Part 1: Active and Passive RFID: Two Distinct, But Complementary, Technologies for Real-Time Supply Chain Visibility

Active RFID and Passive RFID technologies, while often considered and evaluated together, are fundamentally distinct technologies with substantially different capabilities. In most cases, neither technology provides a complete solution for supply chain asset management applications. rather, the most effective and complete supply chain solutions leverage the advantages of each technology and combine their use in complementary ways. This need for both technologies must be considered by RFID standards initiatives to effectively meet the requirements of the user community.

I. Introduction

This paper[1] presents the characteristics and relative merits of Active and Passive RFID technologies and their applicability for real-time supply chain asset management. This paper is organized as follows:

- Description and comparison of the technical characteristics of Active and Passive RFID
- Mapping of the technical characteristics of each technology into functional capabilities
- Discussion of the applicability of each technology to supply chain visibility, based on functional capabilities
- Overview of mixed-use applications and the complementary nature of Active and Passive RFID
- Considerations for RFID standards initiatives
- Conclusions and recommendations

II. Technical Characteristics of Active and Passive RFID

Although they both fall under the "RFID" moniker and are often discussed interchangeably, Active RFID and Passive RFID are fundamentally different technologies. While both use radio frequency energy to communicate between a tag and a reader, the method of powering the tags is different. Active RFID uses an internal power source (battery) within the tag to continuously power the tag and its RF communication circuitry, whereas Passive RFID relies on RF energy transferred from the reader to the tag to power the tag.

While this distinction may seem minor on the surface, its impact on the functionality of the system is significant. Passive RFID either 1) reflects energy from the reader or 2) absorbs and temporarily stores a very small amount of energy from the reader's signal to generate its own quick response. In either case, Passive RFID operation requires very strong signals from the reader, and the signal strength returned from the tag is constrained to very low levels by the limited energy. On the other hand, Active RFID allows very low-level signals to be received by the tag (because the reader does not need to power the tag), and the tag can generate high-level signals back to the reader, driven from its internal power source. Additionally, the Active RFID tag is continuously powered, whether in the reader field or not. As discussed in the next section, these differences impact communication range, multi-tag collection capability, ability to add sensors and data logging, and many other functional parameters.

[1] This white paper was abridged by Q.E.D. Systems from two white papers created by Savi Technologies: *Active and Passive RFID* and *Selecting the Right Active Frequency*

	Active RFID	Passive RFID
Tag Power Source	Internal to tag	Energy transferred from the reader via RF
Tag Battery	Yes	No
Availability of Tag Power	Continuous	Only within field of reader
Required Signal Strength from Reader to Tag	Low	High (must power the tag)
Available Signal Strength from Tag to Reader	High	Low

Table 1. Technical differences between Active and Passive RFID technologies.

III. Functional Capabilities of Active and Passive RFID

Because of the technical differences outlined above, the functional capabilities of Active and Passive RFID are very different and must be considered when selecting a technology for a specific application.

i. Communication Range
For Passive RFID, the communication range is limited by two factors: 1) the need for very strong signals to be received by the tag to power the tag, limiting the reader to tag range, and 2) the small amount of power available for a tag to respond to the reader, limiting the tag to reader range. These factors typically constrain Passive RFID operation to 3 meters or less. Depending on the vendor and frequency of operation, the range may be as short as a few centimeters. Active RFID has neither constraint on power and can provide communication ranges of 100 meters or more.

ii. Multi-Tag Collection
As a direct result of the limited communication range of Passive RFID, collecting multiple co-located tags within a dynamic operation is difficult and often unreliable. An example scenario is a forklift carrying a pallet with multiple tagged items through a dock door. Identifying multiple tags requires a substantial amount of communication between the reader and tags, typically a multi-step process with the reader communicating individually with each tag. Each interaction takes time, and the potential for interference increases with the number of tags, further increasing the overall duration of the operation. Because the entire collection operation must be completed *while the tags are still within the range of the reader*, Passive RFID is constrained in this aspect. For example, one popular Passive RFID systems available today requires more than 3 seconds to identify 20 tags. With a communication range of 3 meters, this limits the speed of the tagged items to less than 3 miles per hour.

Active RFID, with operating ranges of 100 meters or more, is able to collect thousands of tags from a single reader. Additionally, tags can be in motion at more than 100 mph and still be accurately and reliably collected.

iii. Sensor Capabilities

One functional area of great relevance to many supply chain applications is the ability to monitor environmental or status parameters using an RFID tag with built-in sensor capabilities. Parameters of interest may include temperature, humidity, and shock, as well as security and tamper detection. Because Passive RFID tags are only powered while in close proximity to a reader, these tags are unable to continuously monitor the status of a sensor. Instead, they are limited to reporting the current status when they reach a reader. Active RFID tags are constantly powered, whether in range of a reader or not, and are therefore able to continuously monitor and record sensor status, particularly valuable in measuring temperature limits and container seal status. Additionally, Active RFID tags can power an internal real-time clock and apply an accurate time/date stamp to each recorded sensor value or event.

iv. Data Storage

Both Active and Passive RFID technologies are available that can dynamically store data within the tag. However, because of power limitations, Passive RFID typically only provides a small amount of read/write data storage, on the order of 128 bytes (1000 bits) or less, with no search capability or other data manipulation features. Larger data storage and sophisticated data access capabilities require the tag to be powered for longer periods of time and are impractical with Passive RFID. Active RFID has the flexibility to remain powered for access and search of larger data spaces, as well as the ability to transmit longer data packets for simplified data retrieval. Active RFID tags are in common use with 128K bytes (1 million bits) of dynamically searchable read/write data storage.

	Active RFID	**Passive RFID**
Communication Range	Long range (100m or more)	Short or very short range (3m or less)
Multi-Tag Collection	• Collects 1000s of tags over a 7 acre region from a single reader • Collects 20 tags moving at more than 100 mph	• Collect's hundreds of tags within 3 meters from a single reader • Collects 20 tags moving at 3 mph[2] or slower.
Sensor Capability	Ability to continuously monitor and record sensor input; data/time stamp for sensor events	Ability to read and transfer sensor values only when tag is powered by reader; no date/time stamp
Data Storage	Large read/write data storage (128KB) with sophisticated data search and access capabilities available	Small read/write data storage (e.g. 128 bytes)

Table 2. Summary of functional capabilities of Active and Passive RFID technologies.

[2] Lab results using leading 3m range Passive RFID products.

IV. Applicability of Active and Passive RFID to Supply Chain Asset Management

Based on the functionality provided by each technology, Active and Passive RFID address different, but often complementary, aspects of supply chain visibility. Passive RFID is most appropriate where the movement of tagged assets is highly consistent and controlled, and little or no security or sensing capability or data storage is required. Active RFID is best suited where business processes are dynamic or unconstrained, movement of tagged assets is variable, and more sophisticated security, sensing, and/or data storage capabilities are required. In many situations, both technologies play a key role and work together to provide end-to-end, top-to-bottom supply chain visibility.

The following section presents several common application requirements and the relative fit of Active and Passive RFID.

i. Area Monitoring

In many applications, there is a need to continuously or periodically monitor the presence and status of tagged assets and items over a large area. Examples include:

- Collecting real-time inventory information within a warehouse
- Monitoring the location of empty and loaded air cargo containers across an air terminal or tarmac
- Monitoring the security of ocean containers or trailers stored in a yard or terminal

Because of the necessity for long-range communication, area monitoring is only available with Active RFID.

ii. High-Speed, Multi-Tag Portal Capability

Portals of various sizes, shapes, and uses are common throughout supply chains. Essentially, any sort of gate, doorway, or other opening through which items move fits this category, including:

- Dock doors at a distribution center
- Entry/exit gates at an intermodal terminal
- Conveyor checkpoints within a parcel sorting operation

Identifying multiple tagged items moving through a portal requires two capabilities: 1) high-speed multi-tag collection, and 2) the ability to locate all tags within the portal (and none in adjacent areas). For large portal applications, such as roadside monitoring of an eight-lane highway, only Active RFID provides the necessary communication range to cover the portal. For small and medium-sized portals (e.g. dock doors, conveyors).

iii. Cargo Security

RFID-based electronic seals are an effective means of securing all forms of cargo – ocean, air, land, and rail. Both Passive and Active RFID can be used for electronic seals, but each provides different capabilities and levels of security. Passive RFID security solutions are good for applications where simple tamper detection is sufficient, the exact time of a tampering event is not important, and concern about sophisticated thieves attempting to "spoof" the seal are minimal. Because Passive RFID tags cannot be powered while the cargo is in transit, they cannot continuously monitor the presence and status of the cargo seal. They can only report if the seal appears intact at the next read point. Active RFID, on the other hand, can continuously monitor the seal status, detecting minute variations in the seal position or integrity and implementing sophisticated anti-spoofing techniques. Immediately upon detection of a problem, the date and time and event code can be logged in the tag's memory, providing a complete audit trail of all events during the shipment.

iv. Electronic Manifest

For supply chain applications where there is a need to store an electronic manifest within the tag, such as customs inspection, only Active RFID is an appropriate option. Passive RFID does not provide sufficient data storage or data search capabilities.

A key consideration in any implementation of RFID is the impact on business processes. Clearly, the objective is to minimize these impacts, but they are virtually impossible to eliminate completely. As a general rule, Active RFID requires significantly fewer changes to existing business processes than Passive RFID. There are several reasons for this: 1) Passive RFID has a very limited read range, requiring tagged assets and items to move along well-defined paths and past specific read points, 2) Passive RFID has limited multi-tag collection capabilities, requiring large groupings of tagged items to be dispersed before passing a read point, and 3) Passive RFID is unable to read tags moving at high speed[3]. The result is that Passive RFID may require substantial process re-design and worker training to be effectively implemented. The costs associated with business process re-engineering must be considered, along with the costs of software, tags, and readers, when assessing the total cost of implementation and ownership of an RFID system.

	Active RFID	**Passive RFID**
Area Monitoring (e.g. warehouse, terminal, yard)	**Yes**	**No**
High-Speed, Multi-Tag Portal	**Yes**	**Limited**
Cargo Security Applications	**Sophisticated** (continuous tamper detection, anti-spoofing techniques, date/time stamp)	**Simple** (one-time tamper event detection, no time stamp, susceptible to "spoofing")
Electronic Manifest	**Yes**	**No**
Business Process Impacts	**Minimal**	**Substantial**
Application Characteristics	• Dynamic business process • Unconstrained asset movement • Security / sensing • Data storage / logging	• Rigid business process • Constrained asset movement • Very simple security / sensing • Limited data storage

Table 3. Applicability of Active and Passive RFID technologies to supply chain visibility.

V. Complementary Use of Active and Passive RFID

The clear advantage of Passive RFID is its low tag cost. Therefore, Passive RFID is typically the right choice for supply chain applications that meet the characteristics defined in Table 3 – where functional requirements are minimal and there are well-established, rigidly controlled business processes. Examples include tracking of cartons moving along a conveyor, simple vehicle identification where vehicles stop or slow substantially at a reader, and rail car identification (assuming no security monitoring or cargo identification is required). For areas of supply chain visibility requiring additional functionality or flexibility, such as area monitoring, high-speed identification, robust security, or sensor

[3] Passive systems can read a single tag moving at 30 mph or more by operating above unlicensed power levels. Reading multiple tags substantially reduces the maximum speed.

monitoring, Active RFID is required. For most supply chains, the optimal RFID solution in terms of overall cost and capability is a mix of both Active and Passive technologies. Some examples of mixed use include:

i. Example #1: Air Cargo

In a typical air cargo operation, boxes and items are consolidated into Unit Load Devices (ULDs), which in turn are loaded into the belly of an aircraft. The boxes and items only need to be separately tracked up to the point at which they are loaded into the ULD. Once loaded and manifested, the location and status of the items can be determined by tracking the associated ULD. Since the loading process is usually structured and orderly, with dedicated loading stations and conveyors, Passive RFID is often sufficient and most cost-effective for tracking the individual items and boxes. The ULDs, however, present different tracking requirements. They move throughout large air terminals and tarmac areas, requiring area-monitoring capabilities to locate specific ULDs for loading onto the aircraft. There are also significant security concerns, driving requirements for sophisticated sealing and security monitoring capabilities as loaded and empty ULDs are moved throughout the airport facility and loaded onto aircraft. All of these requirements lead to the need for Active RFID technology for the ULD.

Item	Characteristics	Technology
Boxes Individual Items Luggage	• Structured, orderly process for loading -- dedicated loading stations, conveyors	Passive RFID Bar code
ULD (Unit Load Device)	• Unstructured movement throughout airport facility (unstructured) • Security requirements	Active RFID

Table 4. Typical RFID requirements for Air Cargo.

ii. Example #2: Intermodal Cargo

Similar to air cargo, intermodal cargo shipments typically have a hierarchical structure of items within containers. A common hierarchy includes boxes and cartons loaded on pallets, pallets loaded into intermodal containers, and intermodal containers loaded on chassis, rail cars, and ships. The pallets are often loaded with boxes, cartons, and other items as part of an orderly build-up process within a factory or warehouse, making Passive RFID an appropriate fit in many situations. Once loaded, tracking of the pallets may require either Passive or Active RFID, depending on the particular situation. In some cases, pallets move through dedicated portals or dock doors, one or two at a time, and there is no need to monitor their location and status at other times. In other cases, the movement of pallets is more dynamic, within open yards and facilities, and there may be a need to continuously monitor their presence, not just at dock doors or other specific read points. Passive RFID is appropriate for the former, Active RFID for the latter. At the intermodal container level, security is once again a concern, especially as the US and other countries push cargo inspections back to the point of origin and require highly reliable validation of the container integrity at the destination. There may also be the need for roadside monitoring of container movement, and for continuous monitoring of containers within ports, terminals, and other large facilities. Active RFID, therefore, is the right selection at the container level. For chassis, rail cars, ships, and other conveyances, the appropriate technology may be Active RFID or a combination of Active RFID with GPS-enabled wide-area monitoring. With this latter combination, the ability to track in-transit container movements (via GPS) can be combined with continuous monitoring of an Active RFID security seal on the container, providing a highly reliable cargo monitoring and security solution.

Item	Characteristics	Technology
Boxes **Cartons** **Individual Items**	• Structured, orderly process for loading -- dedicated loading stations, conveyors	Passive RFID Bar code
Pallet	• Structured or unstructured movement, depending on situation	Passive RFID or Active RFID
Intermodal Container	• Security requirements • Area monitoring within ports, terminals • Roadside monitoring	Active RFID
Chassis, rail car, other conveyance	• Area monitoring within ports, terminals • Roadside monitoring • Intransit visibility	Active RFID GPS (wide area)

Table 5. Typical RFID requirements for Intermodal Cargo.

VI. Considerations for Standards Initiatives

RFID standards committees must recognize the differences and relative advantages of Active and Passive RFID technologies, along with the power of complementary use of these two technologies, as they establish recommendations, guidelines, and mandates for their user communities. While the desire to standardize on a single technology may seem attractive, it will actually work to the detriment of the users. The user community will be unnecessarily constrained by a single technology that is either too limited in functionality or too expensive to properly address all application needs, and optimal solutions combining the best of both technologies will no longer be an option.

To appropriately embrace the advantages of these two technologies, standards committees must recognize several factors within the standards formation process:

- The parameters affecting frequency selection are very different for Active and Passive technologies. Passive RFID requires significantly higher power levels (1000 times as great), continuous transmissions from the reader (100% duty cycle). Active RFID, on the other hand, operates at very low power levels, can operate effectively with small duty cycles, and operates on a non-interfering basis with other systems – thereby offering much more flexibility in terms of frequency selection.

- Because of the likelihood of interference within mixed-use applications, different frequency bands should be selected for Active and Passive RFID. Because Passive RFID systems are not designed to “share” the frequency with other systems, selection of a single band would prohibit both technologies from operating together.

- Protocol definition will differ for the two technologies. An Active RFID protocol will need to address the complexities of two-way communication, as well as provide access to the enhanced functionality this technology makes available.

VII. Conclusions and Recommendations

- Active RFID and Passive RFID are fundamentally different technologies.
- Active RFID and Passive RFID have different functional capabilities, and therefore address different areas of supply chain visibility.
- Passive RFID is most appropriate where the movement of tagged assets is highly consistent and controlled, and little or no security or sensing capability or data storage is required.
- Active RFID is best suited where business processes are dynamic or unconstrained, movement of tagged assets is variable, and more sophisticated security, sensing, and/or data storage capabilities are required.
- In most cases, neither technology provides a complete solution for supply chain visibility; rather, the most effective and complete supply chain solutions leverage the advantages of each technology and combine their use in complementary ways.
- RFID standards initiatives must embrace and endorse both Active and Passive RFID to effectively meet the needs of the user community.

Part 2: Active RFID: Selecting the Optimal Frequency for Global Applications

I. Introduction

Selecting an optimal radio frequency for operation of an Active RFID system requires consideration of several factors, including technical performance, regulatory issues, and co-existence with other technologies. This paper assesses a broad range of radio frequencies against these parameters, and presents rationale for the selection of 433 megahertz (MHz) as the optimal frequency for global use of Active RFID.

II. Technical Performance vs. Frequency

Two key technical performance parameters of an Active RFID system are directly related to the frequency of operation: maximum communication range and propagation within crowded environments.

i. Maximum communication range

As a general rule, radio signals at lower frequencies will propagate farther than signals at higher frequencies, assuming similar transmitter power levels. The attenuation (or decrease) of a radio signal as it travels through a medium such as air is directly related to its wavelength. All signals experience the same decrease in signal strength *per wavelength* when traveling through the same medium. Because signals at lower frequencies have longer *wavelengths*, signal attenuation occurs at a slower rate. For example, if Signal A decreases by 10% over a distance of 10 feet, then a signal at half of the frequency of Signal A will decrease by 10% over a distance of 20 feet, thereby allowing the lower frequency signal to propagate farther.

At frequencies less than 100 MHz, other factors have a greater impact on practical communication range. Systems at lower frequencies, such as 13.56 MHz, depend on inductive coupling as the primary mode of interaction. The range of an inductively coupled system drops sharply with distance, making communication beyond 10 to 20 feet impractical. Using longer-range electrical coupling at these frequencies is not recommended due to their high susceptibility to noise and interference from other devices.

ii. Propagation within crowded environments

The ability for signals to propagate within crowded environments is also dependent on the signal wavelength, and hence frequency. Within warehouses, truck yards, and other facilities, the ability for an RFID system to operate in and around obstructions is critical. These obstructions are often metal, such as vehicles and metal shelving racks, requiring signals to propagate “around” rather than “through” the obstructions. Active RFID signals propagate “around” obstructions by means of diffraction, and the level of diffraction is dependent on the size of the object versus the signal wavelength. Diffraction occurs when the wavelength approaches the size of the object. For example, at 433 MHz the wavelength is approximately a meter, enabling signals to diffract around vehicles, intermodal containers, and other large obstructions. At 2.4 GHz, the wavelength is approximately a tenth of a meter and diffraction is very limited with these obstructions, creating blind spots and areas of limited coverage. Frequencies above 2 GHz present significant challenges for operation in crowded environments and are therefore not recommended for most RFID applications.

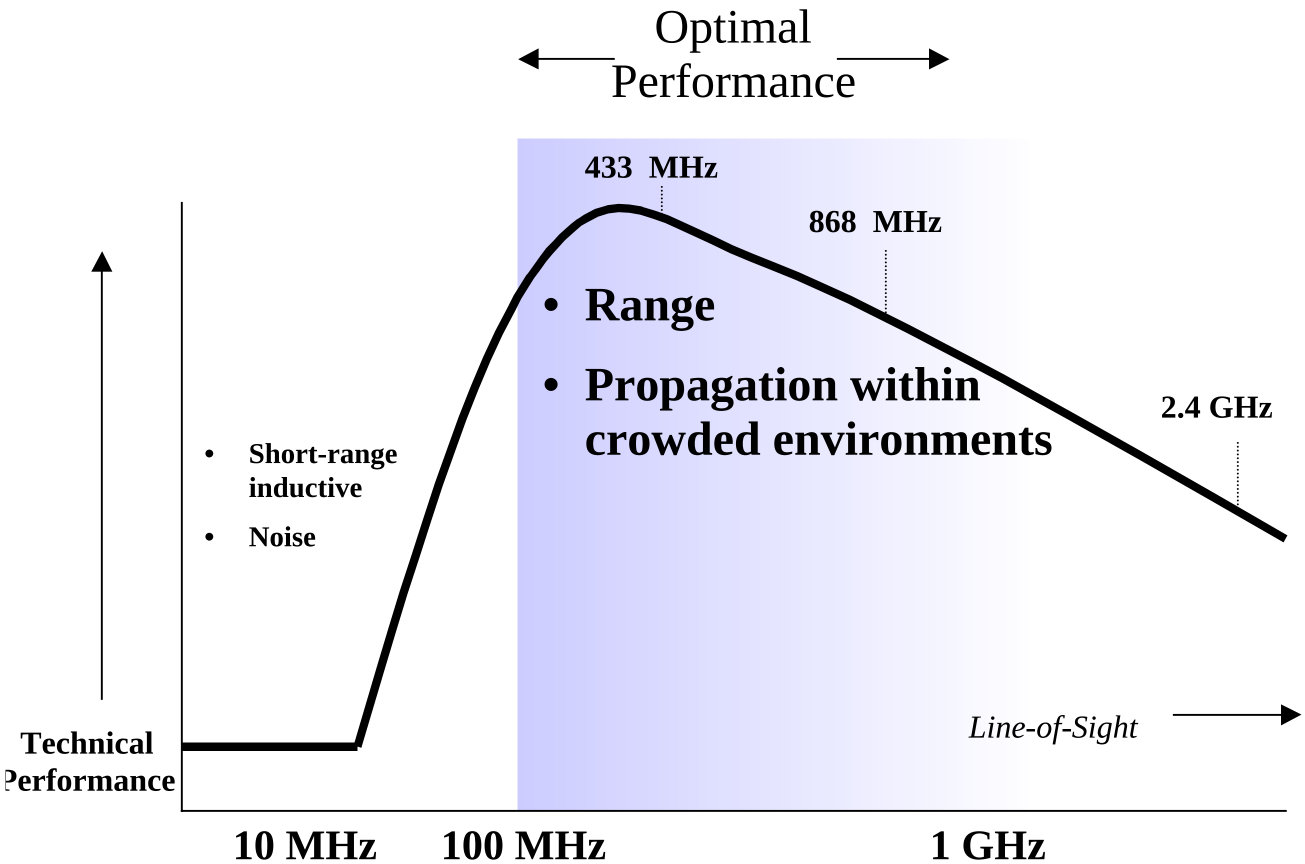

Figure 1. Frequencies between 100 MHz and 1 GHz offer the best technical performance for Active RFID.

III. Regulatory Issues

As discussed above, frequencies in the range of 100 MHz to 1 GHz present the best technical options for Active RFID, with lower frequencies within this range providing better performance. However, several factors other than technical performance affect the choice of frequency -- most importantly, existing frequency regulations within each country or region of interest.

To assess the existing frequency regulations, one must understand that more than just frequency of operation is involved. These regulations address power limits, duty cycle restrictions, and modulation schemes. The impact of these variables on selecting an Active RFID frequency is discussed below:

- <u>Power Limit</u>: Higher frequencies require higher power limits. Although Active RFID has considerably lower power requirements than Passive RFID, one still needs to consider variations in power requirements at different frequencies. For example, a 433 MHz system requires less than 1 milliwatt (mW) for 100 meter communication, whereas a 915 MHz system requires 100 mW or more.

- <u>Duty Cycle</u>: Because of Active RFID's long-range communication capability, there is more flexibility as to when and how often a reader and tag communicate. Whereas Passive RFID requires nearly continuous transmission to ensure communication as tags pass through the limited field of a reader, Active RFID systems can reliably operate by transmitting only 10% of the time (i.e. a 10% duty cycle). Although operation down to 1% or lower is feasible, operation at these duty cycles will impact data transfer rates and could jeopardize overall system reliability.

- Modulation Scheme: Some frequency and power regulations may be dependent on the modulation scheme used. For example, operating within the 915 and 2400 MHz bands typically requires the use of spread spectrum modulation for full power operation. Implementation of spread spectrum modulation may add considerable cost to tags and other components of the RFID system.

A summary of global frequency regulations for the most common Active RFID bands is shown below:

Band	303 MHz	315 MHz	418 MHz	433 MHz	868 MHz	915 MHz	2400 MHz
	302-305 MHz	314.7-315 MHz 42 dBuA/m @10m	418.95-418.975 MHz 10 mW ERP	433.050-434.790 MHz 10mW ERP 10%	868-868.6 MHz 25mW ERP 1%	902-928 MHz	2400-2483.5 MHz
USA	✓	✓	✓	✓		✓	✓
Canada	✓	✓	✓	✓		✓	✓
Great Britain				✓	✓		✓
France				✓	✓		✓
Germany				✓	✓		✓
Netherlands				✓	✓		✓
Singapore		✓		✓	✓	✓	
Taiwan	✓	✓	✓	✓			✓
China / Hong Kong		✓		In process		Limited	Limited
Australia				✓		Limited	Limited
Summary	**Limited acceptance**	**Limited acceptance**	**Limited acceptance**	**Better Choice**	**Limited duty cycle**	**Limited acceptance**	**Poor technical performance**

Table 1. 433 MHz is the most widely accepted frequency for Active RFID.

IV. Co-Existence with Other Technologies

i. Passive RFID

Active and Passive RFID are two fundamentally different technologies, each with unique advantages. While often considered competing technologies, they actually complement each other, balancing cost and capability. Active and Passive RFID offer tremendous potential for combined use within many applications, including air cargo and intermodal cargo management. Along with technical performance and regulatory issues, this opportunity for combined use must also be considered when selecting a frequency for Active RFID.

Because of the need to power the tag from the reader, Passive RFID uses very high radio signal levels, on the order of 1000 times as great as an Active RFID system. For example, Passive RFID systems within the 862 to 928 MHz band require up to 4 watts (4000 mW) of power to achieve a few meters of read range (hence the 4 watt power levels sought by standards initiatives such as SC 31). On the other hand, several commercially available Active RFID systems transmit less than one milliwatt for 100 meter range. Additionally, Passive RFID readers transmit continuously for best performance. This combination of high-power transmissions and continuous operation causes Passive RFID systems to substantially interfere with any low-power systems operating in the same vicinity at a similar frequency, including Active RFID. Therefore, for best performance, a frequency other than those in common use for Passive RFID systems should be selected for Active RFID. Given the widespread use and expected adoption of 862 MHz to 928 MHz for Passive RFID, this is not an ideal band for Active RFID.

ii. Other "Short-Range Devices"

In regulatory parlance, Active RFID typically falls under the category of "Short-Range Devices" – low-power devices with a communication range typically of a hundred meters or less. Other devices in this category include keyless entry systems for vehicles and garage door openers. While there are many of these devices in operation throughout the world, by regulation they are designed to "share" their frequency band. This sharing of a frequency band is accomplished by 1) using a limited duty cycle to ensure other devices get "air time", and 2) using retransmissions to overcome any temporary interference from other devices. Because of these design considerations, Active RFID is able to co-exist with these other short-range devices and operate reliably.

V. Proven Use

The practical result of the data presented above is that Active RFID systems are in global operation today, and 433 MHz is the most widely used frequency. This includes the largest deployment of Active RFID to date – a global supply chain visibility network operating at several hundred sites across more than 20 countries, tracking thousands of ocean, air, rail, and truck-based shipments daily. Within this system, 433 MHz Active RFID has been used reliably and effectively within day-to-day operations at ports, transportation terminals, warehouses, and other industrial facilities for more than seven years. In addition to proving its operational effectiveness, these implementations have also shown that 433 MHz Active RFID can be used without interfering with other systems in the same band.

VI. Conclusions and Recommendations

- Frequencies between 100 MHz and 1 GHz offer the best technical performance for Active RFID -- long range, omni-directional communication within crowded environments
    - Lower frequencies are used for short-range inductive systems
    - Higher frequencies suffer from line-of-sight operation
- Based on international frequency regulations, 433 MHz offers the broadest acceptance for Active RFID
- Because Passive RFID will interfere with Active RFID, frequencies in common use by Passive RFID systems should be avoided, including 862 to 928 MHz; Active RFID can co-exist with other low-power, short-range devices (such as keyless entry systems) with minimal impact
- 433 MHz is the most widely deployed Active RFID frequency today, proven effective for a complete range of global supply chain applications

Based on all of the above, 433 MHz is the optimal frequency for global Active RFID applications, offering the best blend of proven performance and worldwide acceptance.