RFID WORKSHOP

KEELE UNIVERSITY
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Realising Requirements for Intelligent Tagging Systems Suitable for Mass Markets

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Introduction

Specifying requirements is usually the prerogative of the prospective user. In the case of the RFID tag, CEST has made a good start with its IPI consortium (Ref. 1). However, it will take time for CEST's and other Standards bodies' output to be assimilated by the RFID suppliers and their integrated circuit and other component suppliers. Meanwhile, near-term opportunities exist for several very large scale closed systems. Depending how one defines the word "intelligence", some of these applications demand intelligent tagging in the sense that the transponders bring "intelligence" which is up-to-the-minute news on the object to which the transponder is attached, including not only its identity but its recent history and other operational data. An example of timely status intelligence is "paid for"/ "not paid for" marked in the retrieved data as a guide for the system operator to help decide whether tagged goods just scanned are stolen or not.

Some of those demanding functional requirements which do not contravene the Laws of Physics can be reconciled with very low unit cost of transponders. Success here depends in large measure on the skill and ingenuity of R&D people. In particular they have to exploit selected developments in low power short range radio engineering, silicon integrated circuit fabrication processes and their associated design rules.

This paper gives an overview based on recent experience of working on the Supertag™ project at BTG Ltd and in co-operation with the early Supertag™ licensees and option holders.

Requirements

A. System

However expressed in detail users' requirements at the applications interface are for an ADC sub-system which performs quickly and accurately with a minimum of manual involvement. All this must be achieved at minimal cost. Since most applications are tag-rich, the cost per transponder sets lower limits on sub-system price and determines whether the transponders are to be disposable or reusable.

The major elements of cost of a passive (batteryless) transponder are the electronics and the antenna or coil used to transmit two-way messages to and from the reader (interrogator). The transponder electronics must be kept as simple as possible and preferably be realisable as a monochip integrated circuit suitable for large-scale silicon processing. The antenna or coil must be the only additional component to be assembled onto the transponder and needs to be printed or etched rather than wound. Battery operation of transponders provides the easiest route to the longer range required in many applications. Unfortunately specifying a battery-powered (active) tag results in high cost and leads to concerns about the length and variability of operational lifetime. Passive tag systems are therefore preferred. This is notwithstanding the electromagnetic radiated power limits imposed by the Radio Regulatory Authorities (to prevent interference with other electrical equipment, etc). Figures 1and 2 illustrate the basic structures of a transponder powered by the rectification of energy from a transmitter mounted in the interrogator (reader).

B. Reading

As noted above, reading must be quick, convenient and accurate. To facilitate rapid reading, manual involvement in the scanning process must be avoided and there must be a minimum of special mechanical handling to effect the reading process. To achieve these aims the designer of an intelligent tag system seeks to read all transponders of interest in batches or groups. Such bulk reading avoids the need for serial presentation essential with conventional "serial" RFID tags and optically scanned bar code labels.

Grouping may be encountered in an application due to the accident of multiple transponders arriving at the scanning area or it may be by deliberate design. Thus, for example, small groups may be encountered during "tunnel" scanning after the bunching of baggage on a conveyor belt. Deliberate grouping will occur with stacked, shelved or rack-mounted tagged objects. As is well known, the interrogation of more than one tag at a time leads to the likelihood of the tag emitted data messages (packets) arriving simultaneously at the reader of the receiver. This "contention" problem is illustrated in Figure 3. A wide variety of slotless handling-free methods is available to solve the contention problem. Most of these are proprietary and many are kept secret (Ref 2).

General considerations are as follows. The grouped transponders to be read reside in a space called the operating volume. For most applications this volume is stationary relative to the local environment. However there are applications where the operating volume can be moved around. One example would be where the operating volume oscillates in space over time. This results in a so-called "search space". Obviously this can be significantly larger than the operating volume.

In the more common case of a static operating volume, the size of the operating volume is defined by the transponder population and the size and spacing of the tagged objects concerned. Population may be anything from a couple to a cohort. An example of a small population is in a small operating volume would be a tunnel reader straddling a conveyor belt carrying a transient population of large tagged parcels. A large operating volume with a sparse population is typified by tagged assets such as paintings in a picture gallery. Other examples will occur to attendants at this workshop.

Placing the reader's antenna where it can "see" all the present transponders in the operating volume determines antenna size and antenna to transponder distances.

In many grouped transponder reading situations this leads to a read range of several metres. This presents challenges for the passive tag fraternity which will be considered later.

C. Writing

As with reading, writing to a tag needs to be quick, accurate and convenient. Additionally, it must be secure against the unauthorised alteration, addition or substitution of data held in the transponder's memory. The extent of such security depends on the application and the likely threats. Most applications require some degree of security. Often a guarantee of data integrity is sufficient.

In common with the smart card and with labels in general, authorised writing-in or changing of transponder data content may be necessary at all stages of a transponder's existence and even before it is finally assembled. Indeed pre-coding is conventionally effected for some applications at the silicon wafer "probe" stage when a wafer of transponder memory i/c's is being tested before the wafer is broken into individual i/c chips. For audit and other purposes a transponder serial number is best "engraved" onto the chip at this early stage. Preferably it should be indelible, i.e. so-called "ROM" recording.

The next important step for writing is when assembled and tested transponders are about to go into use attached to the chosen object. If no in-service writing is expected, the resulting recording is said to be WORM, i.e. Write Once Read only Memory. Obviously users prefer WORM because they can use existing product and other codes. This is difficult to arrange with pre-coding. If additional or new data is to be written to the transponder whilst it is in operational service, the design must preferably be for R/W (Read/Write) memory.

A systems choice has to be made as to whether tags are written to individually or in groups, so-called bulk writing. There are a few early applications which definitely require bulk writing to grouped transponders. Mostly, however, serial (individual transponder) writing suffices. A number of situations which appear to need in service "write" can be satisfied by changing of the status of recently identified tags. Examples of this are "inspected" tickets, cancel validity stamps, and change from "not paid for" to "paid for". Full write-in-service capability is currently more expensive in transponder complexity. It is fortunate, therefore, that status changes can be satisfied by a "mode" change. Typically two modes can be prescribed to indicate a binary change in tagged object status.

Writing to individual transponders or groups of them is best done without using the electrical contacts present in the transponder circuitry. Instead the requirement of choice is for contactless write. As the name implies this is like the reading process in that it operates via the radio interface, as shown in Figures 2 and 3. If writing can occur concurrently with the transponder transmitting messages by broadcasting them the tag system is categorised in telecommunications terms as "full duplex". If the writing to and transmitting alternate in time the system is classed as "half duplex". Many specifiers state requirements for full duplex and then find a half duplex solution is actually less costly yet still adequate for their needs. Some care is needed in classifying tag systems as the way they operate does not fit easily into this deceptively simple classification scheme. This is true of the multi-mode tag able to report changes in status during service.

Realisations and New Tag Technology

CEST has reported on some hundreds of RFID tag and contactless smart card products available from around 60 suppliers. The extent to which any of these companies is offering an intelligent tagging system is debatable. Given the current absence of standards and the associated definitions it is difficult to decide what is intelligent and what is not. Whatever the final consensus definition there are very few, if any, products which meet the requirements collated above at a sub-dollar transponder price and without a battery in the transponder. This point is illustrated in Figure 4. The goal here is the union of metre plus range, passive transponder operation and batched (grouped) transponders being read (speedily). Speedily in this context is taken by the present writer to mean up to 50 transponders each transmitting 128 bit message packets being successfully decoded in a single second.

In the writer's opinion a promising class of radio tag technologies capable of realising intelligent tagging systems for large scale tag rich applications within the next year or two is the class based on what is called "reflection transmission" or "modulated backscatter". This has been known for some time for road vehicle transponders (Refs 3 and 4). ISD Ltd (Australia) (Ref 5) and the CSIR Laboratories (in South Africa) have devised passive low cost tag technology applying such principles. My company works with the CSIR on their intelligent tag technology. The trademark name for this family of intelligent designs is "Supertag™ " (Ref 6).

A good analogy to show how modulated back scatter works is to think about how the liquid crystal display on a wrist watch works. Ambient light falls on the LCD surface of the watch face. It is modulated with the digit display of the current time and reflected back to the wearer's eyes. Thus we see the time as a modulated pattern on the surface of an LCD "mirror".

Instead of a light mirror, think of a reflection transmission "Supertag™" transponder as a radio mirror. On being illuminated with radio waves of any particular frequency available the transponder reflects back the same radio waves modulated with the transponders' data content, e.g. an identification packet some 128 bits long. The main difference is that the tag case has the modulation resulting in a time sequence. In contrast the LCD modulation is space sequential.

Amongst the several attractions of reflection tags over the alternative "tuned circuit" tags are a very wide range of frequencies at which the system can operate. This "frequency agility" has several benefits. These include the elimination of the need for precision analogue components in the transponder. This in turn results in simpler circuitry and, hence, lower manufacturing costs.

The next challenge from the requirements above is to enable group reading of batched transponders. CSIR has selected a patented series of algorithms based on asynchronous repeated transmissions from each transponder in the operating volume and conditional muting of the transponder's transmissions. Inter alia this allows up to 50 transponders in a group within the operating volume to be read in a single second. It also enables the multi-mode functions suitable for status reporting, e.g. "paid for"/"not paid for" as required for anti-theft uses. Unlike conventional EAS anti-theft tags, deactivation is reversible.

Since the paper, Reference 6, was written, prototype Supertag™ systems operating at 458 MHz have been delivered. Designs for frequencies in the ranges 120-135 kHz and 2-7 MHz are under study, as is a microwave implementation (2.45 GHZ). The data rate for individual transponders is in the range 10 kB to 90 kB depending on the variant. It can be further increased. Each transponder operates under the control of its own on-board clock (RC oscillator derived: not from crystal since long-term stability is not needed).

It is difficult to generalise about interrogator transmitter power emissions by reference to the prototypes so far constructed. These do not make the best possible use of the radio energy incident on the transponder's antenna yet achieve performance within the ETSI European recommendations for 458 MHz (Ref 7).

There is a wide choice of silicon semiconductor processes available for minimal chip realisations of the basic Supertag™ transponder. Attention is currently focussed on low voltage and low power EEPROM and related technologies. Further variants are expected to be based on FRAM (Ferro-electric Random Access Memory). This should simplify the design of R/W versions without necessarily bringing cost penalties.

Low cost methods of printing antennae and flat coils onto high temperature flexible plastic substrates are being considered for a number of applications where the rigid "credit card" substrate of most of the prototypes (Figure 5) is unsuitable. One big advantage of staying with the latter is the ready availability of significant production capacity already laid down for smart card production. The smart card manufacturers' experience of electronics encapsulation at low unit cost should make them natural candidates to mass produce disposable transponders when sales take off.

Conclusions

Suggested requirements for a generic intelligent tagging system suitable for large scale use in closed system applications have been given.

There are good prospects for advanced designs of passive tags using reflection transmission protocols meeting most of the detailed requirements. The multi-modal type of reflection tag provides some of the benefits expected of "Write in Service" transaction recording tags without the electronics complexity associated with R/W design.

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Disclaimer

The views expressed here are purely the author's opinions. They do not necessarily represent those of BTG Ltd.

Acknowledgements

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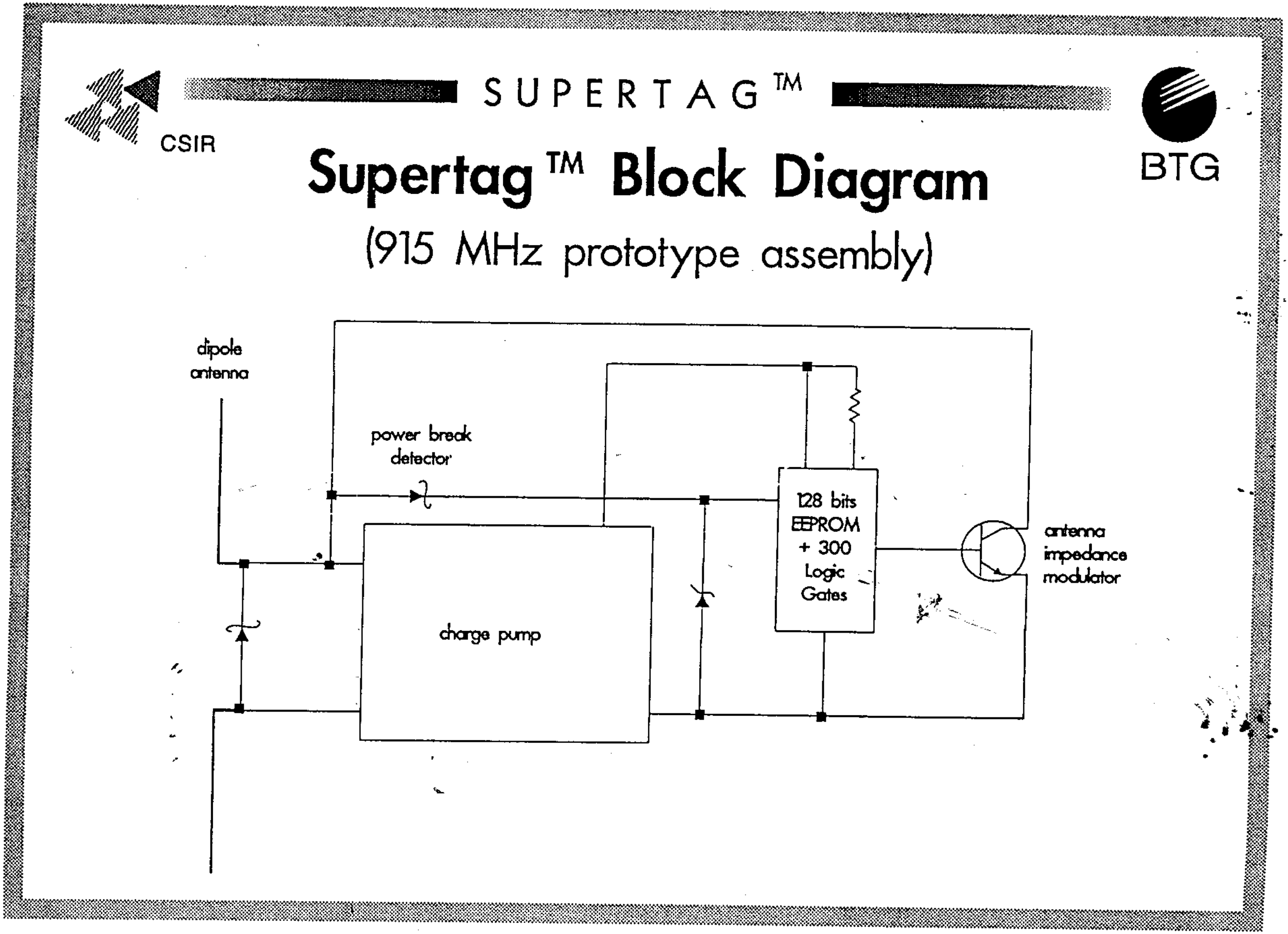

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Supertag™ Block Diagram

(915 MHz prototype assembly)

Figure 1

Figure 2

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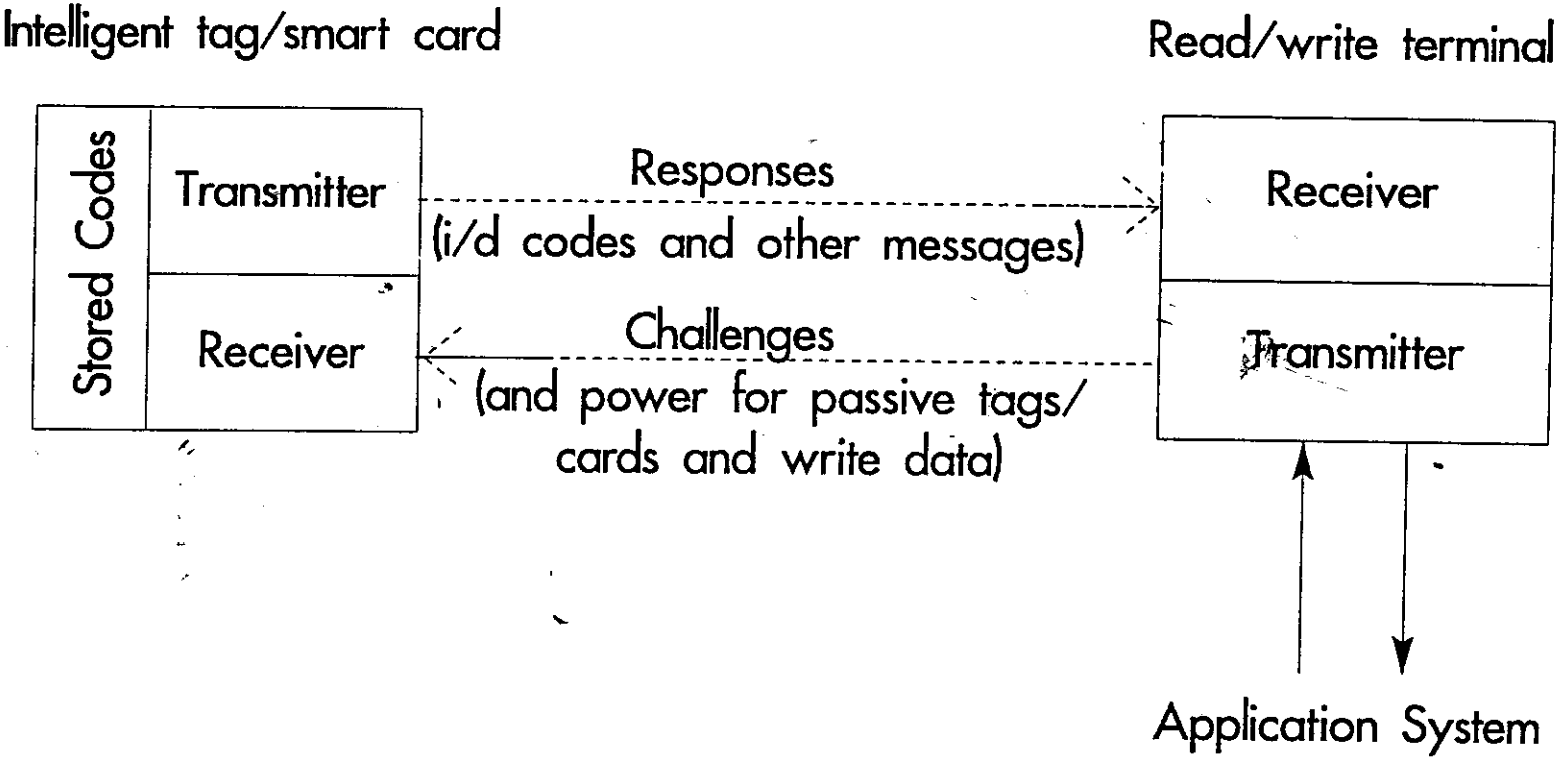
Cordless Communication to/from Tags/Cards



Intelligent tag/smart card

Stored Codes

Transmitter

Receiver

Responses (i/d codes and other messages)

Challenges (and power for passive tags/cards and write data)

Read/write terminal

Receiver

Transmitter

Application System

Figure 3

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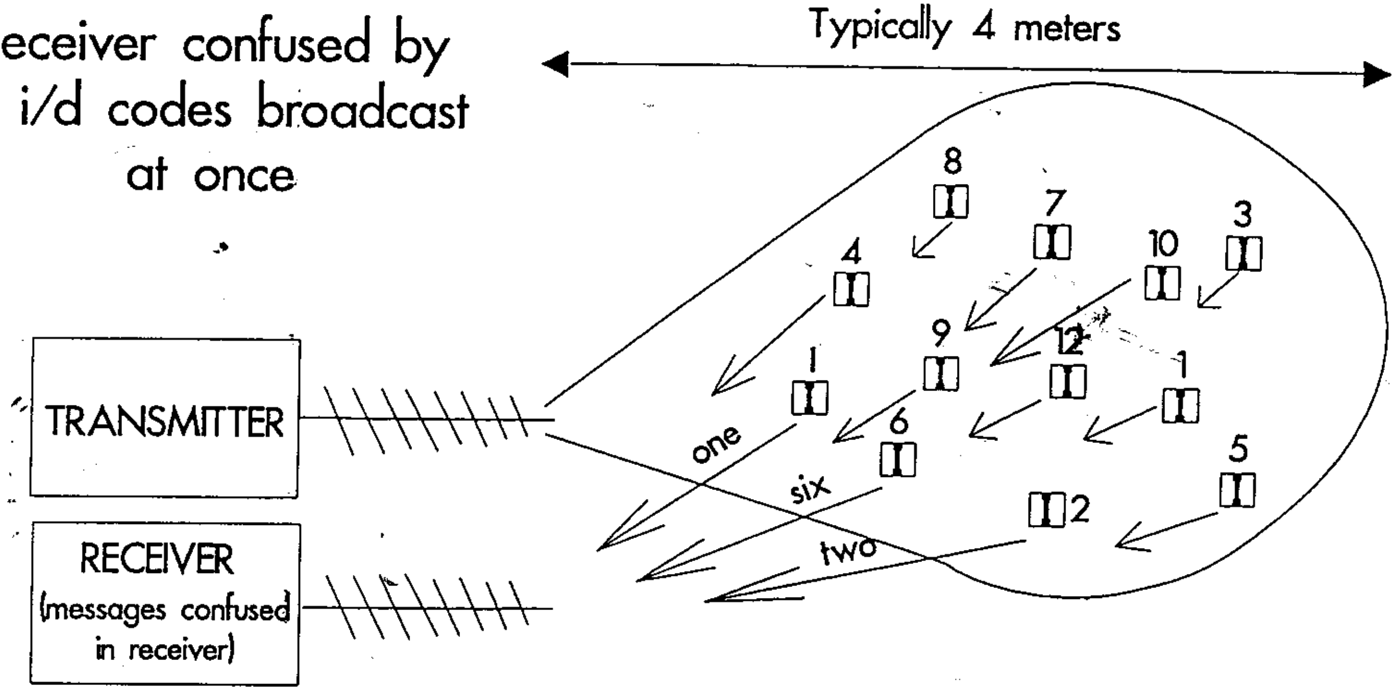
The Contention Problem

Receiver confused by
all i/d codes broadcast
at once



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Tag Functionality

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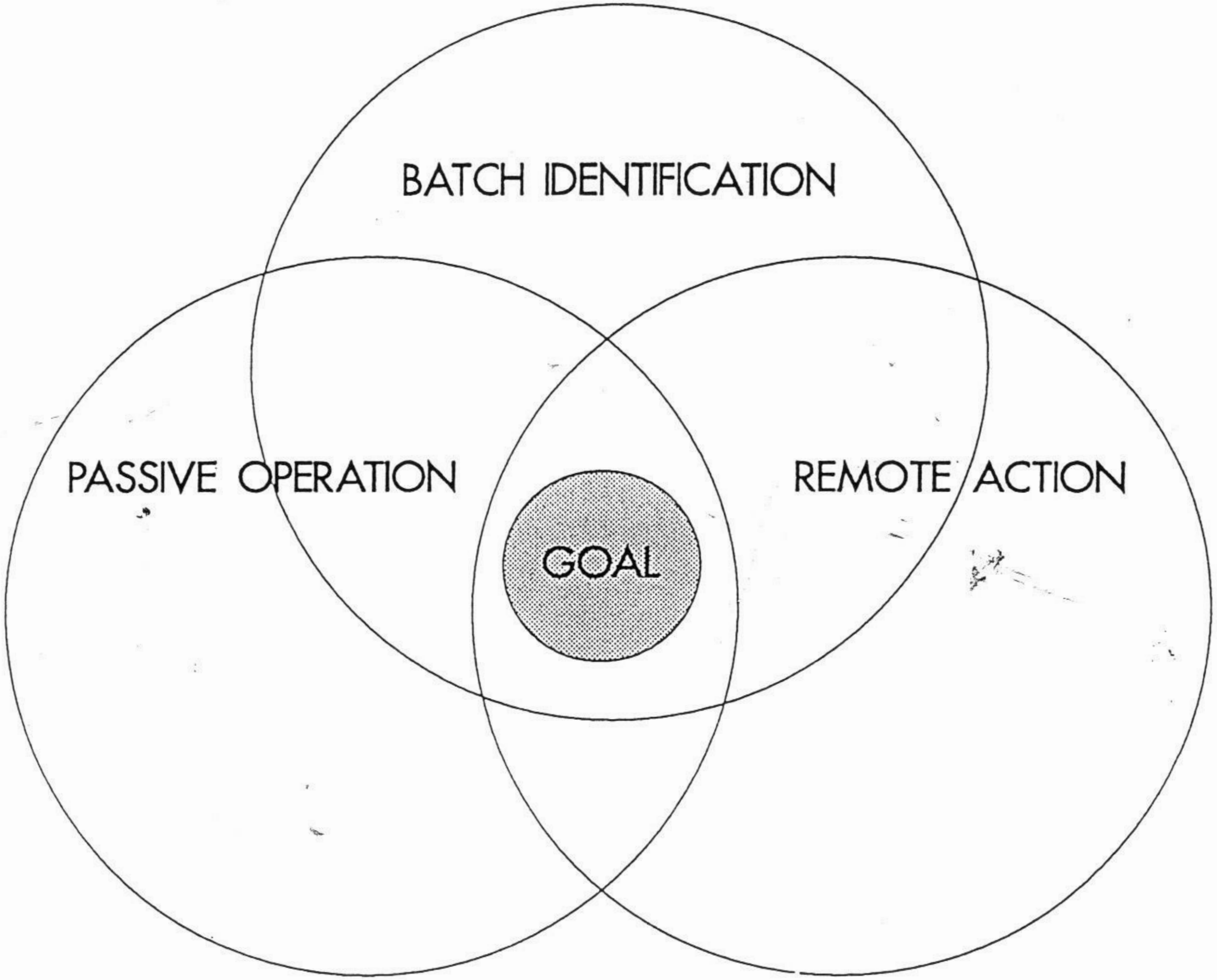

BATCH IDENTIFICATION

PASSIVE OPERATION

REMOTE ACTION

GOAL

Figure 4

Figure 5

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Prototype B (915 MHz)