SECOND SIGHT

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December 18, 2000

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
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Re: ENSC 340 Process Report on the Second Sight Wireless Child Tether in all its glory

Dear Dr. Rawicz,

Attached is the process report for the Second Sight Wireless Child Tether project. Included within the document is the current state of the project, budget deviation, development issues, complications, implementation, and future work to be concluded or pursued at a later date.

Also included are accounts of personal gain from partaking in this exercise, from each of the project members.

Deviations from the plan were minimal and the device implemented is similar to that proposed 4 months ago. Or close with a few additional modifications.

Sincerely,

Ian Foulds
President and CEO
Second Sight Systems

Enclosure: Wireless Child Tether Process Report

Wireless Child Tether

Process Report

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Submitted On: December 18, 2000

Table of Contents

List of Figures

Introduction

Children don't always understand the need to stay close to their guardians and tend to wander. At Second Sight Systems, our goal is to develop technology that helps guardians protect their children. Physical child tethers have been in existence for quite some time now but they have the disadvantage of being unwieldy and awkward. The physical tether is forever getting tangled around objects and even other people. It becomes a nuisance in large crowds, which ironically is where it is needed most. Fortunately, we at Second Sight have devised an elegant alternative – the wireless child tether.

The wireless child tether will allow both parent and child the freedom of movement but will help the parent to keep their child from wandering. An alarm is activated on the parent's unit when the signal strength of the child's transmitter is below a user-defined threshold at the parent's location. The parent's unit can then be used either to determine the direction in which their child has wandered, or set off an alarm on the child's unit.

In this document we describe our product development, the problems that we encountered and possible solutions for future projects. We also give individual testimonials as to what we learned during this course.

Product Development

Overview of Project

Second Sight set out to develop an assistive device to aid parents in the monitoring of their children during excursions to public areas. We planned on implementing a low cost product that would give an alternative to already existing products. Our device the Wireless Child Tether allows a parent to determine if their child is within a user-defined range. It also provides the added safety of alarms, on both the parent's device and on the child's device, to alert the parent that the child is out of range and to aid the parent in locating the child.

What It Does

The main goals of the Second Sight Wireless Child Tether device are:

1. Alert the parent when their child has ventured beyond a predetermined range. This range is a user-defined value that can be input on the device through a dial.
2. After the parent has been alerted we wanted to provide some useful feedback as to the whereabouts of the child. This information comes in the form of a directional indicator.
3. With the flick of a switch the parents' device can turn into a tracking unit that will provide a sense of the direction from which the child's signal is coming. When in directional mode a series of lights will indicate what from what direction the signal is coming. There will be three lights, 1 to indicate forward, left and right. Due to the specifics of RF signals the user will be required to perform some interpretation of the device lights.

For safety purposes there are certain features included in the design of the device.

1. At any given time the parent can press a panic button and set off the alarm on the child unit.

   This feature allows an easier alternative in locating the child. In crowds it may be difficult to see children but hearing them is an alternative.
2. At any time the signal is completely lost between the parent and the child alarms are activated until the connection is reestablished.

Our Solution

Our system employs the use of a Radio Frequency (RF) link between the parent and the child. The link provides a constant communication of data between the parent and child units. Since the radios we used are half duplex they can support only transmission or reception at any given time. Thus the SW must handle the timing and switching between transmit and receive modes on each unit. Timing is important such that you do not end up in the situation where both units are trying to transmit or receive at the same time. The child initially sends a signal to the parent then switches to receive mode. The parent starts in receive mode and upon receiving the signal from the child, switches to transmit mode and responds. The parent then switches back to receiving and the cycle continues with the child unit now listening and then responding. As mentioned above there are safety features implemented. Each unit will only listen for a signal for a certain duration. If the signal is not acquired during that time, the alarm is set to notify the user that the signal is lost. The unit will still continue to look for the signal and will shut off the alarm in the event that the signal is reacquired. An onboard microprocessor evaluates the signals from the radios and buttons and controls the alarm and lights. The alarm alerting the parent can be turned off via the alarm button but there is still a light to indicate that the child is out of range. This light will remain lit until the child is within range again

Technical Implementation of Solution

Hardware

The implementation of our project follows closely to the outline in the design specifications. The parent and child units were built up as shown in the system block diagrams, Figure 1 and Figure 2.

System Block Diagrams Parent and Child Units

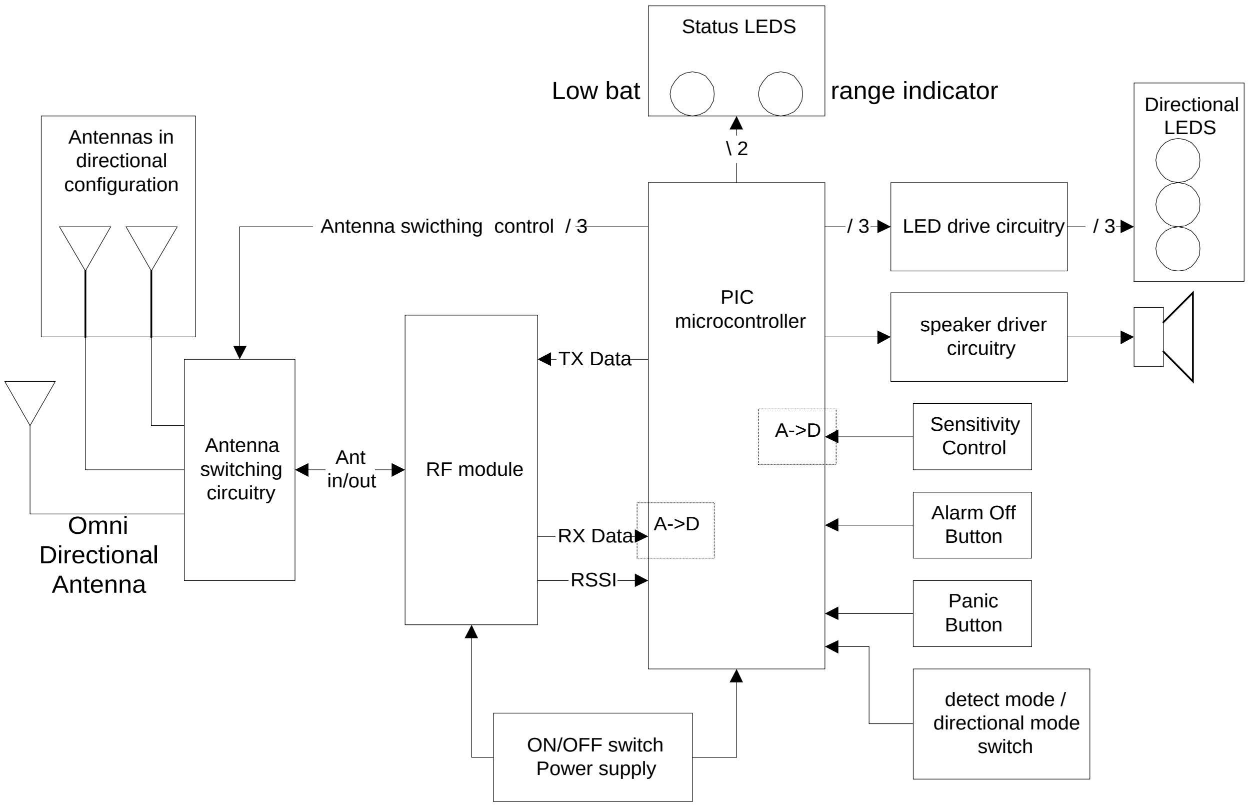

Figure 1: parent unit system block diagram

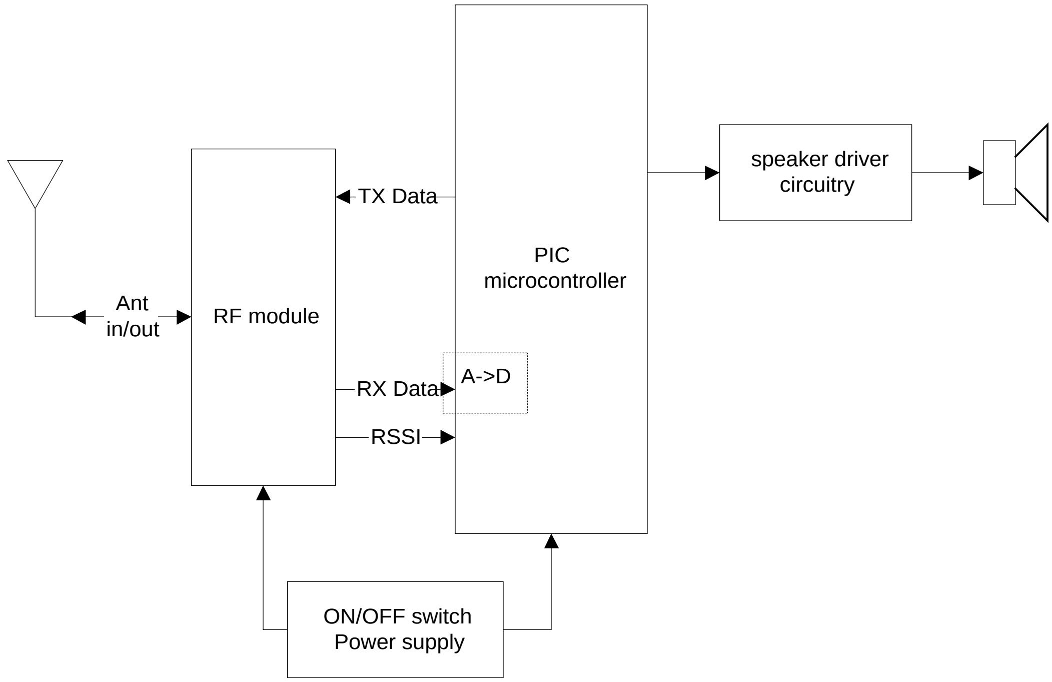

Figure 2: parent unit system block diagram

Microcontroller

PIC 16F876 28 pin SDIP package.

8 channel, 10 bit AD port.

The Analog to digital port is used to measure the RSSI value from the receiver as well as the sensitivity setting .

Serial Communication capable USART.

In our design we use the USART pins to send and receive the data from the RF modules

The LEDs, buttons, switching, and buzzer are connected to general-purpose I/O pins

RF Modules

900 MHz LINX HPII series half duplex radios consisting of transmit and receive pairs.

These modules implement an FM/frequency shift key (FSK) modulation scheme and have 8 channels per frequency of transmitting goodness.

Antennas

Single omni-directional antenna will be shared between receive and transmit modules.

Design of V configuration for directional signal detection

Not yet implemented on the project but is built and tested separately.

(requires proper switching circuitry for implementation)

Additional Circuitry Used for Parent and Child Units.

Antenna Switching

Not yet implemented on the project.

Speaker Drive Circuitry

The speakers are driven based on a high signal from the microcontroller pin to which they are connected.

The parent speaker is a 3 pin electric buzzer.

The child speaker is a 2 pin electric buzzer.

LED Drive Circuitry

The LEDs are driven based on a high signal from the microcontroller pin to which they are connected. The LEDs are low current 1-5mA LED's.

Power Supply

Consists of a 9V battery into a 5-volt regulator.

Variable Sensitivity Switch Circuitry

Consists of a voltage dividing network such that the input to the PIC is varied from 1 to 2.5 volts

Software

The PIC controller software on both the parent and child units run a continuous loop of transmitting, receiving and button handling. The code is highly modularized and can be easily modified in the future for additional features. The main loop flowchart is shown in Figure 3.

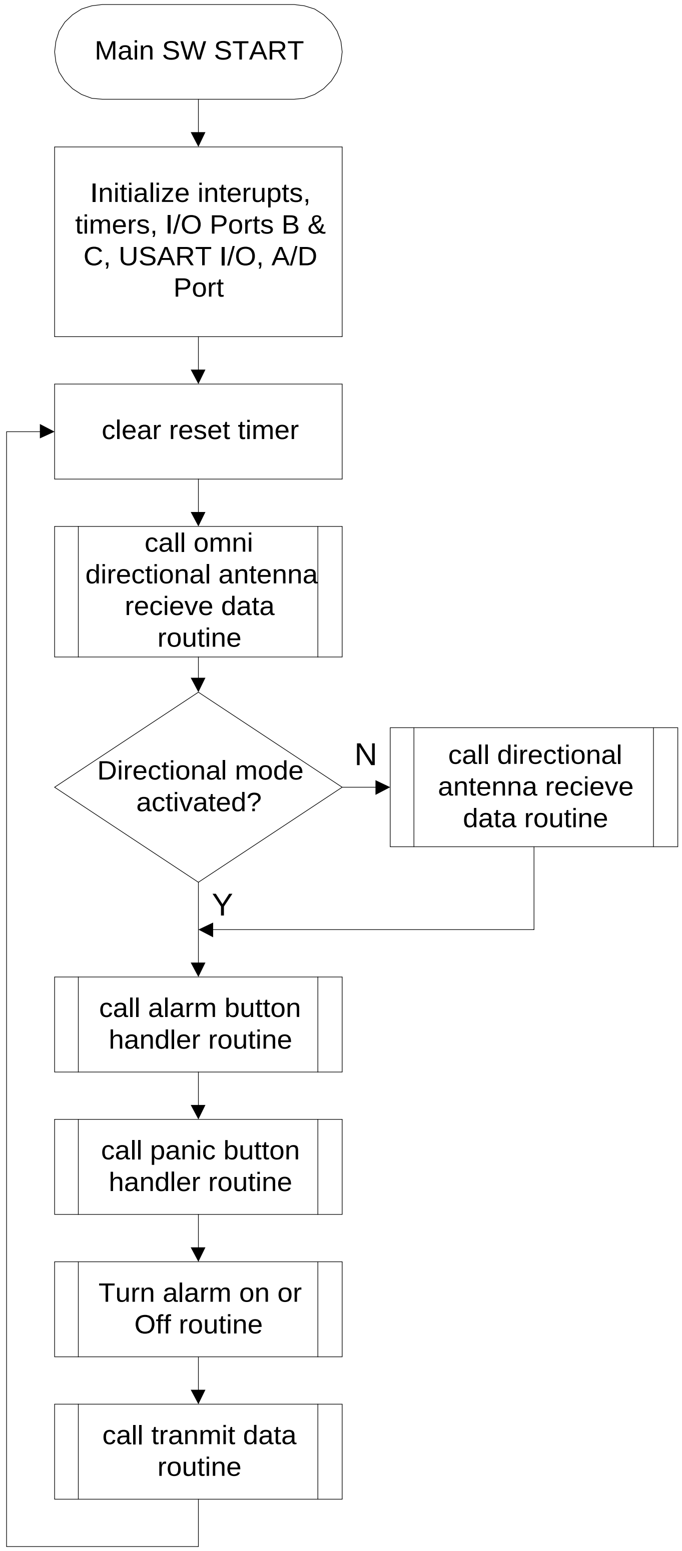

Figure 3: SW main loop block diagram

Subroutine Functionality

We designed the program to call subroutines of the main tasks the device will perform. In the event that an action occurs a corresponding flag will be set that other routines will know what has occurred.

The flag register is an 8-bit register used to track the status of the data sent and received as well track commands to be executed. The register bits are shown below in Table 1.

Table 1: command flag register

TIMER EXPIRE	OMNI MODE	PARENTALARM	POWER BOOST	OVER ROVER	CHILD ALARM	REGULAR	CORRUPTDATA
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

CORRUPTDATA set if the received data stream contains a frame error

REGULAR set if the received data stream is regular or the last byte

CHILDALARM set if the panic button is pushed

OVERROVER set if the received data stream is the last byte

POWERBOOST not implemented at this time

PARENTALARM reset if the alarm off button is pushed

OMNIMODE set if switch is in omni-mode

TIMEREXPIRE set if the maximum time allowed for receiving non-corrupt data expires

The subroutines are listed in Table 2. As well as what flags they set read, and reset. Generally each routine is responsible for setting and resetting the only the flags that they handle.

Table 2: subroutines and flag modification

Subroutine	Function	Flags set	Flags reset
Receive data	1. Set the path to which the antenna the data comes from 2. Obtain non corrupt data from radio	Alarm flag if 1. panic message is received 2. timer expires before receiving non corrupt data	Regular flag OverRover Timer expire

	through the USART connection	Timer expire flag	
*Panic button handler	Poll the panic button	If the panic button is pressed, Set the child alarm flag	Reset child alarm flag
*Alarm button handler	Poll the alarm off button	Sets parent alarm flag	If the alarm button is pressed, Reset the parent alarm flag
*Mode switch handler	Polls the directional/omni directional mode switch.	Set Omni mode flag if switch is set to omni mode	Reset Omni mode flag if switch is set to directional mode
Alarm handler	Turns the alarm buzzer on or off depending on the status of the alarm flag	None	None
Transmit data	Reads the child alarm flag	Checks the child alarm flag	None

*Only on the parent unit

The directional and omni directional sections receive subroutines are similar and differ only on what antenna path signal is coming from. The omni directional receive subroutine is shown below in Figure 4.

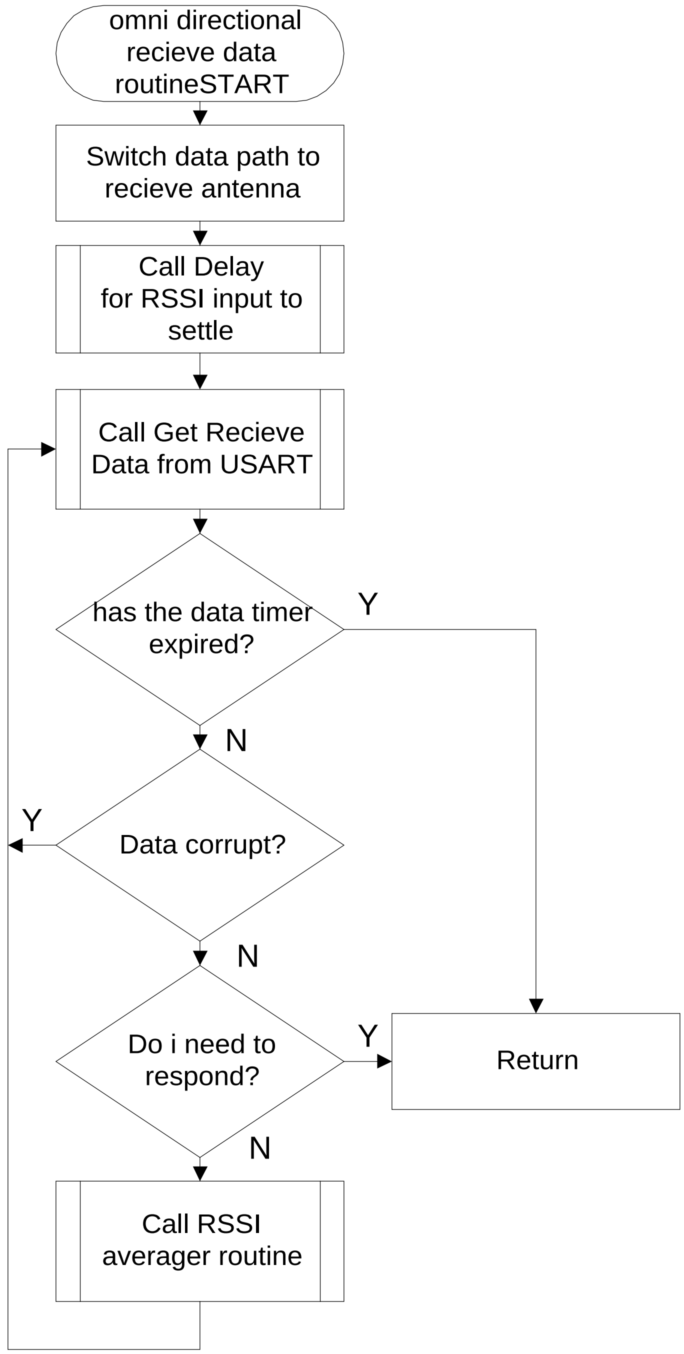

Figure 4: recieve data subroutine. omni directional case

Current Status of the Project

We have not implemented the directional antenna configuration or the antenna switching circuitry required for directional range finding. We are however implementing the directional antenna configuration to prove the concept will provide a differing RSSI value as specified in detail within the Second Sight Wireless Child Tether design specification.

At the time of writing this document we have implemented the wireless link to perform the range detection.

1. Provide the alert to the parent when the child ventures out of range.
2. We have adjustable range

We have also implemented the safety features.

3. Panic alarm sounds on child when parent pushes panic button
4. Child alarm activates when no signal is acquired from parent
5. Parent alarm activates when no signal is acquired from child

Problems Encountered

Technical Issues

Hardware Issues

RSSI worked well in open areas to determine the child distance from the parent, but we noticed that walls surrounding the operating area caused signal reflections and interference patterns to be created. Therefore, instead of getting a nice smooth transition of RSSI values with respect to distance, the RSSI values became jagged which gave variable results. To overcome this problem, an average of the last few values were taken, which tended to smooth out the RSSI transition, but the length of the average was limited by our software design. Our final design for reading the RSSI limited the amount of change due to interference, and gave a quick response with respect to distance changes (not too much lag).

We were unable to implement the directional part of this project because of time and resource constraints. To make the directional part work we required antenna switches to change the incoming signal from the omni antenna to the directional antennae. The switches had to continue the 50-ohm line so that signal reflections would not occur, and this would be difficult since the parts were not going to be mounted on a printed circuit board and we didn't have the resources to get printed circuit boards made. The physical connection of the switches would cause an impedance matching problem, and would create noise in the RF signal.

We also had difficulty finding switches that we could work with if we intended to go forth with the directional implementation. After we realized that the first set of switches we ordered would not work for our implementation, we ordered another set that was suited to our needs. We encountered availability problems with these parts as well, and we received the switches too late in the semester to incorporate the directional functionality. We intend to prove that it possible to determine the direction of the child unit with respect to the parent unit, by providing laboratory data to back up our claims.

During the testing and debugging stage we had to fend off other groups who were trying to destroy the buzzer on the board, which we admit was quite annoying.

Software Issues

There were extreme cases when rapid power ups and power downs of the units created a half-duplex lock up. This caused the systems to enter a state where both were waiting for the other to respond. The problem was solved by using a watch-dog timer that would reset the system whenever the system entered this state, which would allow the unit to re-sync with the other unit and begin normal operations.

At first we encountered some problems with setting up the PIC microcontroller. No one in the group was familiar with the programming of the PIC, and we were unsure of the external configurations needed to get it working. Because of the lack of example code provided on the Microchip website, we didn't know the necessary commands to initialize the chip properly. However, with a bit of luck and a lot of debugging we were able to obtain some written code that had working initialization commands that enabled us to program the chip. We also needed to procure a 20MHz oscillator to drive the clock of the microcontroller, which had an internal clock at 4MHz that was too slow for our purposes.

The instruction set for the microcontroller we were using was very limited in the amount of commands it offered. But the commands offered were quick to learn and made efficient use of the processor. The main hindrance during programming was trying to do an average of the RSSI values. An average requires the addition of all the values and a division by the number of values. The PIC did not have multiply or divide capabilities, so we instead developed a different method for comparing RSSI values, but it can still be thought of as taking an average. This solved the averaging issue, but it also raised another problem with the PIC, and that was its inability to display whether a number is positive or negative, and also to inform whether a number has overflowed or underflowed. We were forced to develop our own checking program that monitors whether these cases have occurred, and is able to report them. This solved the problem, but with a substantial increase in our code length.

Financial Issues

Initially, we underestimated our budget by about 400%, even with allowances for unknown costs. The main reason for the incorrect budget was the uncertainty of the RF module cost. We were researching different companies for the modules at the time, and we used an average for the cost of the RF parts. At the time we procured the parts from LINX we were unable to just buy the transmitter/receiver modules, and instead they insisted that we buy two complete evaluation boards and an increased cost. Therefore, instead of the modules each costing US$30 (four modules) we were forced to buy two evaluation boards at a cost of US$160 each. It should be noted that we would have still been over-budget if we bought the four modules separately.

We also had trouble procuring parts from companies that imported parts from the United States. It seemed that the availability of parts that was reported on their websites differed drastically from the actual availability of the parts in their warehouses. We were satisfied at the end, when we received our package of parts from DigiKey, even though we had to make some minor changes to the order due to availability.

We are very thankful for the grants and funds that we received. In particular we are thankful for the following:

Whighton Fund

EUSS Endowment Fund

Scheduling Issues

We were on target for completing the milestones that the course outline and we had set, up until after the design specifications were completed. This is because we were at the point where we needed to procure the parts. Although it took longer than expected to get the parts for this project, we were fortunate to receive the transceiver modules that we could work with, and that suited our needs.

We made an effort to develop a plan that provided a solid path for us to follow in our software and hardware development. We developed pseudo-code that outlined the operations for our software, and this decreased the amount of initial code development time. The pseudo-code eliminated only the first few stepping-stones, as unforeseen problems arose during the code development.

Group Dynamics Issues

For the first half of the prototype development we split ourselves into two groups, so that one group was able to work on hardware, while the other group worked on software. When the hardware was near completion and could be used to test the code, we conglomerated the two groups to further develop the software. With at least 3 people working at a terminal, we could bounce ideas of one another, and also the extra person was able to debug “on the fly”.

As we spent long days together we found that we became a little frayed by the tenth hour or so. We are quite sure that we will all come out of this as better friends than when we started though.

Andy does not like being called handy.

What We Would Do Differently

An alternative solution we would have liked to implement is to use full duplex radios. Full duplex radios would have allowed us greater freedom in our code. This is because we would not require the timing and handoff issues associated with half duplex communication. In full duplex we would be able to transmit and receive continuously at the same time. However this implementation would be more hardware intensive and cost more.

We would also have liked to have accomplished more of the design earlier to possibly allow time to source better parts or get some PCB's printed. This was a major issue since it is difficult working with RF components without a PCB as they often come in ridiculously small surface mount packages or expensive rack mount size. They also require 50-ohm impedance matched interconnections, which are hard to provide without proper coaxial cable connectors.

What We Learned

Ian

I learned how to kill a man with my bare hands although not in this course. During the development of our project I learned many things both interpersonal and technical. I had the unique experience of being the group leader, which gave me valuable experience in dealing with others from a managerial perspective. I found it a lot harder to organize three people and myself than just myself. If I could change one thing about my performance it would have been that. I would like to have spent a little more time staying organized so that I could have provided a little more direction for the guys. I think that it is really important to stay on top of everything that is going on. Also along the managerial lines I learned as a leader there is time for discussion on a topic and a time to just make a decision. Sometimes in our group we could discuss how a feature should be implemented until the cows came home and it was up to me as a leader to stop the discussion (nice way of saying argument) and choose the implementation so that we could move on in the process.

In the area of technical prowess I gained greatly. I learned a great deal about the PIC16f876 microcontroller. And at a higher level I learned what it takes to setup and operate a microcontroller in general. I discovered that if a pin is not being driven it should pulled either high or low because if the pin is left floating it can bounce around in value. Another of the big things I learned is that if you think it should take one day to debug something give it three days because for every thing that you think is a possible problem there are three or for that you didn't even think of. I've learned about the RF systems and their components. I've learned many other things but they have yet to fully sift through my mind.

Shaun

I learned more about the PIC16F876 than I thought I'd ever need to know. I increased my knowledge of assembly programming, and programming with real-time constraints. During code development, we discovered that we had to downgrade the amount of signal processing by the micro-controller to accommodate the real-time constraints. This had a negative impact on the accuracy of our device for telling distances and angles, but we were still able to make the process feasible.

I learnt some minor concepts about RF design and operation, which will decrease the learning curve when I choose to take a course about RF design. I also observed some of the limitations of RF transmission, such as object interference (walls, barriers) and interference from reflected transmissions, which most people with cellular phones have already observed.

Just as important, I learned that extensive research into choosing parts, such as a micro-controller, should be done to ensure that the part will achieve the given task with minimum effort in integrating it into the whole system. Although the micro-controller we chose was adequate for our job, the instruction set was severely limited and made some simple commands difficult to code.

Andy

Over the course of this project, we were forced to develop our interpersonal communication skills. In particular, we discovered (the hard way, I might add) that, when dealing with people in industry, being kind and patient might make them like you more, but it won't make them finish what you need them to finish any faster. OK, to be honest, this observation is based on only a couple of isolated cases. Still, we noticed in these cases that being assertive (and a bit of a pest) definitely helped get things done. For example, in the later stages of the project, we needed to order three antenna switches. The Alpha Industries applications engineer we subsequently contacted sounded genuinely excited about our project. It turned out he was a former SFU engineering grad and we got to talking about the school and how it had changed since he had graduated. Once we got back on the topic of our project, he assured us he would find us the best switches for our application and send us an email when they had arrived.

Well, as you can probably imagine, this kind of enthusiasm was initially pretty attractive to us. In particular, the fact that we had established a personal connection with this guy made us hopeful that he would give us priority over his other clients. However, after waiting for about a week and getting no email, we decided to press the issue. Once again, he was very enthusiastic and reassured us that the switches were on their way. We also continued to chitchat about SFU and generally talk to each other like buddies instead of business associates. This cycle of waiting and assurances was repeated a couple of times before we finally became fed up and started to pester the Alpha industries rep with calls. We also tried to keep our tone during these calls cordial and business-like, and not overly friendly. Needless to say, he wasn't nearly as friendly in return, but he did start to email us regular progress updates. We also received the switches less than a week later. Of course, other factors could have contributed to the Alpha rep's initially laid back attitude. For example, he may have given us low priority because we are students. However, the bottom line is that, once we showed him how urgently we needed these parts by bugging him twice a day, things seemed to get done much quicker.

We also had to learn how to deal with each of the other members in the group. If it's hard to be assertive with some industry rep that you barely know, it's even more difficult to crack down and demand results from the members of your own group. I'm going to drop the "we" pronoun here and refer to my personal experiences (I'm Andy, by the way) with the other members. I found that each group member had their own set of expectations for the course, which changed the way that they dealt with the tasks given to them. I'm going to be honest – I'm very mark-oriented and competitive (if I don't keep my marks up, I lose my scholarship, so I've got a permanent fear of failure complex). In contrast, the other members, especially Ian and Des, while not unconcerned about their mark, seemed most interested in learning as much as they could from the course. As a result, they spent much of the first third of the course reading and understanding the theory behind the product we were going to be building – even though it wasn't going to be marked! I know, it sickened me too. At first, I hid my frustration and hoped that they would instantaneously morph into a replica of me overnight. However, after a while, it just became too much for me and I voiced my concerns. Rather than dividing us, as I thought it might have, this instead helped break the ice and improve communication between us. Now, if I want to see something done, I'm open about it. Similarly, whenever I'm freakin' out and demanding too much, the other members just ignore me and tell me to get some sleep.

Des

ENSC 340 has been a great learning experience not just technically but in overall project planning and group dynamics. I learned that solid planning of functionality and design are important tasks in the project development. Having well defined project functionality makes the transition to implementation easier. I also gained experience in dealing with PIC microcontrollers. I learned about getting a chip from off the shelf and the required setup and external support circuitry needed before it can be programmed and implemented in the design. I learned budgets should be set higher then expected and parts are never delivered when you want. I also learned about the true spirit of Christmas.

Future Work & Conclusions

For future work we would like to fully implement the directional signal acquisition and antenna switching ability on the prototype unit. As mentioned above we currently have only general range alerting ability. We would also like to design the prototype unit on a PCB and enclose it in a better casing.

This project proved to be as challenging as we imagined it would be. We are satisfied with the approach we took but would have liked to complete the project with everything we had initially designed for. With a little more time we would like to think that we could better implement each section of the project.

Thanks To

Dr. Rawicz,

TA guys Jason and James,

Steve Witmore,

Dr. Cavers,

Optimus Prime,

The numbers 3.14, 8

And the letter K.