Chapter 9 **solutions**

1. *Discuss the applicability of passive LF (low frequency), passive HF (high frequency), passive UHF as well as active UHF RFID technology to solve the following automated identification problems:*
   - Reading bolus tags that are swallowed by livestock and that remains in the stomach of the animal for its entire lifetime.
   - Bulk reading of tags embedded into the caps of bottles filled with pharmaceutical products, typically containing liquids and being stacked multiple deep and multiple high.
   - Identifying tagged vehicles moving through lanes at a multiple-lane customs gate, requiring the verification of the specific lane that each vehicle moved through.
   - Identifying tagged shipping containers at a depot, requiring the implementation of an electronic stock-take of containers at the pressing of a button.

1(a) The type of RFID to be used for this purpose should be passive as well as based on magnetic induction rather than RF E-field propagation. The fact that the required useful life for this application is not fixed will make the use of an active or semi-active tag with limited useful time undesirable. The fact that the reader will have to energize and read the tag through the body of an animal has the implication that virtually all RF propagation in the UHF band will be absorbed.

[BT]The choice between passive LF, HF or near-field UHF is a matter of existing standards and required anti-collision capabilities. The current ISO standard for livestock identification is based on LF technology, which however suffers from limited anti-collision capabilities. Both HF and near-field UHF will provide superior anti-collision using an existing protocol standard..

(b) The requirement for bulk reading of potentially large numbers of items will eliminate LF as possible solution, while active UHF will be too bulky and expensive. Passive UHF is likely to suffer from unreliable reads due to the absorption of UHF by liquid contents and the fact that line-of-sight will not be possible for some of the items, given the mode of stacking. Either HF or near-field UHF can be a workable solution. Currently the pharmaceutical industry has decided on HF as technology of choice for storing electronic pedigrees on pharmaceutical products.

(c) Passive LF and HF is eliminated based on limited read range, given that the required read range for moving vehicles is of the order to 3 m or more (preferably up to 6 m). Active UHF has more than the required read range, but will suffer from many false reads due to the detection of transponders moving through adjacent lanes. Passive UHF will be the optimal choice, as it can achieve the required read range, it can read tags moving at high speeds and it can be set up to pick up very few if any tags from adjacent lanes.

(d) The requirement to do a close to instantaneous stock-take for tagged items spread across and area that may be several hundred meters in cross-section or even bigger, will eliminate all passive RFID technologies as solution of choice. Active UHF will be able to fulfill this requirement, given its typical read range of around 100m. The number of readers and their placement will have to cover the entire area where stock may be present. Passive UHF will be able to fulfill a modified requirement where tagged containers are detected upon entry into and exit from the depot, allowing an automated stock-keeping function, as long as all entries and exits are covered.

2. The two primary factors determining read range are power-up range and range of detecting tag signals at the reader. The former is limited by regulations for spectral radiation within the various frequency bands where each type of RFID may be operated, as well as by the antenna gain of the transponder and the switch-on voltage of the transponder chip. The latter is determined partly by the sensitivity of the receiver of the RFID reader, by the type of modulation used in tag-to-reader communications, and by the presence of noise signals within the frequency band where the tag communications occur. In the case of either LF or HF there may be a large number of unintentional noise generators radiating within the communication band. In the case of passive of active UHF, the most likely sources of noise would be other RFID readers tuned to the same frequency band. In a noise-free environment the energize range would normally be the limiting factor. In noisy environment this is often reversed, with the ability to pick up tag signals becoming the limiting factor..

3. The following criteria must be taken into account:

[BL]Spectral bandwidth requirements: while transportation applications will typically require less than 10 readers in close proximity, supply chain applications may require the use of several hundred readers in relative close proximity. The use of band-width efficient version of RTF protocols (e.g. dense reader mode for ISO18000-6C with Miller subcarrier modulation) or alternatively the use of TTF protocols, where different readers can share the same channel, should therefore be considered.

Anti-collision capabilities (number of items that can be detected in one population): the number of items in a batch, and the time that each tag can be guaranteed to stay within the reader beam, must be determined. The speed at which batches of tagged items are moved past the readers, and/or the physical area covered by the readers, must be adjusted to allow the anti-collision capabilities of the protocol to provide the required read reliability for the application.

Maximum speed at which tags can be detected reliably: the time that each tag will remain within the reader beam must be calculated, based on the physical set-up (including the distance between the reader and the tags, as well as the radiation pattern of the reader antenna). This must be matched with the maximum time that it may take the protocol to detect a new tag. It is advisable to build in a safety factor to allow for the possibility of missing some tag communications (e.g. providing for at least three identifications of the same tag within the available time period).

Flexibility to dynamically adapt to different circumstances: most applications will involve some degree of variability from one read scenario to the next. It will be beneficial if the protocol can adjust itself to prevailing circumstances (e.g. reducing the rate of tag communications if congestion is detected, in the process increasing the effective through-put, or selecting a different frequency channel should the initial choice prove to be used by other readers).[BLX]

4. Based on the information provided, the reader will radiate an area with a cross-section of approximately 6.9m on the road surface (2 x 6m x tan(30°)). This is within the 10m read range of the reader, so the full extent of this area can be utilized. A car traveling at 220km/h will spend approximately 0.11 seconds within this area, which is the maximum time period that the reader will have to reliably detect a tag. In the case of an RTF protocol the reader will have to be able to search the entire tag ID space within this time period, assuming that the tag ID will be unknown to the reader before the event. In the case of a TTF protocol, the tag will have to be able to respond within this time period in a worst-case scenario (i.e. longest tag waiting time).

5. Make the worst-case assumption that all 24 bins on a trolley will be in the reader beam at one point in time, i.e. 24 x 4 = 96 tags are switched on. As seen from Figure 9.10, the average read time for the IP-X V4 protocol with 96 tags in the beam is approximately 0.85s. Each tag will be in the beam over a distance of approximately 1m, implying a tag speed of 1.17 m/s. As this is, however, based on average rather than guaranteed reading time, it will be advisable to build in a safety factor or at least 2, i.e. limit the speed of trolleys to 0.58 m/s. Should the size of the bins be such that not all 96 items will be illuminated at one time, the effective number of tags can be reduced. As seen from Figure 9.10, this will reduce the required read time and hence increase the allowed speed of movement.

6. As can be seen from Figure 9.8, the switch-off versions of the Supertag protocol can accommodate a much larger number of tags for the same limitation as far as time for the tags in the reader beam is concerned. It effectively means that in the case of large tag populations (e.g. problem 5), the tags will be allowed to move at a higher speed and still be detected without tag congestions. This, however, comes at a cost: it will not be possible to keep the error rate down to virtually zero, as tags may be switched off without ever being detected successfully (see Figure 9.9). The reliability of communications from tag to reader will determine the impact of this reduction in reliability: the worse the reliability of each tag-to-reader communication, the higher will the resulting error rate be.

7. Benefits of RTF over TTF include the following:

[BL]No hard limit on anti-collision capability (the number of tags in the beam can be increased indefinitely by increasing the time in the reader beam).

Less so-called “tag pollution” (energized tags can be controlled in terms of when they are allowed to communicated).

Ability to dynamically respond to changes in the read scenario (e.g. reducing tag communication rates when high levels of congestion are detected, by communicating this condition to tags).[BLX]

[FT]Benefits of TTF over RTF:

[BL]Require less frequency spectrum to operate a large number of readers in close proximity.

Simpler protocols lead to smaller and less expensive tag and reader electronics.

Fast tag response times can support very high tag speeds.[BLX]

8. Should RTF tags be used in mixed populations with free-running TTF tags (without the implementation of a TOTAL function), the TTF tags will tend to interfere with the normal operation of RTF systems. When illuminated by an RTF reader, the TTF tags will keep on transmitting while the RTF is establishing communications with the RTF tags, resulting in higher error rates and potentially a total break-down in RTF communications. The use of the TOTAL feature allows the TTF tags to first verify if an RTF reader is present before starting to transmit. The required waiting time depends on the maximum time that it may take an RTF reader to commence communication with RTF tags, once one or more RTF tags have switched on. The TOTAL waiting time should, however, not be extended more than necessary, as it will make the resulting TTF communications much less effective – specifically in the case of applications involving fast moving tags, where time is of the essence. As described in the text, the effective maximum tag speed at which a TOTAL versus a non-TOTAL TTF protocol can detect tags can be much reduced, to the extent that the inherent benefit of TTF versus RTF for such applications is lost.

9. The first aspect to take note of is the fact that writing new data to transponders consumes considerably more time compared to the reading of data from transponders. This is caused by the requirement to verify that written data has indeed been received correctly. This problem is compounded if more than one tag is present – for this reason, it is in general advisable to limit write operations to scenarios where only one tag will be expected to be present at any one time. This will prevent a situation where a tag has moved out of the reader beam before the success of failure of a read operation could be verified. Second, the amount of data to be written to tags and to be read back at various read points must be taken into consideration. In the case of RTF protocols, the proportional increase in the effective required read time, comparing reading the ID or EPC code only versus reading additional data as well, may be more than the increase in the effective amount of data read from the tag, as additional instructions will be required to e.g. inform other tags not to respond while a specific tag is interrogated. TTF can offer the benefit of transmitting the additional data in free-running mode without requiring any reader instructions, hence more or less retaining the effective rate of reading data from tags. This is, however, only valid in cases where the same data must be read from tags every time – once a more flexible situation is required to read different data fields on difference occasions, TTF protocols will also

require reader interrogations, leaving it in effectively the same situation as RTF protocols. In general, the speed at which tags are allowed to move will have to be adjusted to the new required read time, including the extra fields to be read.

10. In general, it can be stated that advances in electronic technology have extended the level of complexity that can be implemented in both RFID transponders and readers at a cost that the market is prepared to pay. This has allowed RTF protocol-based products to eliminate most of the benefit that TTF-based products had in terms of functionality vs. cost. The more complex RTF transponders chips can now be implemented on the smallest footprint that can be handled by current chip mounting technology. The increased processing power of DSP-based RFID readers enabled the implementation of filtering techniques that, combined with improved tag modulation schemes, have virtually eliminated the requirement to operate co-located RTF readers in different bands. The reduction in the switch-on voltages achievable in silicon today has furthermore diminished the impact that non-uniform UHF field strength used to have on the more complex RTF protocols, hence eliminating another of the initial benefits of the simpler TTF protocols.