

RADIO FREQUENCY - BASED DATA COLLECTION NETWORK

by

Prabhu Venkatesh

Project Report submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Engineering

in

Industrial and Systems Engineering

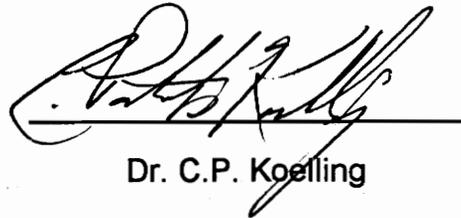
APPROVED:



Dr. R. J. Reasor, Chairman



Dr. S.C. Sarin



Dr. C.P. Koelling

April, 1995

Blacksburg, Virginia

C.2

1D
V855
V851
1995
V465
C.2

Radio Frequency - Based Data Collection Network

by

Prabhu Venkatesh

Dr. Roderick J. Reasor, Chairman

Industrial and Systems Engineering

(ABSTRACT)

In today's competitive global business environment, efficient information transfer and real-time data collection are required to provide a flexible and reliable information management system. RF-based data collection networks are increasingly becoming a strategic technology used to instantly capture, process and transmit the data which is vital to daily management decisions. This project aims to look at the key system building blocks based on the three core technologies of bar code data capture- laser scanning, portable computing, and radio frequency (RF) data communications. The RF equipment in the Automatic Data Collection Systems Lab (ADCSL) at Virginia Tech was integrated into a functional data collection system. RF based systems allow real time transfer of information from source of data to decision makers. Laboratory experiments were designed so that undergraduate students gain practical experience and understanding of this innovative technology. The focus of the experiments will be to expose students to leading-edge laser scanners, hand-held portable computers, and RF communications and network systems.

ACKNOWLEDGMENTS

I would like to thank Dr. R.J. Reasor for the guidance and continual encouragement that he has given me during the research and writing of this report. I would also like to thank Drs. C.P. Koelling and S.C. Sarin for serving on my committee.

I dedicate this report to all of my loved ones. Especially, to my father and mother, for their love, support and encouragement over all these years. To them, I sincerely say Thank You. Special thanks are due to my uncle and aunt, Dr. Puttaiah and Prema for their love and support and for being there for me during the highs and lows.

I would also like to recognize some of my close friends at Virginia Tech: Praveen, Rajive, Hrishi, Ganesh, Prabhakar and Prakash for their help and making my life easier during those tough times.

Finally, I would like to thank The Almighty for the knowledge, the ability and the strength to endure. For I know, this would not have been possible without his blessings.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

1.1 OVERVIEW	1
1.2 PROJECT OBJECTIVE	3
1.3 SCOPE OF THE PROJECT	3

CHAPTER 2: LITERATURE REVIEW

2.1 ADC TECHNOLOGIES	5
2.2 RADIO FREQUENCY IDENTIFICATION	8
2.2.1 APPLICATIONS OF RFID	9
2.3 VOICE RECOGNITION SYSTEMS	10
2.4 BAR CODE TECHNOLOGY	13
2.4.1 SYMBOLOGY	14
2.4.2 BAR CODE APPLICATIONS	18
2.5 RADIO FREQUENCY TECHNOLOGY	21
2.5.1 RADIO FREQUENCY DATA COMMUNICATIONS	23
2.5.2 RFDC SYSTEM CONSIDERATIONS	27
2.6 TECHNOLOGY CONSIDERATIONS	28
2.6.1 NARROW BAND TECHNOLOGY	28
2.6.2 SPREAD SPECTRUM	30
2.6.2.1 Frequency Hopping	30
2.6.2.2 Direct Sequence	31
2.7 APPLICATIONS OF RFDC	31
2.8 BENEFITS OF RFDC	34
2.9 SUMMARY	37

CHAPTER 3: METHODOLOGY

3.1 THE ADCSL- AN OVERVIEW	38
3.2 TECHNICAL RESOURCES	38
3.2.1 HARDWARE	38
3.2.2 SOFTWARE	41
3.3 PROJECT LIFE CYCLE AND METHODOLOGY	42

3.4 SUMMARY AND CONCLUSION.....	44
 CHAPTER 4: RFDC SYSTEM CONFIGURATION	
4.1 SYSTEM COMPONENTS	45
4.2 INSTALLATION AND CONFIGURATION	47
4.3 COMPONENT CONFIGURATION	49
4.4 SOFTWARE INTERFACE.....	49
4.4.1 PORTABLE TERMINAL SOFTWARE.....	50
4.4.2 ACCESS BRIDGE SOFTWARE.....	50
4.5 COMMUNICATIONS AND DATA TRANSFER.....	52
4.6 SUMMARY	54
 CHAPTER 5: TEST AND EVALUATION	
5.1 INTRODUCTION.....	55
5.2 INITIALIZATION OF TERMINALS.....	55
5.3 PORTABLE TERMINAL OPERATION	56
5.4 SUMMARY	57
 CHAPTER 6: DESIGN OF LAB MODULES	
6.1 INTRODUCTION.....	58
6.2 PRACTICE LAB MODULE	58
6.3 LAB MODULE 1: OFF-LINE DATA COLLECTION.....	61
6.4 LAB MODULE 2: FIELD SERVICE REPORTING	63
6.5 LAB MODULE 3: RETAIL INVENTORY MANAGEMENT.....	65
6.6 LAB MODULE 4: INDUSTRIAL INVENTORY MANAGEMENT	69
6.6 SUMMARY	72
 CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS	
	73
 REFERENCES	 75
 APPENDIX A	
FCC Rules Governing License-Free Operation of Spread Spectrum Systems.....	76

APPENDIX B	
System Connections and Pin Diagrams	78
APPENDIX C	
Symbol Terminal Enabler Program (STEP) Files	81
APPENDIX D	
Application Productivity System (APS) files.	85
APPENDIX E	
Lab Modules and Exercise Sheets	86
APPENDIX F	
Operating Instructions for RFDC Equipment.....	107

List of Figures

Figure 2.1 Key building blocks of Information systems	7
Figure 2.2 The Electro-magnetic spectrum	22
Figure 2.3 A simple RF network	24
Figure 2.4 The RF Link	35
Figure 3.1 Flow chart of project life cycle and methodology	42
Figure 4.1 RF network at Virginia Tech	48
Figure 4.2 Portable Terminal Software heirarchy	51
Figure 4.3 Format of data packet	53

List of Tables

Table 2.1 RFDC technology : Narrow Band vs Spread Spectrum	32
Table 4.1 Data fields and functions	53

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Material handling and logistics have become especially important to industrialists because of the competitive advantage that results from using the right methods to provide the right amount of material at the right place, at the right time, in the right condition, in the right sequence, in the right orientation, and at the right cost [White, 1989]. Recent advances in hardware design and software has resulted in the emergence of sophisticated control systems for practically any application. Providing the right amount of material at the required time is especially important due to the emphasis on just-in-time manufacturing and inventory reduction. It is imperative that a material flow control system be requirements-driven, rather than solution-driven. Many situations exist in the manufacturing and distribution in which the wrong amount of material is moved, stored, and/or controlled, a common problem being the mismatch of issue quantities and stocking quantities.

The principal mistakes made in order picking are picking the wrong quantities and picking the wrong merchandise. To facilitate correct item selection, labels are used on cartons and containers. Also, material is put in the wrong place and personnel waste considerable amount of time in locating the material in a warehouse. Providing the material at the right time is a very critical ingredient of an efficient material handling and logistics system. The use of just-in-time techniques has reduced the measurement system from months and days to hours and minutes.

In today's highly competitive global marketplace, companies have realized the key elements of success include smart materials handling methods accompanied by an efficient information system. The efficient flow of materials must be accompanied by a parallel flow of reliable, real-time information. Information about shop-floor and warehouse operations should be fed back to people who retain final decision-making power over these operations. With the aid of data collection technologies, operating information is becoming real-time resulting in effective decision-making and proper control.

Automation simply meant "islands of automation" in the past wherein the various elements were never coordinated into an integrated system. Today, material handling systems are moving towards being truly integrated and real time through the use of automatic data collection systems. Broadly speaking, the types of automatic data collection systems can be listed as -

1. Bar code data collection systems.
2. Radio frequency identification and data collection systems.
3. Voice data collection systems.
4. Optical character recognition systems.
5. Magnetic ink, stripe and smart card systems.
6. Machine vision systems.

Of these, bar code systems are the most popular and established method today. Bar codes have been in use since the early seventies, when they were being used in supermarkets and grocery sales applications. Their use has proliferated ever since, and today bar codes are a billion dollar industry in themselves. Bar codes are used from automatic sortation systems to inventory control applications, from point-of-sale use in retail stores to integration of islands of automation with real time data collection. In fact, bar codes are fast becoming the back-bone of all automatic identification systems.

The key link in Automatic Identification Systems (AIS) is the data communications system. Communications link the labeling and reading equipment with the Management Information System (MIS) where the data is processed to facilitate the management of the operations. Radio Frequency Data Collection (RFDC) is a network technology which transmits data collected by bar code scanning devices over radio frequencies rather than through a wired network. If timely on-line real time data is needed, both hard wired terminals and RF data terminals can provide this capability. However, if the application requires mobile operations, or it is not practical to run wires, an RF data communications link is the obvious alternative.

1.2 PROJECT OBJECTIVE

The objectives of this project was to:

- * Study how bar codes and radio frequency data communications (RFDC) can be used in an automatic data collection system.
- * Use the radio frequency data collection equipment in the Automatic Data Collection Systems Lab (ADCSL) and build an integrated manufacturing data collection system
- * Design a series of laboratory activities to help students gain hands-on experience with the use of radio frequency for data collection.

1.3 SCOPE OF THE PROJECT

The scope of this project is limited to the integration of the RF equipment in the Automatic Data Collection Systems Lab at Virginia Tech. The aim was to develop an RF-based data collection network, where students can gain practical experience through a series of laboratory activities.

The experiments were designed such that the students can gain an understanding of the theory and applications of radio frequency data communications. The students will gain practical experience in using a RF-based network and get exposure to bar code technology, RF hardware and system software.

The RF-based data collection network has two subsystems:

(a) The Automatic Identification System:

This includes the bar code scanners and portable data collection terminals. The equipment provides timely and accurate information regarding products.

(b) The Data Communications System:

This constitutes the transceiver, base controller and RF equipment which preserve the accuracy of data and transmits them to the host computer in real time.

CHAPTER 2 LITERATURE REVIEW

2.1 ADC TECHNOLOGIES

Automatic identification and data collection systems are powerful tools in the manufacturing and material handling environment. Controlling raw material and finished goods inventories is fundamental to effective operations management. When properly implemented, identification and data collection systems can have a direct impact on :

- * Labor Productivity.
- * Space Utilization.
- * Inventory Control.
- * Production Control.
- * Damage and Pilferage losses.
- * Stock rotation.
- * Improved customer Service.
- * Reduced operation costs.

One of the main advantages of automatic data collection systems is timely, accurate data collection. Traditional collection methods produce error rates ranging from one in 30 for handwritten documents to one in 300 for keyboard input. Automatic identification systems operate in the accuracy range of one error in three million entries, and most offer entry feedback for immediate error correction.)

Another benefit is speed. These systems process hundreds of characters per second which is substantially faster than manual data entry at five to seven characters or keyboard at 10 to 15 characters per second. Most data collection systems are on-line applications with concurrent processing. By avoiding manual

records, keyboard entry and batch processing, these systems produce operating reports without a time delay and improve information reporting.

Most automatic data collection systems will be composed of a host computer or processor, communication links to peripherals, identification devices and displays, CRT terminals and system software.

Software is a vital system element, which in addition to converting to source code, provides for real time interaction between users and data collection devices and dynamic communications with the host computer. The software is designed to have data entry/edit routines, an architecture that permits change easily and capability to interface with other industrial devices. Figure 2.1 shows the key system building blocks of a typical automatic data collection system.

Most automatic data collection systems are based on one of the following types of technology:

1. Optical character recognition.
2. Magnetic stripes
3. Smart card.
4. Machine vision.
5. Radio frequency.
6. Voice recognition.
7. Bar codes.

A discussion of all of the above identification techniques and examples of their applications is beyond the scope of this project. However, Radio Frequency Identification is frequently confused with Radio Frequency Data Communications. Voice Recognition System is the other major technology being studied at the Automatic Data Collection Systems Lab (ADCSL) at Virginia Tech. Hence, these two technologies, their applications and functions are described briefly in the following sections.

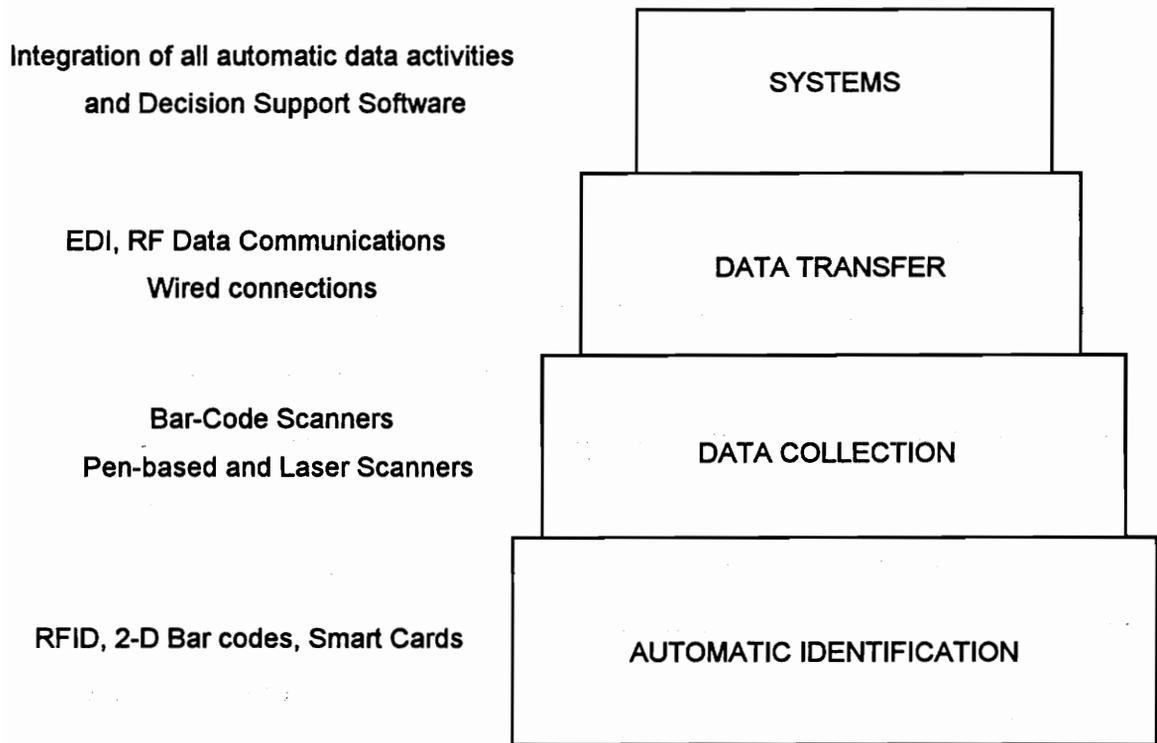


Fig 2.1 : Building Blocks of Automatic Data Collection Systems

2.2 RADIO FREQUENCY IDENTIFICATION

Radio Frequency identification systems involves a machine-readable tag powered by an external radio frequency transmission or radar pulses. When excited by an external source, they return a coded signal. The RF identification tag consists of receive and transmit antennae, a few discrete components, and an integrated circuit chip, all typically loaded onto a printed circuit board. Tag size is determined by the sizes of the transmit and receive antennae, which in turn are a function of operating frequency, range and speed requirements.

Two basic types of tags are currently being used:

1. Passive tags.
2. Active tags.

Passive tags are activated by a reader sending a pulse or unmodulated RF signal at a specific frequency and responds with a unique multi-character code. The tag responds by using a small amount of energy from the received signal to power-up the IC chip which sends the code back to the reader via a modulated RF signal.

Active tags are battery powered tags that can receive, store and transmit data. It uses an on-board, low profile battery for power and to maintain memory. Active tags can usually send signals farther than passive tags. Thus they can be read/written from greater distances.

Radio frequency identification (RFID) consists of three components -

1. Target or RF tag which contains memory or code from which an identification can be made.
2. Antenna or Transceiver which provides power to the tag and acts as a conduit for the information to be sent from the tag to the third component.

3. Control Board which helps interpret the information received from the tag and converts this information into a signal which can be further passed to another controller or provide an action output.

RFID tags are manufactured using different RF wave lengths and according to Federal Communications Commissions (FCC) regulations. RFID can be more cost-effective than bar codes. However, they should be chosen based on the application and requirement.

RFID offers systems in the form of portable, programmable read only tag readers (Passive RF/ID) that offer off-line file storage and file transfer to a host computer. This data from a passive tag is fixed in type and length at the time the tag is manufactured. Fixed readers that automatically read a passive tag and communicate with a host computer are needed with this system. Active RF/ID tags provide read and write capabilities and are highly flexible and portable.

2.2.1 APPLICATIONS OF RFID

RF identification systems play an increasingly important role in production, inventory, and asset and resource management. RF systems have been able to provide solid solutions to environmental challenges that alternative systems have been unable to meet. RFID tags perform reliably in spite of temperature extremes, contamination by paint, dirt or coolants or obstructions in the line of sight. Their ability to capture reliable, accurate information and transfer data in real time enhances the performance of manufacturing systems. The typical applications of RFID systems in industry include:

- * Animal husbandry, pet identification, cattle and wild-life identification and studies.
- *.Inventory control, product location and inventory control.

- * AS/RS controls for determining X and Y co-ordinates.
- * Process sorting of products and de-centralized control of switching equipment.
- * Personnel identification for real-time tracking and secured access. RFID tags can be used as a time card.
- * In process control - Each RFID tag attached to a product contains within its memory, the specifics of all processes to be carried out. Each operation looks to see if the previous operation has been carried out.
- * Quality Control - actual values as measured by each and every station can be encoded and checked eventually.
- * Product Carrier Tracking - Information about a carrier or pallet can be tracked.
- * RFID tags can be a data highway between different stations. Information encoded on one can be read at and used to guide the process at another station.
- * RFID provides for contactless communication.

2.3 VOICE RECOGNITION SYSTEMS

Voice-based data collection systems relies on the ability of computers to recognize syllables and words as input spoken through a microphone. Voice Data Collection is very useful when human judgment is necessary for data collection and the human is busy with a process. The operator hears the questions he would normally read from a paper and speaks the answers he would normally write onto a paper. Thus the process becomes a dialog between the operator and the voice data collection terminal.

The dialog contains two technologies. The computer uses speech synthesis to produce human sounds in the form of a question. The person speaks the answers which the computer recognizes using voice recognition technology.

There are two basic techniques to have the computer ask the questions. A human could pre-record each question and have the system playback the question in the form of a prompt. The second way is to type each question in and use speech synthesis to convert the text to speech. Speech synthesis is the most common technique being used today because it offers maximum flexibility and is easy to implement.

There are several techniques available today , to have a computer recognize a human voice. One of the most popular methods is pattern recognition. This works by having the operator speak each answer and store it as a template. When the system is in data collection mode, the computer converts the spoken word to a digital voice pattern and then attempts a pattern match from all the acceptable responses to the current question. When a match is determined, the system "recognizes" the answer.

A voice-based data collection system generally consists of the following basic components:

1. A microphone for accepting speech input.
2. A recognizer that converts spoken data into digital form.
3. A processor or computer which runs the voice system application software and for storing collected data.
4. A voice synthesizer which is usually a combination of hardware and software , that converts text (digital data) into sounds (analog data) for the speaker.

5. A speaker for broadcasting the output , including prompts and error messages.

There are several parameters associated with voice data collection systems. Based on recognition rates, it can be either Discrete or Continuous. In discrete VDC systems, the VDC terminal takes in and recognizes one word or utterance at a time. In continuous VDC systems, the terminal allows the person to talk in a continuous manner. Another parameter of interest is the vocabulary size. This can be either Small or Large. Typically, voice recognition systems with a few thousand words are considered to have a small vocabulary size, while one with 10,000 to 30,000 recognizable words is considered as having a large vocabulary size.

Voice recognition systems can be -

- Speaker dependent or
- Speaker independent.

In speaker independent systems, almost anyone can speak into the VDC terminal and the word will be recognized. In the case of speaker dependent systems, the operator will have to train the system, initially by "speaking in" each word that is to be part of the system's vocabulary. Speaker dependent systems allow a larger vocabulary, better recognition rates and continuous speech.

Currently, VDC systems are used in material handling and quality control inspection applications. Paint quality inspection teams at the SATURN automobile plant use voice data collection systems. Paint inspection team members constantly use their hands and eyes to collect panel paint inspection data. Bar codes are not very attractive in this situation as the operator will probably have to look at different bar codes on a card representing inspection data and scan a response (say bad or good) with a scanner. This will likely distract the operator from looking at the automobile and paint. Also, bar coding

is inadequate as data regarding human judgment such as defect types and locations will be awkward to specify.

2.4 BAR CODE TECHNOLOGY

A bar code consists of an array of differing width parallel bars and spaces within which information is encoded. The bar code is usually the size of a label and is attached to an object - a grocery product or a piece being manufactured. This code serves as an identifier for the object that it is attached to. This identifier is also part of a database where the other details associated with this particular object are stored. Once the identifier has been decoded, information regarding this particular product can be retrieved from the data base. The decoding and access of the database is usually controlled by the system software.

A bar code data collection system usually has the following three components:

1. The bar code label which is a machine readable symbol in the form of several bars and spaces. The width of a bar or space also contributes to the information content. A wide bar and a wide space are different from a narrow bar or space.
2. The bar code scanning device, which reads a bar code and converts the optical information into electrical signals. The bar code scanner is connected to a centralized data base containing details about the object attached to the bar code. The scanner uses electro-optical techniques to scan the bar code symbol. The scanner illuminates the symbol with light energy and then examines the amount of light reflected by a localized area of the symbol. This light energy is usually in the form of a spot of

light or a beam. The scanner is moved across the symbol so that the entire symbol is covered by the light energy. While a space reflects back all the light thrown on it, a bar absorbs almost all the light thrown on it. This reflected light is directed to a photo-diode detector (or equivalent), which generates a small current proportional to the amount of light returned (amplified). The amount of current is also going to be proportional to the width of the space or bar. Thus a wave form is obtained, that is dependent on the intensity of light reflected and the duration of this intensity. The digital wave form is obtained by converting the analog voltage obtained using a A/D (analog-to-digital) converter.

3. The decoder which receives the signals from the scanning device and converts them into information which is then used for processing. The decoder converts the bar code information, accesses the database and procures the information to the point of use. Thus all the details regarding that particular object can be obtained at the point of use. The data is usually stored on a host computer or can be stored in the memory of the scanning device.

2.4.1 SYMBOLOGY

Symbology is defined as the collection of rules and specifications describing the way in which data is encoded in the bars and spaces of the bar code symbol. There are several symbologies used by the different industries using bar codes today. These symbologies differ in the number of bars and spaces used to represent a character or number, on whether the spaces are used to record information or serve merely as gaps between characters, width

and number of bars and spaces, density of information stored in a given width and so on. Since many different symbologies are used, the decoders used today are capable of decoding symbols represented in different symbologies. A few common characteristics of bar code symbologies and their definitions are discussed below :

DISCRETE & CONTINUOUS SYMBOLOGIES : Each character in a bar code represented in this symbology is independent of the others. Each character is separated from its neighbors by inter-character gaps. A continuous code has no inter-character gaps.

CHARACTER SET : This is a set of all characters and numbers that can be effectively represented by the symbology. Symbologies capable of representing both numbers and letters of the alphabet are called alphanumeric symbologies while those that can represent numbers only are called numeric symbologies.

SYMBOL LENGTH : Symbologies can be fixed or variable length. The decoder needs to be provided this information before it can decode a symbol. This information is usually available with the symbology and thus the decoder knows if a particular symbology allows variable length symbols.

DENSITY : This parameter refers to the amount of data that can be encoded in a given unit length using a particular symbology. Again, this information is symbology specific and decoders know this information before that can decode a symbol coded in a particular symbology.

ELEMENT WIDTHS : Two types of symbologies - those that use wide and narrow spaces (only two possible widths 0 and those that use multiple widths. The symbologies using multiple widths are usually decoded by measuring the distance between similar edges (edges of bars, for instance).

START & STOP CODES : Most symbologies require a start and stop code in the symbols. This is a particular pattern of bars and spaces that is always

identified by a decoder to be a start or stop code. These codes are very useful to ensure reads in both forward and reverse directions. thus the code can be bi-directional and can be read from left to right and in reverse.

Other symbology characteristics include the X-dimension (width of narrow elements), self-checking, unidirectional or bi-directional.

A few common symbologies used in practice and a brief description of each is given below.

UPC :

UPC (Universal Product Code) is a fixed, length, numeric continuous symbology and has 12 digits in one symbol. It is mainly used in the supermarket industry and designed to uniquely identify a particular product and its manufacturer. It has a density of 14.3 characters per inch and a check digit is incorporated into the code and allows bi-directional scanning.

EAN :

The European Article Numbering (EAN) system is used by the grocery and retail industry in Europe and has two versions - EAN-13 and EAN-8. The symbology contains information about the country, product and manufacturer.

INTERLEAVED 2 OF 5 :

This is one of the earliest bar code symbologies developed. It is a high-density, self-checking, continuous numeric symbology and used primarily in the distribution industry. Each symbol contains five bars, two of which are wide and three are narrow. Each character encodes two digits, one in the bars and one in the spaces.

The start and stop codes and check digits are provided.

CODE 128 :

This is a high density alphanumeric symbology which is of variable length, continuous and uses multiple element widths. The symbology can encode all 128 ASCII elements in its character set. It has three different character sets called character sets A, B and C. The start character specifies the character set being used. The length of a symbol in this symbology depends on the character set being used.

CODE 39 :

This was the first alphanumeric symbology to be developed and commonly used in non-retail applications. It is also called as "3 of 9 code". The common character "*" is used for both the start and stop characters. Every character in the symbology has five bars and four spaces. Of these nine elements, three are wide and six are narrow. The symbology uses only two widths - wide and narrow. The symbology uses intercharacter gaps, start and stop codes and contains 43 characters in its character set and is self-checking.

CODABAR :

This symbology is widely used in libraries, blood banks, medical labeling and air parcel applications. It is a self-checking, discrete symbology. All characters are constructed out of four bars and three spaces. It has sixteen characters in its set. It uses four different start and stop codes and allows the concatenation of two different characters by using the appropriate start and stop codes. Other characteristics include self-checking, variable length and bi-directional scanning.

2.4.2 BAR CODE APPLICATIONS

Bar codes find use in a wide variety of applications. They are primarily used in the following areas :

1. Library applications.
2. Inventory Control.
3. Work-in-process tracking.
4. MRP and MRP-II applications.
5. Receiving applications.
6. Shipping Applications.
7. Electronic data interchange.
8. Retail applications.
9. Warehousing applications.

The uses of bar codes in each of the above applications are described briefly, below.

Inventory Control :

The main application of bar codes in industry is inventory control. Bar codes improve the accuracy of inventory data. Each transaction involving removal of parts from inventory and addition to inventory can be recorded by scanning the appropriate bar codes and entering the quantity used or produced. This data can be updated immediately or in a batch, on the host computer. Exact location, number and availability of different components can be known and the old, problematic method of writing down the information can be eliminated. Cycle counting is simplified or can even be totally eliminated as accurate information about the inventory of all parts is available.

Library Applications :

Bar codes are used in tracking and keeping an account of books. Each book is assigned a bar code and every time a book is borrowed, this bar code is scanned along with the ID on the borrower's card and a match is made in the data base. The borrower's name is removed from the data base on receipt of the book and the book is returned to its "available" status. The appropriate information relating to the availability of a book is provided as a bar code at the librarian's desk and is scanned when a book is returned.

Work-in-process tracking :

Flow of materials, sub-assemblies and products can be tracked easily if the bar code symbol attached to the materials or products is scanned each time the product is processed and moved through the shop floor. Thus information can be held on the location of materials, operations that have already been performed on sub-assemblies, sequence of operations and related information on operations that still the to carried out and information on throughput and yield are easily obtained. With this accurate information, bottlenecks can be identified.

MRP and MRP-II applications :

With inventory accuracy, routing accuracy and tracking accuracy improved, the master production schedule and capacity planning reports can be generated in a more accurate fashion. Production schedules will reflect any deviations and discrepancies from the original plan with accurate information about work-in-process.

Receiving, Warehousing and Shipping applications :

The exact quantity of materials received into the factory can be updated in the company's computer data bases on arrival of the materials. Any shortages can be immediately identified and the appropriate orders can be

placed without delay. The materials handlers can easily perform this bar code scanning function and need not wait for personnel from the inventory control department. Thus the materials can be moved to storage locations and the shop floor faster. Picking becomes easier as the exact location of all materials and their availability is accessible from the computer data bases and this information can be easily obtained by the pickers. Thus the storing and the picking functions can be organized well. With the availability of real time information, the efficiency of the warehouse staff can be improved as they can combine storing operations with picking operations and thus avoid "deadheading". With accurate data, the customer orders can be satisfied better and faster.

Retail Applications :

The use of bar codes at the point-of-sale in the grocery stores is well known. The bar codes on different products are scanned at the sales counters and the appropriate information regarding the price, manufacturer, etc. of the product can be obtained from a central data base.

Electronic Data Interchange (EDI) :

EDI refers to conducting of purchase transactions electronically.. EDI describes the direct communication of data between the computers of two companies for conducting a business transaction without any human intervention. For instance, the MRP program of one company may realize the need for a certain material, place an order for the same with the vendor company. The computer in the vendor's company reads in this order and prepares the appropriate master production schedule in its MRP and sends back the confirmation of the order and the delivery date. Thus the customer company's computer can plan its production schedule accordingly. The entire function requires no human intervention and thus is highly accurate.

Thus a paperless, telephoneless purchase transaction is performed. Usually, EDI is carried out through VANS (Value Added Networks) which refer to a common network over which the computers of the customer and vendor company can communicate with each other. EDI is quickly becoming the transaction method of the future and an effective ingredient in JIT systems. Along with an order, the customer company can also send details about the nature and sequence of bar codes to be printed on the materials ordered. Thus the customer can obtain material with the proper bar codes on it and thus the receiving and inventory control functions can be simplified.

2.5 RADIO FREQUENCY TECHNOLOGY

Radio frequency (RF) waves are part of the electro-magnetic spectrum. Figure 2.2 shows the radio communication frequencies within the electromagnetic spectrum. Specific locations in the spectrum can be identified by either the frequency or the wavelength. RF data collection uses radio waves as a medium to transmit information just like hard-wired data collection uses cables.

In a warehouse RF system, electronic or digital data signals are sent to RF transmitters that convert the information into RF signals or waves. The transmitters broadcast the waves over a short range within the warehouse to RF receivers. The receivers accept the waves. These systems are primarily concerned with transmitting data, communications and identification in real time using wireless transmissions in one form or another.

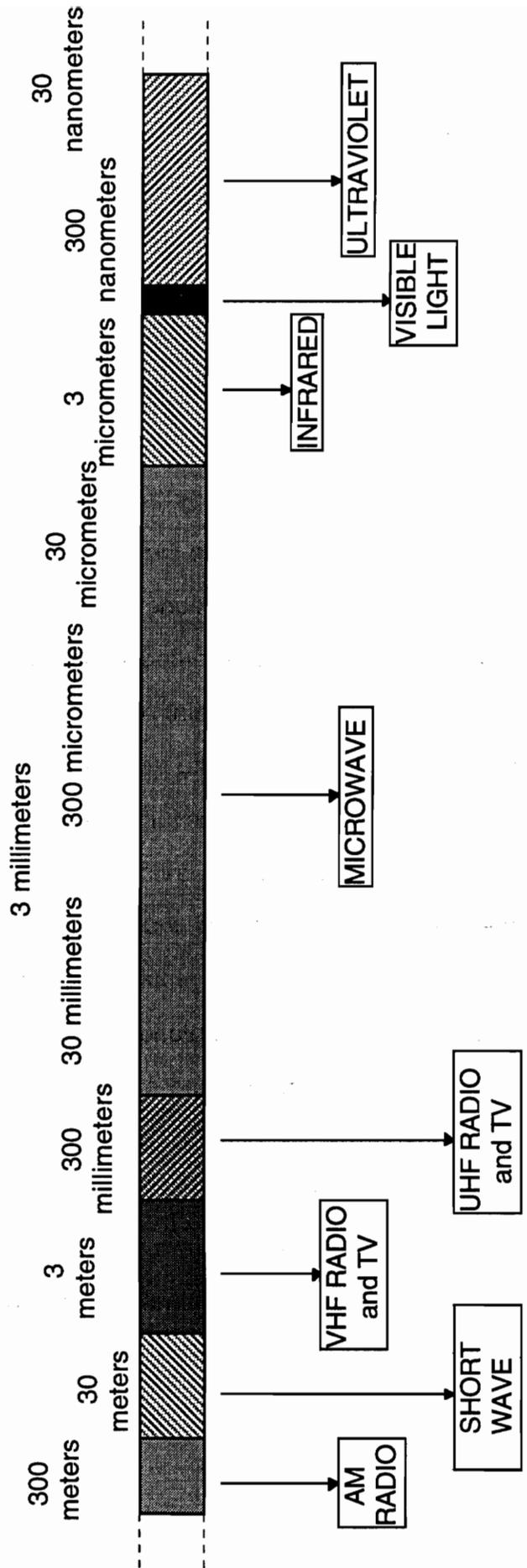


Figure 2.2 : The Electro-magnetic Spectrum

2.5.1 RADIO FREQUENCY DATA COMMUNICATIONS

Radio frequencies are being used in industrial applications as a communications medium to operate cranes or hoists. Radio frequency (RF) data collection is experiencing rapid growth in industrial applications. Radio-linked data collection allows real time interactive communications between a host computer and multiple hand-held vehicle mounted terminals. Instead of being hard-wired, these rugged terminals allow operators on lift trucks or roving cycle counters the flexibility of mobile real time operations.

A radio frequency data collection system essentially consists of three components -

1. Terminals.
2. Network controllers.
3. Radio Frequency Units.

Figure 2.3 shows a simple RF network. The terminal serves as the operator interface. It can be hand-held, vehicle mounted (as in fork-lift trucks) or fixed (wall or table mounted) devices. These terminals are essentially spread around the manufacturing shop-floor or warehouse or wherever the application maybe. These terminals aid in collecting the data and in communications with the central computer. These RF (radio frequency) terminals cannot communicate directly with the central computer and need a network controller to receive the RF signals and convert the data to a form acceptable by the central computer. Typical RF terminals transmit at 1,200 baud to the radio frequency unit (RFU) base station with the base station to host communications at 300 to 9,600 baud.

The Network Controller (NC) is the heart of the RF system. Together with the Radio Frequency Unit (RFU), it forms the Base Station. The base station communicates with each terminal on the shop-floor using each terminal's

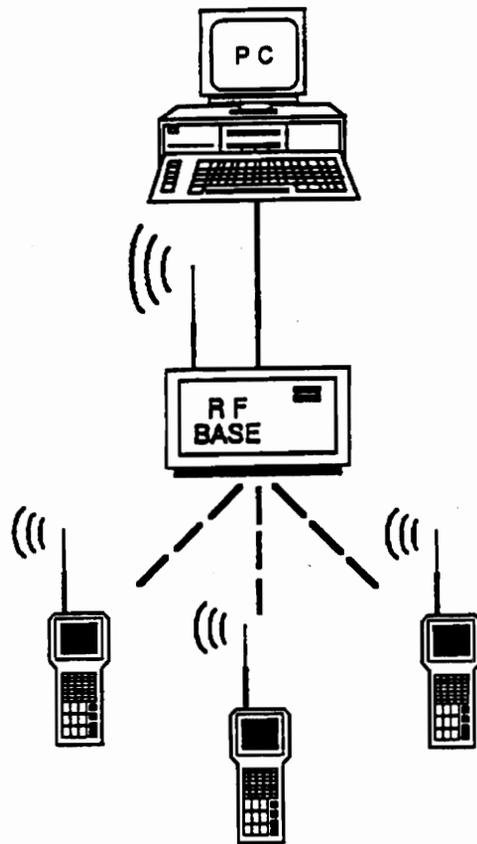


Figure 2.3 : A simple RF network

unique ID and through the RF network. The RF network is a system of antennae placed strategically over the shop-floor. These antennae receive and transmit data between the base station and the terminals.

At the base station, the RFU is responsible for communicating with each of the terminals through the RF network. The RFU in turn receives and transmits information to the NC. The NC communicates with the RFU and with the host computer. Thus the NC controls the message traffic between the RF system and the host computer. The NC controls the message timing, buffering and the protocol matching to the host computer. In an RFDC, it is more common for the terminals to be sending data to the central computer. Often messages sent to the terminals are merely to verify that the information was received. While sending and receiving messages to one or two terminals on the shop floor is easy, the RF network gets crowded easily with increase in the number of terminals. The figure shows a simple RF network. There are two RF protocols that are used. These are -

1. Contention and
2. Polling.

In the contention method, the terminals send messages to the base station if the channel is clear. Accordingly, all the terminals that need to send messages are contending for a slot and are allotted, usually on a first-come-first-serve basis. This method is used for shorter messages requiring high throughput and fast response rates.

In the polling method, the base station polls each terminal in turn, regardless of whether there is a message to be received. Polling is suitable to high throughput situations where there are many terminals with long messages to transmit.

There are two methods to transmit information based on the frequency of the radio waves used. These are -

1. Narrow band transmission &
2. Spread Spectrum transmission.

Narrow band transmission is more commonly used. In this method, the information is sent over a single licensed frequency band that is 25 KHz in width. Thus a narrow band is used. This is an analog transmission channel. In order to transmit digital data (as from a computer), a modem (modulator-demodulator) is commonly used. Thus an analog transmission channel can be used. A modem is needed on both ends of the RF communication channel. The FCC (Federal Communications Commission) has several regulatory rules about the range and frequency used in this mode of transmission. An attempt is made by the FCC to reduce the amount of RF spectrum consumed by a given RF channel so that a large number of simultaneous transmissions can occur in a given range of frequencies. Since the entire RF spectrum is limited in its size, every effort is made to reduce the amount needed for a given application. The data transmission rate is usually slow by this method.

In the spread spectrum transmission method, multiple broad transmissions are allowed to occur in the same portion of the spectrum. The data in a particular band is spread over a range between 902 Mhz and 928 Mhz. Thus these RF waves will have a low amplitude and will be spread over a large frequency. At the receiving station, these waves will be "unspread" so that the original information will be garnered. Since the amplitude of the transmitted wave is low, the system is highly immune to narrow band interference. Unauthorized interception of the transmitted data is highly unlikely because the waves are difficult to detect coherently, unless the band-width of spread is known before-hand. Data transmission rates can be very high, often in excess

of 100 kilobits per second. However, spread spectrum systems are best applied in a well-defined area. In large areas covering cities, a narrow band systems is more appropriate, even though the data rates will be much slower. A more detailed explanation of narrow band and spread spectrum technology is covered in section 2.6.

2.5.2 RFDC SYSTEM CONSIDERATIONS

The key link in automatic identification systems is the data communications subsystem. The various aspects that have to be dealt with during the installation and operation of a radio frequency data communications system are:

ACCURACY: It is very important to preserve the accuracy of the acquired data.

UTILITY : The major benefit of RFDC systems is real time control. This aspect of RFDC should be utilized to the extent possible. It is important to define where and why real time data is required. There is no point in providing real time information where it is not needed.

FLEXIBILITY & EXPANDABILITY : The RFDC system should be designed with future needs in mind and the location of the antennae and the capacity of the host computer should be planned accordingly. It should be easy to reconfigure the system as the operational needs change. Future expansions should only need mere addition of transceivers and data collection terminals.

DATA SECURITY: The system should be designed to prevent unauthorized access and interference to the data transmission process. This requires using a narrow band with FCC approval or a spread spectrum system with the frequency hopping capability.

Other considerations of an RFDC system include the operating environment conditions, which will define the required ruggedness of the system. Operator acceptance is important and it is important to convince the operators that the RFDC is not meant to replace him/her. Programmability at the terminal level is optional (to ensure that alpha or numeric characters are correctly entered). Interface between the RF system and the host should be proven and reliable.

2.6 TECHNOLOGY CONSIDERATIONS

Until recently all commercial radio frequency data communications technology focused on what has become known as Narrow band RF. In 1985 the FCC authorized the use of spread spectrum RF technology in the commercial realm. Most RFDC system vendors are now offering both narrow band spread spectrum products. This section provides a comparative study about these two RF technologies and the advantages of spread spectrum over narrow band.

2.6.1 Narrow Band Technology

Most narrow band RF operates within the Business Radio Bands allocated range of 450-470 MHz (Megahertz) or 800 MHz at a very specific and narrow frequency band, hence the name Narrow Band.

A narrow band license from the FCC gives the user specific rights. If the primary user of a narrow band frequency is interfered with, the FCC can issue a cease and desist order to the interfering station. However, because of extreme demand for channels in some metropolitan areas, some level of interference is considered acceptable by the FCC. A range of narrow band systems can be upto four miles in the open air with a 2 watt transmitter at ground level. Data collection systems; however, are typically used indoors. Inside buildings, the

area of signal propagation is significantly reduced because the signals bounce off some surfaces and are partially absorbed by others. Nevertheless, the signal will sometimes still make it to nearby buildings in the area, hence the need for FCC licensing to avoid serious interference.

Disadvantages

Narrow band data rates are limited to 9600 bps or less. This can severely limit system response time when more devices are attached. If data cannot be successfully transmitted to peripherals the RFDC controller will select a lower baud rate to resend the data. This slower data rate may be unacceptable in many applications because it limits overall throughput and ultimately worker productivity. With spread spectrum systems, that operate at much higher rates, this phenomenon does not occur.

Narrow band signals typically do not contain redundancy, i.e., signals are not spread over several frequencies as only one frequency is transmitted. Consequently, it is vital that a clear channel exists for transmission because any interfering radiation of significant signal strength will prevent reception of the message. For this reason, the FCC license is required for this technology. However, a license does not insure against other interfering signals emitted from motors or other electrical devices.

The 450-470 MHz allocated by the FCC has become very crowded. When it was first allocated the proliferation of RFDC as it exists today was not foreseen. It has become impossible in some metropolitan areas to find a clear channel within this range. If a license is granted for a company to install in one location it does not give them the right to install or clone the system in another location or additional buildings located in the same general area. A new license must be applied for and may or may not be obtainable.

2.6.2 Spread Spectrum

Many applications require greater speed and network throughput than the 9600 baud rate limitation of narrow band technology. One solution to both the regulatory and throughput issues of narrow band RF is spread spectrum technology. Spread spectrum technology is a technique of uniformly distributing the information content of a data signal over a frequency range that is considerably larger than the range normally required for reliable transmission of data.

Advantages

By "spreading" the signal in the frequency range without adding information, significant redundancy is added to the signal, allowing data to be recovered in the presence of strong interfering signals emitted from motors or other electrical devices or other radio users. As the frequency bands around the world become more crowded, this technology has the possibility of assuming great importance by more effectively using the available band widths. It is also resistant to interference from electrical fields generated by welders, motors, generators, etc. There are two methods for uniformly spreading the data signal over a broad frequency spectrum. One is frequency hopping and the other is direct sequence.

2.6.2.1 Frequency Hopping

Frequency Hopping depends upon *avoiding* interference, by spending only minute amounts of time on any one frequency, continually hopping to other frequencies. The premise is that most interference is intermittent; it can be avoided by not staying on any one frequency more than a minuscule amount of time. the FCC prescribed rules for Frequency Hopping allow dividing the three unlicensed bands into channels of any size. But, they must not exceed a width of

500 KHz on the SSI band (902-908 MHz), and 900 MHz on other bands. Transmission on any one channel must not last more than 0.4 seconds, in any 20 second time interval (dwell time) on the SSI band, or any 30 second time interval on the two GHz.

2.6.2.2 Direct Sequence

The Direct sequence method takes advantage of the spreading phenomena of the signal as the data rates are increased. It also uses a redundancy encoding scheme , to produce a transmission method that can tolerate interference. Yet, it must not create disruptive interference for other spread spectrum users. Direct sequence functionally works as described - As with wired transmissions, the data byte is transmitted sequentially, one bit at a time. However, instead of transmitting the bit directly, it is used to perform Exclusively or binary Arithmetic on a spreading code. A spreading code generator provides the spreading code and for a 902-928 spread spectrum band, it must be a binary pattern, with a minimum of ten bits. It is composed of a pseudo-random pattern, usually an equal number of zeros and ones. The pattern is a fixed pattern for a given system, and since the data can be only a zero or one, the result of the exclusive or arithmetic produces one of two ten bit (or more) patterns. They are referred to as chips (to distinguish them from the data bit). It is actually the chips that are transmitted serially.

A table of comparative data between the two technologies is shown in Table 2.1.

2.7 APPLICATIONS OF RFDC

RFDC provides real time control and ensures tight information control because of its simultaneous on-line and mobile capabilities. The main applications of RFDC systems are:

Table 2.1 : RFDC Technology :Spread Spectrum Vs Narrow band

<u>Characteristics</u>	<u>Spread Spectrum</u>	<u>Narrow Band</u>
Transmission Frequency, MHz	902-928	450-470
Data Transmission rate, bps	Typically upto 200,000	upto 9600
Typical Data Transmission range	200-500 ft	essentially unlimited for Indoor Industrial Applications.
Power Output, Watt	1	2
FCC License required	No	Yes

REAL TIME RECEIVING/SHIPPING:

At the receiving dock, a lift truck operator picks up a pallet of product and enters the product part number and quantity via an automatic identification device (laser scanner or RF identification) or manually on the terminal keyboard. The host computer acknowledges the receipt of the message from the terminal and responds by telling the operator to (a) refuse the shipment before unloading as it is unacceptably late (b) cross dock the material right to shipping if it is a back order item or (c) store it in a computer assigned location. Thus, the materials are recognized as soon as they hit the receiving dock and the inventory database is instantly updated.

The same principle applies in the case of real time shipping allowing faster invoicing and reduction of day's sales outstanding. This system of wireless on-line receiving/shipping makes "just in time" inventory possible and reduces paperwork and errors.

WIRELESS PICKING/PUTAWAY:

Pick/Putaway operators equipped with wireless RF terminals can greatly increase inventory accuracy when linked to a host computer. When a computer assigns a store location, a verification will be required from the operator that he is storing it in the right location. This is accomplished by reporting a check digit or scanning a bar code on the bin location. If it is a wrong location, the computer alerts the operator with an error message.

During the picking operation, the operator scans the bar code on the location to make sure that the right product is being collected. Only after the computer relays a verification message will the pick operation be completed. This results in increased accuracy and benefits the user with reduced assets by lowering the work in process and finished goods inventory.

INTERACTIVE CYCLE COUNTING:

Closing a warehouse or zone for physical inventory can be avoided with wireless real time cycle counting. A cycle counter equipped with a portable RF terminal can count in the same area where pick/putaway operations are taking place. AS the cycle counter verifies a count, the inventory database is instantly updated. Discrepancies can be resolved on the spot.

REAL TIME QUALITY CONTROL

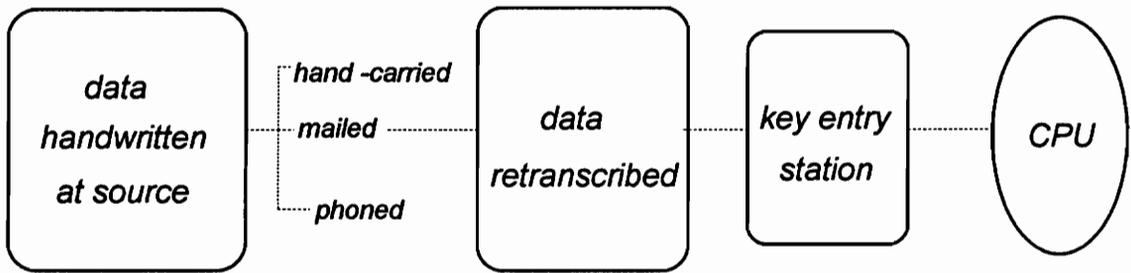
Quality control inspectors can be equipped with portable RF terminals to instantly report quality defects on the shop floor. When an inspector finds a defect, the part number, location and type of defect are recorded via the real time RF terminal. Immediately a supervisor is informed of the defect so that the machine or process causing it can be modified. This application would result in reduce scrap and increased productivity of the roving quality control inspectors.

QUICK RESPONSE

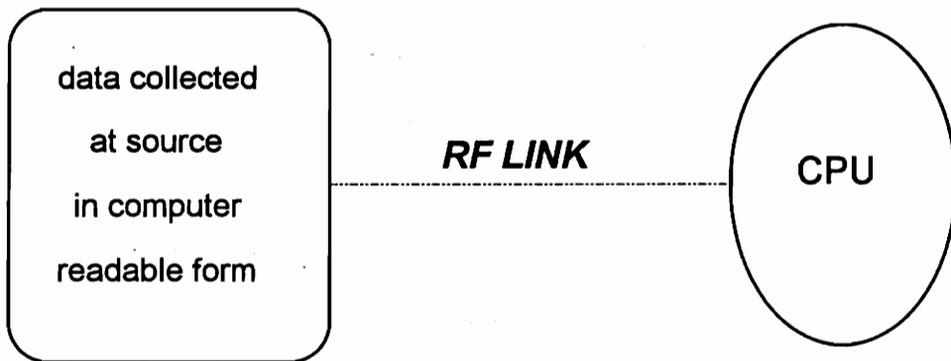
The Quick Response (QR) philosophy is to shorten the cycle time from raw material to finished product at the checkout counter and reduce inventory in every increment of manufacturing and distribution. Radio frequency data collection systems will help implement Quick response because of its real time advantage. The QR tactics will include bar coding the products, collect data in the pipeline automatically by scanning; transmit data in real time through radio frequency links.

2.8 BENEFITS OF RFDC

The RF link is highly reliable, with 99.5 % communications reliability being the norm. Figure 2.4 shows the communications link provided by RF in a data collection and transfer process.



Manual Data Collection Process



RF Data Collection Process

Figure 2.4 : The Radio Frequency Link

Harsh RF environments such as machinery, welding or generators are not a problem for properly installed RF systems. Inventory control has been the most widely accepted use of RF datacollection systems, but the on-line mobile advantages of this technology is also being used for roving real time plant maintenance, calibration and quality assurance functions. Nowadays, RF functions are linked to local area networks linked to larger RF networks controlling inventory, AS/RS and AGV operations.

Receiving:

- Eliminates Receiving Delays
- Permits JIT Receiving
- Permits Cross Docking
- Reduces/Eliminates Staging Areas
- Quality Control

Warehousing:

- Increases Inventory Accuracy
- Reduces Inventory Investment/Area
- Reduces Out-of-Stocks
- Reduces Deadheading
- Permits Real Time Cycle counting
- Allows Accurate FIFO Stock Rotation

Manufacturing:

- Inventory Control
- Material Management
- Work Order Status
- Labor Tracking
- Quality Control

Shipping:

Faster Back Order Fill

Faster Invoicing

Computer Directed Loading (LTL Balancing)

Verifies Complete Shipments

2.9 SUMMARY

This chapter gives a brief overview of Automatic Data Collection Technologies that are being used in industry today. Radio Frequency Identification (RFID) is explained, which is another application of RF waves in Automatic Identification Systems (AIS). The Voice recognition is briefly summarized as it is an integral part of the ADCSL at Virginia Tech. Since the RF network uses bar code for input of data, a thorough study of bar code symbology and applications was undertaken as part of the literature review. An analysis of the Narrow Band and Spread Spectrum technology used in radio frequency data systems was also undertaken.

CHAPTER 3

METHODOLOGY

3.1 THE ADCSL- AN OVERVIEW

The Automatic Data Collection Systems Lab (ADCSL) at Virginia Tech concentrates on three primary automatic identification and data collection technologies.

- * Bar Code Systems.
- * Radio Frequency Data Collection Systems.
- * Voice Data Collection Systems.

The experiments will be designed to be a complementary set of lab routines with the bar code and voice recognition systems. Since the automatic identification sub system in the radio frequency based data collection network is bar-code based, it is assumed that students carrying out the experiments have a working knowledge of bar codes including their symbology. This chapter will review the technical equipment - hardware and software available in the lab for developing an RF based data collection system.

3.2 TECHNICAL RESOURCES

All the equipment for the RF system have been obtained from Symbol Technologies. A list of the hardware and system software with a brief description of their function and place in the RF network is given below.

3.2.1 HARDWARE

Serial Access Bridge:

The Access bridge provides a communication interface between the RF network and the RS-232-C serial link to the host computer. The interface is

accomplished by a combination of hardware connections and the software supplied. The Access bridge will also control the operation of the RF network. It contains the software for the RF network and establishes network topology and maintains a full-duplex logical connection with each device in the network.

LRT 3800 Data Terminal:

This is a hand-held data collection terminal containing an integral bar code scanner and a radio unit for RF communications with the transceivers. An application program running on the portable terminal is complimentary to the application program being run on the host computer.

PRC 3310 Portable data terminal:

This is a battery powered, hand held computer designed for use as a remote, portable data collection device. Data can be entered using the keyboard or a bar code scanner. This high-performance data terminal employs radio communications for data transmission.

APS 3395 data collection terminal:

The APS 3395 is a hands free data collection computer. It lets an operator perform data collection while letting his arms free for other work. The APS 3395 is worn on the arms of the operator and is attached to the console which acts as an host terminal.

LS 3000 Bar code scanner:

The LS 3000 is a hand-held bar code scanner which is based on the visible laser diode technology. It gives the scanner a wider decode zone, greater depth of field and a visible scan beam. It usually is connected to another portable data terminal like the PRC 3310.

HF 2000 Bar code scanner:

The HF 2000 scanner is a wearable scanner and is an ergonomically designed package that mounts on the back of any operator's hand. It weighs less than 5 ounces and usually interfaces with another host data collection terminal.

Spectrum One Transceivers:

Transceivers provide an interface between the Access bridge and the portable terminals. The transceiver has an interface to a coaxial bus for transceiver-transceiver communication and a serial interface for communication with the access bridge. The transceiver also has a radio for portable terminal communications. Transceivers route data received from the portable terminals to the access bridge and pass responses from the access bridge back to the portable terminals.

Portable Terminal Cradles:

The portable terminals provide two major functions for the RF network: direct serial communications and battery charging. The cradle can be connected to the access bridge by a full-duplex serial link and can pass data between the access bridge and the portable terminals placed inside the cradle. The cradle is also used for configuring new portable terminals.

Host Computer:

The host computer is a Zenith-386 SX/20 supporting the Symbol Serial Packet Protocol. Application programs (data collection programs, database programs, etc.) are run on the host computer. In addition to application programs, a basic set of bridge support routines are resident in the host computer. These support functions such as reading a terminal's application program from the host disk and downloading it to a portable terminal in the cradle.

Cables, Connectors and Accessories:

The Automatic Data Collection Systems Lab includes standard cables like the RS 232-C, RS 422 and other wiring necessary for interfacing the equipment into a RF network.

3.2.2 SOFTWARE

Symbol Terminal Enabler Program (STEP):

The STEP program resides in the portable radio terminal and executes a pre-defined set of commands sent from an application program in a host computer. As this software executes the host commands in the terminal, the operator is guided through the data entry process.

Serial Access Bridge Driver:

The Access Bridge Interface consists of a set of software components on the Access Bridge that provides mechanisms for controlling the RF network operations, for accessing file services on the host and for communicating between host based applications and portable terminals.

Protocol Device Driver:

This software is implemented in the portable terminal. The driver consists of several modules like the application programmer interface (API), the transporter, the radio driver and the serial driver.

Symbol ANSI Terminal Program (SATP):

This program lets a remote radio terminal log into a host system in a TELNET TCP/IP network as an ANSI terminal. However, this software cannot be used until the host computer is connected to the local area network.

3.3 PROJECT LIFE CYCLE AND METHODOLOGY

The flowchart shows the developmental activities involved in the accomplishment of this project.

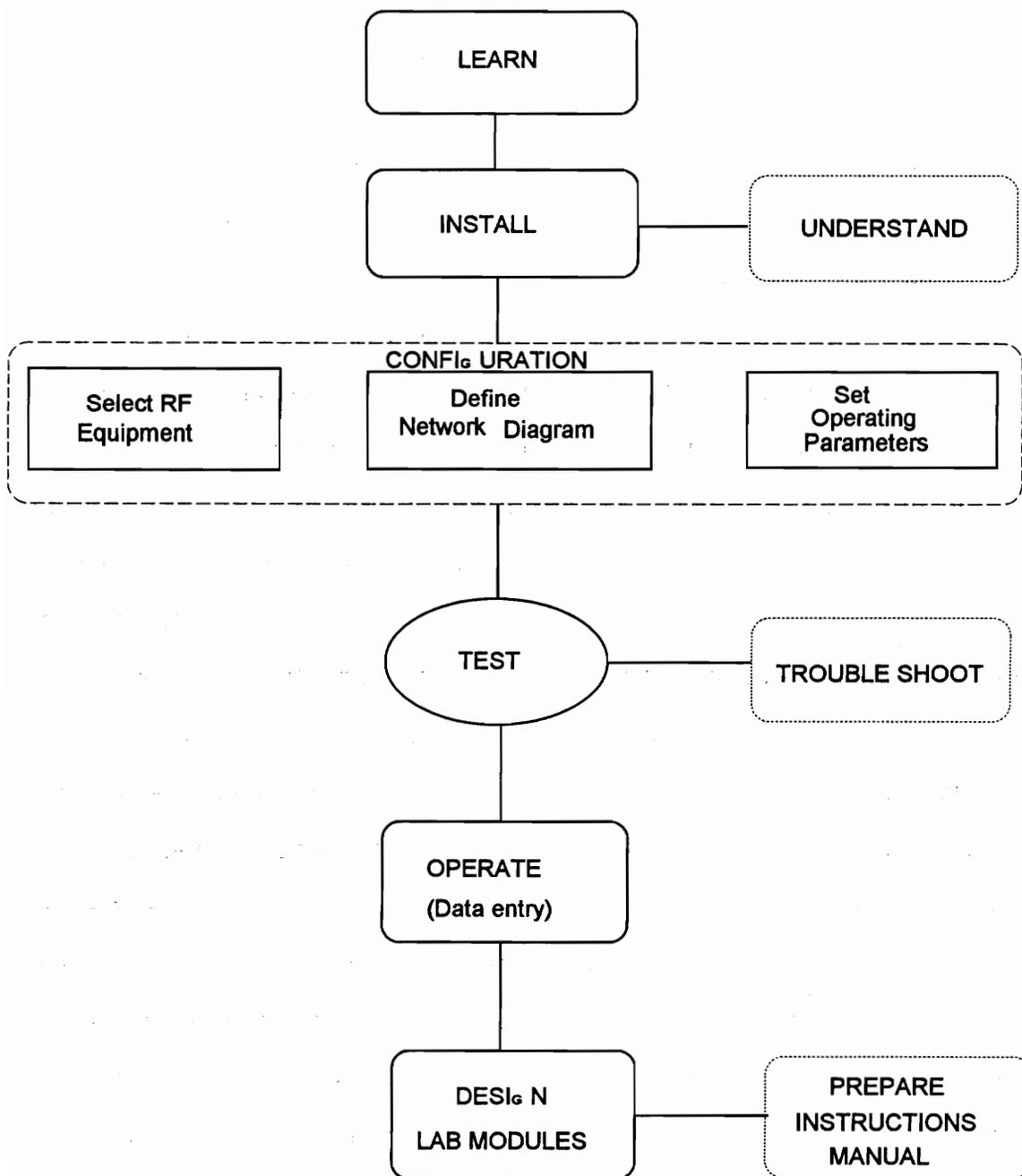


Fig 3.1 : Flow Chart of Project Life Cycle and Methodology

This project was accomplished in three stages:

1. Research Phase:

This phase mainly involved a thorough review of literature and was oriented towards understanding RF technology and how automatic identification and data communications can be accomplished. Based on readings from various technical magazines, a compilation of selected readings was made which would be distributed to the students. The readings cover basic RF technology and some innovative applications of radio frequency based communication networks in industry and research.

2. Network Configuration and Installation Phase:

To investigate and define the network architecture requirements needed to support real time tracking of material flow was the main aim of this phase. The network was set up and problems were diagnosed. All the equipment, including the hardware and software was interfaced with the host computer to function as an automatic data collection system.

3. Experimental Design Phase:

This phase involved the design of lab modules which were structured so that students can carry out various experiments on radio frequency technology. Lab manuals were written out to explain the features of the particular set up and the operating instructions were written down in an easy-to-understand manner.

3.4 SUMMARY AND CONCLUSION

As Radio Frequency (RF) data collection revolutionizes automatic identification, Industrial Engineers will need to understand how this new technology can assist in efficient operations in today's complex manufacturing environment. This project will explore the various aspects of a radio frequency based data collection system. The laboratory modules that will be developed will provide students with an understanding of important factors to be considered during operating such a system. Armed with this knowledge, future industrial engineers will be better prepared to handle complex technology in the automated factory of the future.

CHAPTER 4

RFDC SYSTEM CONFIGURATION

4.1 SYSTEM COMPONENTS

The RFDC network consists of portable terminals, transceivers, portable terminal cradles and the access bridge. The portable terminals communicate with the access bridge either via a radio link with a transceiver connected to the access bridge or serially through a portable terminal cradle. The physical devices in the RF network are:

- One Access Bridge
- One transceiver
- One or more portable terminals
- One or more portable terminal cradles

The serial access bridge is the end node of the RF network and is non-interactive with no monitor or keyboard. The Access Bridge software residing in the access bridge provides the interface between the host system on the serial link and the RF network. All input and output between the host system and the RF network is channeled through the access bridge.

The host system is any mainframe computer, mini-computer, workstation, or PC supporting the Symbol Serial Packet Protocol and communicating via a serial link. The host system serial link connects to the RF network through the access bridge.

The access bridge interface consists of a set of software components on the access bridge that provides mechanisms for controlling the RF network operations, for accessing file services on the host, and for communicating between host based applications and portable terminals. The three major components of the Access Bridge Interface are:

- * Symbol Host Interface Program (SHIP) which permits communication between a portable terminal and an application on a host computer connected via the RS-232C serial link.

- * Administrative Bridge Access Routines (BARs) that provide operational control over the network, such as, radio channel selection, chipping sequences, download, restart, and so forth.

- * File access routines which provide access to file resources and management on the host on behalf of the access bridge.

The purpose of the RF network is to provide communications with a rapid response time between a host computer and many radio terminals over a large area. The application programs running on the remote terminals communicate with the application programs running on the host computer. The remote terminal applications typically involve data entry and queries on the host computer and the host computer applications provide a database interface with responses to the remote terminal.

The RF network uses direct sequence spread spectrum technology. Fifty three frequencies, within the approved spread-spectrum bandwidth (902 to 908 MHz), have been selected and are referred to as channels. Data transmitted by the remote terminal and data returned from the host modulate the frequencies of the selected channel. The data is transmitted by spreading it over multiple channels within a specified band of frequencies. The spreading and selection of frequencies is made to appear random by using a pseudo-random chipping sequence. The pseudo-random chipping sequence causes the assigned frequencies to be selected in a random order. The spreading characteristic of the spread spectrum technology means many users can operate in the same band of frequencies without interference. The signal also has high noise immunity, allowing it to travel a considerable distance and still remain intelligible.

4.2 INSTALLATION AND CONFIGURATION

Prior to installation a site survey is usually conducted which includes radio reception tests. This information is used for determining the RF coverage from all locations of the site and optimum placement of transceiver and length of the cables and connectors. But since the specific RF network is an experimental one within a closed room it was deemed unnecessary. The installation of the hardware and system components with the necessary data links are described briefly. Figure 4.1 shows a schematic diagram of the RF network along with the major system components.

The access bridge has three ports- COM 1, COM 2, COM 3 , for connecting the other system components. A DE-9 connector with a RS-232-C null modem cable is connected to COM 3 at the rear of the access bridge. The DB-9 connector at the other end of the cable is connected to the serial port on the host computer. Since the host- Access Bridge interface uses Request To Send (RTS) and Clear To Send (CTS) signals, the initialization file of the access bridge software was modified. The cable between the primary transceiver and the access bridge is a RS-422 type with twisted pair wires to minimize distortion of the signal due to outside interference. A DB-25 socket at one end of the RS-422 cable is connected to the serial port labeled COM 1 at the rear of the access bridge. The DB-25 plug at the other end is connected to the serial port of the primary transceiver. The cradle which is used for configuring the data terminals is also connected to the access bridge using an RS-232 null modem cable. A DE-9 connector from the serial port labeled COM 2 at the rear of the access bridge was connected to the serial port on the left end of the cradle. The pin diagrams for the hardware connections are shown in Appendix -C. An antenna for receiving the transmitted radio signals was attached to the end of the

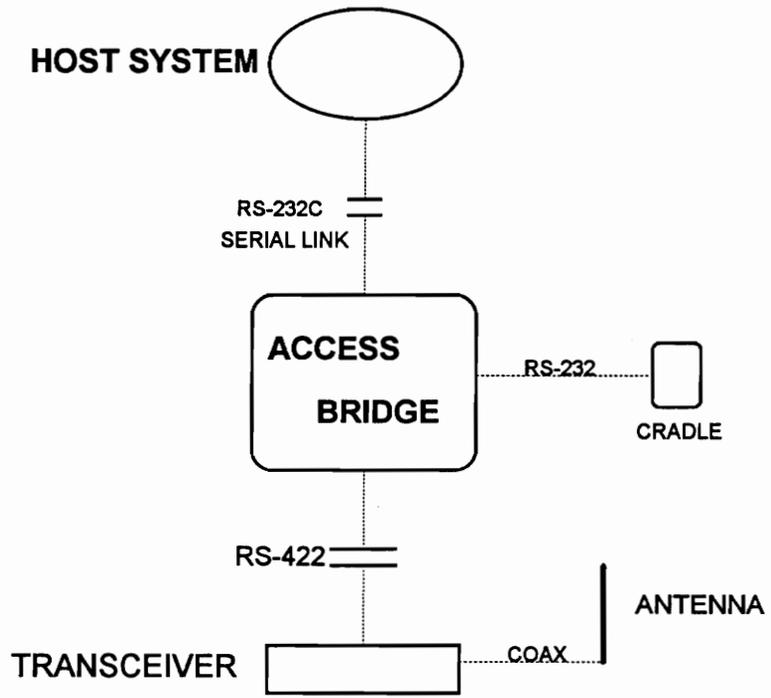


Figure 4.1 : The RF network in the ADCSL at Virginia Tech

transceiver. All the power supply cords were connected to an external AC power outlet.

4.3 Component Configuration:

The transceivers and portable terminals of the RF network need unique identifiers, called unit numbers, in order to communicate with the host system. Unit numbers, as well as the network chipping sequence and frequencies, are sent to these units during configuration by the Server Control Program (SCP). Configuration of the system components is an automatic process controlled by the system software. During the configuration process, the Access Bridge Software allocates unit numbers for each pseudo-base that it uses to address each communication port. Configuration of the portable terminals was automatic when the uninitialized terminals were placed in a cradle. The portable terminal in the cradle was assigned a unit number by the Server Control Program and was then allowed to join the RF network. The unconfigured portable terminal in the cradle sends a Configuration Request to the Access Bridge. After the proper protocol exchange, the terminal received a configuration packet containing the current chipping sequence and assigned radio frequencies. Portable terminal configuration was now complete.

4.4 SOFTWARE INTERFACE

This section describes the two most important software systems in the RF network. The portable terminal software which resides in the radio terminal and the network controller software called the Serial Access Bridge (SAB) software.

4.4.1 Portable Terminal Software

The Protocol Device Driver is implemented in the portable terminal and consists of several modules. The major modules are the Application Programmer Interface (API), the transporter, the radio driver and the serial driver.

The Application Programmer Interface (API) is responsible for translating DOS level commands to network protocol functions. Based on received DOS commands, a network protocol communications session can be started, monitored and terminated. While a communications session is in progress, data can be exchanged with an application on the host processor.

The primary function of the remote transporter is to packetize and depacketize the messages and to ensure end to end transmission of packets to the network controller. This software module is responsible for maintaining error-free data transfer using numbered data packets and acknowledgments.

The RF driver passes the data packets from the transporter. In performing data exchanges, the RF driver schedules the exchanges, prepares data for transmission over the RF link, and decodes the data received over the RF link.

The RF network protocol can be used over a serial connection as when the terminal is placed in a cradle. The serial driver transmits and receives data by forming packets with a start flag. Figure 4.2 shows the portable terminal software modules and their hierarchy.

4.4.2 Access Bridge Software:

The Access Bridge Software is resident on a 3 1/2 " floppy and is inserted into the drive before powering up. The files AUTOEXEC.BAT, SPEC1.CFG and SPEC1.INI are installed on the installation diskette with default values. However, the SABSID.INI file was edited to adjust the configuration of the host serial port

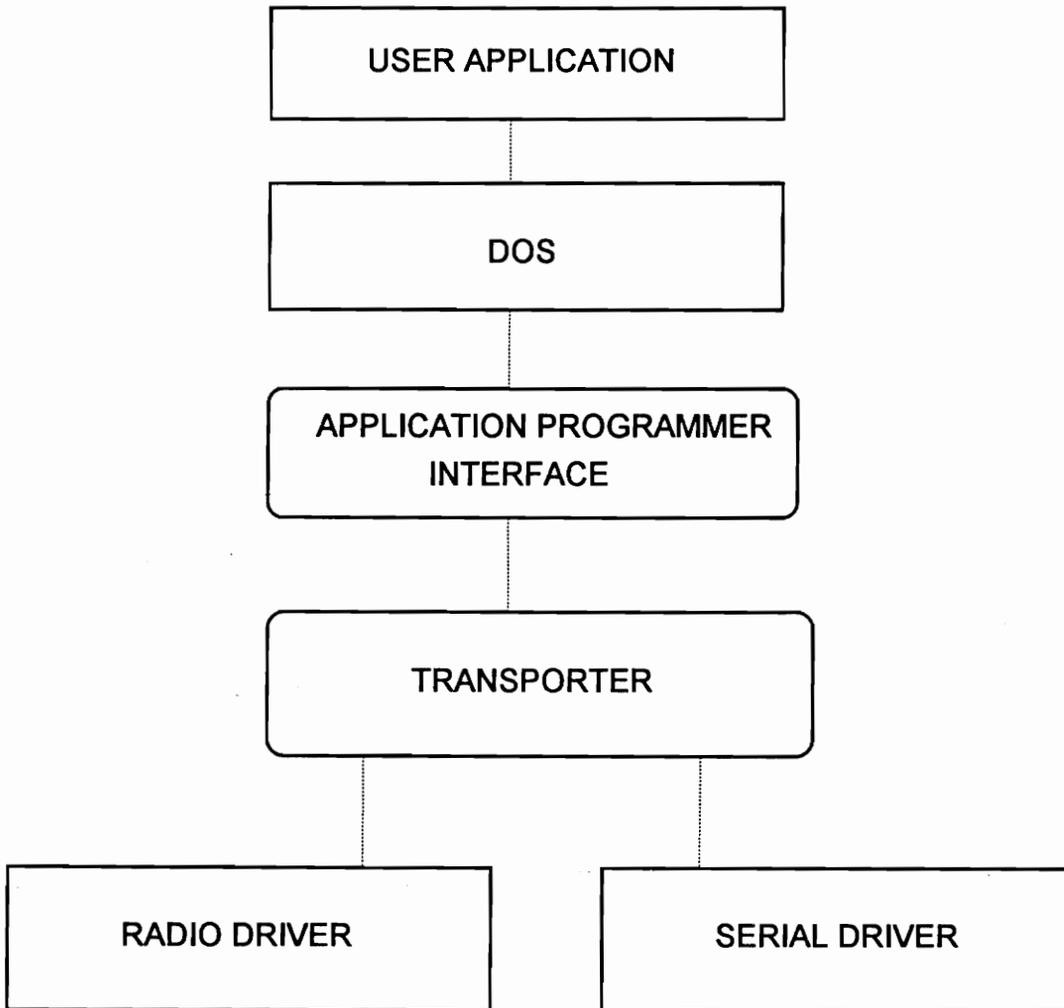


Figure 4.2 : Portable Terminal Software Hierarchy

to match various standard serial formats. The following values were used in the initialization file:

Baud rate set to 9600.

Data Bits set to 8.

No parity.

Number of Stop Bits set to 1.

No Flow Control.

Link Mode set to Rft.

No BAR (Bridge Access Routine) enabled.

Host Delay set to zero.

4.5 COMMUNICATIONS AND DATA TRANSFER

Information is transferred between the Access Bridge and the host through the serial packet protocol. A packet consists of a series of pre-defined data fields containing data codes that are recognized by both the Serial Access Bridge and the host. The general format of the data packet is shown in figure 4.3 along with table 4.1 summarizing the various fields and their respective functions.

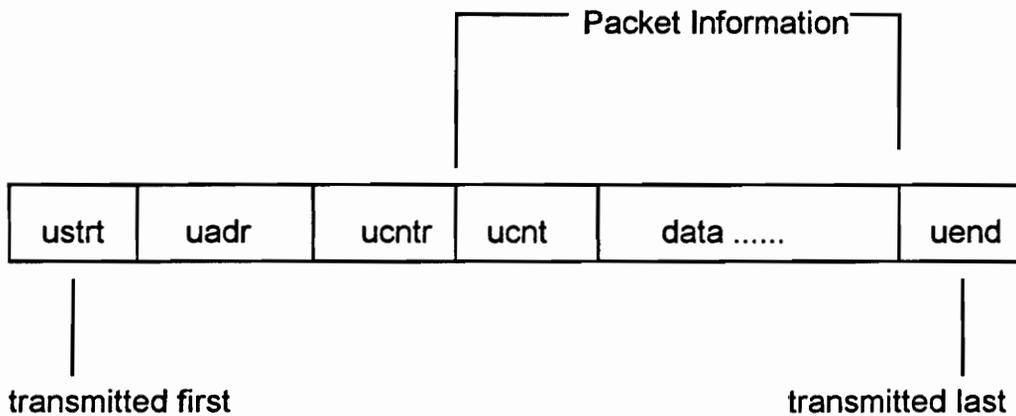


Figure 4.3 : Format of data packet

Table 4.1 : Data fields and functions

FIELD	FUNCTION
ustrt	User Starting Characters. This field always contains the three ASCII characters 'STX' to indicate the start of the packet.
uadr	User Address. This is the address of the portable data terminal assigned by the access bridge.
ucnt	User Control. Defines the type of transaction.
packet information	The packet information consists of two fields (ucnt and data) and contains the actual application data transferred between the portable terminal and host. The ucnt field contains the character count of the data field.
ucnt data	The data field is the only field in the packet that is processed by the portable terminal program. It is considered an optional field due the fact that packet transfers can occur between the access bridge and the host without the packet information as in the case of command packets.
uend	User End. This field contains the ASCII return character to indicate the end of the packet.

4.6 SUMMARY

This chapter provides an overview of the technical aspects of key system components that was studied during the installation phase of the RF project. The Access Bridge and operation of the RF network require implementation of portable terminal software in the data collection terminals. The source code for some of this software will not be released by Symbol Technologies and any changes are to be made by them. However, a understanding of Serial Packet Protocol and data transactions is necessary in trouble shooting potential problems with the RF network.

CHAPTER 5

INSTALLATION, TEST AND EVALUATION

5.1 INTRODUCTION

Once the hardware is set up, the system has to be configured such that all the components work with standard protocols. Real time transfer of information will be accomplished only when the same communication and data transfer protocols are implemented. The Access Bridge was powered on with its software loaded in the disk drive. The connections were made according to the RF network diagram shown in figure 4.1 . The cables were connected to the appropriate terminals and corresponding ports on the host and the Access Bridge.

5.2 INITIALIZATION OF TERMINALS

The Symbol Terminal Enabler Program (STEP) was downloaded into the portable terminals, PRC 3300 and the LRT 3800. The process for downloading STEP into the terminal consisted of two main operations:

1. Copying the hex file and sendhex utility from the floppy disk to the hard disk of the host computer.

2. Down loading the STEP hex file from the computer to the terminal.

The terminal was inserted into the cradle which in turn was connected to the computer. After entering the command mode, the "program loader" option was selected. The terminal then prompted for the communication parameters. The following values were used:

Data Bits = 7

Parity = odd

Flow Control = None

The terminal then downloaded STEP files into the portable terminal. Upon completion, it displayed

```
bytes sent = 53896, 100 %  
done
```

5.3 PORTABLE TERMINAL OPERATION

After STEP was downloaded, the terminal prompted for information about the system. The terminal displayed the following screen:

```
-Network Interface-  
1. NetBIOS ( Block)  
2. Telnet ( Stream)
```

```
Select : --
```

Since the host has a serial interface, NetBIOS was selected.

The terminal then prompted for keyboard type, ANSI or standard.

The STEP main menu was displayed

```
---- STEP MENU ----
```

1. STEP
2. Backup
3. Download
4. Configure
5. Scan

```
Select /Clr : --
```

STEP checks the system configuration files and logs on to the network.

Backup is used to collect data off line.

Download is used to download files from the host computer to the terminal.

Configure is used to save system parameters in the terminal's RAM disk. This prevents having to select parameters each time the terminal is used for data collection.

Scan option is used for a scanning demonstration, setting the scanning configuration and choosing the terminal's scanning device.

5.4 SUMMARY

Installation and configuration of the RF network was successfully completed. Logon and Logoff procedures were found to be working without any problems. The SABSID.INI file which is the software running the RF controller was modified to be compatible with standard communication protocols.

CHAPTER 6

DESIGN OF LAB MODULES

6.1 INTRODUCTION

Three different lab modules were designed to help students understand the use of laser scanning, portable computing and RF network operation. The manuals provided with the equipment make it easy to understand the operation of the equipment. However, some of the terms can be confusing. The first practice module will just help students become familiar with the RF equipment and how to use the laser scanner and proper scanning techniques.

6.2 PRACTICE LAB MODULE

In this module students will be required to run a scanning demonstration and become acquainted with proper laser scanning techniques. They will also be required to perform Logon operations with the host computer.

Part A: Scan Demonstration

First, the STEP main menu is displayed as shown here.

<p>— STEP MENU —</p> <ol style="list-style-type: none">1. STEP2. Backup3. Download4. Configure5. Scan <p>Select /Clr : --</p>

Select option 5 and the terminal displays the following screen.

```
-----MAIN MENU-----  
1. Scan only demo  
2. Configure Scanner  
3. Set key time-out  
4. Select Scanner  
F9 : Exit Program  
  
Selection :--
```

Selecting Option 1, the scan demonstration is executed.

The operator will be required to scan a series of bar codes and see how the portable terminal with the built-in laser scanner decodes the information. The screen also displays the symbology. The same exercise will be repeated with the help of the PRC 3310 (Portable Radio Computer) with the LS 3000 scanner attached to it. The operator can also enter data through the keyboard.

Part B: Logging onto the network:

This exercise helps students become familiar with the RF network configuration and the various system components like the transceiver and communication cradles. The students will be asked to draw a diagram of the RF network and the hardware connections in the system. They will then be required to logon to the host computer and prepare the network for transfer of data in real time. After this they will perform the logoff procedure.

First the STEP main menu is displayed, which appears as soon as the system is booted on.

Choosing the STEP program option, the screen displays the following:

Checking Config...
Place in Cradle or
connect serial now!

The operator is required to place the cradle in a cradle so that the terminal can receive the configuration data from the network controller. After a moment, the following message appears on the screen.

Unit Configured
Remove from cradle/
disconnect serial!

Removing the terminal enables the radio link to be established and the screen display is

Opening comm line....
Request to attach ..
Terminal attached!
Getting host list...

Since there is only one host, the host list does not appear. The screen then prompts for the kind of communication session, which is either session or datagram. The session option is chosen. The screen then prompts the operator for his or her I.D number. The prompt I.D utility can be disabled if needed. The operator I.D will be the students social security number and it is sent to the host by the terminal. After the operator I.D has been entered, the screen displays.

Logon Ready *

This indicates that the terminal has sent the host the Log-on-ready response. The terminal is now logged on to the host through the network. Under control of the host application program, the terminal can now be used to collect data and display information.

6.3 LAB MODULE 1: OFF-LINE DATA COLLECTION

This lab aims to expose the students to the concept of off-line data collection. This off-line data operation is useful when it is not necessary to send immediate responses to the host. It can also be used as a backup to the on-line operation in the event that the host is inoperative due to failure or maintenance.

Using the Backup Option:

First display the STEP main menu as shown here.

```

      — STEP MENU —
          1. STEP
          2. Backup
          3. Download
          4. Configure
          5. Scan

          Select /Clr : —

```

With the STEP main menu displayed, Pressing **2**, brings up the following screen.

BACKUP UTILITY

Enter data:

<F9> Exit

The terminal is now ready to collect data from either keyboard entry or scanning bar codes.

Scanning a few bar codes from the bar code data sheet and inputting a couple of keyboard entries will be done to collect the data.

To exit the backup option and return to the STEP main menu, press Function key **F9**.

Press **CLR** to return to the DOS prompt. Using the *DOS Type* command displays the data that has just been entered.

```
D:> TYPE BACKUP.DAT
```

All the data that had been entered by scanning bar codes or by keyboard entry is displayed on one line using field separators. The students will be required to enter the screen display into the lab work sheet.

Reading collected data:

With the terminal logged on to the network, the host computer can read the terminal's collected data by sending the Read Data File and Read Next commands. The host can then delete the collected data in the terminal by sending the Erase Data File command.

The syntax of the read data command is:

```
RD <filename>.
```

In this case *filename* will be *backup.dat*. As soon as the terminal receives the Read Data File command, it sends the file to the host (upto 510 bytes). For files larger than 510 bytes, the host must send one or more Read Next commands.

Once the transfer has been complete, any editing program can be used to check the contents of the transferred file on the host computer. The students will compare the contents of the file to the screen display of the portable terminal. The format of the displayed file and discrepancies, if any, between the two files will be noted down.

6.4 LAB MODULE 2: FIELD SERVICE REPORTING

This lab module is a simple exercise in field service reporting. It has these main functions:

- * log-On Ready
- * Main menu
- * Sign-out
- * Check-in
- * End-of-day
- * Log-Off

The STEP program starts its communication with the host by sending the Log-On Ready response. As soon as it is activated, STEP sends the response to indicate that it is ready to receive commands form the host. The response starts with the sequence number, time and terminal type and model. The terminal is now ready to receive command strings from the host. The first string of commands will create the main menu of the application program.

Main Menu:

<p style="text-align: center;">Main Menu</p> <p style="text-align: center;">F1 = Sign-Out F2 = Check-In F3 = End-of-Day F4 = Log-Off</p>

From this menu, the terminal allows the operator to select an operation by pressing one of the Function keys.

Sign-Out

This function requires the terminal operator to enter the number assigned to his or her service call. When the operator presses F1 from the main menu, the terminal displays:

<p style="text-align: center;">Sign-out Call No:_____</p>

This prompts the operator to enter a call number. The terminal then sends an Input Data response indicating the entered call number.

Check-In:

This function requires the terminal operator to enter the number of miles driven when checking back in after the service call. When the operator presses F2 from the main menu, the terminal displays.

Check-In
Miles Driven:-----

After the operator has entered the number of miles, the terminal sends an Input Data response indicating the miles he or she has entered.

End-of-Day:

This function displays the total number of calls made and the miles driven. The values for the number of calls and miles are calculated by the host based on data entered by the terminal operator. When the operator presses F3 from the main menu, the terminal displays the following:

End-of-Day

Total Calls ---

Total Miles ---

Log-Off:

When the field service reporting is completed, the terminal operator logs off from the host by pressing F4 from the main menu. The log-off command disconnects the terminal from the network. The terminal is then in an off-line operation with the STEP main menu displayed.

6.5 LAB MODULE 3: RETAIL INVENTORY MANAGEMENT

This lab module performs various database lookup and modification operations in a simplified retail or industrial application. The demonstration

program RIDEMO communicates with either the LRT 3800 or the PRC 3310 using the RF network with the Serial Access Bridge as the RF controller.

The retail exercise consists of the following applications:

Receiving

Shelf Price Audit

Store Ordering

Starting the application:

Change to the *RIDEMO* directory.

Enter *ridemo/1* at the DOS prompt on the host computer.

The host computer's monitor will display the following Main menu:

Retail Demo Industrial Demo Edit Banner eXit to DOS
--

Choose Retail Demo and the following screen is displayed:

Start Demo Modify Data Base

After the Start Demo option is selected, a database screen is displayed with a list of items commonly found in the retail outlets. As the exercise is continued, the quantities displayed will change as new amounts are entered or scanned at the portable data terminal.

VEND	ITEM	DESC	PRICE	QTY ORD	QTY HAND
VEN11	074170054439	Ice Cream Straw 1gal	2.89	50	50
VEN11	074170059649	Ice Cream cones 12pk	1.49	50	50
VEN11	074170054293	Ice Cream, Choc 1gal	2.89	50	50
VEN22	045577002149	Floor Mop model 12	6.50	50	50
VEN22	029441134426	Wire Brush 6inch	3.29	50	50
VEN22	074170055894	Dog Leash six foot	4.89	50	50
VEN33	074170057089	Canned Peas 6oz	0.89	50	50
VEN33	074170048308	Cream Corn 8oz	0.99	50	50
VEN33	000559366824	Apple Sauce 16oz	2.39	50	50

Portable Terminal user Interface:

This section describes the screens displayed for operator entry on the remote terminal. The main menu screen provides a selection of retail applications.

Choosing the *receiving option* screen prompts, the operator for the vendor number. The number may be scanned from the supplied scan sheets or entered at the terminal keyboard. The host application verifies the Vendor # against the vendor database and, if the entry is valid, proceeds to the *receiving item number* screen. If an invalid vendor number (the number is not present in the database), an invalid number message is displayed on the screen and the prompt is redisplayed. The *receiving item number* screen allows the scanning of a UPC bar code (or key item number). The host application verifies whether the item

belongs to the vendor. If the item is valid, the *Receiving quantity* screen is displayed. If the item is not valid, an error message is generated. The *Receiving quantity* screen displays information from the host application database about the item number entered in the *Receiving Item* screen and the operator is required to enter the quantity number.

The terminal displays the record and prompts for the receive quantity. The receive quantity entered is validated in the host to make sure that it is not greater than the quantity on order. If the receive quantity is valid, the host database is updated. The receive quantity is subtracted from the Quantity on Order in the database and the quantity is added to Quantity on Hand.

This part of the exercise shows the ability of the system to interact with a remote database and retrieve active information.

Shelf Price Audit:

When the second option is chosen, the *Shelf Price Audit* screen is displayed. When the operator scans the UPC bar code, the host application compares it to the database. If the entry is valid, the *Price Change* screen displays the item record and allows the operator to accept the current value or enter a new value. If the price is changed, the corresponding new value is entered in the database. Upon completion of this screen, the application returns to the main menu.

Store Ordering:

When the third option is chosen, the *Store Ordering* screen is displayed. When an item is scanned or keyed in, the application verifies it in the database. If the item is found, the *Order Quantity* screen is displayed or else an error message is generated. The *Order Quantity* screen displays information in the

item record and allows the operator to enter a value for the quantity to be ordered. Upon completion of the scanning the database displayed on the host computer's monitor will reflect the changes made form the portable terminal.

6.6 Lab Module 4: Industrial Inventory Management

This exercise provides an emulation of a simple industrial environment.

Starting the application:

Change to the *RIDEMO* directory.

Enter *ridemo/1* at the DOS prompt on the host computer.

The host computer's monitor will display the following Main menu:

Retail Demo Industrial Demo Edit Banner eXit to DOS
--

Choose Industrial Demo and the following screen is displayed:

Start Demo Modify Data Base

After the Start Demo option is selected, a database screen is displayed with a list of items. As the exercise is continued, the quantities displayed will change as new amounts are entered or scanned at the portable data terminal.

VEND	PO	ITEM	DESC	RQTY	LOC	LOC-QY	ODR	STAT
VEN11	PO01	111111	Philips Screw Driver	75	A1	50	ORD1	WIP
VEN11	PO01	222222	Flat Head Screw Drvr	50	A2	50	ORD2	WIP
VEN11	PO02	333333	ClawHammer,BD16oz	50	B3	50	ORD1	WIP
VEN22	PO03	444444	Hack Saw Blade 12 in	50	C4	50	ORD3	WIP
VEN22	PO03	555555	Saber Saw, 4in blade	100	C5	100	ORD2	WIP
VEN11	PO02	666666	Air Compressor 10hrp	100	B6	100	ORD3	WIP
VEN33	PO02	777777	Premium Paint 10 gal	100	B7	100	ORD1	WIP
VEN33	PO03	888888	Paint Brush 3 inches	100	C8	100	ORD2	WIP
VEN44	PO01	999999	Metal Ladder 10 foot	100	A9	100	ORD3	WIP

Portable Terminal Interface

This section displays the screen formats on the portable terminal units. The industrial exercise will have the following main menu.

<p>LRT Spectrum One Industrial Demo</p> <ol style="list-style-type: none"> 1. Receiving 2. Put Away 3. Picking 4. Shipping 5. Logoff <p>Selection (1-5):--</p>

Receiving:

Choosing the Receiving number will display a *Scan P.O Number* Screen. If the item scanned is valid, a *Receiving* screen is generated, which prompts the operator to scan the item number. If the scanned bar code or keyed number is

valid, the user is prompted for the Quantity to be entered. Upon completion of this entry, the host display screen is updated in real time. The application then returns to the main menu.

Put Away:

Choosing the Put Away option prompts the user for the item number. If the item number is valid, a *Put/Away* screen displays the record and allows the operator to scan or manually enter a location code. After completion of this the terminal displays the *Quantity to Move* screen. It displays the same information as earlier but allows the operator to specify a quantity. The number entered is verified by the host application to be less than the Received QTY value in the host database. If the number entered is out of range, an error message is displayed. If the number entered is valid, the quantity entered is added to the location quantity in the host base.

Picking:

The *Picking/Order Number* screen allows you to scan or manually key an order number. The terminal sends the number to the host application where it is compared against existing order numbers in the database. If the database lookup is valid, the terminal displays the location and pick quantity on the screen. The operator scans the bar code with the item number to confirm the right pick up is done.

Shipping:

The *Shipping/Order number* screen lets the operator scan or key an order number. The terminal sends this number to the host for verification. If valid, the

screen displays the status of items as they are scanned. After scanning these items, the database is updated by removing the shipped items.

6.6 Summary

This section has a description of four lab modules. The first one was a practice module to get students oriented to the concept of Laser Scanning, handling portable data terminals and getting a 'feel' of the RF equipment. These exercises include a real world example of field reporting. The retail and Industrial applications exercises are designed to allow students to see the advantages of real-time transfer of information. The first hand exposure to RF equipment will enable students to see how RFDC can help create a dynamic information environment.

CHAPTER 7

CONCLUSIONS AND FUTURE DEVELOPMENT

The Automatic identification subsystem consisting of bar codes and laser scanners which perform data reading was set up. Portable terminal software was implemented and configured according to standard data transfer formats in the portable terminals. The terminals could decode the bar codes with 100 % accuracy in the initial tests. All the important bar code symbologies can be successfully used with the Symbol Technologies terminal software.

The data communications subsystem which includes the RF controller and the host computer was integrated into a fully functional manufacturing data collection system. The RF network, based on Spread Spectrum technology, was capable of transmitting data and commands from the host computer to the terminals and back.

Three lab modules and one practice module were designed to be part of undergraduate lab activities. The three lab modules include a field service reporting exercise and a retail and industrial inventory management exercise. The exercises have an accompanying lab manual which explains in simplistic terms the important features of the laser scanners and the operation of the portable data terminals.

Future work in the Automatic Data Collections Systems Lab (ADCSL) at Virginia Tech could include the following:

1. Implementation of an RF network with multiple hosts.
2. Obtaining access to a mainframe computer and developing an RF network in TELNET mode. This would require a different set of software components.

3. Develop and implement a real time inventory control system with bar code label printers

The software modules supplied by Symbol Technologies can be modified and custom built applications can be developed. This requires a thorough understanding of C programming for serial communications and a good background in wireless communication protocols and their implementation.

REFERENCES

- Advanced Data Systems., "RF in Warehouse Management," ADS, USA.
- Benoit, E.M., "RFDC system keeps inventory 99.5% accurate," Modern Materials Handling, June 1991, pg 66.
- Crosby, B., " Case Study: Airlite Plastics Company," SCAN-TECH 91 Proceedings, AIM USA, Pittsburgh, PA., 1991.
- Farmer, R., "Real Time = RF + EDI for MRO Procurement Cycle," SCAN-TECH 91 Proceedings, AIM USA, Pittsburgh, PA., 1991.
- Forger, G., "How more data + less handling = smart warehousing," Modern Materials Handling , April 1994, pp 42-45.
- Goodman, R.J., "System Design & Installation Consideration for Radio Frequency Data Communications in Inventory Control," SCAN-TECH 91 Proceedings, AIM USA, Pittsburgh, PA., 1991.
- Knill, B., "Radio Frequency Data Communications Starts with Material Handling," Material Handling Engineering, September 1991, pp 53-56.
- LXE Application Sheet, "Focusing on Customer Service Again," LXE Inc, USA
LXE Inc Product Literature, July 1994
- Dyer, S.M., "The Basics of Radio Frequency Data Communications," SCAN-TECH 91 Proceedings, AIM USA, Pittsburgh, PA., 1991.
- Norand Data Systems, "RF Made Simple Handbook," Norand Corporation, USA
- Scaringe, R.A., "The Radio Frequency Control Link: A mobile, Real Time Data Collection Technology," Industrial Engineering, November 1985, pp 63-68.
- Soltis, D.J., "Automatic Identification Systems: Strengths, Weaknesses And Future Trends," Industrial Engineering, November 1985, pp 55-59.
- Sutton, G., "Automatic Identification : The Basics of RFID," SCAN-TECH 91 Proceedings, AIM USA, Pittsburgh, PA., 1991.

White , J.A., Progress in Material Handling and Logistics. Material Handling Research Center, Georgia Institute of Technology, 1989.

Williams, B.J., "Radio Frequency Pilot Project in Microsoft's Domestic Distribution Center," SCAN-TECH 91 Proceedings, AIM USA, Pittsburgh, PA., 1991.

Zencko, W., "Spread Spectrum Radio for Indoor Wireless Networks," SCAN-TECH 91 Proceedings, AIM USA, Pittsburgh, PA., 1991.

APPENDIX A

FCC Rules Governing License-Free Operation of Spread Spectrum Systems.

Federal Communication Commission Rules.

Part 15, Section 247

Operation within the bands, 902-928 MHz, 2400-2438.5 MHz, and 5725-5850 MHz.

a) Operation under the provisions of this section is limited to frequency hopping and direct sequence spread spectrum intentional radiators with the following provisions:

1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 KHz or 20 dB bandwidth of the hopping channel, whichever is greater. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo random ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

b) Frequency hopping systems operating in the 902-928 MHz band shall use at least 50 hopping frequencies. The maximum allowed 20 dB bandwidth of the hopping channel is 500 KHz. The average time of occupancy of any frequency shall not be greater than 0.4 seconds within a 30 second period.

2) For direct sequence systems, the minimum 6 dB bandwidth shall be at least 500 KHz.

b) The maximum peak output power of the transmitter shall not exceed 1 watt. If transmitting antennas of directional gain greater than 6 dB are used, the power shall be reduced by the amount in dB that the directional gain of the antennas exceeds 6 dB.

c) If any 100 KHz bandwidth outside these frequency bands, the radio frequency power that is produced by the modulation products of the spreading sequence, the information sequence and the carrier frequency shall be either at least 30 dB below that in any 100 KHz bandwidth within the band that contains the highest level of the desired power or shall not exceed the general levels specified in 15.209. , whichever results in the lesser attenuation. All other emissions outside these bands shall not exceed the general radiated emission limits specified in 15.209 (a).

d) For direct sequence systems, the transmitted power density averaged over any 1 second interval shall not be greater than 8 dB in about 3 KHz bandwidth within these bands.

e) The processing gain of a direct sequence system shall be at least 10 dB. The processing of the signal to noise ratio with the system spreading code turned off to the signal to noise ratio with the system spreading code turned on, as measured at the demodulated output of the receiver.

f) Hybrid systems that employ a combination of both direct sequence and frequency hopping modulation techniques shall achieve a processing gain of at least 17 dB from the combined techniques. The frequency hopping operation of the hybrid system, with the direct sequence operation turned off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by the hybrid system.

NOTE: Spread spectrum systems are sharing these bands on a non-interference basis with systems supporting critical government requirements that have been allocated the usage of these bands, secondary only to ISM equipment operated under the provision of part 18 of this chapter.

Many of these government systems are airborne radio location systems that emit a high EIRP which can cause interference to other users. Also, investigations of the effect of spread spectrum interference to U.S government operations in the 902-928 MHz may require a future decrease in the power limits allowed for spread spectrum operation.

APPENDIX B

System Connections and Pin Diagrams

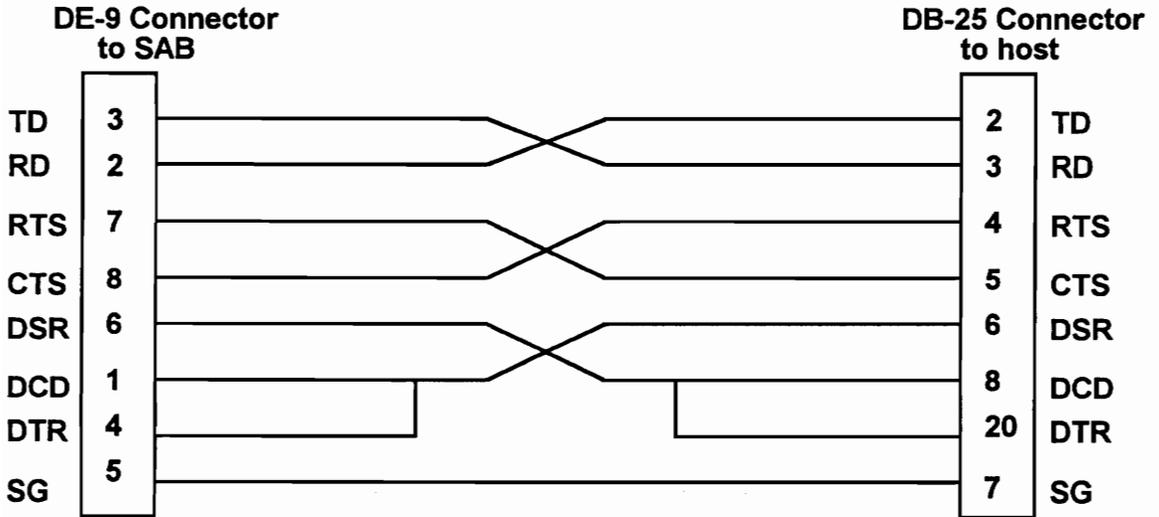


Fig 1. Serial Access Bridge- Host Cable Wiring (RTS/CTS)

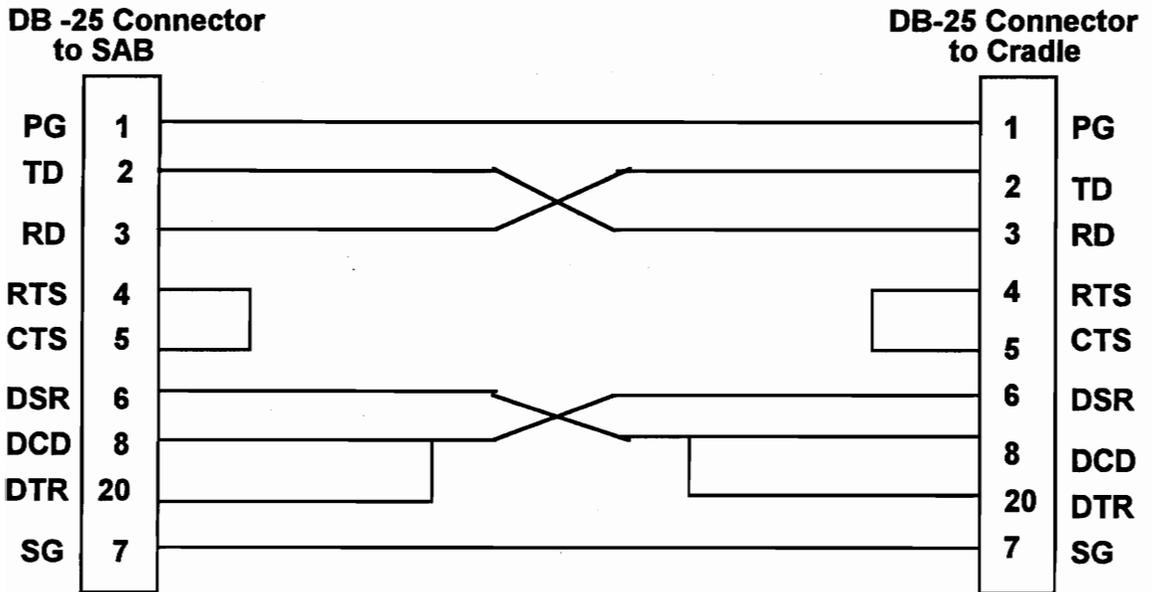


Fig 2. Cradle Cable Wiring

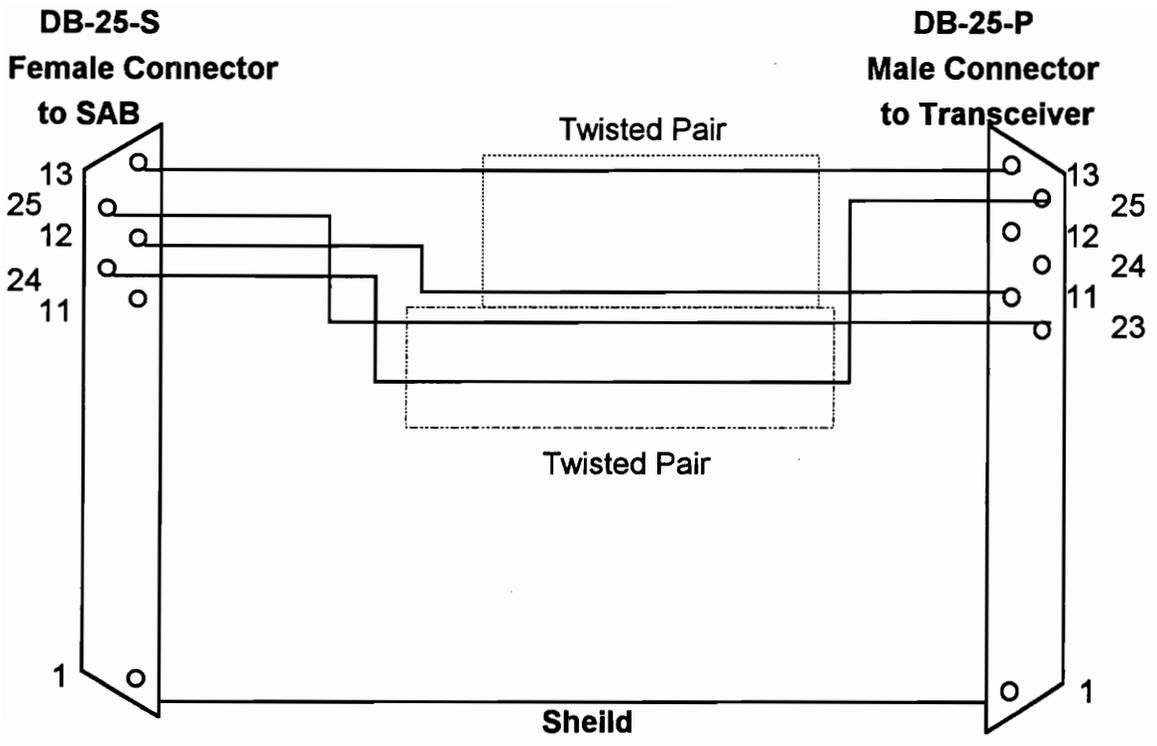


Fig 3. Transceiver - Serial Access Bridge (SAB) Connection

APPENDIX C

Symbol Terminal Enabler Program (STEP) Files

BACKUP <DIR> Subdirectory for STEP Backup Operation. It contains:

BACKUP	Make file
BACKUP .C	Source file
BACKUP .EXE	Executable
BACKUP .MAP	Map file
BACKUP .NMK	NMake file
BACKUP .OBJ	Object file
BACKUP .RSP	Response file for linking

CUSTOM <DIR> Subdirectory for STEP Custom Processing. It contains:

CUSTINT.OBJ	Object file used to build the user exit.
CUSTOM.OBJ	Object file that the users custom application is linked with to complete the custom processing user exit.
QUSER	Compiles QUSER.C and links it with CUSTOM.OBJ and CUSTINT.OBJ to create QUSER.EXE
QUSER .C	Example file that demonstrates the use of development of customized functions for STEP
QUSER .EXE	Executable of customized functions
QUSER .MAP	Map file for QUSER.EXE
QUSER .NMK	NMake file to build QUSER.EXE
QUSER .OBJ	Object file
USER	CUSTINT.OBJ to create USER.EXE
USER .C	the USER.EXE file
USER .EXE	Executable template for custom processing
USER .MAP	Map file for USER.EXE
USER .NMK	NMake file to build USER.Exe
USER .OBJ	Object file

STEPCUSTOM.H Definitions for the custom processing applications

SATP <DIR> Subdirectory for Symbol ANSI Terminal Program. It contains:

SATP .CFG Sample configuration file
SATP .EXE Executable ANSI Terminal Program
SATP .MAP Map file for SATP.EXE

The source for SATP is not released. Any changes to it are to be made by Symbol Technologies.

SRCP <DIR> Subdirectory for Symbol Remote Connection Program and Symbol Remote Disconnection Program. It contains:

SRCP Make file
SRCP .C Source file
SRCP .CFG Sample configuration file
SRCP .EXE Executable connection program
SRCP .H Header file to compile SRCP.C
SRCP .MAP Map file
SRCP .NMK NMake file
SRCP .OBJ Object file
SRCP .RSP Response file for linking

SRDP is used to disconnect a terminal from the network. It closes the protocol and the radio line.

SRDP Make file
SRDP .C Source file
SRDP .EXE Executable disconnection program
SRDP .H Header file to compile SRDP.C
SRDP .MAP Map file
SRDP .NMK NMake file
SRDP .OBJ Object file

SRDP .RSP Response file for linking

STEP <DIR> Subdirectory for Symbol Terminal Enabler Program. It contains:

AUTOSTEP.BAT	Autoexec.bat file when system is booted up
KEYBOARD.ANS	Sample dummy file for LRT 35-key ANSI keyboard
KEYBOARD.STD	Sample dummy file for LRT 35-key standard keyboard
STEP-HEX	Make file to build STEP.HEX
STEP-HEX.RSP	Response file for USRCFG to make STEP.HEX
STEP .CFG	Sample configuration file
STEP .CFL	Executable Enabler Program
STEP .INI	Dummy file for STEP's configuration
STEP .MAP	Map file for STEP.EXE
STEP .SYS	Config.sys file when system is booted up
STEP .TCP	Sample dummy file for TELNET interface
STEP .TR	Sample dummy file for Token Ring interface
SYMBSTEP.BAT	Batch file to run STEP from DOS prompt
INIT .EXE	ADK file to configure minimum TPA size needed by STEP

UTILS <DIR> Subdirectory for utility files. It contains:

CLICK .EXE	enable/disable keyclick executable
CLICK .MAP	Map file for CLICK.EXE
COMM .DOC	documentation on how to use COMM.OBJ
COMM .H	Header file to use COMM.OBJ
CONFIRM .EXE	confirm when resetting configuration
CONFIRM .MAP	Map file for CONFIRM.EXE
LOADKB .EXE	load ANSI keyboard executable
LOADKB .MAP	map file for LOADKB.EXE
MENU .EXE	program to setup a menu and get a selection

MENU .MAP	Map file for MENU.EXE
SCAN-UTL.DOC	ocumentation on how to use SCAN-UTL.OBJ
SCAN-UTL.H	Header file to use SCAN-UTL.OBJ
SCANON .EXE	Enable the scanner
SCANON .MAP	Map file for SCANON.EXE
SETSCR .EXE	et virtual screen size executable
SETSCR .MAP	ap file for SETSCR.EXE
UTILS .DOC	ocumentation on the utility (.EXE) files

<MED> Subdirectory for medium memory model objects:

COMM .OBJ	Communication routines (OpenComm, ReadComm, WriteComm, CloseComm, ConfigureComm, OpenLine, CloseLine, SelectProtocol, StartProtocol, CloseProtocol, AbortProtocol, CharsInQ, ConfigValid, SetXchgRate, and SetTimeout)
POWERINT.OBJ	Power Interrupt Service Routine to build STEP.EXE
PRINTER .OBJ	Printer object file to build STEP.EXE
SCAN-UTL.OBJ	Scanner utility routines (SetScanParms, ScanOn, and ScanOff)
UTIL-ASM.OBJ	Assembly-language utility routines (InCradle, GetVern, BiosSetSpkrVol, and BiosSound)
UTILS .OBJ	Utility routines to build SRCP.EXE

b. Disk 2 – "STEP Hex"

This disk contains the following files:

STEP.HEX	STEP hex image to download to NVM
SENDHEX .EXE	Utility to download STEP.HEX to NVM

APPENDIX D

Application Productivity System (APS) files.

This disk contains the following files:

INSTALL.EXE	The ACIP installation program
INSTALL.LIS	The installation program script file
ACIPINIT.EXE	The ACIP initialization program
ACIP.EXE	The auxiliary console interface program
AARM.EXE	The ACIP arming / disarming utility program
ACHK.ASM	A sample assembly language program for determining if ACIP is loaded
ACIPKEYS.TBL	A sample keyboard redefinition table defining the standard Gladiator keyboard.
ACIP.LIB	A library containing a the C language interface routines
ACIP.H	A C header file giving the prototypes for the user interface calls
ACIPXMPL.C	An example of a C program which calls the ACIP user interface
APS_STEP.HEX	Symbol Terminal Enabler Program) Configured with Symbol ANSI Terminal Program) ACIP

APPENDIX E
LAB MODULES
RADIO FREQUENCY DATA COMMUNICATIONS

The Radio Frequency based data collection network set up in the lab will be used for all the following exercises.

You will be required to complete the following practice module and four exercises as part of the RF lab modules.

1. A practice Module
2. Off line data collection.
3. Field service reporting
4. Retail Inventory Control
5. Industrial Inventory Control

You are expected to follow the directions on the lab work sheets and hand in the results of the exercise.

IMPORTANT: Please read the accompanying lab manual and familiarize yourself with the RF equipment in the lab. It contains basic operating instructions for the portable data collection terminals. Do not modify the software or delete any of the programs on either the host computer or the terminal.

PRACTICE LAB MODULE:

This lab module is simply aimed at getting you to familiarize yourself with the RF set up in the lab. It introduces the concept of laser scanning (non-contact scanning) , portable computers and Radio Frequency Communications.

This exercise has two parts: a scan demonstration and a network logon operation. Please follow the steps given below.

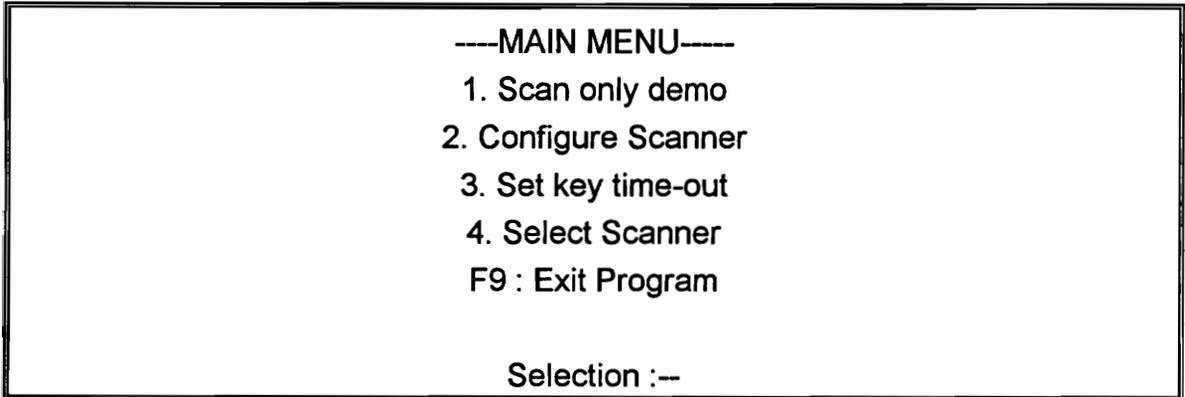
Equipment Required: LRT 3800 Laser Radio Terminal

Part A: Scan Demonstration

1. Turn on the LRT by pulling the scan trigger or pressing the **PWR** button on the key pad.
2. The STEP main menu is displayed on the terminal as shown here.

```
----- STEP MENU -----  
  
1. STEP  
2. Backup  
3. Download  
4. Configure  
5. Scan  
  
Select /Clr : --
```

3. Select option 5, and the terminal displays the following screen.



4. The portable terminal works with a number of different kinds of bar code scanners. Choose option 4 to select the right type of scanner. In this case, the choice will be *laser only*, since the LRT 3800 has a built-in laser scanner.

5. Exit from the *select scanner* menu, by pressing **F9**.

6. From the main menu, choose *scan only demo*.

7. You will be given a bar code test sheet which contains a series of bar codes. Scan them using the proper scanning techniques that have been listed in the RF manual.

8. You will be required to note down the following results.

* For each bar code scanned, note if it was a successful first decode. (did you pull the trigger just once?). A successful decode is indicated by a short beep.

* Note down the decoded information and the symbology of each of the bar codes.

9. If you are having problems with any of the bar codes, enter the information given below the bar code using the key board.

Part B: Logging onto the network:

This exercise helps you to become familiar with the RF network configuration and the various system components like the transceiver and communication cradles.

1. Take a moment and look at the set up of the RF network . Draw a rough diagram of the RF network set-up. (It is not necessary for you to name the components with the their technical names). Notice the hardware connections and the wirings in the system.
2. You will be required to logon to the host computer and prepare the network for transfer of data in real time.
3. Display the STEP main menu by turning on the terminal. This should appear as soon as the system is booted on.
(If you are having problems with the terminal, cold-boot it . The procedure is described in the RF manual)
4. Choose the STEP program option from the main menu screen.
5. Note down what the screen displays.

The screen should display the following message:

Checking Config...
Place in Cradle or
connect serial now!

6. Place the cradle in a cradle so that terminal can receive the configuration data from the network controller. After a moment, the following message appears on the screen:

Unit Configured
Remove from cradle/
disconnect serial!

7. Remove the terminal from the cradle . This enables the radio link to be established and the screen display is:

Opening comm line....
Request to attach ..
Terminal attached!
Getting host list...

8. Since there is only one host, the host list does not appear.

9. The screen then prompts for the kind of communication session, which is either session or datagram. Choose the session option.

10. The screen then prompts the for the operator I.D number. The prompt I.D utility can be disabled if needed. The operator I.D will your social security number and it is sent to the host by the terminal. After the operator I.D has been entered, the screen displays:

Logon Ready *

11. This indicates that the terminal has sent the host the Log-on-ready response. The terminal is now logged on to the host through the network. Under control of the host application program, the terminal can now be used to collect data and display information.

LAB MODULE 1: OFF-LINE DATA COLLECTION

This lab aims to expose you to the concept of off-line data collection. This off-line data operation is useful when it is not necessary to send immediate responses to the host. It can also be used as a backup to the on-line operation in the event that the host is inoperative due to failure or maintenance.

Using the Backup Option:

1. First display the STEP main menu as shown here:

```

      --- STEP MENU -----

          1. STEP
          2. Backup
          3. Download
          4. Configure
          5. Scan

          Select /Clr : --

```

2. With the STEP main menu displayed, Pressing **2**, brings up the following screen:

```

      BACKUP UTILITY
      Enter data:
      -----

      <F9> Exit

```

3. The terminal is now ready to collect data from either keyboard entry or scanning bar codes.

4. Scan a few bar codes from the bar code data sheet and input a couple of keyboard entries as part of the data collection activity.

5. To exit the backup option and return to the STEP main menu, press Function key **F9**.

6. Press **CLR** to return to the DOS prompt.

7. Use the DOS *Type* command.

```
D:> TYPE BACKUP.DAT
```

8. Note down what ever is displayed on the screen into the lab work sheet.

Reading collected data:

1. Perform the net work log-on operation as you did in the practice module. With the terminal logged on to the network, the host computer can read the terminal's collected data by sending the Read Data File and Read Next commands.

2. Run the STEP utility on the host computer, by entering the *step* at teh DOS prompt on the host computer.

3. The syntax of the read data command is:

```
RD <filename>.
```

In this case *filename* will be *backup.dat*. As soon as the terminal receives the Read Data File command, it sends the file to the host (upto 510 bytes). For files larger than 510 bytes, the host must send one or more Read Next commands.

4. Once the transfer has been complete, any editing program can be used to check the contents of the transferred file on the host computer.

Enter edit *backup.dat*

Note down the editing program display into your lab work sheet.

5. The host can then delete the collected data in the terminal by sending the Erase Data File command.

The syntax is ED <filename>

6. Compare the contents of the file to the screen display of the portable terminal. Note down the format of the displayed files and presence of field separators and discrepancies, if any, between the two files.

LAB MODULE 2: FIELD SERVICE REPORTING

This lab module is a simple exercise in field service reporting. It has these main functions:

- * log-On Ready**
- * Main menu**
- * Sign-out**
- * Check-in**
- * End-of-day**
- * Log-Off**

Equipment required:

LRT 3800 Laser radio Terminal or the PRC 3310. This experiment should be done in groups of three or more. (You will not need a laser scanner or bar codes for this exercise. All data is to be inputted using the key pad)

1. Log on to the network as you have done in previous lab modules.

2. At the STEP prompt on the host computer, enter *field* . This is the name of the host application program which is written using STEP modules.

3. The STEP program starts its communication with the host by sending the Log-On Ready response and the terminal is ready to receive command strings from the host. The first string of commands will create the main menu of the application program.

4. Main Menu:

Main Menu

F1 = Sign-Out

F2 = Check-In

F3 = End-of-Day

F4 = Log-Off

5. From this menu, the terminal allows you to select an operation by pressing one of the Function keys.

6. Choose Sign-Out

This function requires you to enter the number assigned for a particular service call. When you press F1 from the main menu, the terminal displays:

Sign-out

Call No:-----

Enter any random number from 1 to 9. Make a note of the number you entered in to the terminal. The terminal, then, sends an Input Data response indicating the entered call number. After entering, the terminal displays the main menu again.

7. Choose Check-In:

This function requires you to enter the number of miles driven when checking back in after the service call. When you press F2 from the main menu, the terminal displays:

Check-In

Miles Driven:-----

Enter any random number as miles driven, the terminal sends an Input Data response indicating the miles he or she has entered. The terminal displays the main menu again.

8. Let the other members of the group repeat the above steps. They should also make a note of the call number and the number of miles driven respectively.

9. When all the members in your group have completed keying in the data, Choose End-of-Day:

This function displays the total number of calls made and the miles driven. The values for the number of calls and miles are calculated by the host based on data entered by the terminal operator. When you press F3 from the main menu, the terminal displays the following:

<p>End-of-Day</p> <p>Total Calls ---</p> <p>Total Miles ---</p>

10. Manually calculate the number of calls and the total number of miles driven by all the members in your group.

The numbers displayed on the terminal should match your calculations.

11. Log-Off:

When the field service reporting is completed, the terminal operator logs off from the host by pressing F4 from the main menu. The log-off command disconnects the terminal from the network. the terminal is then in an off-line operation with the STEP main menu displayed.

LAB MODULE 3: RETAIL INVENTORY MANAGEMENT

This lab module performs various database lookup and modification operations in a simplified retail or industrial application. The demonstration program RIDEMO communicates with either the LRT 3800 or the PRC 3310 using the RF network with the Serial Access Bridge as the RF controller.

The retail exercise consists of the following applications:

Receiving

Shelf Price Audit

Store Ordering

Equipment Required: PRC 3310 with an LS 3000 Scanner attached to it.

Bar Code Sheet for Receiving, Shelf price Audits.

1. Starting the application:

Change to the *RIDEMO* directory on the host computer.

Enter *ridemo/1* at the DOS prompt on the host computer.

The host computer's monitor will display the following Main menu:

<p>Retail Demo Industrial Demo Edit Banner eXit to DOS</p>
--

2. Choose Retail Demo and the following screen is displayed:

<p>Start Demo Modify Data Base</p>
--

3. After the Start Demo option is selected , a database screen is displayed with a list of items commonly found in the retail outlets. As the exercise is continued, the quantities displayed will change as new amounts are entered or scanned at the portable data terminal.

VEND	ITEM	DESC	PRICE	QTY ORD	QTY AND
VEN11	074170054439	Ice Cream Straw 1gal	2.89	50	50
VEN11	074170059649	Ice Cream cones 12pk	1.49	50	50
VEN11	074170054293	Ice Cream, Choc 1gal	2.89	50	50
VEN22	045577002149	Floor Mop model 12	6.50	50	50
VEN22	029441134426	Wire Brush 6inch	3.29	50	50
VEN22	074170055894	Dog Leash six foot	4.89	50	50
VEN33	074170057089	Canned Peas 6oz	0.89	50	50
VEN33	074170048308	Cream Corn 8oz	0.99	50	50
VEN33	000559366824	Apple Sauce 16oz	2.39	50	50

4. The main menu screen provides a selection of retail applications.-
RECEIVING, SHELF PRICE AUDIT, STORE ORDERING

Receiving:

5. Choose the *receiving option* and screen prompts you for the vendor number. The number may be scanned from the supplied scan sheets or entered at the terminal keyboard. The host application verifies the Vendor # against the vendor

database and, if the entry is valid, proceeds to the *receiving item number* screen. If a valid vendor number (the number is not present in the database), an invalid number message is displayed on the screen and the prompt is redisplayed.

6. The *receiving item number* screen allows the scanning of a UPC bar code (or key item number). The host application verifies whether the item belongs to the vendor. If the item is valid, the *Receiving quantity* screen is displayed. If the item is not valid, an error message is generated. The *Receiving quantity* screen displays information from the host application database about the item number entered in the *Receiving Item* screen and the you are required to enter the quantity number.

7. The terminal displays the record and prompts for the receive quantity. Enter any random whole number. The receive quantity entered is validated in the host to make sure that it is not greater than the quantity on order. If the receive quantity is valid, the host database is updated. The receive quantity is subtracted from the Quantity on Order in the database and the quantity is added to Quantity on Hand.

8. Notice that the quantity on hand has changed from it's previous value and the quantity on order has been reduced by the same amount.

9. Take a print out of the data base.

This part of the exercise shows the ability of the system to interact with a remote database and retrieve active information.

Shelf Price Audit:

1. Chose option 2 and the *Shelf Price Audit* screen is displayed. Scan the UPC bar code and the host application compares it to the database.
2. If the entry is valid, the *Price Change* screen displays the item record and allows you to accept the current value or enter a new value. Change the price and notice the corresponding new value being entered in the host database.
3. Take a print out of the modified host database. Upon completion of this screen, the application returns to the main menu.

Store Ordering:

1. Chose the *Store Ordering* option. When an item is scanned or keyed in , the application verifies it in the database. If the item is found, the *Order Quantity* screen is displayed or else an error message is generated.
2. The *Order Quantity* screen displays information in the item record and allows you to enter a value for the quantity to be ordered.
3. Enter any random number for the order quantity and the terminal will send the response to the host computer.
4. Take a print out of the host databse.

Upon completion of the scanning the database displayed on the host computer's monitor will reflect the changes made from the portable terminal.

Compare the print-outs of the host database with the original database listed in this work sheet. Circle all the changes that you notice between the databases. Write the retail application that brought about the change in the host database next to it.

Turn in your work sheets for evaluation.

LAB MODULE 4: INDUSTRIAL INVENTORY MANAGEMENT

This exercise provides an emulation of a simple industrial environment. This is a hands-free data collection exercise. You might find triggering the scanner a bit cumbersome.

Equipment Required: APS Application Productivity System . See the lab manual on how to hook up and wear the APS system.

1. Starting the application:

Change to the *RIDEMO* directory.

Enter *ridemo/1* at the DOS prompt on the host computer.

The host computer's monitor will display the following Main menu:

Retail Demo Industrial Demo Edit Banner eXit to DOS
--

2. Choose Industrial Demo and the following screen is displayed:

Start Demo Modify Data Base

3. After the Start Demo option is selected , a database screen is displayed with a list of items. As the exercise is continued, the quantities displayed will change as new amounts are entered or scanned at the portable data terminal.

VEND	PO	ITEM	DESC	R-QTY	LOC	LC-QY	ODR	STAT
VEN11	PO01	111111	Philips Screw Driver	75	A1	50	ORD1	WIP
VEN11	PO01	222222	Flat Head Screw Drvr	50	A2	50	ORD2	WIP
VEN11	PO02	333333	ClawHammer,BD16oz	50	B3	50	ORD1	WIP
VEN22	PO03	444444	Hack Saw Blade 12 in	50	C4	50	ORD3	WIP
VEN22	PO03	555555	Saber Saw, 4in blade	100	C5	100	ORD2	WIP
VEN11	PO02	666666	Air Compressor 10hrp	100	B6	100	ORD3	WIP
VEN33	PO02	777777	Premium Paint 10 gal	100	B7	100	ORD1	WIP
VEN33	PO03	888888	Paint Brush 3 inches	100	C8	100	ORD2	WIP
VEN44	PO01	999999	Metal Ladder 10 foot	100	A9	100	ORD3	WIP

4. the main menu screen on the terminal displays the options that you need to choose from. The industrial exercise will have the following main menu:

<p>LRT Spectrum One Industrial Demo</p> <ol style="list-style-type: none"> 1. Receiving 2. Put Away 3. Picking 4. Shipping 5. Logoff <p>Selection (1-5):--</p>

Receiving:

1. Choose the Receiving option and Receiving number will display a *Scan P.O Number* Screen. If the item scanned is valid, a *Receiving* screen is generated, which prompts you to scan the item number.

2. If the scanned bar code or keyed number is valid, you will be prompted for the Quantity to be entered. Enter any random number using the keypad.
3. Upon completion of this entry, the host display screen is updated in real time. The application then returns to the main menu.
4. Take a print out of the database on the host computer.

Put Away:

1. Choosing the Put Away option prompts you for the item number. Enter or scan any item number from the bar code data sheet.
2. If the item number is valid, a *Put/Away* screen displays the record and allows you to scan or manually enter a location code. Enter a location code from the database.
3. After completion of this the terminal displays the *Quantity to Move* screen. It displays the same information as earlier but allows you to specify a quantity. The number entered is verified by the host application to be less than the Received QTY value in the host database. If the number entered is out of range, an error message is displayed. If the number entered is valid, the quantity entered is added to the location quantity in the host base.
4. Take a print out of the database displayed on the host computer.

Picking:

1. Choose the picking option
2. The *Picking/Order Number* screen allows you to scan or manually key an order number. The terminal sends the number to the host application where it is compared against existing order numbers in the database. If the database lookup is valid, the terminal displays the location and pick quantity on the screen.

3. Scan the bar code with the item number to confirm the right pick up is done.

Shipping:

1. Choose the shipping option.

2. The *Shipping/Order number* screen lets you scan or key an order number. Scan any order number from the bar code sheet.

3. The terminal sends this number to the host for verification. If valid , the screen displays the status of items as they are scanned.

4. Notice the status of the shipped items

5. After scanning these items, the database is updated by removing the shipped items.

6. Take a print out of the modified database.

Compare the print-outs of the host database with the original database listed in this work sheet. Circle all the changes that you notice between the databases.

Write the retail application that brought about the change in the host database next to it.

Turn in your work sheets for evaluation.

APPENDIX F

OPERATING INSTRUCTIONS FOR RFDC EQUIPMENT

VIRGINIA TECH

AUTOMATIC DATA COLLECTION SYSTEMS LAB

(ADCSL)

DEPT. OF INDUSTRIAL AND SYSTEMS ENGINEERING

*** BAR CODE SYSTEMS**

VOICE RECOGNITION SYSTEMS

RADIO FREQUENCY DATA COLLECTION*

Manual for RF Equipment

LRT 3800- Portable Laser Scanner

PRC 3310- Portable Computer

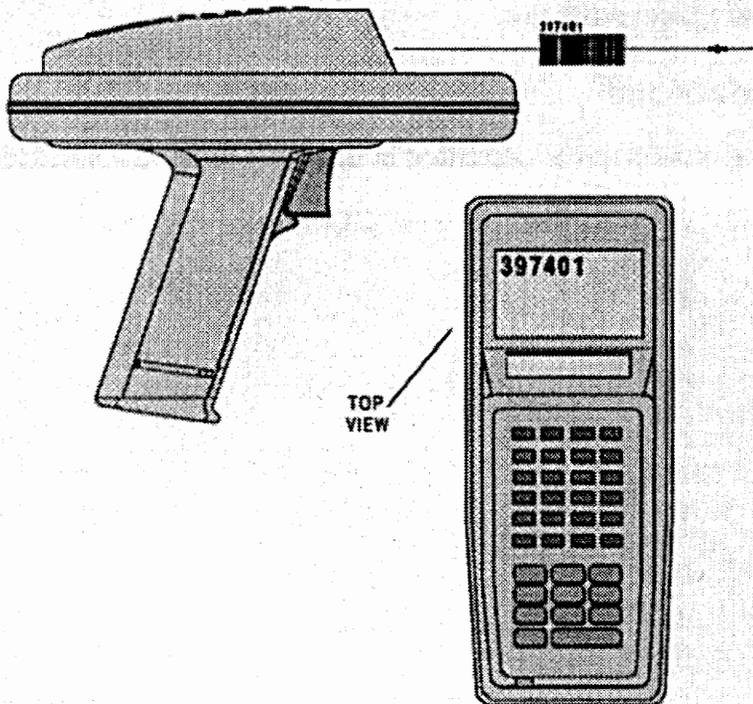
APS 3395-Hands-free data collection system

Instructions on Laser Scanning

LRT 3800

The LRT 3800 (Laser Radio Terminal) is a hand-held, portable data collection device that lets you gather information quickly, easily and accurately. The terminal has a trigger on the handle for laser scanning and a 46-key keyboard with an 8-line by 20-character display. The terminal also has a built in radio module for transmitting data to a host computer via a transceiver.

The LRT 3800 sits on a 3865 cradle base unit which also helps to charge the NiCad (Nickel-Cadmium) battery packs and communicates between terminals and a host, a modem, or a printer.



OPERATING INSTRUCTIONS:

POWERING ON THE LRT 3800

Normal Power On/Off: To turn on the LRT 3800, Press On/Off.

The system also powers on when the scanner trigger is pressed.

ENTERING DATA:

The LRT 3800 terminal provides two methods of data entry:

- * entering data from the keyboard.
- * scanning data with the built in scanner.

Take a moment and familiarize yourself with the Keyboard Key Definitions:

The keyboard has 46 keys and uses the alphabetic keys as the primary keys.

The important keyboard definitions include:

CLR (Clear) allows you to completely or partially escape from an application level or screen.

You can use CLR to clear all data you have typed from the display.

CTRL (Control) lets you use the control command.

FUNC (Function) lets you use the function command for certain utilities, such as turning on the backlight.

PWR (Power) turns the terminal on and off.

BKSP (Backspace) erases information entered into the display one character at a time.

Arrow Keys move up, down, left or right.

0-9 Numerical entries.

ENTER places entered data into the terminal's memory.

Entering Data By Keyboard

To enter data using the keyboard, press the appropriate keys and press ENTER.

Entering Data With The Laser Scanner

1. Pull the trigger on the terminal handle to power on the terminal and the laser scanner.

2. Hold the terminal within the specified range of distance from, and at a slight angle to the bar code and pull the trigger. A thin red laser beam appears over, and must cover the entire length of the bar code. Do not hold the scanner directly over the bar code. The larger the bar code, the farther away you should hold the scanner.

CAUTION !!!!

Do not look into the laser beam or point it at another person. Lasers can cause eye damage.

3. If the red light does not touch the bar code, re-aim the scanner and repeat step 2.

Forced Power Off:

If pressing the PWR key does not turn off the terminal, force the power off to reduce battery drain and preserve your data. To do this, Press and hold the PWR key for 15 seconds, until the terminal powers down.

Restarting after a forced power off:

If you use the forced power off because of a hardware or software failure, use the following methods to restart.

1. Use the warm boot procedure for a software failure. A warm boot resets the operating system while preserving the RAM disk.

Turn off the terminal

Press and hold 4 and 5 keys.

Press and release the PWR key.

Release the 4 and 5 keys.

If this warm boot procedure fails, use the cold boot procedure.

2. A cold boot resets the BIOS and operating system; it erases and recreates the RAM disk.

Turn off the terminal.

Press and hold the A, B and D keys.

Press and release the PWR key.

Release A, B and D keys.

Back Lighting:

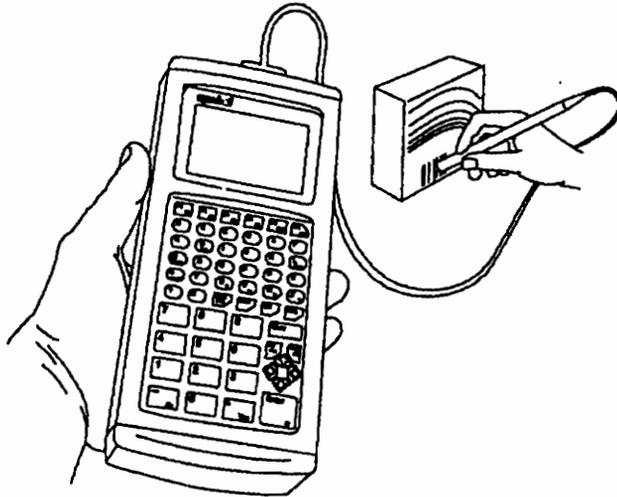
The terminal has a back light that can be used for working in dimly lit areas.

To turn the back light on or off- **Press FUNC L**

PRC 3310

The PRC 3310 is an environmentally sealed, lightweight, battery powered, hand-held computer designed for use as a portable data collection device that lets you gather information quickly, easily and accurately. Data can be entered using the keyboard, a bar code scanner, or other devices. In most applications, the PRC 3310 computer is used as a remote terminal which helps to collect data and store data that is later uploaded to a host computer. The device has an internal radio transmitter/receiver allowing these system to be used as part of an radio frequency based data collection network.

The PRC 3310 sits on a 3865 cradle base unit which also helps to charge the NiCad (Nickel/ Cadmium) battery packs and communicates between terminals and a host, a modem, or a printer.



OPERATING INSTRUCTIONS:

POWERING ON THE PRC 3310.

Normal Power On/Off: To turn on the PRC 3310, Press On/Off.

The system also powers on when the scanner trigger is pressed.

ENTERING DATA:

The PRC 3310 terminal provides two methods of data entry:

- * entering data from the keyboard.
- * scanning data with an attached scanning device.

Take a moment and familiarize yourself with the Keyboard Key Definitions:

The keyboard has 56 keys and uses the alphabetic keys as the primary keys.

The important keyboard definitions include:

CLR (Clear) allows you to completely or partially escape from an application level or screen.

You can use CLR to clear all data you have typed from the display.

CTRL (Control) lets you use the control command.

FUNC (Function) lets you use the function command for certain utilities, such as turning on the backlight.

PWR (Power) turns the terminal on and off.

BKSP (Backspace) erases information entered into the display one character at a time.

Arrow Keys move up, down, left or right.

0-9 Numerical entries.

ENTER places entered data into the terminal's memory.

Entering Data By Keyboard

To enter data using the keyboard, press the appropriate keys and press ENTER.

Entering Data With The Laser Scanner

1. Pull the trigger on the terminal handle to power on the terminal and the laser scanner.

2. Hold the terminal within the specified range of distance from, and at a slight angle to the bar code and pull the trigger. A thin red laser beam appears over, and must cover the entire length of the bar code. Do not hold the scanner directly over the bar code. The larger the bar code, the farther away you should hold the scanner.

CAUTION !!!!

Do not look into the laser beam or point it at another person. Lasers can cause eye damage.

3. If the red light does not touch the bar code , re-aim the scanner and repeat step 2.

Forced Power Off:

If pressing the PWR key does not turn off the terminal, force the power off to reduce battery drain and preserve your data. To do this, Press and hold the PWR key for 15 seconds, until the terminal powers down.

Restarting after a forced power off:

If you use the forced power off because of a hardware or software failure, use the following methods to restart.

1. Use the warm boot procedure for a software failure. A warm boot resets the operating system while preserving the RAM disk.

Turn off the terminal

Press and hold **On/Off**.

Press and hold **L** and **Shift**.

Release **On/Off**, and then release **L** and **Shift**.

If this warm boot procedure fails, use the cold boot procedure.

2. A cold boot resets the system and clears memory, including clearing the RAM disk. Any programs and data that have been stored in memory or on RAM disk will be deleted.

Turn off the terminal.

Press and hold **On/Off**.

Press and hold **Enter**, **F4** and **F1**.

Release **On/Off**, and then release **Enter**, **F4** and **F1**.

Back Lighting:

The terminal has a back light that can be used for working in dimly lit areas.

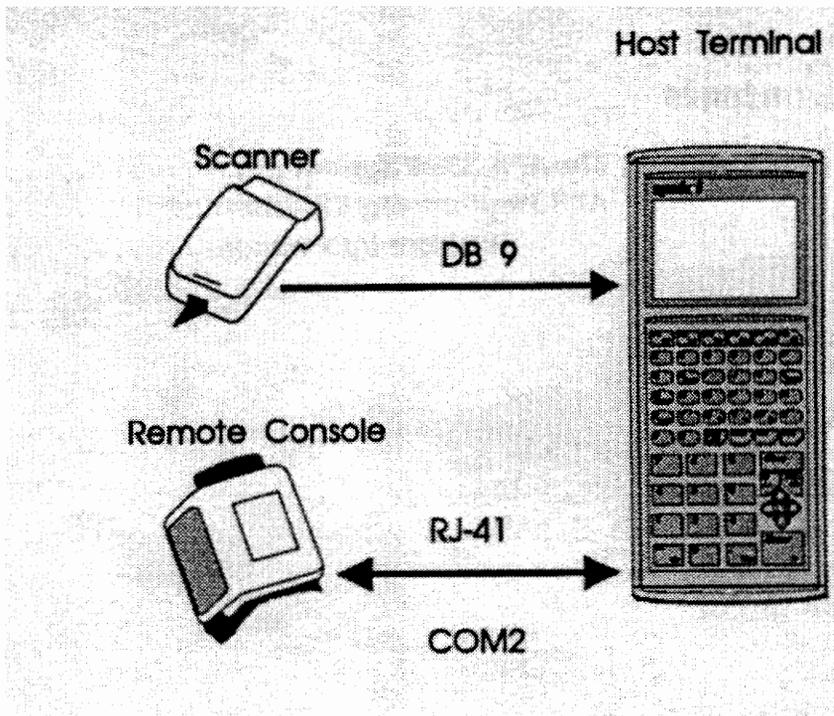
To turn the back light on or off- **Press FUNC** and **L**

APS 3395 SYSTEM

The APS 3395 is a hands-free data collection system. To free the operator's hands, the APS uses a remote console worn on the arm and a scanner worn on the hand.

The APS uses a set of programs called the Auxiliary Console Interface Programs (ACIP) to simultaneously operate the remote console and the console on the PRC 3310. Keystrokes coming from the remote console are processed as though they came from the host. Screen output is directed to both screens. It is specifically designed to meet the requirements of item picking and receiving where the user needs both hands free to handle materials.

The fig below shows the major components of the APS 3395 system.



The APS 3395 system has the following parts:

PRC 3310 which acts as the host terminal.

AP 3390 which acts as the remote console.

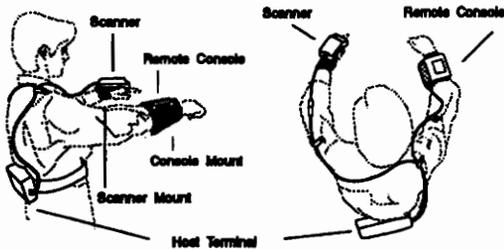
HF 2000 or HF 2000 LR scanner for scanning bar code data into the terminal.

The attached guide shows you how to wear and use the APS 3395 system.

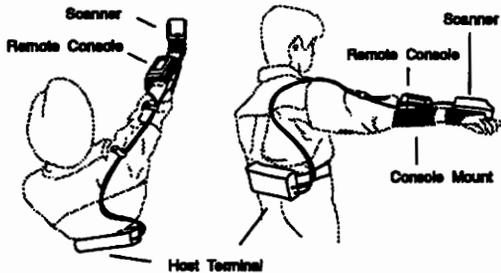
Wearing the APS 3395

There are three ways to wear the APS 3395:

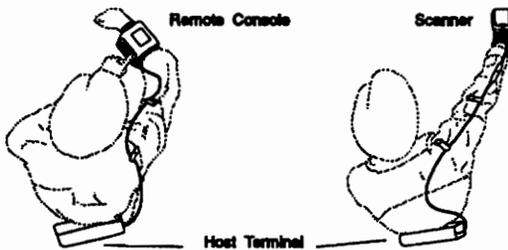
- 1 With the scanner and console on different arms.



- 2 With the scanner and console on the same arm.

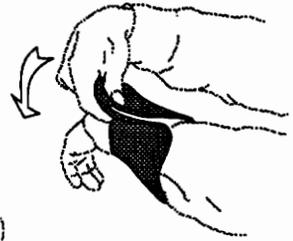


- 3 With either the scanner or the remote console by itself.



Attaching the Console

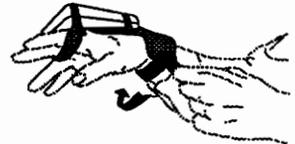
Wrap the console mount around your arm. Adjust it as necessary.



Place the remote console on the mount. The fasteners keep the console in the proper position.

Attaching the Scanner

Insert your middle and index fingers through the finger strap. Adjust the wrist strap.



Adjust the scanner's front and back retaining straps.

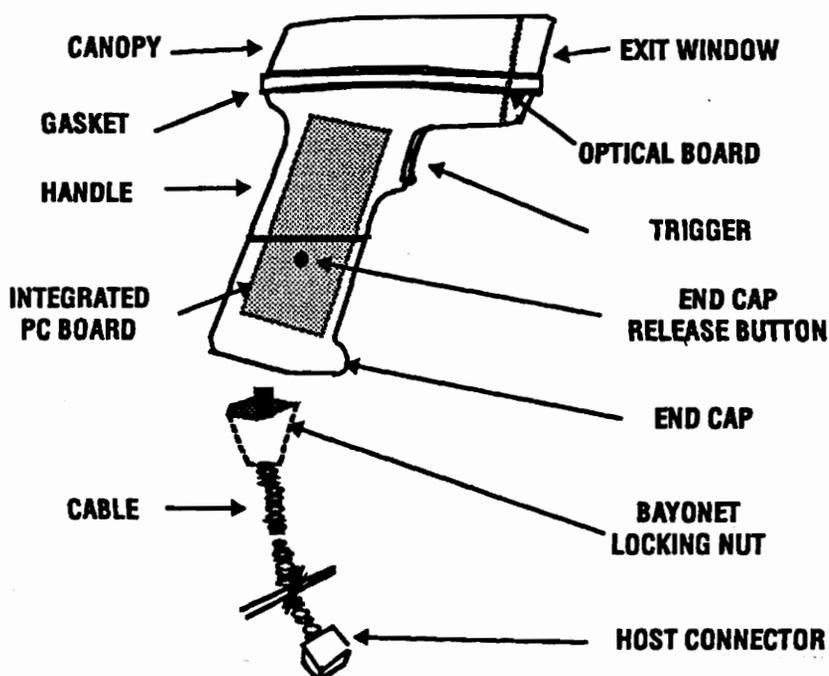


Note:

Use the arrow marks on the unit to align the connector on the end of the scanner cable with the connector on the end of the scanner pigtail.

SCANNING TIPS

The figure below shows the major parts of the LS 3000 scanner.



Using the Laser Scanner:

Pull the trigger to power on the terminal and scanner.

Point the laser scanner at the bar code. Pull the trigger and adjust the aim so the red laser beam covers the entire bar code.

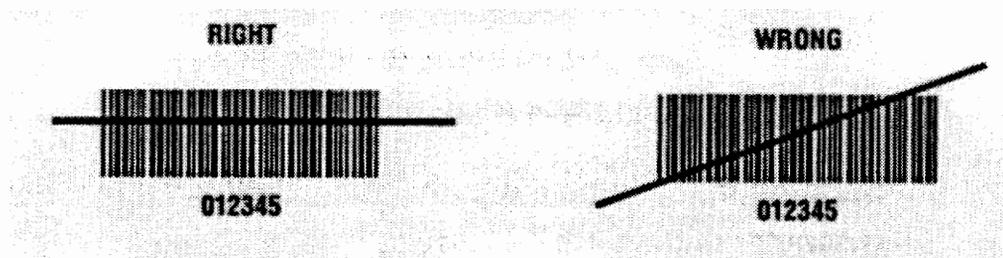
WARNING: Do not look into the laser beam.

Aiming:

Do not hold the scanner directly over the bar code. In this position, light can bounce back into the scanner's exit window and prevent a successful decode.

Scan the Entire Symbol:

- * Your scan beam must cross every bar and space on the symbol.
- * The larger the symbol, the farther away you should hold the scanner.
- * Hold the scanner closer for symbols with bars that are close together.
- * A short high-tone beep indicates a good decode.



VITA

Prabhu Venkatesh, the second son of Muniswamappa and Tara Venkatesh, was born on July 15, 1970 in Bangalore , India. He did his schooling at The National English School, Bangalore, India and his pre-university at St. Joseph's College , Bangalore, India. He graduated in August 1992 with a Bachelor of Engineering Degree in Industrial and Production Engineering from Bangalore University, Bangalore, India. He then enrolled in the Department of Industrial and Systems Engineering at The Virginia Polytechnic Institute and State University and completed his Master of Engineering Degree with a concentration in Manufacturing Systems Engineering in May 1995.



Prabhu Venkatesh