver's input, which is supplied to and processed by the time-of-arrival-based multi-lateration processor section 400.

[00116] Processor section 400 could use a standard multi-lateration algorithm that relies upon time-of-arrival inputs from at least three readers to compute the location of the tag transmitter. The algorithm may be one which uses a
weighted average of the received signals. In addition to using the first observable signals to determine object location, the processor also can read any data read out of a memory for the tag transmitter and superimposed on the transmission. Object position and parameter data can be downloaded to a database where object information is maintained. Any data stored in a tag memory may be augmented by altimetry data supplied from a relatively inexpensive, commercially available altimeter circuit. Further details of such circuit are found in the incorporated by reference '926 patent.

It is also possible to use an enhanced circuit as shown in the incorporated by reference '926 patent to reduce multipath effects, by using dual antennae and providing spatial diversity-based mitigation of multipath signals. In such systems, the antennas are spaced apart from one another by a distance that is sufficient to minimize destructive multipath interference at both antennas simultaneously, and also ensure that the antennas are close enough to one another so as to not significantly affect the calculation of the location of the object by a downstream multi-lateration processor.

The multi-lateration algorithm executed by the location processor 26 could be modified to include a front-end subroutine that selects the earlier-to-arrive outputs of each of the detectors as the value to be employed in a multi-lateration algorithm. A plurality of auxiliary "phased array" signal processing paths can be coupled to the antenna set (e.g., pair), in addition to any paths containing directly connected receivers and their associated first arrival detectors that feed the locator processor. Each respective auxiliary phased array path is configured to sum the energy received from the two antennas in a prescribed phase relationship, with the energy sum being coupled to associated units that feed a processor as a triangulation processor.

The purpose of a phased array modification is to address the situation in a multipath environment where a relatively "early" signal may be canceled by an equal and opposite signal arriving from a different direction. It is also possible to take advantage of an array factor of a plurality of antennas to provide a reasonable probability of effectively ignoring the destructively interfering energy. A phased array provides each site with the ability to differentiate between
received signals, by using the "pattern" or spatial distribution of gain to receive one incoming signal and ignore the other.

[00120] The multi-lateration algorithm executed by the location processor 26 could include a front end subroutine that selects the earliest-to-arrive output of its input signal processing paths and those from each of the signal processing paths as the value to be employed in the multi-lateration algorithm (for that receiver site). The number of elements and paths, and the gain and the phase shift values (weighting coefficients) may vary depending upon the application.

[00121] It is also possible to partition and distribute the processing load by using a distributed data processing architecture as described in the incorporated by reference '976 patent. This architecture can be configured to distribute the workload over a plurality of interconnected information handling and processing subsystems. Distributing the processing load enables fault tolerance through dynamic reallocation.

[00122] The front end processing subsystem can be partitioned into a plurality of detection processors, so that data processing operations are distributed among sets of processors. The partitioned processors are coupled in turn through distributed association processors to multiple location processors. For tag detection capability, each reader could be equipped with a low cost omnidirectional antenna, that provides hemispherical coverage within the monitored environment.

[00123] A detection processor filters received energy to determine the earliest time-of-arrival energy received for a transmission, and thereby minimize multi-path effects on the eventually determined location of a tag transmitter. The detection processor demodulates and time stamps all received energy that is correlated to known spreading codes of the transmission, so as to associate a received location pulse with only one tag transmitter. It then assembles this information into a message packet and transmits the packet as a detection report over a communication framework to one of the partitioned set of association processors, and then de-allocates the detection report.

[00124] A detection processor to association control processor flow control mechanism equitably distributes the computational load among the available association processors, while assuring that all receptions of a single location pulse
transmission, whether they come from one or multiple detection processors, are directed to the same association processor.

[00125] FIG. 9 shows a plan view of three slots or vehicle lanes 502, 504 and 506 with one tag interrogator 510 as a WherePort device positioned over the center vehicle lane 504 at an entry/exit or vehicle gate 511. Each lane could correspond to a parking lane, however, and not part of an entry/exit or vehicle gate. The vehicle gate is typically located at a vehicle lot, such as a rental car agency. Each vehicle lane is parallel to each other and contiguous. The interrogator has an identification number of "1234". The dashed line at 512 indicates the reach of the signal corresponding to the magnetic signal source or "range" of the tag interrogator, and it is seen to "interrogate" all vehicle lanes 502, 504, 506 identified as lanes 1-3. If a car with a tag transmitter is parked in or passing through the center lane 504 indicated at lane number 2, the RSSI value reported by that tag transmitter will be greater than the RSSI value reported by any cars in either the outside lanes 502, 506 and identified as lane numbers 1 and 3. This information is used to ascertain the exact lane as the center lane through appropriate processing at the tags or at a processor as part of an access point or location processor as described before.

[00126] FIG. 10 is a plan view of six contiguous and parallel traffic vehicle lanes 502, 504, 506, 520, 522 and 524 and showing two tag interrogators 510, 530 as WherePort devices with the identification numbers of "1234" and "1235". The dashed lines at 512 and 532 indicate the reach of the interrogation signal as noted before. The range of the interrogators are for different lanes such that a first tag interrogator emits a signal that covers a first plurality of vehicle lanes (1-3 in this example), and a second interrogator emits a signal that covers a second plurality of vehicle lanes (4-6 in this example). The combination of the interrogator identifications and RSSI reported by each tag transmitter allow the exact lane to be determined. An example is shown in the table below.
It should be understood that RSSI is a measurement of the strength of received radio signals as known to those skilled in the art. It is typically used as part of the IEEE 802.11 protocol family. RSSI is often done in the IF stage of a radio circuit at baseband. RSSI output in some circuits is often at a DC analog level. The RSSI can be sampled by an internal ADC and any codes available directly or via peripheral or internal processor bus.

RSSI has been used in wireless networking cards to determine when the amount of radio energy in the channel is below a certain threshold, at which point the network card is clear to send (CTS). Once the card is clear to send, a packet of information can be sent such applications can be applied to the system as described.

RSSI measurements in some non-limiting examples can vary from 0 to 255 depending on the type of device using one byte integer value. A value of 1, for example, will indicate the minimum signal strength detectable by the wireless card, while 0 indicates no signal. The value has a maximum of RSSI\_Max. Some circuits will return a RSSI of 0 to 100. In this case, the RSSI\_Max is 100. Some circuits can report 101 distinct power levels. Other circuits as will return a RSSI value of Oto 60.

A location optimization algorithm could be incorporated by using a rule-based matching algorithm. An event trigger is generated by a mobile asset or from a fixed location to indicate the gain or loss of another asset. The system and method could use a location optimization algorithm to determine automatically the asset transaction associated with the event trigger to a very high accuracy. The

<table>
<thead>
<tr>
<th>TAG IN LANE</th>
<th>WP 1234</th>
<th>WP 1235</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes – RSSI = medium</td>
<td>Yes or no, low</td>
</tr>
<tr>
<td>2</td>
<td>Yes – RSSI = High</td>
<td>Yes or no, low</td>
</tr>
<tr>
<td>3</td>
<td>Yes – RSSI = med</td>
<td>Yes or no, low</td>
</tr>
<tr>
<td>4</td>
<td>Yes or No – RSSI = low</td>
<td>Yes – RSSI = med</td>
</tr>
<tr>
<td>5</td>
<td>Yes or No – RSSI = low</td>
<td>Yes – RSSI = High</td>
</tr>
<tr>
<td>6</td>
<td>Yes or No – RSSI = low</td>
<td>Yes – RSSI = High</td>
</tr>
</tbody>
</table>
illustrated example includes a rental car lot exit lane detecting the presence of a vehicle for automated check-out from a large inventory of possibilities. The location optimization algorithm determines data from relevant real-time tracked, assets to determine a correct association. Further details are set forth in commonly assigned U.S. Patent Publication No. 2007/0182556, the disclosure which is hereby incorporated by reference in its entirety.

A high-level block diagram illustrating a flow sequence for a rule-based algorithm is shown in FIG. 11. The process starts at an event trigger (block 500). All possible association candidates are collected (block 502). A numerical score is assigned to each candidate based on how well it matches the event according to a set of rules (block 504). A determination is made whether the score is above a minimum score (block 506). This is an optimization to report quickly a candidate if it looks good rather than waiting for a maximum time. If the score is above a minimal score, a report of the best candidate is performed (block 508), and the winning candidate is reported. If the score is not above a minimum score, a determination is made whether the time is above a maximum time (block 510). If yes, the report for the best candidate is accomplished (block 508). If the time is not above a maximum time, the system waits "X" amount of seconds (block 512) and the system waits for more information to arrive before re-scoring the candidates.

Each candidate can be scored for how well it matches the event. For example, the Total Score = \[ \sum_{RULE} \text{Weight}_{RULE} \left| \text{Score (Rule, Candidate)} \right| \]

weight is a value between 0 and 1 and indicates the importance of this rule relative to other rules. The sum of the weights of all rules typically should be 1.0. The score (rule, candidate) typically is a number normalized between -10 and 10. The negative 10 signifies that this candidate is highly inconsistent with this event based on this rule. The positive 10 indicates that this candidate is highly consistent with this event based on this rule.

A rule can be written to score a candidate for consistency with a specific point of information. For example, sources of information in a marine terminal or car rental agency could include location, timing, telemetry, database state, sensors, directional bearing such as from a compass, and other sources of
information. Some of the rules that can be used to evaluate a candidate include a proximity rule, which is a distance an associate candidate (AC) was located from the Event Trigger (ET) at the time of process initiation. A moving rule is where the AC was stopped or moving at the time of ET. Data can come from motion sensors and/or a location trail. A bearing rule includes a heading direction for both the ET asset and AC asset. Data can come from a compass, inertial navigation sensors and/or location trails. Inclusion sensors can refer to other AC Sensor's data inclusion for consistency with an event. Exclusion sensors on the AC or other tracked assets could exclude the possibility of the AC being valid. An asset type allows consistency of the traced asset in a Database (DB) associated with the AC. [00134] The event trigger is important, and typically there has been no real-time way to capture an event if this fails. It could be over determined (multiple sources) to improve reliability. AC data over-determination allows correct transaction recording, even in the event of erroneous data elements. The location optimization algorithm can alert for a data element error source such as a broken sensor, or similar problems either instantaneously or based on an accumulated history of results. The location optimization algorithm is operative with an engine as part of the system and typically can automatically adjust weighting for known data element errors. [00135] There are various benefits of the system as described. The system can consider all possible candidates and can determine a solution with low latency if a candidate has a sufficiently high score. The system can handle inconsistent and over-determined datasets, and can choose not to report a solution if all candidate scores are lower than desirable. The confidence level can readily be determined and reported based on the score. The system can take into account many kinds of information including location, telemetry, database, timing, sensors, and similar information sources. The algorithm can be readily extended by adding new rules and adjusting weights. [00136] Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific
embodiments disclosed, and that the modifications and embodiments are intended to be included within the scope of the dependent claims.
THAT WHICH IS CLAIMED:

1. A system for determining the entry or exit lane of vehicles passing through a vehicle gate, comprising:
   a vehicle gate comprising a plurality of vehicle lanes through which vehicles enter or exit;
   a tag interrogator positioned at a predetermined location of the vehicle gate for emitting a signal containing a tag interrogator ID identifying the tag interrogator such that a plurality of vehicle lanes are within range to receive the signal; and
   a tag transmitter mounted on a vehicle that enters or exits a vehicle lane and receives the signal emitted from the tag interrogator, wherein said tag transmitter is operative for determining the received signal strength indication (RSSI) and in response to receiving the signal, transmitting an RF signal containing the tag interrogator ID and the RSSI for determining which vehicle lane the vehicle is located based on the tag interrogator ID and RSSI.

2. The system according to Claim 1, wherein said plurality of vehicle lanes are parallel and contiguous to each other and the range of the signal emitted from the tag interrogator is limited to about said vehicle lanes.

3. The system according to Claim 1, and further comprising a plurality of tag interrogators positioned at the vehicle gate at different locations and emitting signals having a range covering different vehicle lanes such that a first tag interrogator emits a signal that covers a first plurality of vehicle lanes and a second tag interrogator emits a signal that covers a second plurality of vehicle lanes.

4. The system according to Claim 3, wherein said first plurality and second plurality of vehicle lanes are different vehicle lanes.

5. The system according to Claim 1, wherein said tag interrogator is operative for transmitting a magnetic signal carrying the tag identifier ID that
activates a tag transmitter in proximity to the magnetic signal for initiating transmission of the RF signal from the tag transmitter.

6. The system according to Claim 1, wherein said RF signal comprises a spread spectrum wireless signal.

7. The system according to Claim 1, and further comprising a vehicle lot at which said vehicle gate is located to control entry and exit to and from the vehicle lot.

8. The system according to Claim 7, wherein said vehicle lot comprises a rental car agency lot.

9. A system for determining the entry or exit lane of vehicles passing through a vehicle gate, comprising:
   a vehicle gate comprising a plurality of vehicle lanes through which vehicles enter or exit;
   a tag interrogator positioned at a predetermined location of the vehicle gate for emitting a signal containing a tag interrogator ID identifying the tag interrogator such that a plurality of vehicle lanes are within range to receive the signal;
   a tag transmitter mounted on a vehicle that enters or exits a vehicle lane and receives the signal emitted from the tag interrogator, wherein said tag transmitter is operative for determining the received signal strength indication (RSSI) and in response to receiving the signal, transmitting an RF signal containing the tag interrogator ID and the RSSI;
   at least one access point positioned at a known location that receives the RF signal from the tag transmitter; and
   a processor operatively connected to said at least one access point for receiving and processing the data received from the tag transmitter and determining which vehicle lane the vehicle is in based on the tag interrogator ID and RSSI of the signal received from the tag interrogator.
10. The system according to Claim 9, and further comprising a plurality of spaced apart access points that receive said RF signal from said tag transmitter.

11. The system according to Claim 9, wherein said processor is operative for geolocating the tag transmitter.

12. The system according to Claim 11, wherein said processor is operative for correlating a signal as a first-to-arrive signal for locating the tag transmitter.

13. The system according to Claim 12, wherein said processor is operative for conducting differentiation of time of arrival signals received from the tag transmitter.

14. The system according to Claim 9, wherein said plurality of vehicle lanes are parallel and contiguous to each other and the range of the signal emitted from the tag interrogator is limited to about said vehicle lanes.

15. The system according to Claim 9, and further comprising a plurality of tag interrogators positioned at the vehicle gate at different locations and emitting signals having a range covering different vehicle lanes such that a first tag interrogator emits a signal that covers a first plurality of vehicle lanes and a second tag interrogator emits a signal that covers a second plurality of vehicle lanes.

16. The system according to Claim 9, wherein said first plurality and second plurality of vehicle lanes are different vehicle lanes.

17. The system according to Claim 9, wherein said tag interrogator is operative for transmitting a magnetic signal carrying the tag identifier ID that activates a tag transmitter in proximity to the magnetic signal for initiating transmission of the RF signal from the tag transmitter.
18. The system according to Claim 9, wherein said RF signal comprises a spread spectrum wireless signal.

19. The system according to Claim 9, and further comprising a vehicle lot at which said vehicle gate is located to control entry and exit to and from the vehicle lot.

20. The system according to Claim 19, wherein said vehicle lot comprises a rental car agency lot.

21. A method for determining the entry or exit lane of vehicles passing through a vehicle gate, comprising:
   providing a vehicle gate comprising a plurality of vehicle lanes through which vehicles enter or exit;
   emitting a signal containing a tag interrogator ID from a tag interrogator positioned at a predetermined location of the vehicle gate that identifies the tag interrogator, wherein the plurality of vehicle lanes are within range of the signal at the vehicle gate and receive the signal;
   receiving the emitted signal from the tag interrogator within a tag transmitter mounted on a vehicle that enters or exits one of the vehicle lanes in proximity to the signal emitted from the tag interrogator and determining the received signal strength indication (RSSI) and in response to the signal received from the tag interrogator, transmitting an RF signal containing the tag interrogator ID and the RSSI of the signal emitted from the tag interrogator to determine which vehicle lane the vehicle is located based on the tag interrogator ID and RSSI.

22. The method according to Claim 21, which further comprises receiving and processing data received from the tag transmitter within a processor for determining which vehicle lane that vehicle is located based on geolocation and the tag interrogator ID and RSSI.
23. The method according to Claim 21, which further comprises emitting signals having a range covering different vehicle lanes such that a first tag interrogator emits a signal that covers a first plurality of vehicle lanes and a second tag interrogator emits a signal that covers a second plurality of vehicle lanes.

24. The method according to Claim 21, which further comprises transmitting the RF signal from the tag transmitter to at least one access point.

25. The method according to Claim 21, which further comprises transmitting a magnetic signal carrying the tag identifier ID that activates a tag transmitter in proximity to the magnetic signal for initiating transmission of the RF signal from the tag transmitter.
FIG. 7