MicroTrak Inc.
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6
340-group@sfu.ca

October 31, 2002

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 340 Project Design Specifications of MicroTracker

Dear Dr. Rawicz:

Attached is the *Design Specifications of MicroTracker*, which describes the design of the functions listed in the *Functional Specifications of MicroTracker*.

We have just finished the design of the phase 1 functions listed in the *Functional Specifications of MicroTracker* and are proceeding into the implementation stage. The phase 2 functions will be designed and implemented, if time permits. The attached document discusses the design considerations and details of the MicroTracker.

MicroTrak Inc. consists of five enthusiastic and dedicated, fourth-year engineering students: Lawrence Li, President and Chief Executive Officer; James Dykes, Chief Financial Officer; Victor Leung, Chief Operations Officer; Herman Lo, Chief Technology Officer; and Bernard Ng, Chief Hardware Engineer. If you have any questions, feel free to contact us at (604) 525-9185 or via email at 340-group@sfu.ca.

Sincerely,

Lawrence Li

Lawrence Li
President and CEO,
MicroTrak Inc.

Enclosure: *Functional Specifications of MicroTracker*

Design Specifications of MicroTracker

Project Team: James Dykes
Victor Leung
Lawrence Li
Herman Lo
Bernard Ng

Contact Person: Lawrence Li
340-group@sfu.ca

Submitted To: Dr. Andrew Rawicz - ENSC 340
Steve Whitmore - ENSC 305
School of Engineering Science
Simon Fraser University

Issued Date: October 31, 2002

Revision: 1.1

Executive Summary

Most of us are exhausted from information overload and having to remember where we place our belongings does not help. To lighten this overload, MicroTrak Inc. has come up with a simple, compact, and easy-to-use tracking device - MicroTracker. By attaching tags onto objects, users can located these objects using a tracker. In addition, MicroTracker has the capability to alarm users of left behind items.

MicroTracker will be developed in two phases. Phase 1 of development includes building a tracker and two tags with the following key features:

- Compact
- Cost effective
- Maximum operating range of 400 feet
- Multiple alarm settings
- Selectable alarm activation range
- Separate range and alarm modes
- Voltage regulation
- Emergency button on tags
- Tag and tracker power status indicator
- Range indicator

In phase 2, the following features will be added to the device:

- A selective power down mode for power conservation
- A RF burst input to reactivate the system from power down mode
- Dual solar-battery powered for longer battery life
- Changeable tag mount
- Enhance the alarm mode to allow for automatic sweep of all tag frequencies associated with a tracker
- RFID compatible for supporting increased number of tags

This document discusses the design of the Phase 1 functions. The Phase 2 functions will be designed and implemented, if time permits.

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Scope

MicroTracker is a compact, handheld tracking device for locating multiple tags. This document provides a system overview, descriptions of the tag and tracker design, and some of the design limitations in the MicroTracker.

1.2 Acronyms

DIP	Dual Inline Package
FCC	Federation Communication Commission
FSK	Frequency Shift Keying
ISM	Industrial/Scientific/Medical
LED	Light Emitted Diode
MHz	Megahertz
MTBF	Mean Time Between Failure
MTI	MicroTrak, Inc.
PWR	Power
RF	Radio Frequency
RFID	Radio Frequency Identification
RSSI	Received Signal Strength Indicator
SOS	Save Our Souls
VSWR	Voltage Standing Wave Ratio

1.3 Referenced Documents

[1] Connecterized ¼ wave Antennas. Linx Technologies.
[2] Data Guide: "Splatch" Planar Antennas. Linx Technologies.
[3] Duracell 9V Battery Speification. Duracell Corporation.
[4] HP Series-II Evaluation Kit Data Guide. Linx Technologies.
[5] HP Series-II RF Reciever Module Design Guide. Linx Technologies.
[6] HP Series-II RF Transmitter Module Design Guide. Linx Technologies.
[7] Resource Document: Legal considerations for Linx products in operational areas governed by the Federal Communications Commission (FCC). Linx Technologies.
[8] Proposal for a Hand-held Tracking Device. MicroTrak Inc.
[9] RF Systems, Components, and Circuits Handbook.

1.4 Notation

The following convention is used throughout this document to denote functional requirements:

[R #] A functional requirement for Phase 1 development

2 System Overview

MicroTracker consists of a handheld tracker and multiple tags, as illustrated in Figure 1.

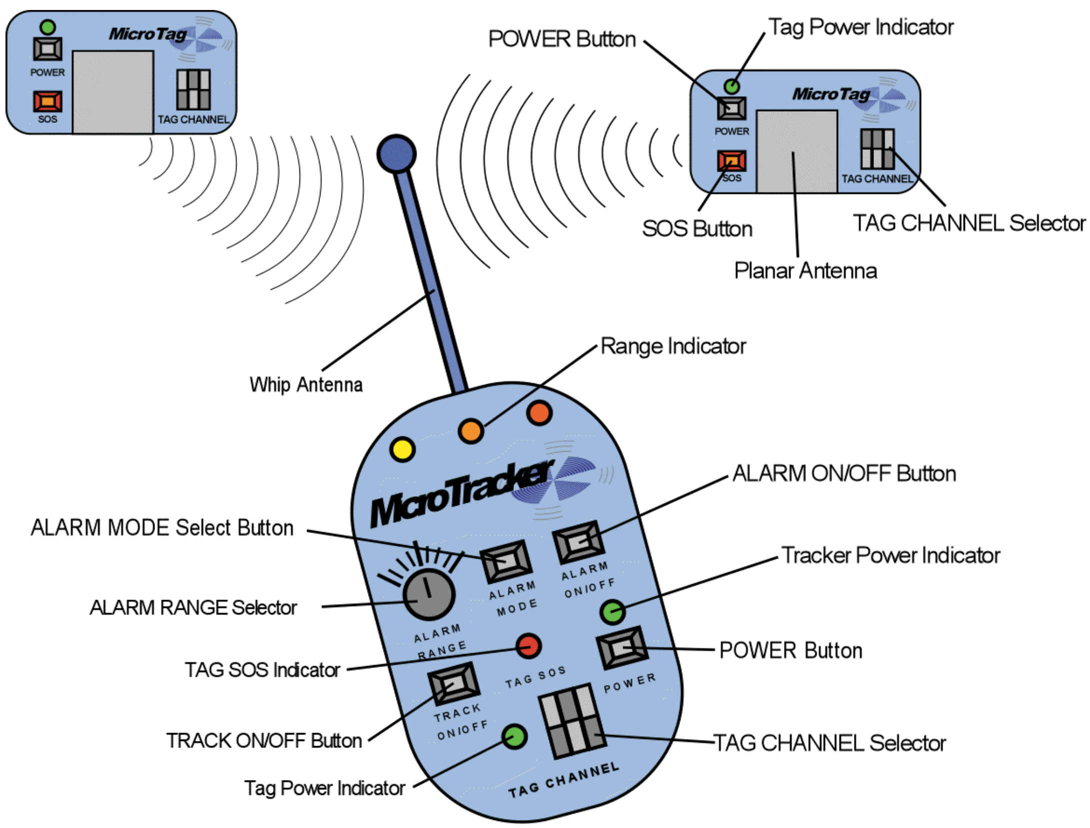

Figure 1. MicroTracker System Diagram

The MicroTracker is designed to track tagged objects, to alert users when the tracker and the target tags are a certain distance apart, and to alarm users of the onset of the tag's SOS signal. After powering on, a tag will continuously transmit a signal to the tracker. By turning on the tracker and tuning into the target tag's channel, the target tag can be tracked using the range indicator.

In the alarm mode, users will be notified when the tracker and the tag are a certain distance apart. This function is achieved by comparing the tag's transmitted signal strength against a voltage reference as set by the users. Users also have the option of being alarmed when the tracker and the tag are too close together. This function again is achieved using signal strength comparisons. Furthermore, when the emergency button on the tag is pressed the buzzer and the emergency LED on the tracker will activate.

3 System Design

3.1 Tag Design

3.1.1 High Level Design

The phase 1 prototype of a tag fulfils the following functional requirements:

[R 1] Power On/Off button
[R 2] A three-switch mechanism for selecting one of eight channel frequencies for the tag
[R 3] An LED on each tag and a signal to the tracker to indicate the tag's power status
[R 4] A button on each tag for sending emergency signal to tracker
[R 5] An antenna to transmit the signals to the tracker

Figure 2 illustrates the black box diagram of the tracker.

Figure 2. Tag Blackbox Diagram

The signals associated with the blackbox diagram in Figure 2 are required to fulfil the tag's functional requirements. Table 1 contains the descriptions of these signals.

Table 1. Tag's Signals

Signal Type	Signal Name	Functions
Input	POWER	Turns tag on or off.
	TAG CHANNEL	Configures tag channel.
	SOS	Emergency signal to tracker.
Output	ANT OUT	Signal to receiver; consists of the range test bit, SOS signal, and power status bit.
	Tag Power Indicator (LED)	Indicates the tag's power status. Turns off when the tag's power is low.

3.1.2 Internal Design

The detailed block diagram of the internal tag design is illustrated in Figure 3.

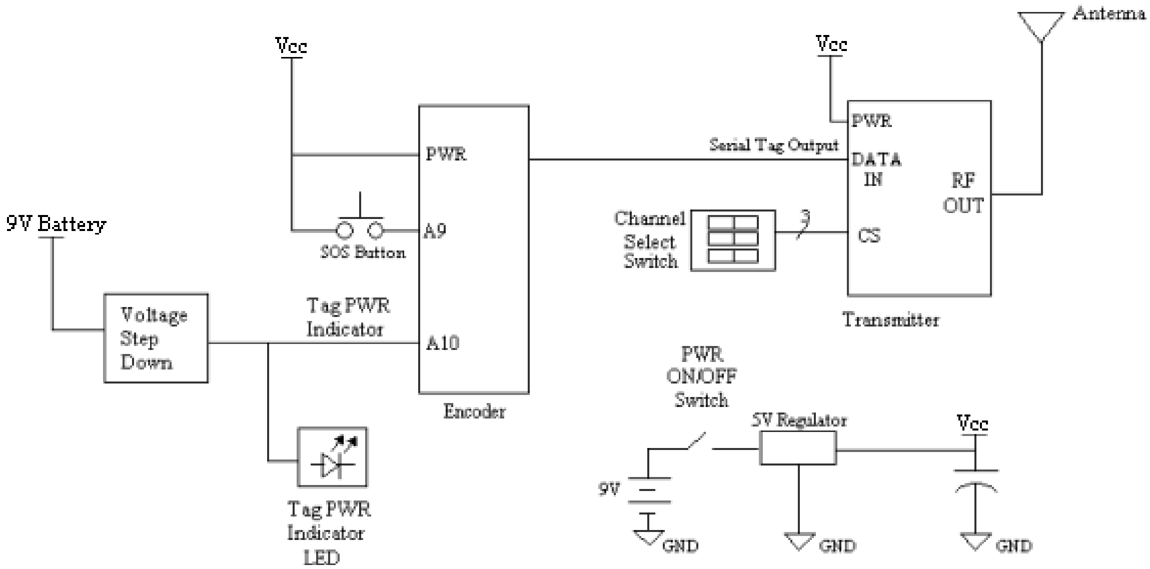

Figure 3. Tag Block Diagram

A tag consists of a 9V battery, a 3-bit DIP switch, an encoder, an LED, a planar antenna, a SOS push button, a power switch, and a transmitter. The main function of the tag is to continuously transmit a signal so that when attached to an object, the location of the object can be determined by detecting this signal with the tracker. By turning on the power and setting the channel select switch, the transmitter will send the serial tag output signal to the tracker over the channel set by the channel select bits. The power on/off switch allows the user to turn off the tag when the tag is not in use to conserve power. Also, the tag has a SOS button for sending emergency signals to the tracker. To indicate tag's power status, a stepped down voltage is used to drive the Tag PWR indicator LED. This voltage is also input into the encoder to be sent to the tracker. The encoder is used to transform the tag's SOS and PWR indicator signals into a serial signal, which is sent to the tracker over the selected channel on the transmitter. We have preliminarily decided to use the Holtek 680 encoder with 18 input lines and 1 serial output, but a smaller scale encoder with fewer input lines can be used for the final prototype for lower cost and smaller size.

Each tag must fulfil the functional requirements listed in the functional specifications, whose designs are discussed in Sections 3.1.2.1 to 3.1.2.6.

3.1.2.1 [R 1] – Power On/Off button

Figure 4 illustrates the block diagram of the power supply circuit.

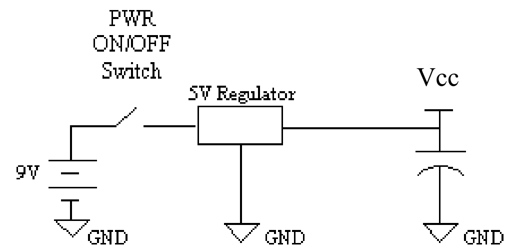

Figure 4. Power Supply Circuit

To achieve the On/Off function, a power switch withstanding 9V is required. A 5V regulator is used to step down the 9V battery to match the transmitter and encoder operating power requirements. Also, to minimize the occurrence of the complete loss of communication between the tag and the tracker, a 9V battery was chosen, since its lifetime is longer than a 5V battery and its size is appropriate for the tag's physical requirements. A capacitor is used to further filter power fluctuations.

3.1.2.2 [R 2] – Carrier frequency of each tag can be configured by user

A 3-bit DIP switch is used to select one of the eight unique carrier frequencies for transmitting the tag signal to the tracker. Each selectable carrier frequency, also called a channel, is encoded by 3 binary bits as listed in Table 2.

Table 2. Tag Channel Encoding Scheme

Channel Select Bits			Channel	Frequency (MHz)
CS2	CS1	CS0		
0	0	0	0	903.37
0	0	1	1	906.37
0	1	0	2	907.87
0	1	1	3	909.37
1	0	0	4	912.37
1	0	1	5	915.37
1	1	0	6	919.87
1	1	1	7	921.37

The reason for using channels between 900 to 922 MHz is that this band is free of tight FCC restrictions on content and duration. Any signal in this frequency band can be transmitted continuously, which is an absolute requirement for the proper tracking operation. Another advantage to operate in this band is that the higher legal power limit, compared to other frequency, bands allows the transmitted signal to travel further. In addition, high carrier frequency permits for shorter antenna, whose length is inversely proportional to frequency (Length of antenna = 234/frequency).

However, we decided not to use a higher carrier frequency since at higher frequencies, more radiation power is required to transmit a signal – radiation power is dependant on the 4^{th} power of the frequency of the signal.

3.1.2.3 [R 3] – An LED on each tag and a signal to the tracker to indicate the tag's power status

The power status LED and the power status signal to the tracker are used to prevent the complete loss of communication between the tag and the tracker before the battery runs out. According to the battery life characteristics of a Duracell 9V battery as shown in Figure 5, the battery voltage decreases gradually at a rate dependent on power consumption from 9V to ~7V as service time progresses.

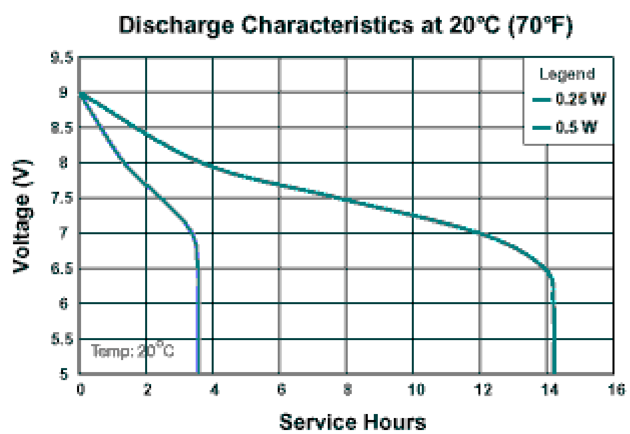

Figure 5. Battery Life Characteristics

Therefore, the voltage across the battery can be used to track the power status of the battery. Since the power comsumption of the transmitter and encoder are only ~100mW and ~2.5mW respectively, the battery life characteristics for the 0.25W in Figure 5 should be appropriate for our system. Assuming 0.25W characteristics and setting the power status indicator signal low when the battery voltage drops below 7.5V, the user will have at least 6 hours of notice to replace the battery before the tag runs out of battery.

Figure 6 illustrates the power indication circuit.

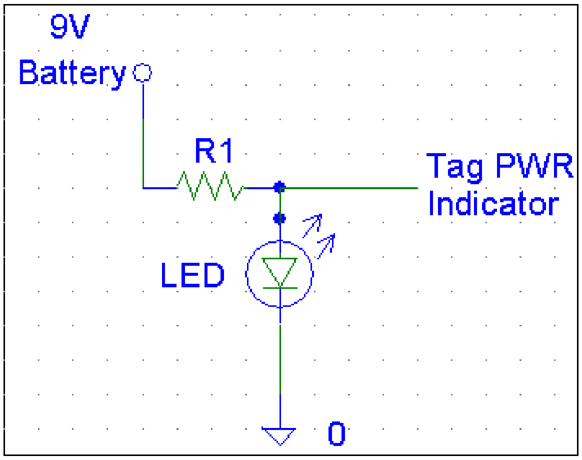

Figure 6. Tag Power Indication Circuit

In our power indication design, the brightness of the LED is used to quantify the amount of power left. When the tag's battery is running low (less than 80% of battery), the voltage of tag power indicator line will reduce, resulting in the LED's brightness decreasing. Also, a signal indicating the power status of the tag is sent to the tracker. This signal becomes low when the battery drops below 7.5V, notifying the user to change the battery within 6 hours.

However, a potential problem to our power indication design is that the power indicator signal at the tracker is low even when the tag is out of detection range. Therefore, to distinguish between these two cases, users must check whether the tag is out of detection range before using the tag PWR indicator LED.

3.1.2.4 [R 4] – A button on each tag for sending emergency signal to tracker

The tag is equipped with a lock-down pushbutton to notify the tracker of an emergency. The advantage of a lock-down pushbutton over a momentary pushbutton is that the user needs to only push the button on the tag once to continuously send an emergency signal to the tracker. When the button is pressed, the emergency signal to the encoder is activated and sent to the tracker via the transmitter. A pushbutton is chosen over a switch for ease of use.

3.1.2.5 [R 5] – An antenna to transmit the signals to the tracker

The purpose of the antenna is to transmit the tag's signals to the tracker. The antenna is attached to the transmitter, which accepts serial data consisting of the SOS and tag PWR indicator signals from the encoder. The choice for the tag's antenna is based on size and tolerance of nearby obstruction and detuning, since the tag must be compact and susceptible to most environments. For details about the chosen antenna, please refer to section 3.1.2.10.

3.1.2.6 [R 6] to [R 11] – Physical Design

Table 3 lists the physical parameters of the tag design.

Table 3. Tag's Physical Design Parameters

Requirement No.	**Physical Features**	**Descriptions**
[R 6]	Standalone Size (Length x Width x Thickness)	70mm x 50mm x 20mm
[R 7]	Mounted Size (Length x Width x Thickness)	70mm x 50mm x 40mm
[R 8]	Weight	100 grams
[R 9]	Packaging	Plastic casing. Fully Enclosed. 6 feet drop sustainable. Shock Resistant.
[R 10]	Pushbuttons	Pushable 100 thousand times.
[R 11]	LEDs	5 year lifetime.

The transmitter chip is 31.75mm x 19.05mm x 6.604mm. The encoder is approximately 20mm x 5mm x 2mm. The battery is 46.5mm x 26.5mm x 17.5mm. The SOS button is approximately 10mm x 10mm x 10mm. Therefore, building a tag of size 70mm x 50mm x 20mm should be achieveable.

The mounted size requirement could be achieved with a mount of no more than 20mm thick. Since a battery weighs 46.5 grams, which is already the heaviest component, meeting the weight requirement should not present any problems.

The tag must be fully enclosed with a plastic casing to be fully weatherized. Also, plastic is chosen over metal to minimize the signal attenuation. The 6 feet drop sustainable and shock resistant criterias are necessary for durability against harsh operating environments and user abuse.

We will purchase reliable pushbuttons and LEDs that fulfils [R 10] and [R 11] as listed in Table 3.

3.1.2.7 [R 12] to [R 18] – RF Design

Table 4 lists the RF parameters of the tag design.

Table 4. Tag's RF Design Parameters

Requirement No.	RF Features	Min.	Typical	Max.	Units
[R 12]	Channel Frequency Range[1]	902	-	928	MHz
[R 13]	Number of Channels	-	8	-	-
[R 14]	Channel Spacing	1.5	3	4.5	MHz
[R 15]	Overall Frequency Accuracy	-50	-	50	KHz
[R 16]	Harmonic Emissions[2]	-	-	-50	DBc
[R 17]	Output Power	-3	0	4	DBm
[R 18]	Occupied Bandwidth	-	32	-	KHz

Note 1: Signal modulated to higher frequency (carrier frequency) for easier demodulation.
Note 2: Power lost due to harmonics

The HP Series-II transmitter is used in our tag design, since its channel frequency range and its 8 selectable channels fulfils our RF requirements. The minimum channel spacing of 1.5MHz and frequency accuracy of 50KHz are just sufficient to prevent adjacent channel interference in most cases. The low output power limits the interference created by the tag's signals. The low harmonic emissions rating provides higher efficiency of the transmitter, where power loss due to harmonics is insignificant. The relatively narrow bandwidth allows for the use of slower oscillator, since signal bandwidth is directly porportional to the sampling rate.

3.1.2.8 [R 19] to [R 21] – Electrical Parameters

Table 5 lists the electrical parameters in our tag design, which are compliant to [R 19] to [R 21] in the functional specifications.

Table 5. Tag's Electrical Parameters

Requirement No.	Electrical Parameters	Value	Units
[R 19]	Operating Voltage Range	5	Vdc
[R 20]	Current Average	20	mA
[R 21]	Power Consumption	100	mW

3.1.2.9 [R 22] to [R 25] – Maximum Ratings

Table 6 lists the maximum ratings of the tag design.

Table 6. Tag's Maximum Ratings

Requirement No.	Category	Min.	Max.	Units
[R 22]	Supply Voltage	-0.3	18.0	Vdc
[R 23]	Operating Temperature	0	70	^{o}C
[R 24]	Storage Temperature	-45	85	^{o}C
[R 25]	Humidity	5%	80%	-

The transmitter chip used in our design has maximum ratings that comply with [R 22] to [R 25] as listed in Table 6. These ratings ensure that the tag can handle most commercial power supplies and survive in most environments.

3.1.2.10 [R 26] to [R 32] – Antenna Design

Since our tag must be small and compact, a planar antenna will be the most suitable for our purposes. Figure 7 illustrates the "Splatch" planar antenna by Linx Technologies.

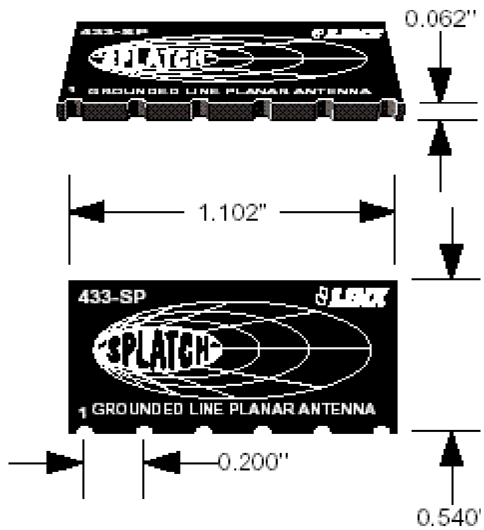

Figure 7. Planar Antenna with Physical Dimensions

Table 7 lists the Splatch antenna specifications.

Table 7. Tag's Antenna Specifications

Requirement No.	Features	Values	Units
[R 26]	Physical Dimensions (length x width x thickness)	1.102 x 0.54 x 0.062	Inch
[R 27]	Electrical Length	¼ wavelength	-
[R 28]	Center Frequency	916	MHz
[R 29]	Useable Bandwidth	40	MHz
[R 30]	Characteristic Impedance	50	Ohm
[R 31]	VSWR[1]	<1.7	-
[R 32]	Loss	-1	-

Note 1: VSWR is a measure of the efficiency of the antenna.

The electrical length is chosen to be ¼ wavelength over ½ wavelength, since a shorter electrical length allows for a shorter antenna to be used. The center frequency and the useable bandwidth are chosen to be 916 MHz and 40 MHz respectively, to match the tag's allowable channel frequency range of 900 MHz to 922 MHz. Since the HP transmitter's output power is higher than the legal limit, a less efficient but more economic and compact antenna could be used to achieve the full legal power; thus, the VSWR is chosen to be only 1.7. Besides fulfilling these requirements, a planar antenna is also immuned to signal deviations caused by interference. Planar antennas have more transmitting surface area, thus allowing for more directional variations in the radiated signals. Other parameters such as characteristic impedance and power loss fits our requirements as well.

3.1.2.11 [R 33] to [R 34] – Response Time

The transmitter of the tag has limited response times to two signifcant events which are listed in Table 8.

Table 8. Tag's Response Time

Requirement No.	Events	Response Time	Units
[R 33]	Tag Power Off	1	Milliseconds
[R 34]	Channel Change	1.2	Milliseconds

The tag power off and channel change response times are short enough such that the tracking system's performance is not significantly affected.

3.2 Tracker Design

3.2.1 High Level Design

The phase 1 prototype of a tracker fulfils the following functional requirements:

[R 35] A Power On/Off button
[R 36] A three-switch mechanism for selecting the target tag's channel
[R 37] An alarm On/Off button
[R 38] A buzzer for the alarm
[R 39] A knob for adjusting alarm activation range
[R 40] An alarm mode button for choosing the away and close modes
[R 41] A set of 3 LEDs for indication of the target tag's range by signal strength
[R 42] A Track On/Off button for the range indicator
[R 43] An LED and a buzzer to indicate the activation of the emergency signal at the target tag
[R 44] An LED to indicate the tracker's power status
[R 45] An LED to indicate the target tag's power status
[R 46] An antenna for receiving the tag's signal

Figure 8 illustrates the black box diagram of the tracker.

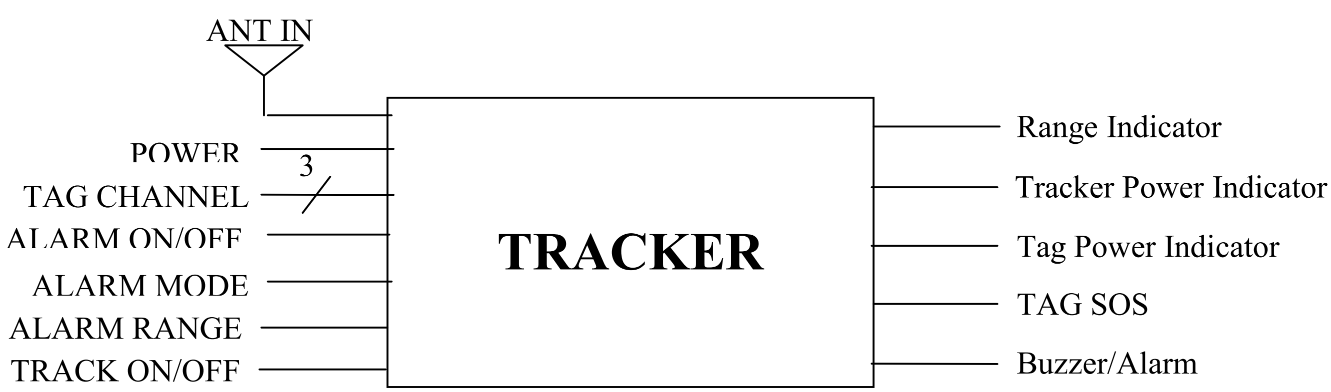

Figure 8. Tracker Blackbox Diagram

The signals associated with the blackbox diagram in Figure 8 are required to fulfil the tag's functional requirements.

Table 9 contains the descriptions of these signals.

Table 9. Tracker's Signals

Signal Type	Signal Name	Functions
Input	POWER	Turns tracker on or off.
	ANT IN	Signal from transmitter tag. The signal consists of the range test bit, SOS signal, and tag power status bit.
	TAG CHANNEL	Sets the target tag's channel.
	ALARM ON/OFF	Turns alarm setting on or off.
	ALARM MODE	Sets alarm to either activate when tag is a user-specified distance away from the tracker or close to the tracker. (away mode or close mode)
	ALARM RANGE	Sets the relative distance between tracker and tag at which the alarm activates.
	TRACK ON/OFF	Turns tag range indicator on or off.
	RF Burst Button (Phase 2)	Forces tag out of power down mode and activates the tag[1].
	Input Buttons for LCD Display (Phase 2)	Allows naming of tags, setting target tag channel, and configuring the alarm settings on LCD display.
Output	Range Indicator (3 LEDs)	Indicates the distance between the tracker and the tag by signal strength.
	Alarm/Buzzer	Indicates the tag is either too far from (away mode) or too close to (close mode) the tracker.
	TAG SOS (Buzzer and LED)	Indicates SOS signal activation at the target tag.
	Tag Power Indicator (LED)	Indicates power status of the tag. Off when tag's power is low.
	Tracker Power Indicator (LED)	Indicates power status of the tracker. Off when tracker's power is low.
	RF Burst signal (Phase 2)	Signal to tag that forces tag out of power down mode[1].
	LCD Display (Phase 2)	Displays menus for tracker settings and tag information.

Note 1: In phase 2, the tag has the option of active and sleep mode for power saving. The RF Burst signal will be Implemented to drive the tag out of sleep mode. The tracker has to be a transceiver for this function.

3.2.2 Internal Design

The detail block diagram of the internal tracker design is illustrated in Figure 9.

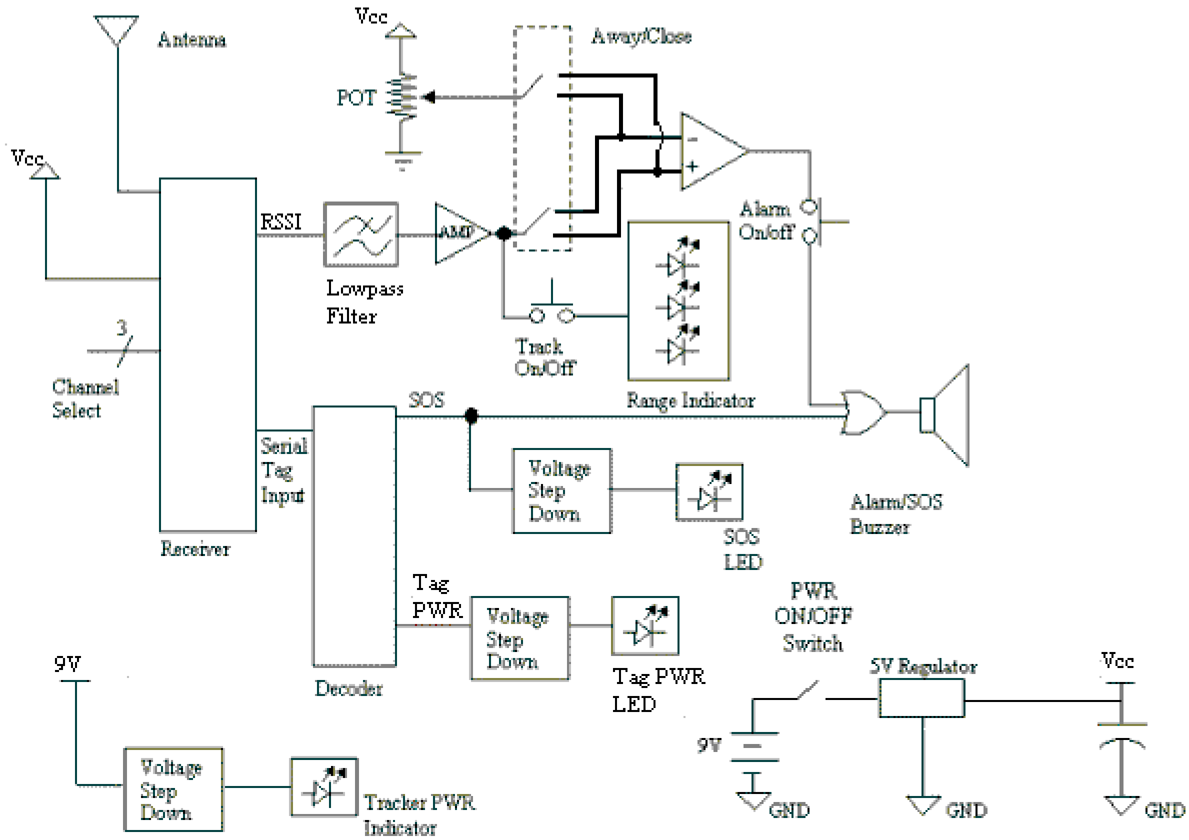

Figure 9. Tracker Block Diagram

The tracker consists of a 9V battery, a buzzer, a decoder, 3 bit DIP switch, capacitors, LEDs, opamps, an OR gate, pushbuttons, resistors, a receiver, a power switch, transistor, a trim-potentiometer, and a whip antenna. The main functions include locating tagged objects, alarming users that the tracker and the target tag are a certain distance apart, and receiving SOS signals from the target tag in case of emergency. Upon powering up and setting the channel select bit to tap into the target channel, the antenna on the tracker will pick up the signal from the target tag. This signal will then be processed by the receiver which outputs the RSSI signal and the serial tag data. The decoder accepts the serial tag data and splits this signal into the SOS and tag power signals. The RSSI signal will then be amplified and compared to a voltage reference set by user through the trim-pot. If the amplified RSSI signal exceeds the reference voltage, the buzzer will activate. The amplified RSSI signal is also feed into the range indicator, where signal strength will be used to determine range.

3.2.2.1 [R 35] – A Power On/Off button

Refer to Section 3.1.2.1 for details of the power On/Off button.

3.2.2.2 [R 36] – Three-switch mechanism for selecting the target tag's channel

Refer to Section 3.1.2.2 for details of the 3-bit DIP switch.

3.2.2.3 [R 37] – An alarm On/Off button

Figure 10 illustrates the design of the Alarm On/Off option.

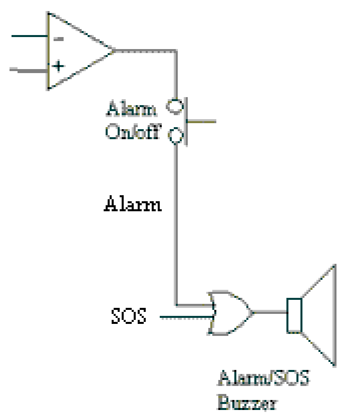

Figure 10. Alarm On/Off Circuit

To disable the alarm, the alarm On/Off button is used to break the connection between the comparator and the buzzer.

3.2.2.4 [R 38] – A buzzer for the alarm

Referring to Figure 10, the buzzer is shared between the alarm and emergency signal. The buzzer sounds when either the alarm signal or the SOS signal activates.

3.2.2.5 [R 39] – A knob for adjusting alarm activation range

Figure 11 illustrates the tracker's alarm circuit.

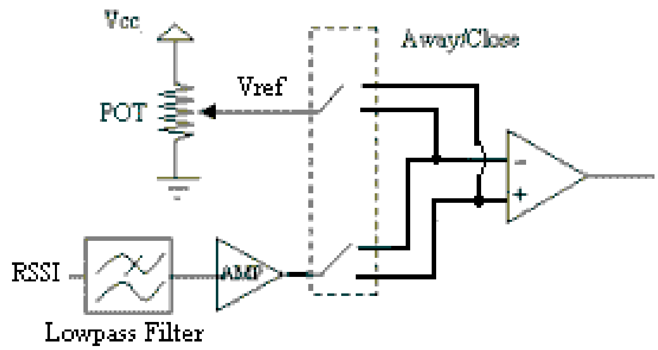

Figure 11. Alarm Circuit

The alarm circuit consists of a lowpass filter, an amplifier, a comparator, and a trim-potentiometer. The Alarm signal activates when the input at the positive terminal is greater than the voltage at the negative terminal of the comparator. The reference voltage, Vref, is compared with the RSSI signal, whose voltage level is dependent on distance. Thus, by adjusting the trim-potentiometer, different reference voltages can be obtained to set different activation ranges.

3.2.2.6 [R 40] – An alarm mode button for choosing the away and close modes

A single-pole-double-throw switch, a set of two switches controlled together, is used to implement the away and close mode. As shown in Figure 11, the away option is chosen by flipping the switch up. When the tracker and the tag are too far apart, the RSSI voltage will drop below the threshold voltage that is set by the trim-potentiometer, thus railing the output of the comparator. When the close option is chosen by flipping the switch down, the RSSI voltage will increase beyond the threshold if the tracker and the tag are too close together, thus railing the output of the comparator as well.

3.2.2.7 [R 41] – A set of 3 LEDs for indication of the target tag's range by signal strength

Figure 12 illustrates the range indication circuit.

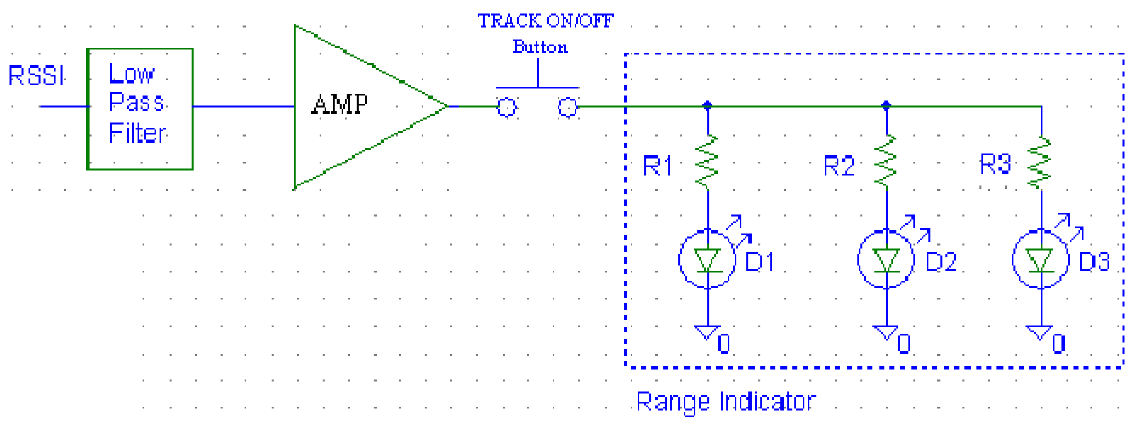

Figure 12. Range Indication Circuit

The range indicator is created using three resistors in series with three diodes. R_3 is chosen to be greater than R_2, while R_2 is chosen to be greater than R_1. When RSSI is low, only D_1 will light up, since the more voltage will drop across R_2 and R_3 than across R_1. As the tracker and the tag become closer together, the RSSI signal will increase; thus, D_2 will also began to light up. Eventually, when the tracker and the tag are close enough together, D_3 will light up. Depending on the state and brightness of each LED, the relative distance between tracker and the tag can be determined.

3.2.2.8 [R 42] – A Track On/Off button for the range indicator

Figure 13 illustrates the range indicator block diagram.

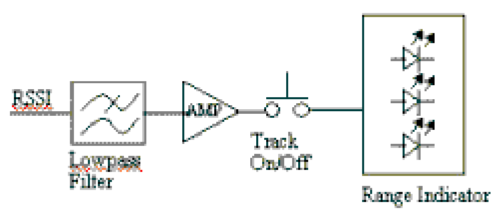

Figure 13. Range Indicator Block Diagram

To disable the range indicator, the Track On/Off button is used to break the connection between the RSSI signal and the Range Indicator. This function is for saving power when range indication is not required.

3.2.2.9 [R 43] – An LED and a buzzer to indicate the activation of the emergency signal at the target tag

Figure 14 shows the circuit that processes the SOS signal from the tag via the decoder.

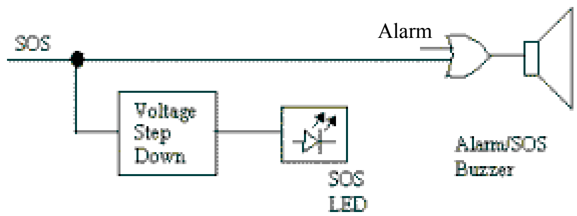

Figure 14. Emergency Circuit

To turn on the LED with the SOS signal, a voltage step down device is used to tune down the voltage to prevent LED from current overload. The LED is used to provide users a visual indicator to differentiate the SOS signal from the alarm signal, since both signals activate the buzzer. Another solution to differentiate the SOS signal from the alarm signal is to have a different sound for these signals. Using a buzzer along with an LED to alarm users of emergency is better than just using the LED alone, since users are more attentive to an audio alert than a visual one.

3.2.2.10 [R 44] – An LED to indicate the tracker's power status

Figure 15 illustrates the tracker power indication circuit.

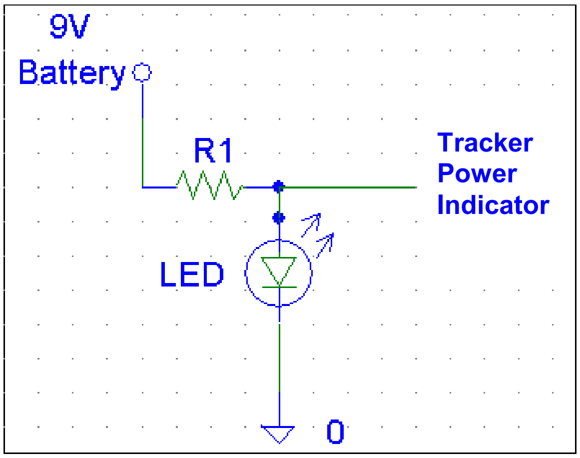

Figure 15. Tracker Power Indication Circuit

The power supply is connected to an LED through a voltage step down device. When power supply drops below a specific voltage, the LED will be turned off due to insufficient current through the diode.

3.2.2.11 [R 45] – An LED to indicate the target tag's power status

Figure 16 illustrates the target tag power indicator circuit.

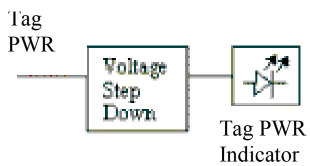

Figure 16. Target Tag Power Indicator

Tag PWR signal is connected to an LED through a voltage step down device. When tag's power supply drops below a specific voltage, the LED will be turned off due to insufficient current through the diode.

3.2.2.12 [R 46] – An antenna for receiving the tag's signal

The purpose of the antenna is to receive the tag's signals. The antenna is attached to the receiver, which accepts serial data consisting of the SOS and tag PWR indicator signals from the decoder. The choice for the receiver's antenna is mainly based on its efficiency and accuracy, since the receiver has to pick up the target tag's signal with minimal interference. For details about the chosen antenna, please refer to section 3.2.2.17.

3.2.2.13 [R 47] to [R 52] – Physical Design

Table 10 lists the physical parameters of the tracker design..

Table 10. Tracker's Physical Parameters

Requirement No.	Physical Features	Descriptions
[R 47]	Standalone Size (Length x Width x Thickness)	100mm x 50mm x 20mm
[R 48]	Mounted Size (Length x Width x Thickness)	100mm x 50mm x 40mm
[R 49]	Weight	150 grams
[R 50]	Packaging	Plastic casing. Fully Enclosed. 6 feet drop sustainable. Shock Resistant.
[R 51]	Pushbuttons	Pushable 1 million times.
[R 52]	LEDs	10 year lifetime.

The receiver chip is 48mm x 21.59mm x 8.89mm. The decoder is approximately 20mm x 5mm x 2mm. The battery is 46.5mm x 26.5mm x 17.5mm. The buzzer is approximately 25mm x 25mm x 10mm. Therefore, building a tracker of size 100mm x 50mm x 20mm should be achieveable.

The mounted size requirement could be achieved with a mount of no more than 20mm thick. Since a battery weighs 46.5 grams, which is already the heaviest component, meeting the weight requirement should not present any problems.

The tracker must be fully enclosed with a plastic casing to be fully weatherized. Also, plastic is chosen over metal to minimize the signal attenuation. The 6 feet drop sustainable and shock resistant criterias are necessary for durability against harsh operating environments and user abuse.

We will purchase reliable pushbuttons and LEDs that fulfils [R 51] and [R 52] as listed in Table 10.

3.2.2.14 [R 53] to [R 56] – RF Design

Table 11 lists the RF parameters of the tag design.

Table 11. Tracker's RF Parameters

Requirement No.	RF Features	Min.	Typical	Max.	Units
[R 53]	Center Frequency	903.37	-	921.37	MHz
[R 54]	Noise Bandwidth	-	280	-	KHz
[R 55]	Data Bandwidth	300	-	50000	Bps
[R 56]	RSSI Voltage Range	0.8	-	2.5	V

The HP Series-II receiver is used in our tracker design, since its center frequency lies in the 900MHz range, which fulfils our RF requirement. The receiver processes the signal so that the noise bandwidth is reduced to 280 KHz to improve the signal to noise ratio. The low harmonic emissions rating provides higher efficiency of the receiver, where power loss due to harmonics is insignificant. The relatively narrow bandwidth allows for the use of slower oscillator, since signal bandwidth is directly porportional to the sampling rate.

3.2.2.15 [R 57] to [R 59] – Electrical Design

Table 12 lists the electrical parameters in our tracker design, which are compliant to [R 57] to [R 59] in the functional specifications.

Table 12. Tracker's Electrical Requirements

Requirement No.	Electrical Features	Min.	Typical	Max.	Units
[R 57]	Operating Voltage Range	2.7	9.0	16.0	Vdc
[R 58]	Current Average	18	20	22	MA
[R 59]	Power Range	48.6	180	352	MW

3.2.2.16 [R 60] to [R 63] – Maximum Ratings

Table 13 lists the maximum ratings of the tracker design.

Table 13. Tracker's Maximum Ratings and Limitations

Requirement No.	Category	Min.	Max.	Units
[R 60]	Supply Voltage	-0.3	18	Vdc
[R 61]	Operating Temperature	0	70	^{o}C
[R 62]	Storage Temperature	-45	85	^{o}C
[R 63]	Detection Range	-	400	Feet

The receiver chip used in our design has maximum ratings that comply with [R 60] to [R 63] as listed in Table 13. These ratings ensure that the tracker can handle most commercial power supplies and survive in most environments.

3.2.2.17 [R 64] to [R 70] – Antenna Design

A basic CW-series ¼ wave whip style antenna by Linx Technologies is chosen for the receiver. A whip style antenna is used due to its superior range performance compared to other antenna styles, such as planar and helical styles at the same center frequency. The tracker antenna's parameters are listed in Table 14.

Table 14. Tracker's Antenna Parameters

Requirement No.	Features	Values	Units
[R 64]	Physical Length	3.13	Inch
[R 65]	End Radius	0.57	Inch
[R 66]	Electrical Length	¼ λ	-
[R 67]	Center Frequency	916	MHz
[R 68]	Useable Bandwidth	25	MHz
[R 69]	Characteristic Impedance	51.19	Ohm
[R 70]	VSWR	<1.2	-

Using 900MHz carrier frequency for the tracker allows for a relatively short antenna, whose length is inversely proportional to frequency (Length of antenna=234/frequency~3 inches). Choosing an electrical length of ¼ λ results in shortening the physical antenna length for ½ λ by 100%. The center frequency and the useable bandwidth are chosen to be 916 MHz and 25 MHz respectively, to match the tag's allowable channel frequency range of 900 MHz to 922 MHz. To minimize radiated power loss and reject off-frequency signals, the receiver antenna's efficiency is much more critical than the transmitter's. Therefore, the VSWR is chosen to be at least 1.2 for optimal antenna performance.

3.2.2.18 [R 71] to [R 74] – Response Time

The receiver of the tracker has limited response times to certain signifcant events which are listed in Table 15.

Table 15. Tracker's Response Time

Requirement No.	Events	Response Time	Units
[R 71]	Data Output Transition	33	Milliseconds
[R 72]	Channel Change	10	Milliseconds
[R 73]	Tracker Turn On	12	Milliseconds
[R 74]	Tracker Turn Off	1	Milliseconds

The data output transistion, channel change, and power on/off response times are short enough such that the tracking system's performance is not significantly affected.

3.2.2.19 [R 75] to [R 80] – Operating Modes

The tracker has the operating modes listed in Table 16.

Table 16. Tracker's Operating Modes

Requirement No.	Mode	Range On/Off	Alarm On/Off	Alarm Mode
[R 75]	Range/Alarm Off	Off	Off	-
[R 76]	Alarm Away	Off	On	Away
[R 77]	Alarm Close	Off	On	Close
[R 78]	Tracking On	On	Off	-
[R 79]	Range On/Alarm Away	On	On	Away
[R 80]	Range On/Alarm Close	On	On	Close

The functions associated with these operating modes are described in 3.2.2.1 to 3.2.2.11.

3.3 [R 81] to [R 82] – Reliability and FCC Standards

[R 81] Due to the simplicity of the circuitry, the tag and tracker should have an MTBF of 100,000 hours. After the complete circuit design is constructed, the MTBF can be calculated using the Bellcore model, which is a common electronics reliability model for commercial products.

[R 82] The MicroTracker will comply to the Federal Communications Commission (FCC) regulations since the transmitter and receiver chips used in our system are manufactured to comply to FCC standards. The required regulatory measures regarding equipment authorization and RF devices are described in Part 2 and Part 15 of the CFR 47 document, which is included in referenced document [5].

3.4 Design Limitations

3.4.1 Multipath

Figure 17 illustrates one possible multipath scenario.

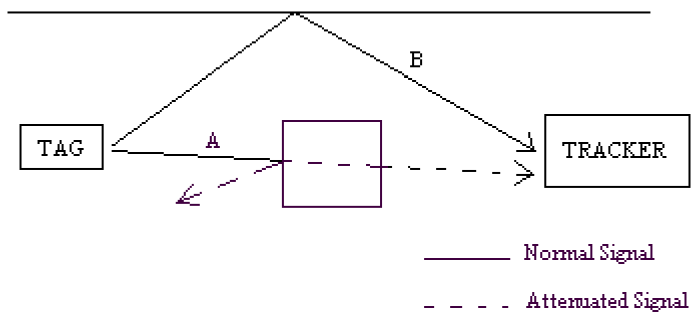

Figure 17. Multipath Scenario

Referring to Figure 17, the signal along path B will have stronger signal strength than signal along path A, since path A is blocked by an obstruction. Therefore, users will have to travel a longer path compared to the path A to locate the tag. On the other hand, since an obstruction exists in path A, taking path B will avoid running into the obstruction. Although the path the tracker suggests (path B) to the user is not the shortest path, the user should eventually reach the tag.

3.4.2 Interference

Sources of interference include narrow band, spread spectrum, and ISM devices such as cordless phones. However, since FCC limits the maximum signal strength to less than 50mV within 3 meters for the 900-928 MHz frequency band, the effect of interference to our system is limited. In addition, since weak noises can be filtered out by our system while strong noises are usually momentary, users can wait until the range indicator stabilizes before continuing the search for the tag.

4 Test plan

Please refer to section 6.1 to 6.3 of functional specifications for the tag, tracker, and system testing procedures.

5 Conclusion

This document provides the design specifications for all the phase 1 functions listed in the *Functional Specifications of MicroTracker*.

We have just finished the design of the phase 1 functions and will proceed into the implementation stage. The phase 2 functions will be designed and implemented, if time permits.

A demo prototype with all the phase 1 features will be completed by December of 2002.

