TRACKING VEHICLES USING GPS AND PACKET RADIO

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ABSTRACT

English

This report describes Automatic Vehicle Location and Navigation (AVLN) systems and more particularly systems using the Global Positioning System (GPS) and amateur packet radio, with a database of geographic information to implement a real time vehicle tracking system.

Two different possibilities to locate a Vehicle have been studied and experimented with and are described in this report: standalone GPS and Differential GPS (DGPS). In both cases we must use a Computer running Windows 95 with a map display carefully chosen, a Terminal Node Controller (TNC) and a VHF receiver at the base station which was situated in Gillin Hall. In each vehicle, we needed at least a GPS receiver, a TNC, a VHF transmitter, and a laptop computer. In the case of the DGPS system, we must also have a beacon receiver for the corrections.

There are many potential applications for this type of system such as truck fleet management, dispatching and monitoring for taxi or bus companies, and even use by rental car firms.

Français

Ce rapport décrit les systèmes automatiques de location de véhicules, et plus particulièrement ceux utilisant le GPS (Global Positioning System), et la packet radio, le tout relié à un système d'information géographique permettant le suivi de véhicules en temp réel.

Deux différentes possibilités, pour positionner le véhicule, ont été experimentées et décrites dans cette étude: Le GPS et le DGPS (GPS différentiel). Dans les deux cas la base, située à Gillin Hall fonctionnait avec un ordinateur doté de Windows 95 utilisant une interface cartographique choisie avec soins, un récepteur VHF, ansi qu'un TNC (Terminal Node Controler) qui permet l'interface entre la radio VHF et l'ordinateur. Dans les deux cas le système embarqué dans le véhicule était composé au minimum d'un récepteur GPS, d'un ordinateur portable, d'un émetteur VHF ainsi que d'un TNC. Dans le cas du système utilisant le DGPS, il y avait besoin en plus d'un récepteur pour capter les corrections émises sur une fréquence différente.

Il existe plusieurs applications pour un système de ce type tel que l'organisation d'une entreprise de transport routier, de taxi, ou de bus.

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ABBREVIATIONS AND SYMBOLS

AC	Alternating Current
AM	Amplitude Modulation
APRS	Automatic Position Reporting System
AS	Anti-Spoofing
AUTONAV	AUTOnomously NAVigate
AVLN	Automatic Vehicle Location and Navigation
C/A	Coarse/Acquisition
CCITT	Consultative Committee in International Telegraph and Telephone
CSMA	Carrier Sense Multiple Access
DC	Direct Current
DGPS	Differential Global Positioning System
DOD	Department Of Defense
DOP	Dilution of Precision
DTE	Data Terminal Equipment
EOT	End Of Transmission
FM	Frequency Modulated
GIS	Geographic Information System
GPS	Global Positioning System
IF	Intermediate Frequency
IGN	Institut Géographique National
ISO	International Standards Organisation
LEO	Low Earth Orbit
LORAN	LOng RANge positioning system
LOS	Line Of Sight
NMEA	National Marine Electronics Association
NNSS	Navy Navigation Satellite System
PPS	Precise Positioning Service
PRN	Pseudorandom Noise
RDBS	Radio Data Broadcast System
RDS	Radio Data System
RF	Radio Frequency
SEP	Spherical Error Probable
SIS	Signal-In-Space
SPS	Standard Positioning Service
SSID	Sub-Station IDentification
SV(s)	Space Vehicle(s)
TAPR	Tucson Amateur Packet Radio Corporation
TNC	Terminal Node Controller
UHF	Ultra High Frequency
UTC	Coordinated Universal Time
VADCG	Vancouver Amateur Digital Communication Group
VHF	Very High Frequency

PART I. INTRODUCTION

From the very beginning of humankind, people always traveled on earth, for different reason: hunting commerce…. The problem is that, when you travel you always want know where you are, how you came there and how you will reach your destination. Therefore people invented techniques to locate themselves on earth.

It began in prehistoric times when people left some sign to know how to come back or to locate the best hunting areas. Then, people constructed roads and villages and named them. Later with the development of commerce they draw maps to locate, not only the different villages and the roads, but also the impediments one could encounter during a journey, like mountains and rivers... For centuries these techniques didn't improve very much. Now with the evolution of technology in the 19^{th} and 20^{th} centuries we have got many different way to situate ourselves: old techniques like maps still exist, but we also have new techniques like satellites, radio, telephone…

We will study here some of these positioning systems, orientating our work on how to locate a moving vehicle in real time. We will do a quick review of most of the different current systems, concentrating especially on GPS (Global Positioning System). Then we will experiment with one of these techniques that seems to have the most advantages.

PART II. BACKGROUND

2.1 AVLN Systems

2.1.1) Introduction

Automatic vehicle location and navigation (AVLN) systems involve the integration of several technologies [*E.J. Krakiswky, C. Harris*, 1994]:

- Positioning devices to determine the coordinates (latitude, longitude, and height) of the vehicle in a mathematical world.
- Digital maps to define the location of the vehicle in the real world.
- Communications devices to send information to the driver and back to the dispatcher.
- Computers to control the operation and to perform the necessary calculations.

2.1.2) Historical Overview

According to Clyde B. Harris in is report, *Prototype for a land based automatic vehicle location and navigation system*, in December 1989, here is the main point in the AVLN History:

For century AVLN technology for land based application has slowly been unfolding, emerging from ancient civilizations of Egypt, Greece, Rome, and China, only to dawn now, at the end of the 20th century. Ranging from ancient mechanical odometers to modern electronic satellite receivers, this technological evolution is marked by significant breakthroughs.

The earliest AVLN systems date back some 2,000 years. The most famous of these is the Chinese South Pointing Carriage, which is credited to Chang Heng (circa 120 AD) and Ma Chün (circa 255 AD). By keeping track of how much more (or less) one wheel moves than other, the ancient Chinese could keep track of the change in heading and distance of two-wheeled carriage as it moved across vast, featureless tracts of land. This motion was mechanically compensated for, thereby keeping the outstretched arm of a statue mounted on the carriage continuously pointed toward the south or some other chosen reference direction.

Other way, in the Mediterranean regions, the first AVLN related device to emerge was the hodometer, the ancient forefather of the present day automobile odometer. The world hodometer originating from the Greek words *hodos*, meaning 'way', and metron, meaning 'measure'. Heron of Alexandria (circa 60 AD),of the ancient University of Alexandria, wrote of an ancient hodometer which employed a reduction gear train interlocked to wheel of a cart. Distances journeyed were recorded by dropping stone pebbles into a container at regular interval representing perhaps the first AAAVLN related analogue-to-digital format ever used. Other great men associated with early developments of the hodometer were as follows:

- Ctesibius (circa 300-230 BC), of the University of Alexandria.
- Archimedes (circa 287-212 BC), the renowned Greek scholar.
- Vitrivius (circa 20 AD), the famous military architect and engineer of Caesars of Rome.

Before the age of automobile, AVLN quietly evolved. The magnetic compass was invented (circa 1111 AD), hodometer developments was revised by Leonardo DaVinci (circa 1452-1519 AD) and by the German monk Athanasius Kircher (circa 1602-1680 AD). With the evolution of the preoccupation with contemporary map in the latter half of the 16th century, people developed an instrument which integrated a hodometer with a magnetic compass, this integrated device could automatically record distances and direction simultaneously by imprinting a spiked compass needle at regular intervals of distance into a hodometer synchronized, paper strip roll.

At the very beginning of the 20th century, the Chadwick concept, years ahead of its time, included on-board alarm bells and signal arms controlled by programmed route discs to guide the driver accordingly which is very similar to the modern AVLN route guidance. At the same time an American, E. Sperry, and a German, H. Aschütz, made initial developments of the gyrocompass. During the Second World War, the US military constructed a vehicular odograph (jeep's position plotted on paper map), Doppler radar techniques for positioning were tested, and the electronic radio navigation LORAN (LOng RANge positioning system) was born. During this period, the first operational inertial guidance system was developed. IN the 1960's satellite positioning was pioneered, roadside proximity beacons were implemented, and in the early 1970's a clever and economical position and location update concept entitled map matching for on-road AVLN applications was conceived.

The recent advancement in microcomputer technology and Geographic Information System (GIS) and satellite positioning systems (i.e. GPS: Global Positioning System) permit a tremendously increase in the AVLN system.

2.1.3) Definition

According to Pr. Skomal, in 1981, the AVLN is *"an assembly of technologies and equipment that permits centralized and automatic determination, display and control of the position and movement of multiple vehicle throughout and appropriately instrumented area"*.

According to Pr. E.D. Krakiwsky, in 1987, the AVLN is a system used to *"position a vehicle using signal from satellite and information from on-board differential positioning device, plot the position on a CRT or flat panel display, call up a digitized electronic map of the area and see the vehicle's position relative to a desired location, and obtain instruction (visual and audio) using an expert system on how to proceed from the present location to the desired location"*.

According to Pr. E.D. Krakiwsky, in October 1993, in the Vehicle Navigation and Informations Systems Conference, you can put the AVLN systems in four categories:

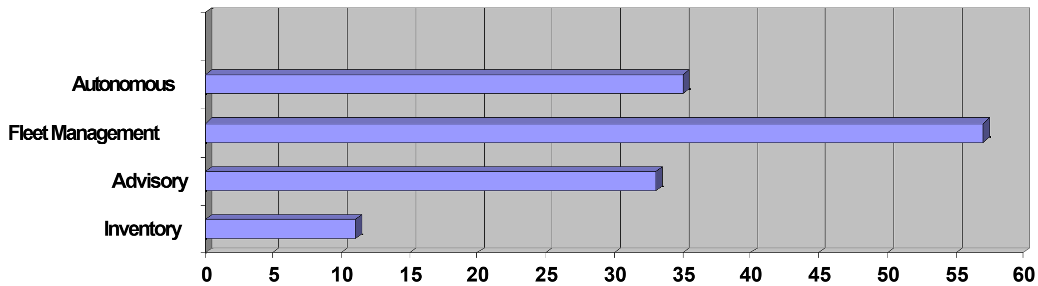
Autonomous systems are stand-alone vehicles with an on-board positioning device and a map database. No communications link is available with the outside world.

Fleet management systems, on the other hand, consist of fleet vehicles linked to a control center via a communications link. Although positioning sensors are available in vehicle, the map databases are not necessarily on board. The control center may be responsible for the transmit of the necessary information from the database to the vehicle on call.

Advisory navigation system is a blend of autonomous and fleet management architecture. It is an autonomous system in the sense that is not controlled by a dispatched center, yet it is a part of a fleet that is being served by a traffic control center.

Inventory systems usually include autonomous vehicle equipped with video or digital camera to capture time and coordinate tagged site information necessary for road inventory or any other surveillance purposes. Inventory vehicle may have a communication link with a control center.

Figure 1: Types of Systems



From the Vehicle Navigation and Informations Systems Conference October 12-15, 1993

TABLE 1: TYPES AND NUMBERS OF AVLN SYSTEMS THAT USE COMMUNICATIONS IN VARIOUS PARTS OF THE WORLD

	Fleet management	Advisory	Inventory	Total
North America	44	3	1	48
Pacific Rim	1	12	1	14
Europe	21	12	1	34
Worldwide	66	27	3	96

From GPS WORLD November 1994

2.1.4) The Positioning Technologies

These are different of technologies used in the AVLN system to position a vehicle:

The **Radio navigation system** is a navigation method in which the unit receives positioning signal from outside communication facilities and calculates car's location in term of absolute position by trilateration.

The following are known as radio navigation systems.

- A system, which uses navigation radio waves from, ground stations such as DECCA, OMEGA, and LORAN-C.
- A system, which uses positioning, signals from the signpost like beacons. The location beacons is a means to signal its coordinates to the car passing nearby. These beacons are installed on overpasses, guideposts, and traffic lights…

- A system using satellites such as NNSS (Navy Navigation Satellite System) and GPS (Global Positioning System). More information on GPS are given in section 2.3.

The **Dead reckoning** is a form of navigation that determine the position of a vehicle by advancing a previous position to a new one on the basis of assumed distances and direction moved. The parameters of dead reckoning are direction of motion and distance traveled. A compass is used to indicate direction, which is expressed as angular distance from a reference direction, usually north; it may be Magnetic North, when you use magnetic compass, Gyro North, when you use a gyrocompass or grid north when you are near the pole. Distance is usually determined indirectly by measurement of speed and time, but it may be measure directly [*A.B. Moody*, 1992].

The **Inertial guidance system** is a self-contained system, which can automatically determine the position, velocity, and attitude of moving vehicle. Based on prior knowledge of time, gravitational field, initial position, initial velocity, and initial orientation relative to know reference frame, an inertial guidance system is capable of determining its present position, velocity and orientation without the aid of external information. The basic measurement of an inertial guidance is acceleration. Some accelerometers are put on three directions, north, east, down axes, which on down axe compensated for gravity. Then by a first integration you know velocity on these three axes, and by a second integration you distance. The real problem of inertial guidance system is to maintain and to stay pointed in one direction [H.L. Dupont, 1992].

The **map matching** is a system to locate vehicle on a digital or paper map. The precision of the location depend of the scale of the map, typically you make an error of one millimeter on the map. But map matching can not be use alone, because you need a system to locate the vehicle

TABLE 2: NAVIGATION SYSTEMS

Name	Accuracy	Starting	Merit	Demerit
DECCA	20 to 500 m	1944	· Existing facility in usable	· Not usable in bad transmittal conditions · Usable only in the limited area becaus it is for offshore use
OMEGA	2 to 50 km	1958	· Cover world with 8 stations	· Many error due to change of transmitta speed
LORAN-C	0.1 to 1.5 km	1959	· Existing facility is usable	· Usable only in the limited area becaus it is for offshore use
Signpost	Depends on density	90's	· Easy to find absolute position	· Usable only in the place where facilitie on ground is available · Need to invest initially
NNSS	100 to 500 m	1967	· Detectable with one satellite	· Necessary to receive for 10 minute continuously
GPS	20 to 200 m	1992	· Possible to know 3 dimensional location · Measurable accurately at once	· Impossible to use during bad receptio conditions
Dead reckoning	5 to 10% of the traveled distance	18 C	· Autonomous system	· Have to know the initial values · the accuracy increase with the travele distance
Inertial guidance	5 to 10% of the traveled distance	end of the 19 C	· Autonomous system	· Have to know the initial values · the accuracy increase with the travele distance
Map matching	1 mm on the map		· Increase the Accuracy of other systems	· Can not be use alone.

2.1.5) Digital Maps

2.1.5.1 Components

According to T.H. Schiff, in October 1993, in the Vehicle Navigation and Informations Systems Conference, you required some indispensable component to make a high quality database:

Accurate and Current Road Geometry is necessary because as the traveler transverse the route, their movement needs to be precisely matched to the road geometry in the database. You have to know precisely where is the vehicle, especially in the area where there is a high density of road.

Other way you have to know **Physical and Functional Road Classification**. The physical classification is based on physical attributes of the road, for example a highway with fully controlled access is different than a residential street with access to individual parcels, or a one-way street is different than a two way street. The functional classification indicates how the roadway is used which is important to determine the fastest route to a designated destination.

When two intersect it is not always in the same plan, so you have to take care about the **Overpasses and Underpasses**. Generally you give a level: level 0 for the ground floor, negative level for the underpasses and positive level for the overpasses.

The **Street Names** are very important too but it is not easy to define, sometime one road have several legitimate names and you have to put all these names in your database.

You have to know the **Addresses**, but in different way due to the different utilization of the software. For example to locate stolen vehicle, you require a simple address range, but navigation requires the exact location of a specific single address. You don't need only the roadway segment to identify an address, but also which side of the street is odd.

Finally you need **Routing Data** to complete navigable database: Navigation data, Time-of-day restriction, flow restricted roadway, construction projects, signage.

2.1.5.2 Different Sources of Data

There is different possibility to obtain data for your database:

You can **digitize existing paper maps** that are made by a governmental office (like IGN for France, USGS for USA, or Geographical Service for Canada). The scale usually used are 1/25,000 (Europe) or 1/24,000 (North America) for the large scales and 1/100,000 for the small scales. The strengths of these maps are first, the facility to obtain the paper maps, second, the facility of digitize them, third, the existence of geodetic point in these maps for the reference. But the main weakness of these maps is that the data are often outdated.

You can use **numeric photogrammetry**, technique, which permit to obtain digital maps from aerial photography. The strengths of this technique are first, you can have the maps of the area you want, second, you can choose any scale you want for your maps, it only depend of the altitude during the flight, third it provide immediately digital maps (no errors of digitization), fourth it is easy to update the information. But the main weaknesses are first the price, second the difficulty to obtain a map in the towns.

In Canada you can ask data at the **provincial offices**. These data are often updated and you can have postal addresses in the province, but the main weakness is that there isn't homogeneity between the different data codes in the different provincial offices. But efforts have been made to have a standard map database in North America.

2.1.6) The Communication

According to E.D. Krakiwsky, and C.B. Harris in November 1993, there are different sorts of communication systems:

ABLE 3: COMMUNICATION SYSTEMS SORTED BY GEOGRAPHICAL REGION.
ingle means that a single communications technology is used; multi means that several are combined or ma e used. As a result of some AVLN systems using more than one means of communication, the total add up t iore than the 96 AVLN systems identified as incorporating communication links.

		Conventional radio	Satellite	Beacons	Cellular	Paging	Radio data system	Packet Network	Trunked radio	Othe
North America	Single	7	1	0	2	0	0	0	2	7
	Multi	20	14	3	10	3	1	6	15	8
	Total	27	15	3	12	3	1	6	17	15
Pacific Rim	Single	0	0	1	1	0	0	0	0	0
	Multi	1	0	19	1	1	0	0	1	1
	Total	1	0	20	2	1	0	1	1	1
Europe	Single	7	1	0	1	0	4	0	1	2
	Multi	8	7	5	4	0	1	4	4	10
	Total	15	8	5	5	0	5	4	4	12
Worldwide		***43***	***23***	***38***	***19***	***4***	***6***	***11***	***22***	***28***

from : GPS WORLD November 1994

<u>*2.1.6.1 Conventional Radios*</u>

The conventional radios are, today, the most common type of communications system used in AVLN designs throughout the world. In general the conventional radio is a term used to describe a standard radio communications system. The frequency ranges normally used UHF (400 to 500 MHz) and VHF (25 to 175 MHz). These radios are portable. When you use a conventional radio the system share a common radio frequency (RF) channel, so when two users transmit at the same time there is collision. To resolve that problem, radio etiquette has been established: Users must monitor a channel and announce a line clear before attempting a call. But conventional radio is primarily designed for voice, not data. To solve that problem you can use a separate data radio with a dedicated frequency channel to handle data over conventional radio.

2.1.6.2 Satellite Technology

The satellite communication is seen as a complementing existing terrestrial-based systems by some satellite-based system manufacturers because it can be used in remote area not covered by cellular and specialized mobile radio techniques. Satellite communications systems fall into two category: those that utilized geostationary satellites and those that plan to incorporate low earth orbit (LEO) satellites.

The geostationary satellites orbiting at altitudes of 36,000 kilometers in synchronization with the earth rotation, those satellites remain approximately over the same locations on the earth's surface near the equator. Due to their vast distance above the earth, they require relatively large antennas to send and receive signals, making the equipment somewhat bulky. This technology is effective for AVLN applications that require wide-area coverage, but the equipment and services are relatively costly.

The LEO satellites orbit at a distance of less than 1,800 kilometers. LEO satellites will provide global, low-powered, handheld communication.

2.1.6.3 Beacons and Signpost

Beacons and signpost are communications devices that transmit and receive information by microwaves, infrared light waves, or short distances RF. Beacon and signpost systems are typically situated at intersections. As a vehicle drives through an intersection an information exchange takes place that may include a position update. Some beacons broadcast one way to the vehicle, others are designed for two way exchange. Up to now beacon-based systems have been introduced in highly populated urban centers mainly in Japan and Europe. The beacon systems is based on a exchange of information: first the vehicle receives map data, traffic information and suggested routes, and beacon position for updates, In return the vehicle's travel times along selected routes are sent from the vehicle to the traffic management center by way of beacons

2.1.6.4 Cellular

Due to his wide acceptance and coverage, cellular technology is a attractive for the AVLN, and a cellular system is ideal for applications with infrequent position-reporting rates and requiring voice communications. When a connection is made, the cell site links the call to a central controller switch, which ten connects to a conventional landline or to an other cell site, depending on the location of the receiver. Adjacent cells use different frequencies to avoid overlap, and cell site handoffs occur automatically when moving from cell to cell. The biggest problem for the moment is that voice cannot be used, however, until the modem that send data, is disconnected. But with digital technology, that uses binary code, data and voice can be mixed together.

2.1.6.5 Paging

One way paging can be used to transmit data from a base station to roving vehicles. OEM paging modules are now available and in the future could potentially be used for AVLN base-to-vehicle short-messaging services.

Two-way paging is now available. Typically the goal of two way paging is to provide four kinds of response communications: acknowledgments, requests, registration and short messages. The short-messages response can be used to send data such as vehicle position and diagnostics back to a central monitoring station

2.1.6.6 Radio Data System (RDS)

The RDS developed in Europe is intended for one way communication to vehicles; consequently it is used primarily in advisory-type AVLN systems. In the United States the equivalent of RDS is RDBS (Radio Data Broadcast System) which is used primarily to carry DGPS correction to enhance the GPS Standard Positioning Service, but communication will undoubtedly follow.

2.1.6.7 Packet Network

A packet network is a packet-switched communications system designed for data only. Data are transmitted in small packet through an interconnected network of nodes. These packets of information are relayed from node to node until they reach their designated destination. A packet network can cover a wide area, enabling vehicles equipped with the technology to roam the nation along selected corridor and still remain in contact with their base. That is accomplished through a series of base stations, repeaters, trunking systems, and landlines.

As these systems take advantage of classic analogue voice system designs, they are often categorized as analogue even though they are in fact digital. In certain cases, the system can be used inside buildings. Transmission costs are low because billing is based upon data transmitted and not on connect time.

More information on packet radio are given in section 2.2

2.1.6.8 Trunked Radio

A trunked radio system is a two-way radio communications system with a central controller that acts as an automatic switchboard, handling many users and talk groups. A trunked radio system can have as many as 28 channels, one of which dedicated control channels that links all users and assigns open channels automatically. Each user talk group has exclusive use of the same channel to maintain privacy. As it was the case for conventional radio, trunked systems were traditionally designed for voice communications, and can become overtaxed when dealing with data. Digital trunked radio systems that are just rolling out are much better suited for voice and data.

2.2 Global Positioning System or GPS

2.2.1) Introduction

The Global Positioning System is an universal positioning or navigation system that provides for the first time three dimensional position accuracy to 10 meter velocity to an accuracy of 0.03m/s, and time to atomic clock accuracy. This information is available anywhere on earth. It is composed of a space segment, a control segment and a user segment.[*Louis Feid*, 1992]

According to Peter H. Dana, in February 1999:

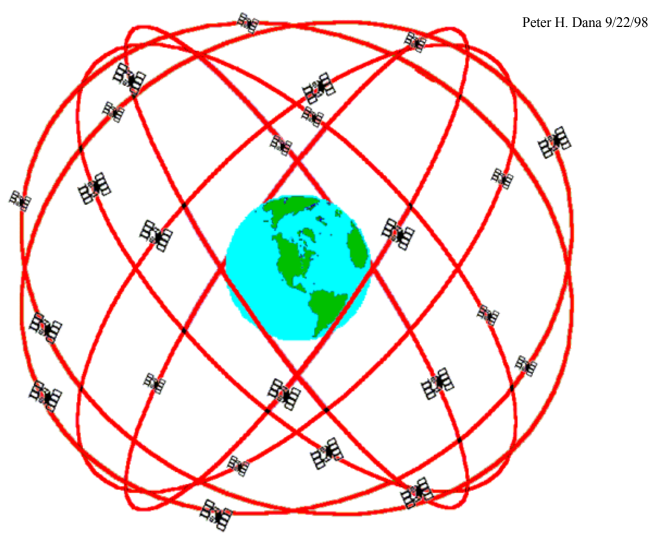
The Space Segment is an earth-orbiting constellation of 21 Navstar satellites (plus 3 on-orbit operational spares) in six planes staggered by 60 degrees. The nominal circular orbits are 20,200-kilometer altitude orbits inclined at an angle of 55 degrees with a 12-hour period. The spacing of satellites in their orbital planes are arranged such that a minimum of four satellites will be in view everywhere on and near the surface of the earth at any time. Each Navstar satellite is designed to broadcast a pair of L-band radio frequency (RF) signals, known as Link 1 (L1 = 1575.42 MHz) and Link 2 (L2 = 1227.6 MHz). The L1 signal carries a precision ranging code and coarse / acquisition code, while

L2 carries only the precise ranging code. The signals are broadcast using spread spectrum techniques, employing two different spreading functions: a 1.023 MHz coarse / acquisition (C/A) code on L1 only and a 10.23 MHz precision (P) code on both L1 and L2. The minimum signal powers for the different signals at a GPS receiver are:

L1 C/A=-160dBW; L1 P=-163 dBW; and for L2 P=-166 dBW.

Superimposed on these codes are low-rate navigation message data, including satellite clock and ephemeris parameters, satellite signal health data, and Coordinated Universal Time (UTC) synchronization information.

Figure 2: Orbital Plans



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Planes
20,200 km Altitudes, 55 Degree Inclination

From http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html

The Control Segment consists of a system of tracking stations located around the world. The Master Control facility is located at Schriever Air Force Base (formerly Falcon AFB) in Colorado, the other monitor stations are located in Hawaii (Pacific ocean), Ascension Island (South Atlantic ocean), Diego Garcia (Indian ocean), and

Kwajalein (Oceania). These monitor stations measure signals from the SVs (Space Vehicles), which are incorporated into orbital models for each satellites. The models compute precise orbital data (ephemeris) and SV clock corrections for each satellite. The Master Control station uploads ephemeris and clock data to the SVs. The SVs then send subsets of the orbital ephemeris data to GPS receivers over radio signals.

The GPS User Segment consists of the GPS receivers and the user community. GPS receivers convert SV signals into position, velocity, and time estimates. Four satellites are required to compute the four dimensions of X, Y, Z (position) and Time.

2.2.2) Historical Overview

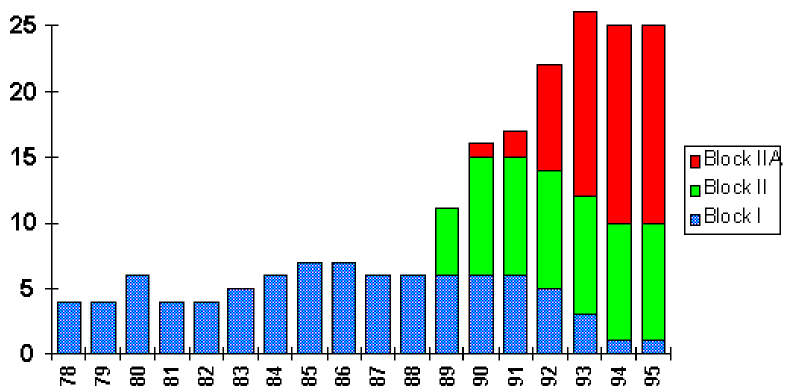
According to the Navstar GPS joint program office:

The Block I SVs, built by Rockwell International as developmental prototypes, were launched between 1978 and 1985 from VAFB, California. These SVs supported most of the system testing. Out of a total of 11 Block 1 SVs launched on the Atlas-Centaur, one was lost as a result of a launch failure, three have reached end-of-life due to wear-out of their atomic clocks, and two suffered failures of their three-axis attitude control system. The oldest Block I SV (PRN #6) has operated reliably for more than double its five-year design life.

Block II SVs were built by Rockwell International. The first of 28 Block II SVs, SV PRN number 14, was launched on 14 February 1989 from Cape Canaveral Air Force Satellites, Florida using a Delta II Medium Launch Vehicle and was set "healthy" in its broadcast 50 Hz navigation message for global use on 15 April 1989. The last Block IIA was launched.

During the middle of 1989, procurement began for 21 additional satellites ("replenishment SVs") from Lockheed Martin, formerly General Electric. The Block IIR SVs will present an identical Signal-In-Space (SIS) interface to the User Segment. Under a survivability scenario, the Block IIR SVs will have the capabilities to autonomously navigate (AUTONAV) themselves and generate their own 50 Hz navigation message data. These AUTONAV capabilities will enable the Block IIR SVs to maintain full SIS accuracy for at least 180 days without Control Segment support. AUTONAV will also significantly improve both the reliability and integrity of the broadcast SIS. Accuracy improvements are expected to be approximately 7 meters spherical error probable (SEP) in a full Block IIR constellation.

Figure 3: Evolution of the Use of the Different GPS Satellites



From http://www.laafb.af.mil/SMC/CZ/homepage/space/s_config.htm

2.2.3) How Does It Work?

All the information in this paragraph comes from a web page of Peter H. Dana, Department of Geography, University of Texas at Austin:

http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html

2.2.3.1 *GPS Codes*

The SVs transmit two microwave carrier signals. The L1 frequency (1575.42 MHz) carries the navigation message and the SPS (Standard Position Service) code signals. The L2 frequency (1227.60 MHz) is used to measure the ionospheric delay by PPS (Precise Position Service) equipped receivers. Three binary codes shift the L1 and/or L2 carrier phase:

The **C/A Code** (Coarse Acquisition) modulates the L1 carrier phase. The C/A code is a repeating 1 MHz Pseudo Random Noise (PRN) Code. This noise-like code modulates the L1 carrier signal, "spreading" the spectrum over a 1 MHz bandwidth. The C/A code repeats every 1023 bits (one millisecond). There is a different C/A code PRN for each SV. Their PRN number, the unique identifier for each pseudo-random-noise code, often identifies GPS satellites. The C/A code that modulates the L1 carrier is the basis for the civil SPS.

The **P-Code** (Precise) modulates both the L1 and L2 carrier phases. The P-Code is a very long (seven days) 10 MHz PRN code. In the Anti-Spoofing (AS) mode of operation, the P-Code is encrypted into the Y-Code. The encrypted Y-Code requires a classified AS Module for each receiver channel and is for use only by authorized users with cryptographic keys. The P (Y)-Code is the basis for the PPS.

The **Navigation Message** also modulates the L1-C/A code signal. The Navigation Message is a 50 Hz signal consisting of data bits that describe the GPS satellite orbits, clock corrections, and other system parameters.

2.2.3.2 GPS Data

The GPS Navigation Message consists of time-tagged data bits marking the time of transmission of each subframe at the time they are transmitted by the SV. A data bit frame consists of 1500 bits divided into five 300-bit subframes. A data frame is transmitted every thirty seconds. Three six-second subframes contain orbital and clock data. SV Clock corrections are sent in subframe one and precise SV orbital data sets (ephemeris data parameters) for the transmitting SV are sent in subframes two and three. Subframes four and five are used to transmit different pages of system data. An entire set of twenty-five frames (125 subframes) makes up the complete Navigation Message that is sent over a 12.5-minute period.

Data frames (1500 bits) are sent every thirty seconds. Each frame consists of five subframes.

Data bit subframes (300 bits transmitted over six seconds) contain parity bits that allow for data checking and limited error correction.

Clock data parameters describe the SV clock and its relationship to GPS time.

Ephemeris data parameters describe SV orbits for short sections of the satellite orbits. Normally, a receiver gathers new ephemeris data each hour but can use old data for up to four hours without much error. The ephemeris parameters are used with an algorithm that computes the SV position for any time within the period of the orbit described by the ephemeris parameter set. Here is an Example of Ephemeris and Clock Data Parameters, decoded from Subframes 1, 2, and 3 of GPS Data Bit Frames, gathered 4/18/95 21:36:00, Austron 2201A GPS Satellite Receiver:

EPHEMERIS FOR SATELLITE 7:		Rate of right ascension (rad/sec):	-8.3357E-09
PRN number for data:	7	Right ascension @ ref time (rad):	2.81765
Issue of ephemeris data:	5	Sqrt (1 - e^2):	0.999976
Semi-Major Axis (meters):	2.656E+07	Sqr root semi-major axis, (m^1/2):	5153.63
C(ic) (rad):	1.91852E-07	Reference time ephemeris (sec):	247904
C(is) (rad):	-1.08033E-07		
C(rc) (meters):	300.719	CLOCK FOR SATELLITE 7 :	
C(rs) (meters):	-94.0938	PRN number for data:	7
C(uc) (rad):	-4.81494E-06	Week number:	797
C(us) (rad):	4.06802E-06	Predicted user range accuracy:	32
Mean motion difference (rad/sec):	4.6902E-09	Health of satellite:	0
Eccentricity (dimensionless):	0.00693839	L1 - L2 Correction term:	1.39698E-09
Rate of inclination angle (rad/sec):	-1.53578E-10	Issue of clock data:	5
Inclination angle @ ref. time (rad):	0.964094	Time of clock data:	247904
Mean Anomaly at reference time (rad):	-2.73317	Clock offset:	0.000703468
Corrected Mean Motion (rad/sec):	0.000145862	Clock drift:	2.27374E-13
Computed Mean Motion (rad/sec):	0.000145857	Rate of clock drift:	0
Argument of perigee (rad):	-2.56914		

Almanacs are approximate orbital data parameters for all SVs. The ten-parameter almanacs describe SV orbits over extended periods of time (useful for months in some cases) and a set for all SVs is sent by each SV over a period of 12.5 minutes (at least). Signal acquisition time on receiver start-up can be significantly aided by the availability of current almanacs. The approximate orbital data is used to preset the receiver with the approximate position and carrier Doppler frequency (the frequency shift caused by the rate of change in range to the moving SV) of each SV in the constellation. Here is an example of Almanac Parameters, decoded from Subframes 4 and 5 of GPS Data Bit Frames, Gathered 4/18/95 21:36:00, Austron 2201A GPS Satellite Receiver:

ALMANAC FOR SATELLITE 16:		Right ascension @ ref time (rad):	-1.3188
PRN number for data:	16	Sqrt semi-major axis (m^1/2):	5153.76
Health of SV:	0	Clock correction term 1:	-8.4877E-05
Reference Week of Almanac:	797	Clock correction term 2:	0
Eccentricity:	0.00119495	Reference time almanac:	380928
Corr: inclination angle (rad):	0.00536537	Semi-Major Axis (meters):	2.6561E+07
Mean Anomaly @ ref time (rad):	-0.501614	Corrected Mean Motion (rad/sec):	0.000145847
Argument of Perigee (rad):	-1.11801	Inclination angle (rad):	0.959334
Rate right ascension (rad/sec):	-7.9089E-09		

Each complete SV data set includes an ionospheric model that is used in the receiver to approximate the phase delay through the ionosphere at any location and time. Here is an example of Ionospheric Parameters, decoded from Subframe 4, Page 18 of GPS Data Bit Frames, Gathered 4/18/95 21:36:00, Austron 2201A GPS Satellite Receiver:

Alpha[0] :	1.397E-08	Beta[0]	1.044E+05
Alpha[1] :	2.235E-08	Beta[1] :	9.83E+04
Alpha[2] :	-1.192E-07	Beta[2] :	-1.966E+05
Alpha[3] :	-1.192E-07	Beta[3] :	-3.932E+05

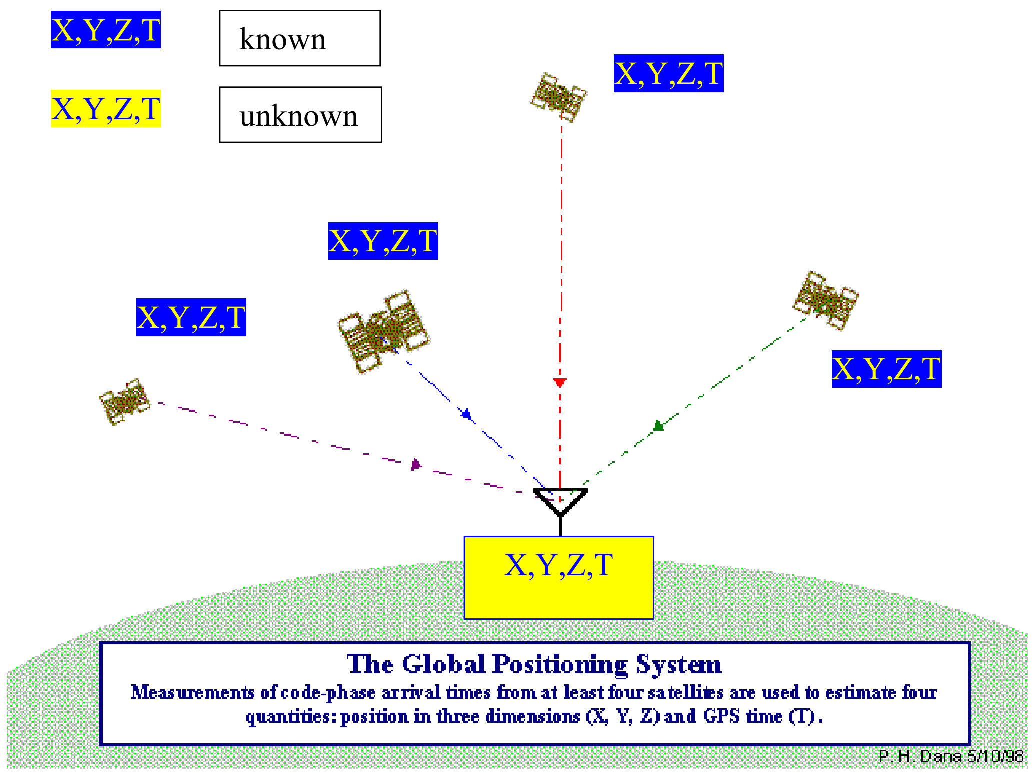
Each SV sends the amount to which GPS Time is offset from Universal Coordinated Time. The receiver to set UTC to within 100 ns can use this correction. Here is an example of UTC Parameters, decoded from Subframe 4, Page 18 of GPS Data Bit Frames, gathered 4/18/95 21:36:00, Austron 2201A GPS Satellite Receiver:

A0:	-9.3132E-09 sec	WNt:	2.9000E+01 weeks
A1:	-4.5297E-14 sec/sec	WNlsf:	2.4300E+02 weeks
dtLS:	1.0000E+01 sec	DN:	5.0000E+00 days
Tot:	4.6694E+05 sec	dtLSF:	1.0000E+01 sec

Other system parameters and flags are sent to characterize details of the system.

All these information permit to know exactly the position of the satellites: X, Y, Z, T then the location of the receiver can be calculated by determining the distance from each of the satellites to the receiver. GPS takes these 3 or more known references and measured distances and "triangulates" an additional position. Then the position in X, Y, Z, is converted within the receiver to geodetic latitude, longitude and height above the ellipsoid or to other user-required datums.

Figure 4: The Positioning of a Receiver on Earth.



From http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html

2.2.3.3 GPS Error Sources

GPS errors are a combination of noise, bias, and blunders.

Noise errors are the combined effect of PRN code noises (around 1 meter) and noise within the receiver noises (around 1 meter).

Bias errors result from Selective Availability and other factors:

· Selective Availability SA is the intentional degradation of the SPS signals by a time varying bias. SA is controlled by the DOD to limit accuracy for non-U.S. Military and government users. The potential accuracy of the C/A code of around 30 meters is reduced to 100 meters (two standard deviations). The SA bias on each satellite signal is different, and so the resulting position solution is a function of the combined SA bias from each SV used in the navigation solution. Because SA is a changing bias with low frequency terms in excess of a few hours, position solutions or individual SV pseudo-ranges cannot be effectively averaged over periods shorter than a few hours. Differential corrections must be updated at a rate less than the correlation time of SA (and other bias errors).

- SV clock errors uncorrected by Control Segment can result in one-meter errors.
- Ephemeris data errors: 1 meter.
- Tropospheric delays: 1 meter. The troposphere is the lower part (ground level to from 8 to 13 km) of the atmosphere that experiences the changes in temperature, pressure, and humidity associated with weather changes. Complex models of tropospheric delay require estimates or measurements of these parameters.
- Unmodeled ionosphere delays: 10 meters. The ionosphere is the layer of the atmosphere from 50 to 500 km that consists of ionized air. The transmitted model can only remove about half of the possible 70 ns of delay leaving a ten-meter unmodeled residual.
- Multipath: 0.5 meters. Multipath is caused by reflected signals from surfaces near the receiver that can either interfere with or be mistaken for the signal that follows the straight line path from the satellite. Multipath is difficult to detect and sometime hard to avoid.

Blunders can result in errors of hundred of kilometers. Control segment mistakes due to computer or human error can cause errors from one meter to hundreds of kilometers. User mistakes, including incorrect geodetic datum selection, can cause errors from 1 to hundreds of meters. Receiver errors from software or hardware failures can cause blunder errors of any size.

Noise and bias errors combine, resulting in typical ranging errors of around fifteen meters for each satellite used in the position solution.

2.2.4) GPS Receiver Architecture

All the information on the GPS receiver is from the article *GPS Receiver: An Introduction,* written by R. B. Langley, in the GPS WORLD, in January 1991

2.2.4.1 Antenna

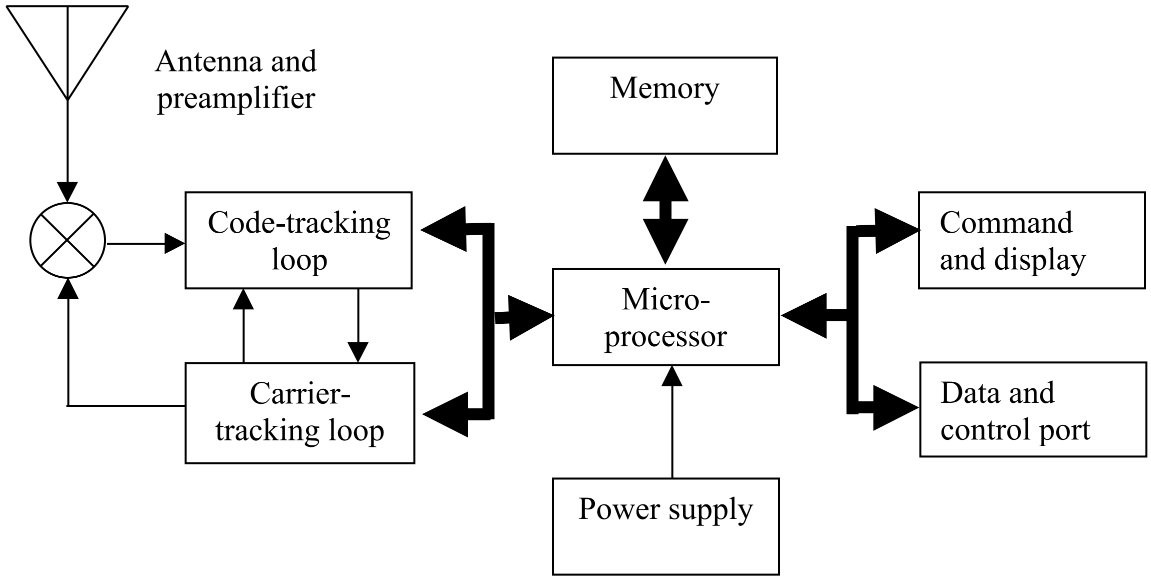
The job of an antenna is to convert the energy in the electromagnetic waves arriving from the satellite into an electric current that can be handled by the electronics in the receiver.

The **size and shape** of the antenna are very important because they govern, in part, the ability of the antenna to pick up the very weak GPS signal. The antenna may need to operate at just the L1 frequency or at both the L1 and L2 frequencies. Also because GPS signals are circularly polarized, all GPS antenna must be circularly polarized. Despite these restriction there is several type of antennas: monopole or dipole configurations, quadrifilar helices (also known as volutes) spiral helices, and microstrips which is the most common antennas because of its ruggedness and relative ease of construction.

Other important characteristics of a GPS antenna are its **gain pattern,** which describes its sensitivity over some range of elevation and azimuth angles, and its ability to discriminate against multipath signals, that is, signal arriving at the antenna after being reflected off nearby objects.

Finally a GPS antenna must generally be combined with a low-noise preamplifier that boosts the level of the signal before it is fed to the receiver itself.

Figure 5: Major Components of a Generic One-Channel GPS Receiver.



From: *GPS Receiver: An Introduction,* R. B. Langley, GPS WORLD, January 1991

2.2.4.2 RF Section

The RF section of a GPS receiver translates the frequency of signals arriving at the antenna to a lower one, called an intermediate frequency (IF), that is more easily managed by the rest of the receiver. This is done by combining the incoming signal with a pure sinusoidal signal generated by a component in the receiver knows as a local oscillator. Most GPS receivers use precision quartz crystal oscillators, enhanced versions of the regulators commonly found in wristwatches. The IF signal contains all the information that is present in the transmitted signal, only the carrier as been shifted in frequency. The frequency of the shifted signal is simply the difference between the original received carrier frequency and that of the local oscillator. It is often called a beat frequency in analogy to the beat note that is heard when two musical tones very close together are played simultaneously. Most receivers employ multiple IF stages, reducing the carrier frequency insteps. The final IF signal passes to the workhorse of the receiver, the signal trackers.

2.2.4.3 Signal Trackers

The omnidirectional antenna Of the GPS receiver simultaneously intercepts signals from all satellites around the antenna's horizon. The receiver must be able to isolate the signal from each particular satellite in order to measure the code pseudorange and the phase of carrier. The signals from different satellites may be easily discriminated by the unique C/A-code or portion of the P-code they transmit and are assigned to a particular channel. Three way are developed:

· The dedicated channels which are continuously tracking a particular satellite. So it might have at minimum four channels in the receiver.

· The sequencing channel, which listens to a particular satellite for a period of time (about 30 second), make measurement and then switches to an other satellite. The time for first fix and the time between position update can be reduced by having a pair of sequencing channels

· The multiplex channel, which is a variation of the sequencing channel. With this design a receiver sequence through the satellites at a fast rate, essentially acquiring all the broadcast messages from the individual satellites at the same time, then the first fix is 30 seconds or less.

Receivers with a single channel are less expensive but because of their slowness, are restricted to low-speed applications. Receivers with dedicated channels have greater sensitivity because they make measurement on the signals more often, but they have inter-channel biases that must be carefully calibrated. This calibration is usually done by the receiver's microprocessor.

The GPS receiver uses tracking loops to measure pseudorange and to extract the broadcast message. A tracking loop is mechanism that enables a receiver to tune into, or track, that is changing either in frequency or in time. It is a feedback device that basically compare incoming (external) signal against a locally produced signal (internal), generates an error signal that is the difference between the two, and uses this signal to adjust the internal signal to match the external one in such a way that the error is reduced to zero or minimized. A GPS receiver contains two kinds of tracking loops: the delay-lock, or code-tracking loop and the phase-lock or carrier-tracking loop.

The delay-lock loop is used to align a PRN code sequence (from either the C/A-or P-code) that is present in the signal coming from a satellite with a identical PRN code sequence generated within the receiver using the same algorithm that is employed in the satellite. Alignment is achieved by appropriately shifting the receiver-generated code chips in time so that a particular chip in the sequence is generated at the same instant its twin arrives from the satellite

2.2.4.4 Microprocessor

Because a receiver has to perform many different functions, a GPS receiver's operation is controlled by a microprocessor. The microprocessor's software, which contains the instructions for running the receiver, is imbedded in memory ship within the receiver.

The microprocessor works with digital samples of pseudorange and carrier phase. These data sample are acquired as a result of analog-to-digital conversion at some point in the signal flow through the receiver. The receiver uses these samples to establish its positions and may record them for future processing. The microprocessor may run routines that do some filtering of these raw data to reduce the effect of noise or to get positions and velocities that are more reliable when the receiver is in motion.

The microprocessor may compute waypoint information or convert coordinates from the standard WGS 84 geodetic datum to a regional one. It also managed the input of commands from the user, the display of information, and the flow of data through its communication port, if the unit has one.

2.2.4.5 User Interface

The majority of self-contained GPS receivers have a keypad and a display of some sort to interface with the user. The keypad can be used to enter commands for selecting different options for acquiring data, for monitoring what the receiver is doing, or for displaying the computed coordinates, time, or other details. Users may also key in auxiliary information, such as that required for waypoint navigation or weather data and antenna height for geodetic surveying. Most receivers have well integrated command and displays capabilities with menus, prompting instructions, and even one-line help. Some receivers have a basic default mode of operating that require no user input and can be activated simply by turning the receiver on.

Some GPS receivers are designated as sensors to be integrated into navigation systems and, therefore, don’t have their own keypads and displays, input and output are accessed only via data ports.

2.2.4.6 Data Storage and Output

In addition to a visual display, many GPS receivers provide a means of saving the carrier-phase and pseudo range measurements and the broadcast messages for use in post processing. This feature is a necessity for receivers used for surveying and for differential navigation.

In surveying applications, the pseudorange and phase observation must be stored for combination with like observations from other simultaneously observing receivers and subsequent analysis. Usually the data are stored internally in the receiver using semiconductor memory. Some receivers store data on magnetic tape or directly on a floppy disk using an external computer.

Some receivers, including those that store their data internally for subsequent analysis and those used for real-time differential positioning, have an RS-232 or some other kind of communication port for transferring data to and from a computer, modem, or radio. Some receivers can be remotely controlled through this port.

2.2.4.7 Power Supply

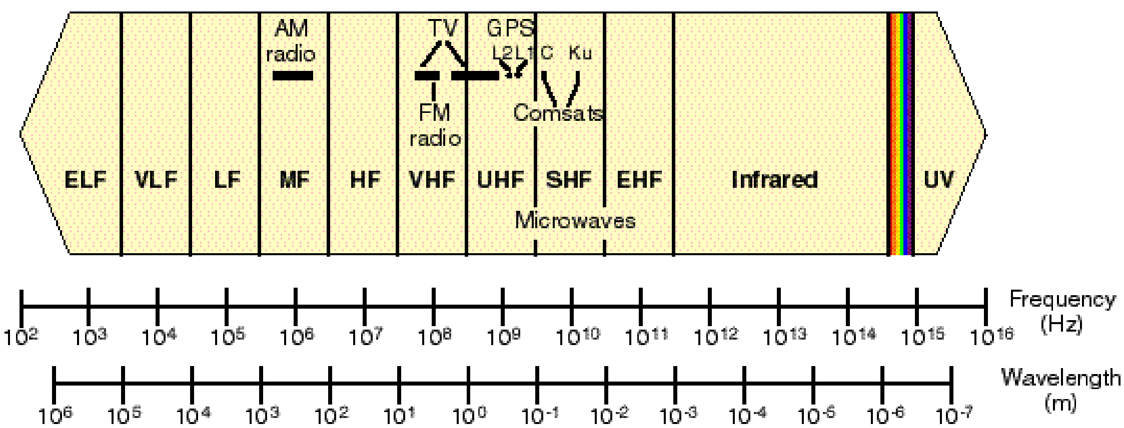
Most GPS receivers have internal DC power supplies, usually in the form of rechargeable nickel cadmium (NiCd) batteries. The newest receivers are designed to draw as little current as possible, extending the operating time between batteries charges. Most receivers also make a provision for external power in the form of a battery pack or AC-to-DC converter.

2.3 Radio Frequency

2.3.1) Introduction

Radio Frequency (RF) encompasses all the electromagnetic spectrum, RF energy is classified according to frequency and the range of frequency is called the radio spectrum

Figure 6: The Radio Spectrum



2.3.2) Technical History [J.D. Singleton, 1992]

In 1840 two separates events began the long history of radio. Joseph Henry first produced high frequencies oscillations, and at the same time Samuel F.B. Morse was demonstrating the telegraph in Washington, D.C. The theories of Henry and Morse to Explain the theory of propagation of energy from wires. he also showed, at least mathematically, that these generated waves would travel at the speed of light.

Heinrich Hertz was able to demonstrate practically Maxwell's theory in 1888, by passing a rapidly alternating current through a wire, creating what were to become known as Hertzian waves. Guglielmo Marconi made practical application of Hertz's work between 1895 and 1898.

But the first significant radio applications employed frequencies of about 500 kHz for ship communications. In the 1920's, the first real overseas radio complex was established, upon discovery that frequencies of 3,000 to 30,000 kHz traveled over great distances by reflection from the Ionosphere. In later years many other services such as television, FM broadcasting, radar and microwave relaying, were developed as the unique properties of much higher frequencies was discovered and exploited.

Different method to transmit information have been found since the radio appeared:

· For the **Code telegraphy**, the carrier is keyed on and off to form dot and dashes.

· For the **Frequency-shift transmission**, the carrier frequency is shift a fixed amount to correspond with telegraphic dots and dashes or with combination of pulse signals identified with the characters on a type writer.

· For the **Amplitude Modulation** the amplitude of carrier is made to fluctuate, to conform to the fluctuations of a sound wave.

· For the **Frequency Modulation** the frequency of the carrier is made to fluctuate around an average axis to correspond to the fluctuation of the modulating wave.

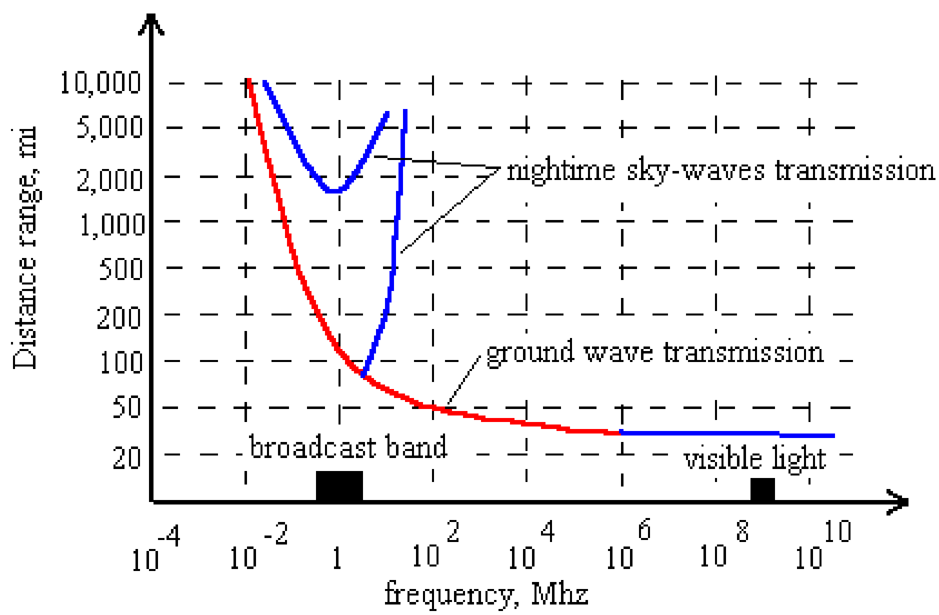
· For the **Pulse Transmission** the carrier is transmitted in short pulses, which change in repetition rate, width or amplitude or in complex group of pulses which vary from group to succeeding group in accordance with the message information.

2.3.3) The Radio Wave Propagation [Kenneth Bullington, 1992*]*

Radio signals are electromagnetic waves, which travel with the velocity of light and can be reflected, refracted, diffracted, scattered and absorbed. The radio frequencies are between 10 kHz and 60,000 MHz, which correspond to the wavelengths between 30,000 meters and 0.5 centimeters

Since frequency is an important parameter, radio propagation varies over a wide range. The power radiated from a transmitting antenna is ordinarily spread over a relatively wide area, as a result, the power available at host receiving antennas is a very small fraction (10^{-8} to 10^{-16} or less) of the radiated power. For example the frequencies around 20 kHz can be reliably at distances of thousand kilometers but are limited to telegraph-type signal and require very large transmitting antenna. In addition, as the frequency increase the transmission range tends to decrease, for example frequencies above 100 MHz can transmit wide band signal, but they are limited to approximately line-of-sight with the usual equipment.

Figure 7: Transmission Range of Electromagnetic Waves. 1 mi=1.6 km.

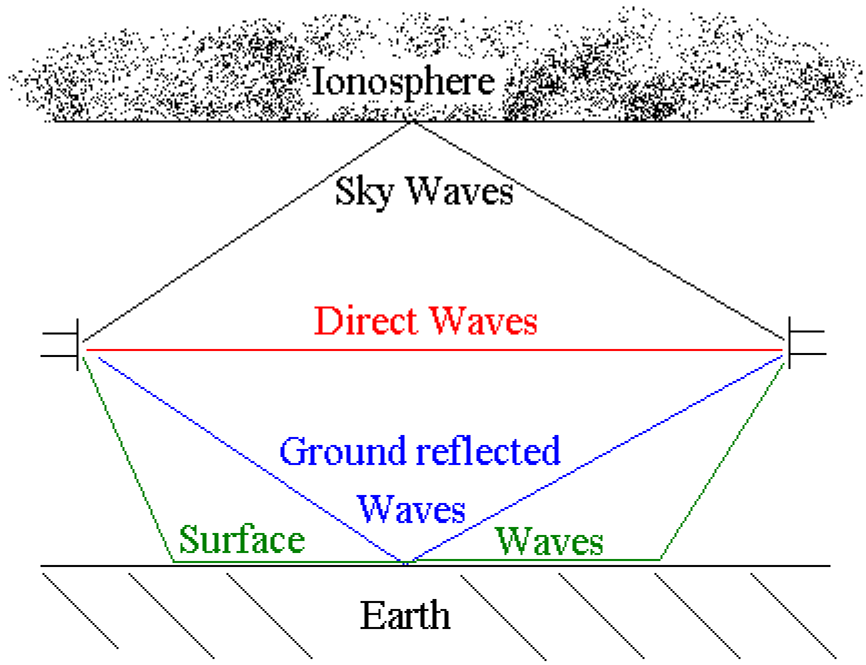


From "Radio Wave Propagation", *Mc. Graw-Hill Encyclopaedia of Science & Technology*

Like you can see on figure 9, there is four different way for the radio waves. **Sky Waves,** which are reflected by the Ionosphere, and **Surface Waves**, which follow the ground, have frequencies between 10 and 30 MHz. **Direct Waves**, and **Ground**

Reflected Waves, which are reflected by the Earth, have frequencies between 30 and 50 MHz. Although Sky, Direct and ground reflected waves could be easily visualised as ray, the surface waves are more difficult to understand. It originates at the air-Earth boundary because Earth is not a perfect reflector.

Figure 8: Different Type of Waves



From "Radio Wave Propagation", *Mc. Graw-Hill Encyclopaedia of Science & Technology*

2.3.3.1 Fading

Variations in the signal level with time are by changing atmospheric conditions. The severity of fading usually increases as either the frequency or path length increase.

At frequencies above 5,000-10,000 MHz the presence of rain, snow or fog introduce an absorption in the atmosphere that depend upon the amount of moisture, the particle size and the frequency. At frequencies higher than 15,000-20,000 MHz the additional attenuation caused by the heavy rain tends to limit the path length to only a few kilometers, if high reliability is required. The first absorption peak due to water vapor occurs at about 23,000 MHz and the first absorption peak for oxygen occurs at about 60,000 MHz.

2.3.3.2 Type of Radio Transmission

Radio transmission beyond the light-of-sight, can be achieved by three principal methods called refraction, diffraction, and reflection, but when these effect are intermixed and cannot be separate easily, the energy is said to be scattered.

The **Refraction** is function of the dielectric constant. The dielectric constant of the atmosphere normally decreases gradually with increasing altitude. The result is that on the average the radio ray is bent or refracted toward the Earth. The amount of refraction is variable, and exceptionally long-range transmission may occur occasionally.

Radio waves are also transmitted around the Earth by the phenomenon of **diffraction**. The amount of energy diffracted around an obstruction decreases as the frequency is increased. Typically obstruction include hills, trees, and buildings as well as the curvature of Earth.

Most of the experimental data at points far beyond the horizon are intermediate between the values expected for diffraction over a smooth sphere and for diffraction over a ridgelike obstruction. Various theories have been advanced to explain these effects, and the explanation most commonly accepted is that energy is **reflected or scattered** from atmospheric layers and turbulent air masses.

Ionospheric reflection returns to the Earth useful radio energy at frequencies up to 25 MHz and possibly up to 60 MHz, but there is variation in such transmission. First, there is a variation of the critical value between night and day that means that most skymove circuits require two or more frequencies for reliable service covering all hours. Second, In addition of these diurnal variations there are systematic change with season, latitude and the 11-year sunspot cycle. Third, in addition to the normal day time absorption, there is a second type of absorption which is particularly troublesome on transmission path that travel near or through the polar regions, it is the magnetic storm.

As the frequency is increased above that normally reflected from the ionosphere the signal intensity decreases rapidly, but it does not drop out completely, when this phenomenon happened the energy is said to be **scattered**. Although the signal intensity is low, reliable transmission can be obtained at frequencies up to 50 MHz or higher and to distances up to 1900 to 2400 km. Such ionospheric-scatter circuits require much higher power and largest antennas than are ordinary used in ionospheric transmission.

2.3.3.3 Noise

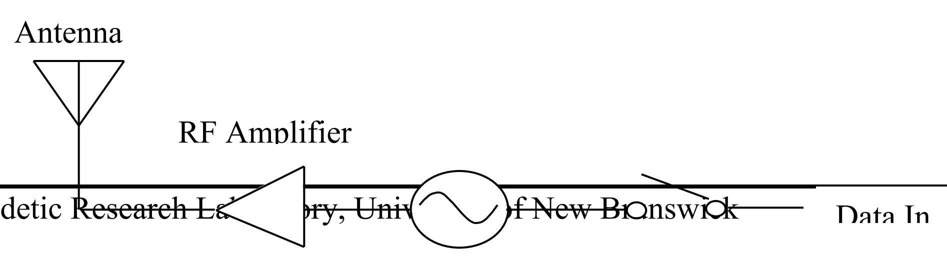
The usefulness of radio signal is limited by noise. The noise may be either unwanted external interference or noise originating by the receiver itself.

2.3.4) Transmitter and Receiver [Linx technologies, 1997]

In order for a signal to be transmitted wireless, it is necessary for the signal to be convoyed into free space, then recovered and restored to its original form. Two devices are used to accomplish this task:

2.3.4.1 The Transmitter

Figure 9: Simple RF Transmitter



The function of the transmitter is to take an analog or digital signal and, through an antenna, deliver into free space a simple transmitter is illustrated below.

You will notice the transmitter has three primary components:

· A frequency source, **the oscillator**, which generates the frequency at which the transmitter. This frequency is called fundamental

· There is also a gain stage, **the amplifier**, because it is necessary for the signal to be amplified before being transmitted effectively through the resistance of free space

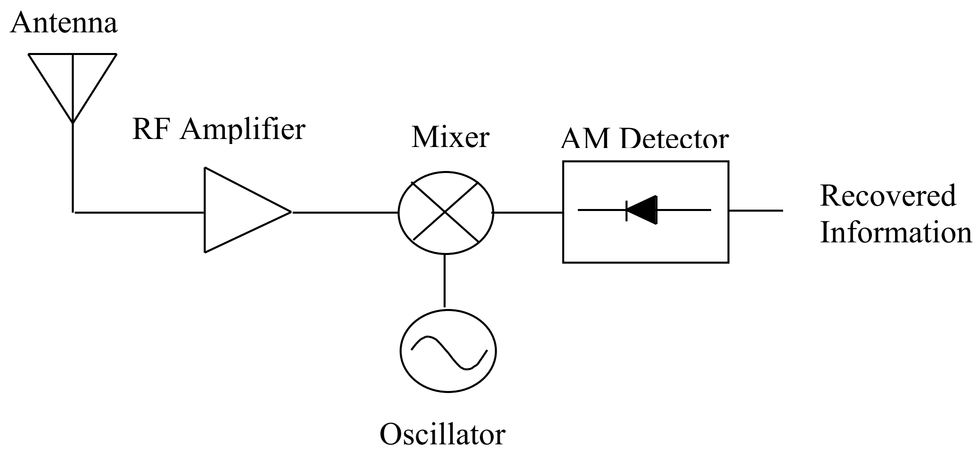
· The free space coupler, **the antenna**, provides the means by which the frequency contained within conductors makes the transition into free space. The transmitting antenna allows the RF energy into free space. It is in essence, a bridge between a guided wave and free space.

2.3.4.2 The Receiver

The purpose of a receiver is to receive the modulated carrier, remove it, and recover the original program signal. This process is called Demodulation.

Figure 11 illustrates a single conversion superheat AM receiver. While receiver topologies vary widely all involve several stages to effect the reception and recovery process. First the receiving antenna intercepts the electromagnetic waves radiated from the transmitting antenna. When these waves impinge upon the receiver antenna, they induce a small voltage in it. This voltage causes a weak current to flow, which contains the same frequency as the original current in the transmitting antenna. That frequency is amplified to more useable level and then fed into a device called a mixer. The mixer takes the incoming signal and combines it with an on-board frequency source called a local oscillator. This converts the signal to a new lower frequency called the Intermediate Frequency (IF). The detector then strips out the IF and leaves present only the original information content.

Figure 10: Simple Superhet Receiver



2.3.5) Application in the AVLN System

The radio, that is made at the beginning for verbal communication, can be use to transport information, but you have to choose carefully your frequency

TABLE 4: BAND CHARACTERISTIQUES

	Low VHF	High VHF	Low UHF	High UHF
Environment	Rural	Semi-urban	Urban	Urban
Penetration	Low	Medium	High	Very high
Vegetation effects	Low	Medium	High	Very high
Multipath	Low	Medium	High	Very high
Interference	High	Medium	Low	Very low
Noise	High	Medium	Low	Very low
Channel availability	Very low	Low	Low	Medium
Antenna size	High	Medium	Low	Very low
Antenna gain	Low	Medium	High	Very high
Equipment cost	Low	Medium	High	High
Coverage		Medium	Low	Low

From the Vehicle Navigation and Informations Systems Conference October 12-15, 1993

2.4 Packet Radio Network

2.4.1) History

According to Greg Jones, in 1995, Data packet technology was developed in the mid-1960's and was put into practical application in the ARPANET, which was established in 1969. Initiated in 1970, the ALOHANET, based at the University of Hawaii, was the first large-scale packet radio project. But the first time amateur packet was seen, was in Montreal, Canada in 1978. The first transmission occurring on May 31st. This was followed by the Vancouver Amateur Digital Communication Group (VADCG) development of a Terminal Node Controller (TNC), also known as the VADCG board, in 1980.

The current TNC standard grew from a discussion in October of 1981 at a meeting of the Tucson Chapter of the IEEE Computer Society. A week later, six of the attendees gathered and discussed the feasibility of developing a TNC that would be available to amateurs at a modest cost. The Tucson Amateur Packet Radio Corporation (TAPR) formed from this project. On June 26th 1982, Lyle Johnson, WA7GXD, and Den Connors, KD2S, initiated a packet contact with the first TAPR unit. The project progressed from these first prototype units to the TNC-1 and then finally to the TNC-2. Ten years ago, the packet radio revolution ignited when TAPR sold over a thousand TNC-2 kits. The TNC-2 was what was needed to make this mode, which a few experimenters were playing with, into something that every amateur could enjoy. From its humble beginnings, where it was good luck to have more than three packet operators in the same city, packet radio now has thousands of amateurs using it daily, various manufacturers making and selling TNCs (Terminal Node Controllers), and over a hundred thousand TNCs having been sold to date. What growth! No other mode of amateur radio has seen such explosive growth!

2.4.2) What Is It?

Packet radio is a particular digital mode of Amateur Radio ("Ham" Radio) communications, which corresponds to computer telecommunications. The telephone modem is replaced by a "magic" box called a terminal node controller (TNC); the telephone is replaced by an amateur radio transceiver, and the phone system is replaced by the "free" amateur radio waves. Packet radio takes any data stream sent from a computer and sends that via radio to another amateur radio station similarly equipped. Packet radio is so named because it sends the data in small bursts, or packets [*Greg Jones*, 1995].

2.4.3) What Do You Need?

According to Greg Jones, in 1995, you need three different things a Terminal Node Controller (TNC), a computer and a radio.

2.4.3.1 TNC

A TNC contains a modem, a computer processor (CPU), and the associated circuitry required to convert communications between your computer (RS-232) and the packet radio protocol in use. A TNC assembles a packet from data received from the computer, computes an error check (CRC) for the packet, modulates it into audio frequencies, and puts out appropriate signals to transmit the packet over the connected radio. It also reverses the process, translating the audio that the connected radio receives into a byte stream that is then sent to the computer. Most amateurs currently use 1200 bps (bits per second) for local VHF and UHF packet, and 300 bps for longer distance, lower bandwidth HF communication. Higher speeds are available for use in the VHF, UHF, and especially microwave region, but they often require special (not plug-and-play) hardware and drivers.

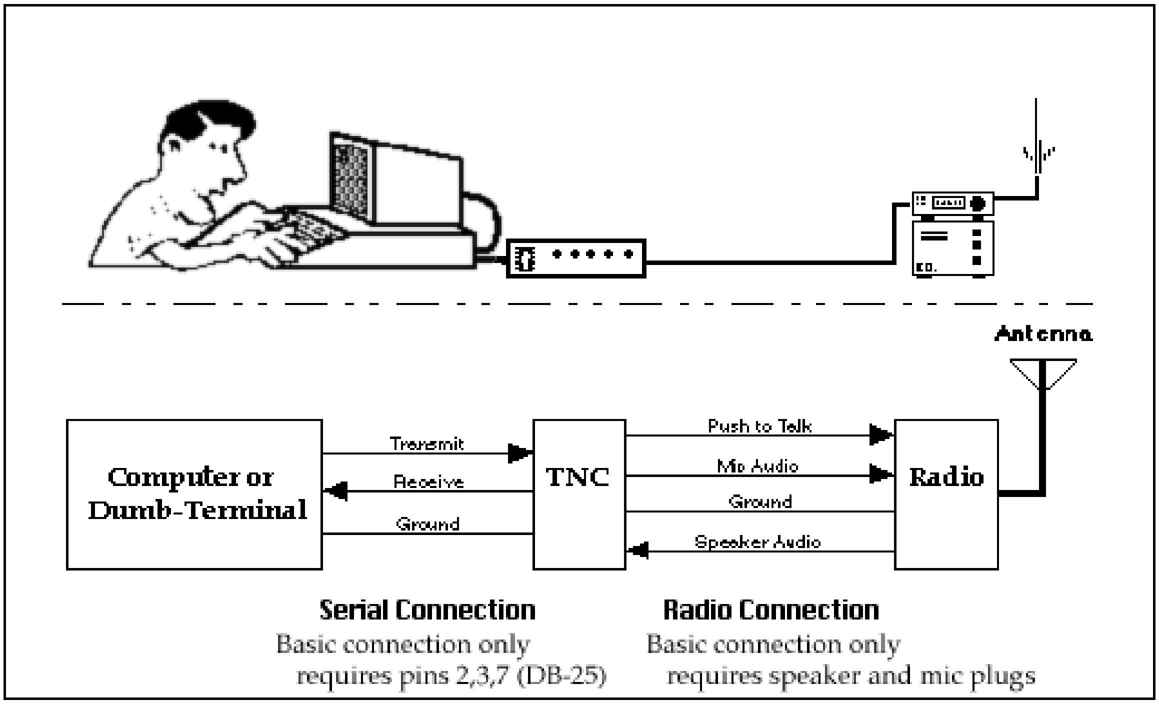
2.4.3.2 Computer or Terminal

This is the user interface. A computer running a terminal emulator program, a packet-specific program, or just a dumb terminal can be used. For computers, almost any phone modem communications program (i.e. Procomm+, Bitcom, X-Talk) can be adapted for packet use, but there are also customized packet radio programs available. A dumb terminal, while possibly the cheapest option, does have several limitations. Most dumb terminals do not allow you to scroll backwards, store information, upload, or download files.

2.4.3.3 A Radio

For 1200/2400 bps UHF/VHF packet, commonly available narrow band FM voice radios are used. For HF packet, 300 BPS data is used over single side band modulation. For high-speed packet (starting at 9600 bps), special radios or modified FM radios must be used. 1200 bps AFSK TNCs used on 2-meters (144-148Mhz) is the most commonly found packet radio.

Figure 11: Packet Radio Station



from http://www.tapr.org/tapr/html/pktf.html

The radio provides connectivity to a number of neighboring radios but typically *is not in direct connectivity with all radios in the network.* Thus the controller needs to provide for store and forward operation, relaying packets in order to accomplish connectivity between the originating and destination users. So the packet radios are intended to provide data communications to users located over abroad geographic region, where direct radio or wire connection between the source and destination users is not practical.

2.4.4) How Does It Work?

According to Barry M. Leiner et al., in 1987, the packet radio, based on the notion of packet switching applied to radio, usually share a single channel.

The link connectivity clearly depends on radio propagation parameters, such as the radio frequency, the distance between nodes, type of terrain, and the transmit power. Connectivity depends in addition on the data rate requirement, the channel RF bandwidth, and the data encoding and modulation schemes. For example propagation is typically better at lower frequencies (longer distances can be achieved with less sensitivity to the terrain) but data rates are lower at lower frequencies, and therefore the network ability to cope with mobility may be reduce. In the other hand, higher data rates would require a higher frequency bandwidth and probably Line Of Sight (LOS) propagation. This would result, though, in more capability to support overhead of network algorithms to handle changing connectivity resulting from mobility coupled with LOS propagation.

2.4.4.1 How to Allocate the Bandwidth?

According to Barry M. Leiner et al., in 1987, when you have chosen frequency band and RF bandwidth, You have to see how to allocate the bandwidth in time and space to the nodes in the network. Four techniques are available, all of which may coexist:

The **frequency division** refers to the partitioning of bandwidth into separate radio channels orthogonal in frequency domain. It is adequate if period of use for channel is long and the channel utilization high. Other way it can be useful in the provision of several channels, each of which is used for different function ability, but is shared in the time or code domain by many users.

The **Time division** refers to the allocation of a given radio channel to different users at different times. It is useful for the problems of channel access and capture modes.

The **Code division** refers to the provision of orthogonal spread spectrum codes to different (radio channels) users, so that these may use the same channel simultaneously without interference. It is useful for the problems of channel access and capture modes.

The **Spatial reutilization of the bandwidth-time resources** refers to the simultaneous use of a given portion of the channel bandwidth in different location without causing interference.

2.4.4.2 The Channel Access

According to Barry M. Leiner et al., in 1987, for the channel access you can choose between two systems: Narrow band and Spread Spectrum.

Aside from the limited effects of power am FM capture, the overlap of two or more packets at some receiver in Narrow Band systems results in the destruction of all. We say in this case that the system operates under a zero-capture mode. At glance time, the solution appears to be one, which guarantee orthogonality in the time domain. Time sharing of a channel by users can be achieved via random access schemes. The decision as to the whether to transmit or not is entirely left to the node and collisions may occur. There is two type of random access. First, the ALOHA scheme allows a node to transmit any time it wishes. Second, there is the Carrier Sense Multiple Access (CSMA) where a node transmits only if it does sense any carrier. In a fully connected network CSMA is better than ALOHA but ALOHA is cheaper and CSMA is limited by hidden nodes (i.e., nodes within range of the intended destination but not of the transmitter).

The spread spectrum system is quite the same but have two main differences. First the code division refers to the fact that transmission with orthogonal spreading codes may overlap in time with little or no effect on each other. Second time capture refers to the ability of receivers to successfully receive a packet with a given code despite the presence of other time overlapping transmission with the same code.

2.4.5) The AX.25 Protocol

The amateur radio community has expressed the need and desire to define a protocol that can accept and reliably deliver data over a variety of communications links between two signalling terminals. The AX.25 version 2.2 Link-Layer Protocol provides this service, independent of the existence of any upper layer.

This protocol conforms to International Standards Organisation (ISO) Information Standards (IS) 3309, 4335 and 7809 High-level Data Link Control (HDLC) and uses terminology found in these documents. It also follows the principles of Consultative Committee in International Telegraph and Telephone (CCITT) Recommendation Q.920 and Q.921 (LAP-D) in the use of multiple links, distinguished by the address field, on a single shared channel. Parameter negotiation was extracted from ISO IS 8885. The data-link service definitions were extracted from ISO IS 8886.

As defined, this protocol works equally well in either half- or full-duplex amateur radio environments, and has been improved for operation over partially impaired HF circuits. It works equally well for direct connections between two individual amateur packet radio stations, or between an individual station and a multi-port controller.

It permits the establishment of more than one link-layer connection per device, if the device is so capable. It also permits self-connections. A self-connection occurs when a device establishes a link to itself using its own address for both the source and destination of the frame.

Most link-layer protocols assume that one primary (or master) device (generally called a Data Circuit Terminating Equipment, or DCE), is connected to one or more secondary (or slave) device(s) (usually called a Data Terminating Equipment, or DTE).

This type of unbalanced operation is not practical in a shared RF amateur radio environment. Instead, AX.25 assumes that both ends of the link are of the same class, thereby eliminating the two different classes of devices.

Link layer packet radio transmissions are sent in small blocks of data, called frames.

There are three general types of AX.25 frames: Information frame (I frame);Supervisory frame (S frame); and Unnumbered frame (U frame).

Each frame is made up of several smaller groups, called fields. Figures and illustrate the three basic types of frames. Note that the first bit to be transmitted is on the left side.

TABLE 5: U AND S FRAME CONSTRUCTION

Flag	Address	Control	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	N*8 bits	16 Bits	01111110

TABLE 6: I FRAME CONSTRUCTION

Flag	Address	Control	PID	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	8 Bits	N*8 bits	16 Bits	01111110

Notes [*William A. Beech, Douglas E. Nielsen, Jack Taylor,* 1997]:

· The Info field exists only in certain frames

· FCS is the Frame Check Sequence field

· PID is the Protocol Identifier field

PART III. EXPERIMENT

3.1 The GPS Receiver

3.1.1) The Receiver

The GPS receiver used for this experiment is the NovAtel receiver RT20, 12. We have chosen this receiver because its configuration can easily be changed. For example one can choose what sort of data you want to send out of the receiver:

· NMEA Format, like GPGGA, GPGLL, GPRMB, or GPRMC, all in ASCII format

· NovAtel Format, both in ASCII or binary format

· RTCA Format

· RTCM Format

But the only format that interest us is the NMEA one because it is a standard format and it is accept by most of the display interfaces.

The NovAtel receiver has got GPSCard OEM. The GPSCard OEM series are multi-channel parallel tracking, C/A code (Coarse Acquisition) GPS receiver operating on the L1 (1575.42 MHz) frequency. Each dedicated channel independently tracks the code and carrier phase of a satellite in view and can provide a pseudorange accuracy within 10 cm [*NovAtel Communication Ltd*., 1994]. The standard deviation of this type of GPS for the position is about 100 meters on both latitude and longitude. You can see on appendix I a sample of the accuracy of the NovAtel receiver

3.1.2) The MBX-2 Beacon Receiver

To improve the accuracy of the GPS receiver you can use correctional data for the GPS. The MBX-2 receives RTCM-SC 104 messages that are broadcast by public radio beacons operating in the 283.50 to 325.00 MHz frequency range (You can see the DGPS Radio Beacon Listing for North America in Appendix II). The differential error correction messages are output via a serial port for use in the associated GPS receiver. The result is a 1 to 5 meters accuracy in differentially corrected position data. You can see in appendix I a sample of the accuracy of the combination of the MBX-2 Beacon Receiver and the NovAtel receiver.

3.1.3) The Internet Correction

Now you can find a site that provides some RTCM correction in real time over the Internet: http://www.wsrcc.com/wolfgang/gps/dgps-ip.html. All you need is some software that can read the RTCM sentences coming from the Internet, you can find some on the same site. For the moment two Beacons provide some corrections, one situate in Point Blunt, California, the other is in Columbia University, New York City, New York.

3.2 The Software

3.2.1) Different Software Tested

I found several different interfaces on different web sites.

TABLE 7: DIFFERENT SOFTWARE

Name	type	Price	Where can you find them
WinAPRS	Shareware	$60 US	ftp://aprs.rutgers.edu/pub/hamradio/APRS/WinAPRS/
GPS Positioner Pro	Freeware		http://home.multiweb.net/~toornenb/
Navigate	Shareware	$30 US	http://www.intranet.ca/~pmouland/index.html

Navigation Wonder	Shareware	$79 to 89 US	http://www.vader-abraham.com/gpssoft.htm
Nav Pack	Shareware	$60 US	Http://www.globenav.com/
Win GPS	Shareware	$60 US	Http://ourworld.compuserve.com/homepages/wingps/

All these programs have been found on the Web and can be use by the university, sometime only for a definite period, sometime some function are not available. After a few tests on each of these programs, I can tell you the advantage and the disadvantages of each of them.

APRS

Advantages

· Made for packet radio
· Good interface

Disadvantages

· Have is own map format
· The software is $50 US

GPS Positioner Pro

Advantages

· Good interface
· Freeware
· Can import your own maps
· Can parameter the communication with the GPS.

Disadvantages

· Can't see where you are on the map

Navigate

Advantages

· Good interface
· Very simple utilisation
· Can import your own maps

Disadvantages

· No access to parameter the communication with the GPS

Navigation Wonder

Advantages	Disadvantages
· Very simple utilisation	· The software is $79 US
· Can parameter the GPS communication	· Time limited access
· Can import your own maps	· Computer often crash
	· Problem of calibration for certain maps

Nav Pack

Not adapted for the use we wanted because you can't import your own maps, and because it is essentially made for the boat navigation.

Win GPS

Advantages	Disadvantages
· Don't need the software version	· software version: $60 US
· Good interface	
· Can parameter the GPS communication	
· Very simple utilization	
· Can import your own maps	

3.2.2) Choose of the Software

The software chosen to locate vehicles is APRS, first of all because it is the only one we checked that have all the function we need for the work:

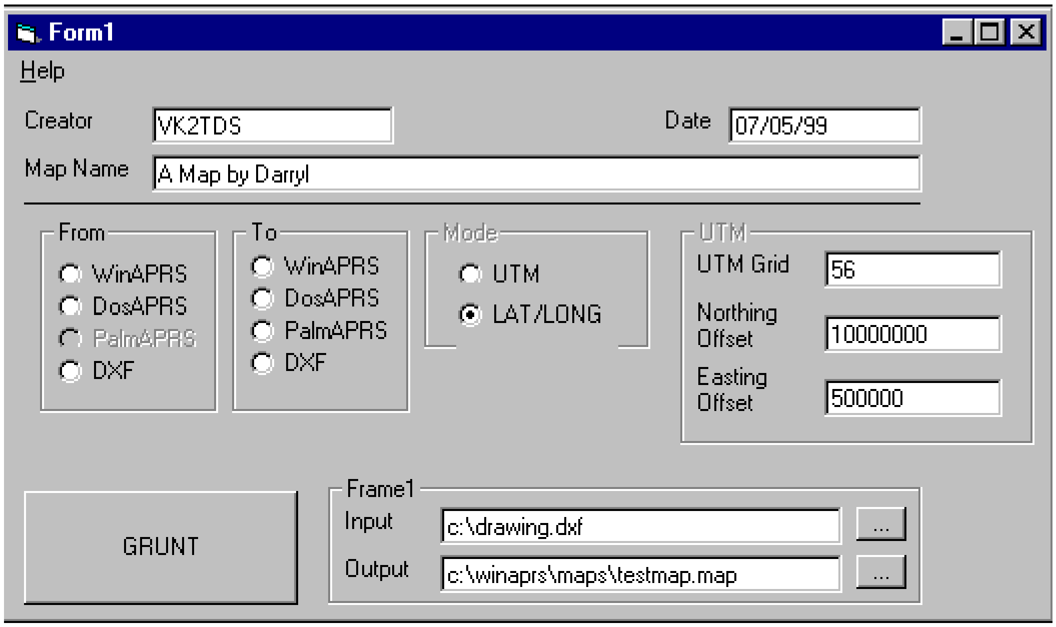
- Can import your own map.
- The calibration of the map is very easy to do
- Can track several vehicles at the same time
- Can have further information on the area via the packet-radio broadcast or internet.

3.2.2.1 Import Your Own Map

There is two different kind of map in WinAPRS:

The .MAP format that is the "official" format for the map in the program. But the problem is the difficulty to import some map in this format. Several programs exist to transform .DXF map into .MAP (like DXF2MAP from Darryl Smith, VK2TDS)

Figure 12: The Interface DXF2MAP



The only problem is that you have to get, a first the map in **geographical coordinates**, you can't import a map with any kind of projection, and the conversion from a project map to the geographical is not difficult in practice if you do it point by point, but it's very long.

WinAPRS also supports GeoTIFF files. GeoTIFF is a TIFF image with geo-referencing information added. It is important to realize that, if these files work well, you will probably need 64 Megs of memory to be able to use VERY LARGE IMAGES with WinAPRS. Because of their size, they may also be very slow to read and display. The author has tried some different kind of images, like satellite images, or DRG (Digital Raster Graphic) files.

But sometimes these GeoTIFF file do not work with WinAPRS. For these files you have to use and other way to import them, like if they haven't any Geo-references.

If you have an image, *Fredericton.gif* for example, and if it doesn't already have the Geo-Reference information, place it in the IMAGES directory, then create a file called *Fredericton.GEO* and place it in IMAGES as well. The .GEO file has the following format:

```
FILENAME	Fredericton.gif
#	x	y	Longitude	latitude
TIEPOINT	51	98	-66.664057	45.984431
TIEPOINT	678	450	-66.637014	45.952074
#1 - Sunset Dr E - Main Street
#2 - University - Landswone
#Accuracy 2.5 meter (come from 1:10000 SNB provincial map)
```

· Tabs, not spaces, must separate the fields.

· The first line refers to which image it is for, this is for future use.

· The minus is for West in Longitude and South in Latitude.

· Any line starting with '#' is a comment.

You have to have 2 "TIEPOINTs", these associate a Lon/lat. with an x/y of the image. The X and Y are in pixels of the image, the Lon/lat. of the point are respectively the Longitude and the latitude in DECIMAL degrees of the points specified by X and Y. The more accurate that you have this, the better the image map will work. The second point MUST be to the right and below the first point. It is best to have the first point as close to the top left as possible and the second point as close to the bottom right as possible.

Note: The image MUST be OTHOGONAL, this means that the map lines up square with lat./Lon.

3.2.2.2 Track Several Vehicle at the Same Time

You can see on the figure 13 next page different type of symbols to represent the vehicle tracked. To choose the symbol you wanted you simply have to add an extension (-n), between 1 and 15, to your callsign

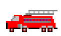
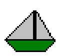
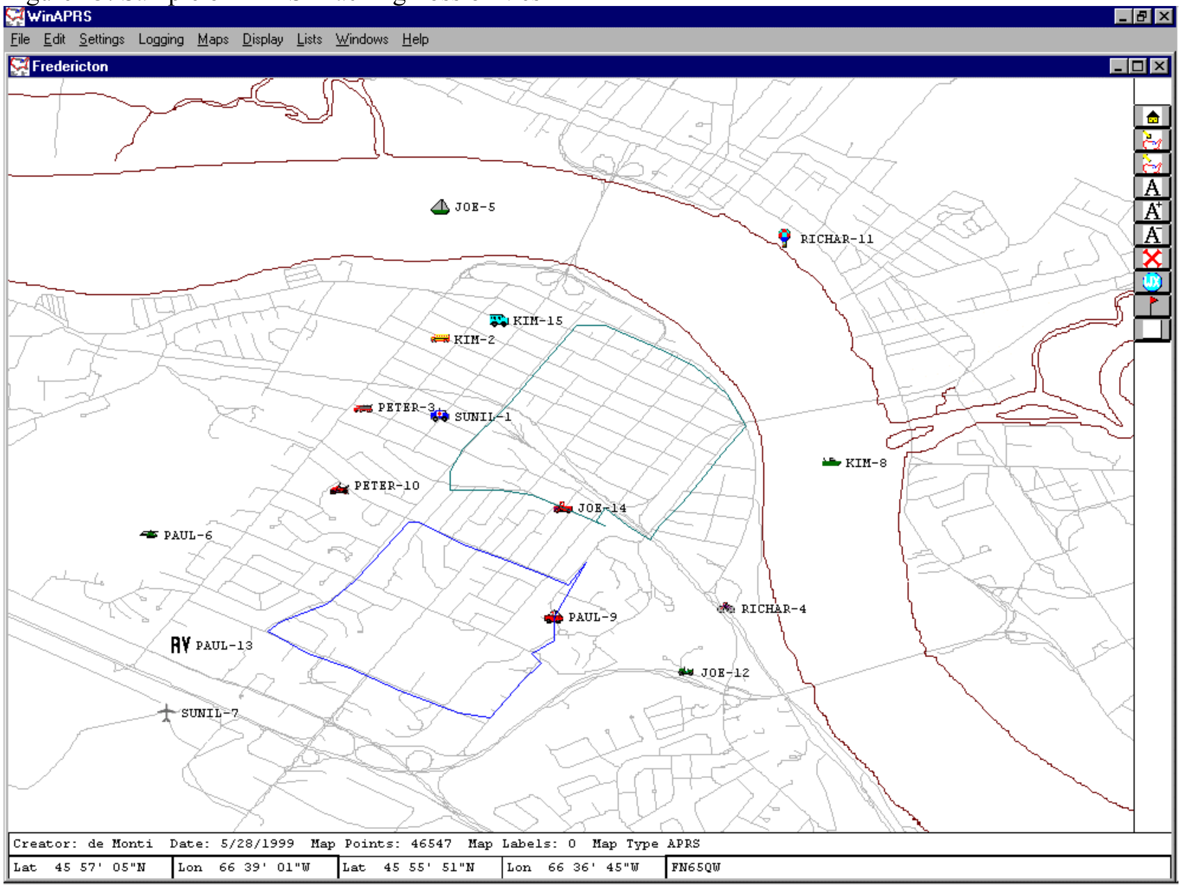
	Ambulance	SSID-1
	Bus	SSID-2
	Fire Truck	SSID-3
	Bicycle	SSID-4
	Yacht	SSID-5
	Helicopter	SSID-6
	Air Plane	SSID-7
	Ship	SSID-8
	Car	SSID-9
	Motorcycle	SSID-10
	Balloon	SSID-11
	Jeep	SSID-12
	Recreational Vehicle	SSID-13
	Truck	SSID-14
	Van	SSID-15

Figure 13: Sample of APRS Tracking Possibilities



3.2.2.3 Other information you can have

if you are on one of these frequencies, you can "hear" the other radio and see them on the current map:

· VHF -144.390 MHz this is the new frequency most people are moving to

· VHF -145.790 MHz this is no longer used in most of the US

· HF - 10.151.51 Lower side band, NOTE, the carrier is actually 2125 KC down from this so it IS within the ham bands even though it doesn't seem like it.

You can also have some weather information sent by other ham radio and finally, with a TCP/IP connection you have access to different APRS servers on the internet to see where are situated the other hams radio you can't reach by the broadcast.

3.3 The Link Between Receiver and Interface

3.3.1) Hardwired Connection

I only tried to connect the GPS with the software in which you can import your own map. The NMEA sentences sent from the receiver was the GPRMC or GPGGA sentence that show the GPS Specific information.

$GPRMC	Utc	Pos status	Lat.	Lat. Dir	Lon	Lon dir	Speed Kn	Track true
Date	Mag var.	Var. dir	*xx	[CR] [LF]				

$GPGGA	Utc	Lat.	Lat. dir	Lon	Lon dir	GPS qual	# sats	Hdop	Alt.
Units	Null	Null	age	Stn ID	*xx	[CR] [LF]			

TABLE 8: STRUCTURE OF THE GPRMC SENTENCE

Field	Structure	Field description	Symbol	Example
1	$GPRMC	Log header		$GPRMC
2	Utc	UTC of position	hhmmss.ss	182753.0
3	Pos status	Position status: A= data valid; V= data invalid	A	A
4	Lat.	Latitude (DDmm.mm)	lll.ll	4557.0098130
5	Lat. Dir	Latitude direction (N= North, S= South)	a	N
6	Lon	Longitude(DDDmm.mm)	yyyyy.yy	06638.4883092
7	Lon dir	Longitude direction (E= East, W= West)	a	W
8	Speed Kn	Speed over ground, knots	x.x	0.557
9	Track true	Track made good, degrees True	x.x	8.7
10	Date	Date: dd/mm/yy	xxxxxx	080499
11	Mag var.	Magnetic variation, degrees	x.x	0.0
12	Var. dir	Magnetic variation direction E/W	a	E
13	*xx	Checksum	*hh	*73
14	[CR] [LF]	Sentence terminator		[CR] [LF]

From GPSCard™ Command Description Manual

TABLE 9: STRUCTURE OF THE GPGGA SENTENCE

Field	Structure	Field description	Symbol	Example
1	$GPGGA	Log header		$GPGGA
2	Utc	UTC of position	hhmmss.ss	183055.2
3	Lat.	Latitude (DDmm.mm)	lll.ll	4557.01633456
4	Lat. Dir	Latitude direction (N= North, S= South)	a	N
5	Lon	Longitude(DDDmm.mm)	yyyyy.yy	06638.5370995
6	Lon dir	Longitude direction (E= East, W= West)	a	W

7	GPS qual	GPS quality indicator 0 = fix not available or invalid 1 = GPS fix 2 = Differential GPS fix	x	1
8	# sats	Number of satellites in use (00-12). May be different to the number in view	xx	08
9	Hdop	Horizontal dilution of precision	x.x	0.9
10	Alt.	Antenna altitude above/below mean sea level (geoid)	x.x	18.362
11	Units	Units of antenna altitude (M = meters)	M	M
12	Null	(this field is not available on GPS card)		,,
13	Null	(this field is not available on GPS card)		,,
14	Age	Age of differential GPS data (in second)	xx	,,
15	Stn ID	Differential reference station ID, 0000-1023	xxxx	,,
16	*xx	Checksum	*hh	*48
17	[CR] [LF]	Sentence terminator		[CR] [LF]

From GPSCard™ Command Description Manual

The parameters of the receiver for the link with the interface are the same than the parameters of the link between the antenna and the receiver:

TABLE 10:PARAMETER OF THE HARDWIRE TRANSMISSION

Syntax	Possible Value	Description	Value
COMn	n=1 or 2	Specify COM port	com 1
Baud	300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600 or 115200	Specify baud rate	9600
Parity	N (none), O (odd), E (even)	Specify parity	N
Databits	7 or 8	Specify number of data bits	8
Stopbits	1 or 2	Specify number of stop bits	1
Handshake	N (none), XON (Xon/Xoff) or CTS (CTS/RTS)	Specify handshaking	N
Echo		Specify echo	OFF

From GPSCard™ Command Description Manual

Pay Attention to have the same configuration for parameter of the communication in your software.

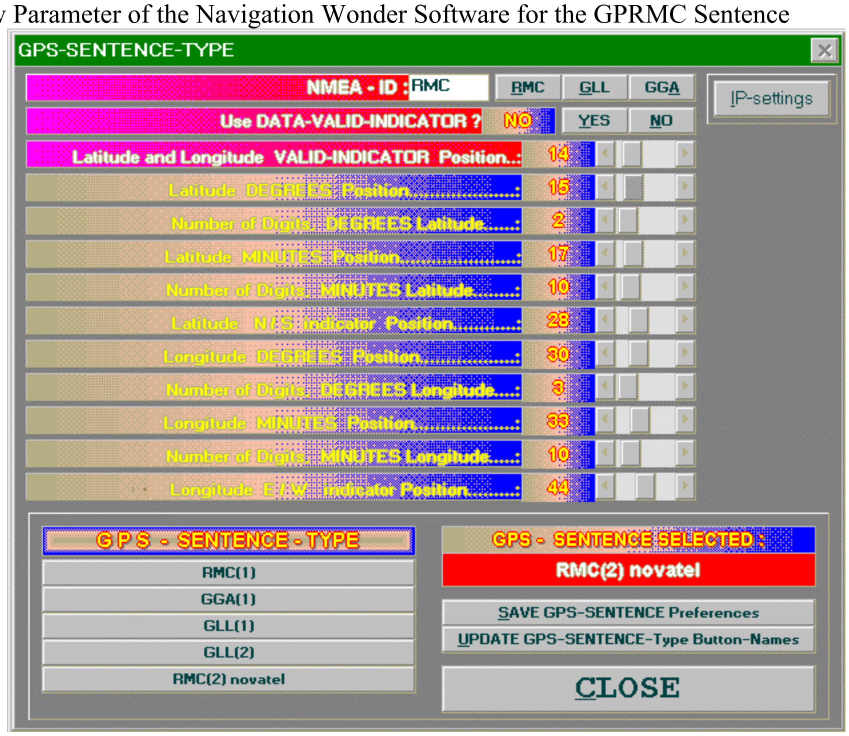
No main problem have been encounter with **GPS Positioner Pro** to visualized the receiver position in the software, but you only have the coordinate of the receiver, you don't have a pointer on the map to show you where you are.

The parameters of the communication with the GPS receiver are easily accessible, and the windows are very explicit.

No problem with **Navigate** about the GPS communication, but you can't access the parameters of the link between the receiver and the interface.

The main problem of **Navigation Wonder** was that you didn't receive the GPRMC sentence correctly, because the parameter wasn't made for the NovAtel receiver.

Figure 14: New Parameter of the Navigation Wonder Software for the GPRMC Sentence



The interface to configure the parameter of the hardwire connection is very convivial.

No main problems have been encounter with **WinGPS** and the interface to configure the parameter of the hardwire link is very simple to use.

3.3.2) The RFM 96W Connection

The RFM 96W is a radio modem that can transport data in different modes [*Pacific Crest Corporation,* 1996]:

· The **Transparent mode EOT character** is used to simulate a transparent interface between the data terminal equipment (DTE) which are communicating over the radio modem link. In this mode data are send in free format and the character which initiates transmission is user defined

· The **Transparent mode EOT time-out** is similar to the Transparent mode EOT character, except that it uses a time-out value instead of a particular character to initiate transmission.

· In **Packet mode** of operation, the DTE send format data packets to the RFM 96W. This mode is used to send data to a specific modem in a network of modems.

· In **Digipeater mode**, the RFM 96W is used as a stand-alone repeater with no data being passed to the local communication port.

· The **Fast asynchronous mode** allows the most efficient use of the radio channel by transmitting data in a raw format with no packet overhead or forward-error-correction information.

The radio modem used for this experiment was the 97099123 as Transmitter and the 97099125 as receiver. The first try of communication was executed with the next radio configuration (same for the transmitter and the receiver):

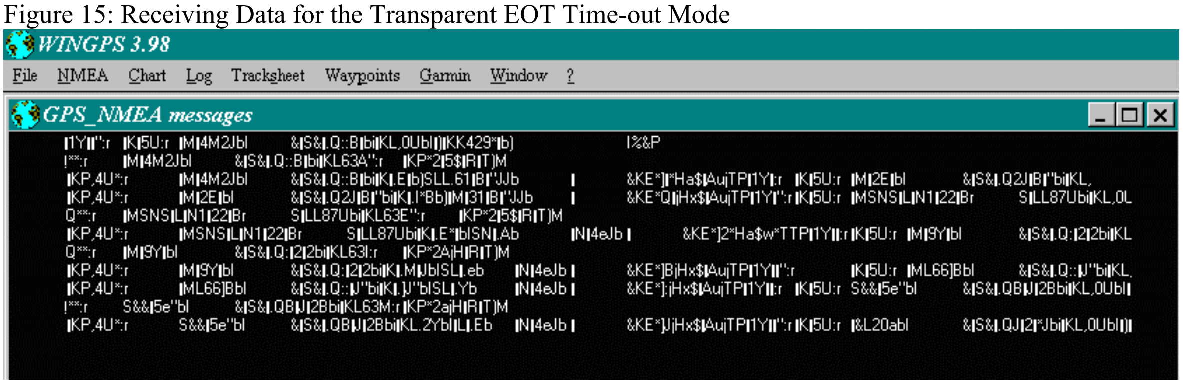
Config Date	: Apr 7,1999	DTE-DCE baud	: 9600
Model	: RFM96W 150-173 2	DTE-DCE Parity	: None
Serial Number	: 97099123 (transmitter)	RS-485 Delays	: 0
	: 97099125 (receiver)	Break to Command	: Off
Firmware Rev	: 4.01	Mode	: Transp w/EOT timeout
Owner	: Ocean Mapping Group, GGE, UNB	EOT	: 5
		Digi Delay	: 0.00
Channel	: 0	Local Node	: Non-Repeating

Link Rate	: 9600
Retries	: 3
CSMA Monitor	: On
FEC	: On
Scrambling	: On
Digisquelch	: Moderate
TX ACK Time-out	: 0.10

Address (Local)	: 0
Address (Dest)	: 255
Features	: Advanced Comm, 9600 Link Rate
Channel 0	TX Frequency: 172.7250
	RX Frequency: 172.7250

The receiving data was:

Figure 15: Receiving Data for the Transparent EOT Time-out Mode



So I decided to change the configuration of the transmitter and the receiver:

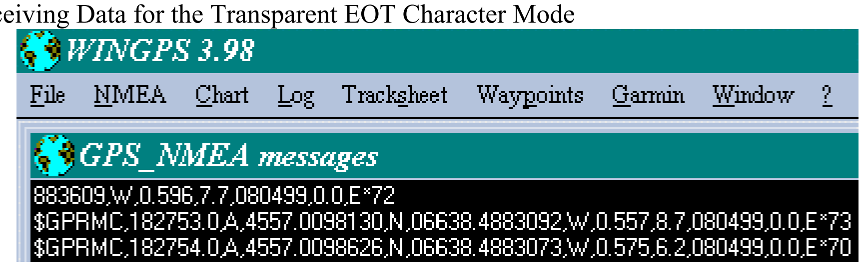
Config Date	: July 7,1999
Model	: RFM96W 150-173 2
Serial Number	: 97099123 (transmitter)
	: 97099125 (receiver)
Firmware Rev	: 4.01
Owner	: Ocean Mapping Group, GGE, UNB
Channel	: 0
DTE-DCE baud	: 9600
DTE-DCE Parity	: None
RS-485 Delays	: 0
Break to Command	: Off
Mode	**: Transp w/EOT character**
EOT	**: 10**
Digi Delay	: 0.00

Local Node	: Non-Repeating
Link Rate	: 9600
Retries	: 3
CSMA Monitor	: On
FEC	: On
Scrambling	: On
Digisquelch	: Moderate
TX ACK Time-out	: 0.10
Address (Local)	: 0
Address (Dest)	: 255
Features	: Advanced Comm, 9600 Link Rate
Channel 0	TX Frequency: 172.7250
	RX Frequency: 172.7250

The EOT (End Of Transmission) is the character marking the end of each packet transmitted and 10 in decimal correspond to linefeed, <LF>, in ASCII modes [*Pacific Crest Corporation,* 1996] that is the term finishing the GPRMC sentence like said in the 3.3.1 paragraph.

This time something was received but nothing was appearing on the screen, it was Only a problem of configuration of the parameter in the software: You have to put 2 for the number of stopbits in the message because you have one coming from the GPS receiver and one coming from the radio modem.

Figure 16: Receiving Data for the Transparent EOT Character Mode



The transmission can be ameliorate if you change the local address and the destination address of the transmitter and the receiver because 255, for the destination, address means that the message is transmitted to all the radio which receive on the frequency 172.7250 MHz. For example (you can choose any number between 0 and 244):

Transmitter	: Local address	0
	Destination address	1
Receiver	: Local address	1
	Destination address	0

In that way you don't disturb the other radio users, and you have got only a few disturbance by the others.

The only limitation is that you can only use it for a one way communication and you cannot use several GPS receivers at the same time because there are no specifications for where the message come from when it is sent.

3.3.3) The Packet Radio

To program the packet radio (see Appendix III) you must use software that enable your computer to operate with an ordinary telephone modem. There are many sources of free or low cost communication software for use with the TNC, like the HyperTerminal from Windows. You can also find some samples on ftp://ftp.tapr.org/software_lib/terminal/. For the Experiment I have chosen to use UltraPack 4.0 (copyright © 1995 T.D. Kearsley, G4WFT) and the HyperTerminal from Windows.

3.3.4) Choosing The Link

The best link to use with APRS is the packet radio link because the software was design for that sort of communication, other way that is the only one that can handle to track several vehicles at the same time. When a TNC (terminal node controller) send a message on the broadcast, it send this one by packet with the "address" of the transmitter and the "address" of the receiver (see table 4 and 5 pp. 22), so you can separate the information on the map, like you can see on figure 13 pp. 53.

3.4 The Data Collected

3.4.1) 22 June 1999

The data were collected on a trip of about 25 kilometers in and around Fredericton. According to the data (appendix V), received or not, we can see, on the next picture, the different problems encounter during the experiment.

· In blue are the part of the circuit there wasn't any problems

· In Green are the part of the circuit the GPS receiver lost the signal

· In red are the part of the circuit the radio lost the signal

Figure 17: Results Shown by APRS of the Experiment of 1999-06-22

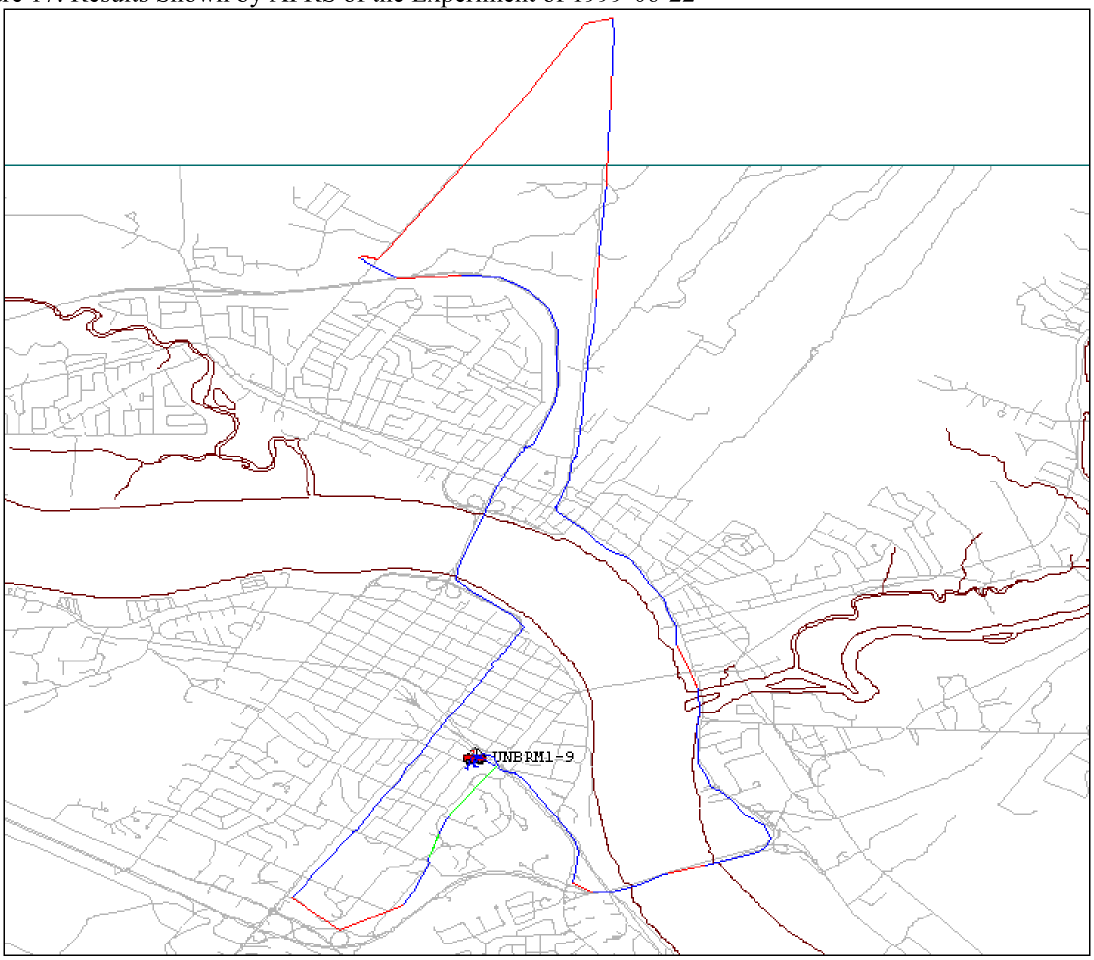


Figure 18: Base Station

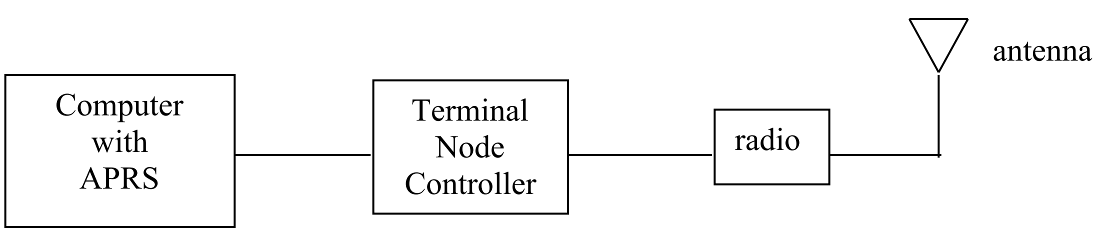
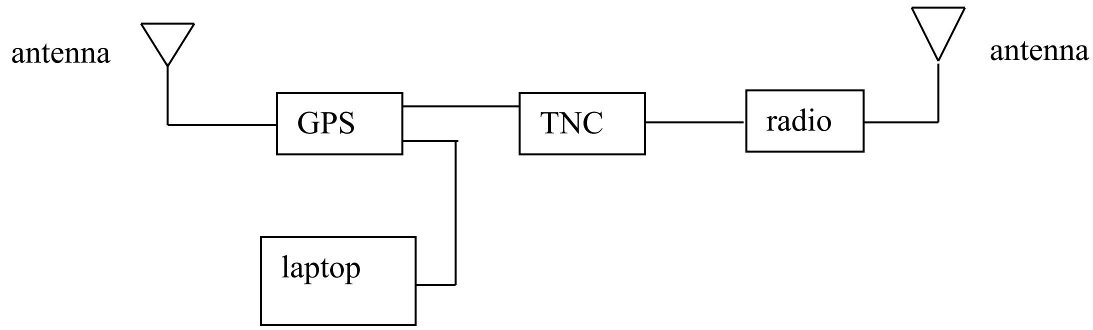


Figure 19: Part of the System in the Vehicle



For more information on the settings, see the section *Normal Setting* in Appendix IV.

The GPS antenna and the radio antenna of the vehicle, were put as far as possible one to the other to limit the problem of interference.

The GPS was set to send to the TNC a GPGGA sentence every 10 seconds and the experiment was 45 minutes long. At the beginning the packet received was form with junk characters but after a few packet the system was receiving some GPGGA sentences. During the trip, the system worked quite well except some lost of data during the transfer between the GPS receiver and the software, and some lost of signal by the GPS receiver. When the GPS receiver lost the signal it send the GPGGA sentences, but without any coordinate and with a differed time (you can see part of the file in appendix V)

You can see every GPGGA sentences received by the radio in appendix VI. Each one is symbolized with a circle that is 100 metres in radius. According to this map all the result are in the 100 meters you can expected with the SPS (Standard Positioning Service). You can see that this precision is enough for the part of the experiment in the country but not in the town.

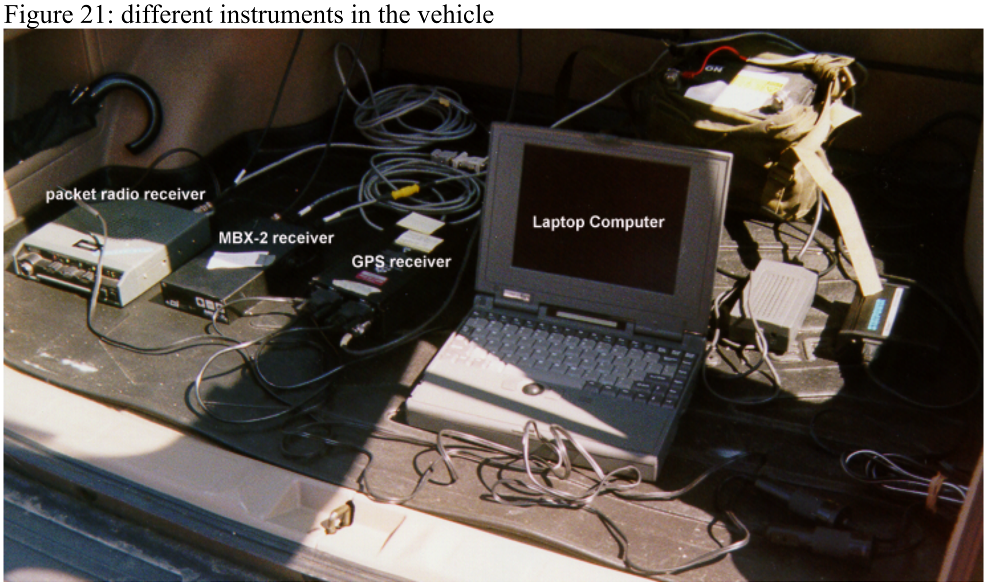
Only one major problem happened during the experiment at the intersection between Brockside road and the ring. We were able to “hear” the problem because all along the experiment we were scanning the radio transmissions. At this crossroad, apparently the data were send correctly but were not received because there was a lot of noise and interference.

The experiment was very interesting but showed me what was missing for the next one: we also needed to register the data in the car to make some comparison.

3.4.2) 15 July 1999

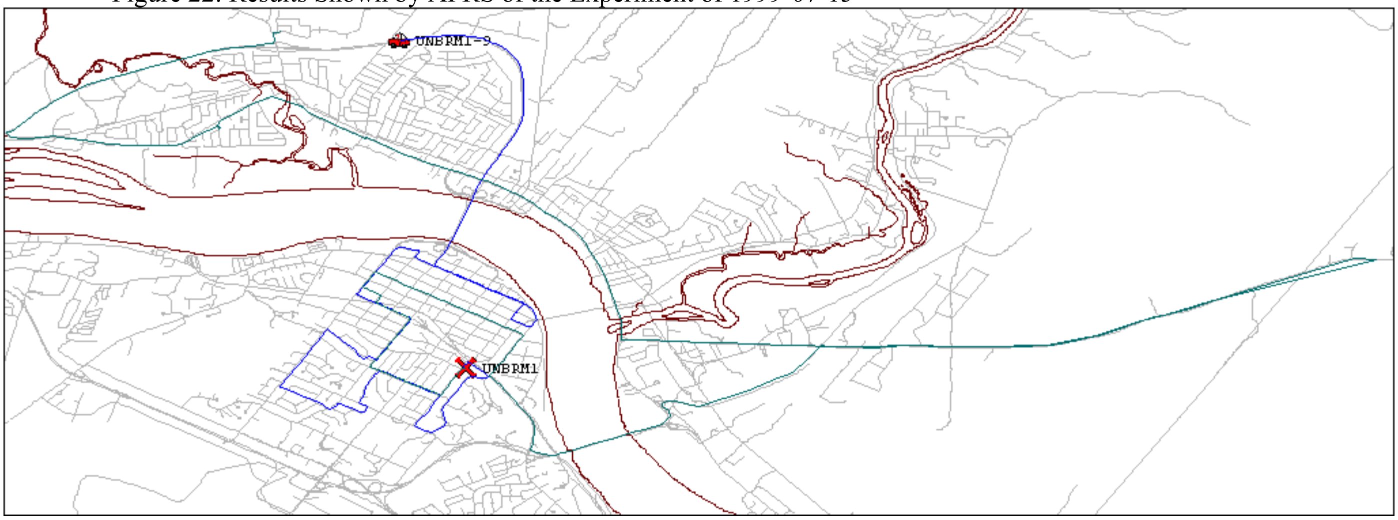
Figure 20: different antennas on the vehicle

Figure 21: different instruments in the vehicle



The data were collected on a trip of about 67 kilometres in and around Fredericton. All the information on the settings, for this experiment are given in appendix IV, DGPS settings.

Figure 22: Results Shown by APRS of the Experiment of 1999-07-15



This second experiment was undertaken with a radio beacon receiver that can receive RTCM corrections: The MBX-2 (see section 3.1.2).

We only had an accuracy of 10 meters, however we expected an accuracy of 1 to 5 meters. The first reason is the movement of the vehicle increases the lost of the beacon signal so the RTCM correction was, in certain case, too old to give us the best accuracy. Secondly, we transformed a projected map, Stereographic projection on ATS77 ellipsoid, in a geographical projection only with a translation and scale change. The problem is that we received the coordinate in geographical coordinate but on WGS84 ellipsoid. Therefore we have a difference of coordinate of about 1 metre because of the difference of ellipsoid and some more errors due to the transformation. Thirdly, the points used for the calibration were known at 2.5 meters because they come from a 1:10000 SNB provincial map.

The GPS receiver was set to send a GPGGA sentence to the TNC every 5 seconds (see appendix VII), in the same time it send GPGGA and GPGSA (satellites used for navigation and DOP values) sentences every 5 seconds to the laptop to make some comparison (see the comparison in appendix VIII).

Like on the first experiment, when the TNC set up itself, some junk characters appears on the transmission. During the first part of the trip (before the crossroad between the ring and Brockside road) the transmission appears to work properly even in the city. At the crossroad, the TNC stop to transmit and then we got a lot of interference on the scanner (like for the first experiment). When we stop to see what happened it occurs that the GPS receiver comes back to the default settings (position fixed), therefore we had to reset the GPS. But something we only notice when we came back is that the TNC comes back to the default setting too. It wasn't a problem, we just had some junk characters like at the beginning and then instead sending Unproto messages to GPS it sends them to CQ. The other change was that instead sending the GPGGA sentences in one packet it sends it in two packets. The same problem occurs several times (four time to be precise) after this, only those times the TNC didn't reset, before noticing that the problem was the connection between the laptop and the cable of the GPS receiver. After we tapped them together, we didn't have the problem anymore.

Instead of what we projected, there occurs only a few separate lost of GPS signal during the trip below 15 seconds (see appendix VIII), therefore we always lost less than two plot on the screen, except on Baker Point Bypass where we lost 5 plot (between 25 and 30 second).

The radio signal was lost a along the track but only for not more than two consecutive sentences each time (see appendix VIII). However when we were on Greenwood drive (NB

10) further than 6.5 kilometres where the radio signal didn't pass throw except when there were no obstruction at all between the transmitter and receiver.

PART IV. CONCLUSION

We've seen that there are many different ways to locate a vehicle on the earth. Most of these techniques are associated with a map display, which is a more convivial way to locate something. Of course you can only give the coordinates of the locations, and the coordinates of the destination and let people find their way but this is not necessarily enough information about the environment to succeed. Even if it is an important part of the positioning concept, we didn't test any map display interfaces using map matching (section 2.1.4), because we didn't want to restrict our investigation to positioning vehicles only on known roads. We can also use this system for other purpose like project advancement, cross-country travel or riding…

As you've seen in section 3.4.2, the calibration of the map you use is very important because you can add some errors to the position of your vehicle. Here is some advises for good map calibration:

· Make sure that the ellipsoid that the projection uses is the same as the ellipsoid the GPS receiver uses for its coordinates (the most common ellipsoid used by GPS receivers is WGS84).

· Most of the maps you can find are given in projected coordinates, but most of the GPS receivers give you the geographical coordinates (some map display programs, as APRS, only use geographical coordinates). Therefore you need to find a program to transform your coordinates, because for the small scale maps the error, if you only do a translation and change of scale, can be more than a meter.

For our purpose we used a basic GPS receiver which only uses the code on L1 (section 3.1.1) in determining coordinates. This allows us to have 100 metres accuracy in SPS and 5 meters accuracy in DGPS. You can also use some better GPS receivers, like a GPS receiver which tracks the carrier phase and the code on both L1 and L2, if you want a better accuracy, but it will cost you more. With that kind of GPS receiver the manufacturers claim that you can have a 1 centimetre accuracy in differential mode on short or medium baselines but at the worst you can have between 5 and 10 centimeters accuracy.

During our research via the Internet, we found a site that gives DGPS corrections (section 3.1.3). These corrections can be used even if the baselines to the DGPS stations are extremely long (over 4500 kilometres for the one in Point Blunt, California, and about 1000 kilometres for the one in New York City). We observed interesting results for vehicle tracking: about 10 meters accuracy (appendix I). Therefore after the exploration of the GPS and the radio beacon DGPS positioning systems, we can explore a third way: The Internet DGPS positioning system. To run this with APRS we just need to make a program that correct pseudo-GPGGA sentences with the help of pseudo-GPGSA sentences and GPRMC sentences. I name Pseudo NMEA sentences according to:

SSID-n>SSID: [NMEA sentence]

where SSID-n is the usual packet radio callsign of less than six letters with an extension between 1 and 15, SSID is either the usual callsign or one of the following generic callsign: APRS, BEACON, ID, CQ, QST, MAIL, SKYWRN, GPS, DFNET, TEST, DRILL, or SPCL. You can look at appendix V and VII for some examples of pseudo-GPGGA sentences.

As you can see the systems can be improved to be easier to use. In particular the arrangement of the hardware concept to be installed in a vehicle could be better integrated, but you can also explore some other ways like Eric MacIntosh and James Tam did in their thesis. They used a map display interface that allows connections with the Internet.

PART V. REFERENCES

Beech, W.A., Nielsen, D.E., Taylor, J, (1997) AX.25 Link Access Protocol For Amateur Packet Radio, Version 2.2, http://www.tapr.org/tapr/html/fax25.html.

Bullington, K. (1992). "Radio Wave Propagation", *Mc. Graw-Hill Encyclopedia of Science & Technology,* Volume 15, pp. 92-96.

Dana, P.H. (Feb, 1999). "Global Positioning System Overview" http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html [last modified, 01-Feb.-1999]

Dupont, H.L. (1992). "Inertial Guidance System", *Mc. Graw-Hill Encyclopedia of Science & Technology,* Volume 9, pp. 129-130.

Feid, L. (1992). "Satellite Navigation System", *Mc. Graw-Hill Encyclopedia of Science & Technology,* Volume 16, pp. 57-61.

Harris, C.B. (Dec. 1989). *Prototype for a land based automatic vehicle location and navigation system*, UCSE Report.

Jones, G. (1995) "What is packet radio", http://www.tapr.org/tapr/html/pktf.html [last modified 31-Jan.-1999].

Krakiswki, E.D (Oct. 1993). "The diversity among IVHS Navigation systems Worldwide", *Vehicle Navigation and Informations Systems Conference,* pp. 433-436.

Krakiswki, E.D. and Harris, C. (Nov. 1994). "Communications for AVLN Systems" in ***GPS*** *WORLD,* pp. 44-50.

Langley, R.B. (Jan. 1991). " GPS Receiver: An Introduction", *GPS WORLD*.

Leiner, B.M., Donald, L.N., and Fouad, A.T. (Jan. 1987), "Issues in Packet Radio Network Design", *Proceeding of the IEEE*, pp. 6-20.

Linx Technologies, Inc (1997). *Application Note RF 101 Information for RF Challenged.*

Moody, A.B. (1992). "Dead Reckoning", *Mc. Graw-Hill Encyclopedia of Science & Technology,* Volume 5, pp. 47-50.

MacIntosh, J., Tam, J., (April 1999). *GPS-Based Vehicle Tracking System*, Department of Electrical and Computer Engineering, University of New Brunswick.

Navstar GPS joint program office, http://gps.laafb.af.mil/

NovAtel Communication Ltd. (1994). *GPSCard^{TM} OEM Series Installation and Operating Manual*

NovAtel Communication Ltd. (1995). *GPSCard^{TM} Command Description Manual*

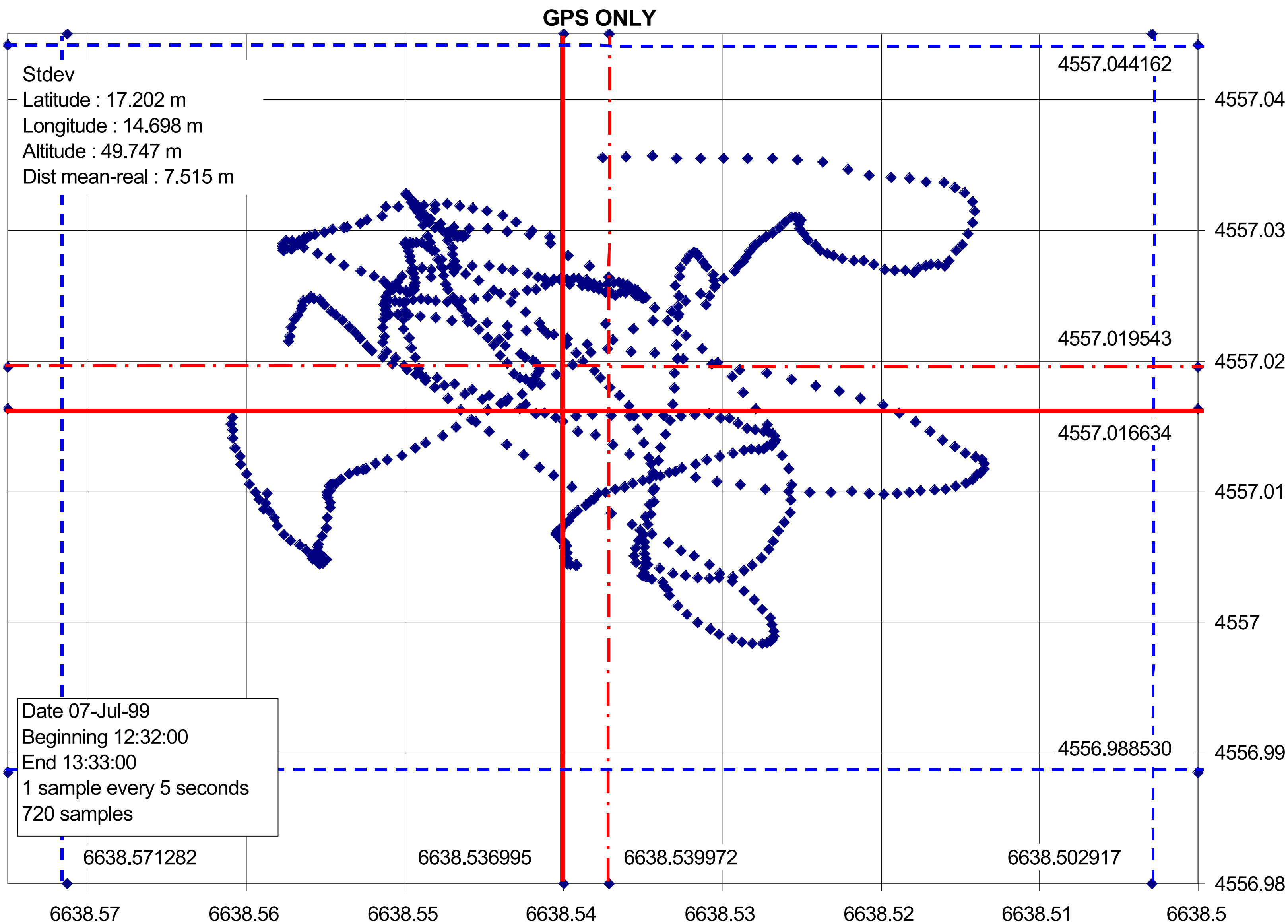
Pacific Crest Corporation (1996) *RFM 96 Radio Modem User's Guide* Revision 3.0

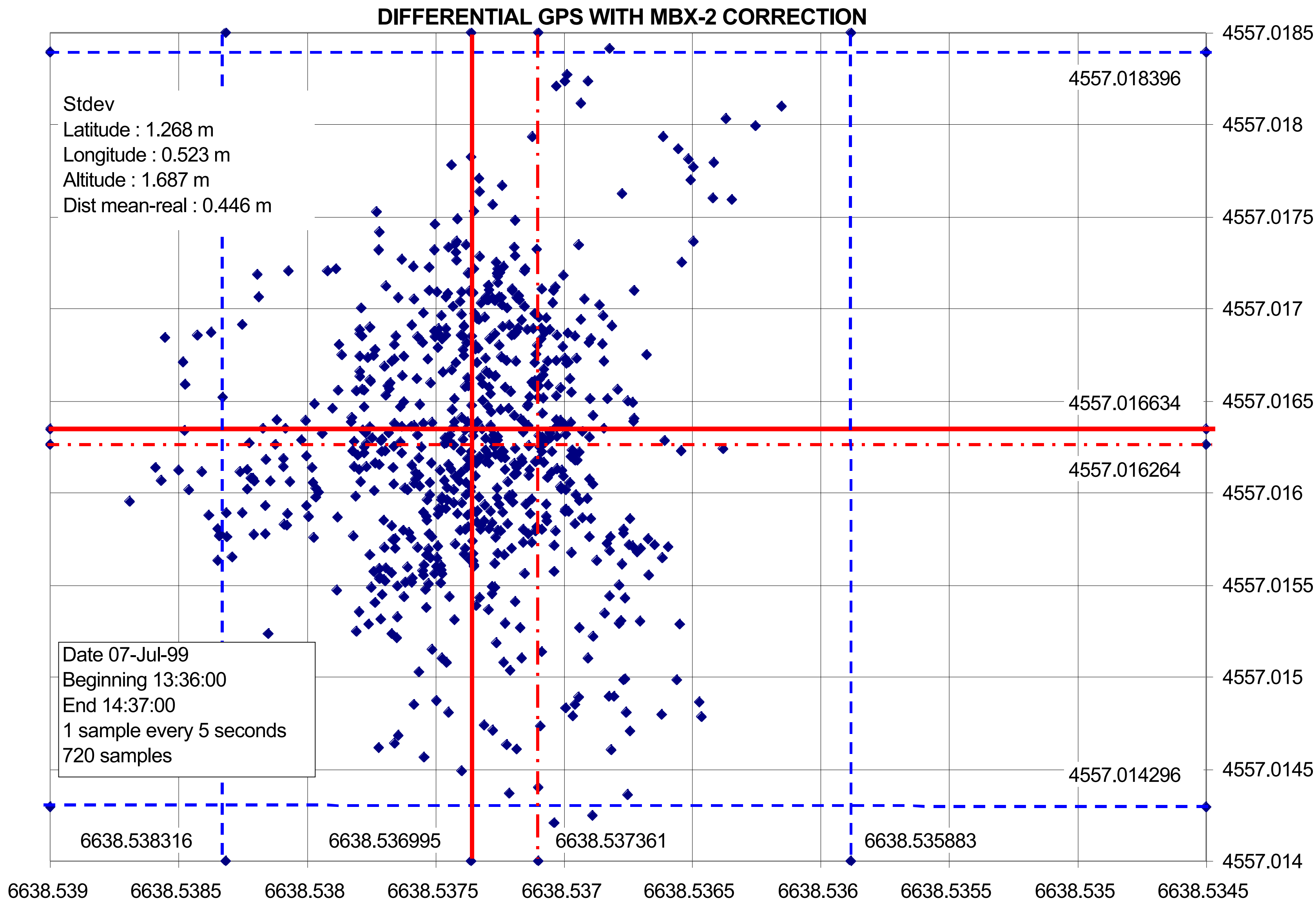
Schiff, T.H. (Oct. 1993). "Data sources and consolidation methods for creating, improving and maintaining navigation database", *Vehicle Navigation and Informations Systems Conference,* pp. 3-7.

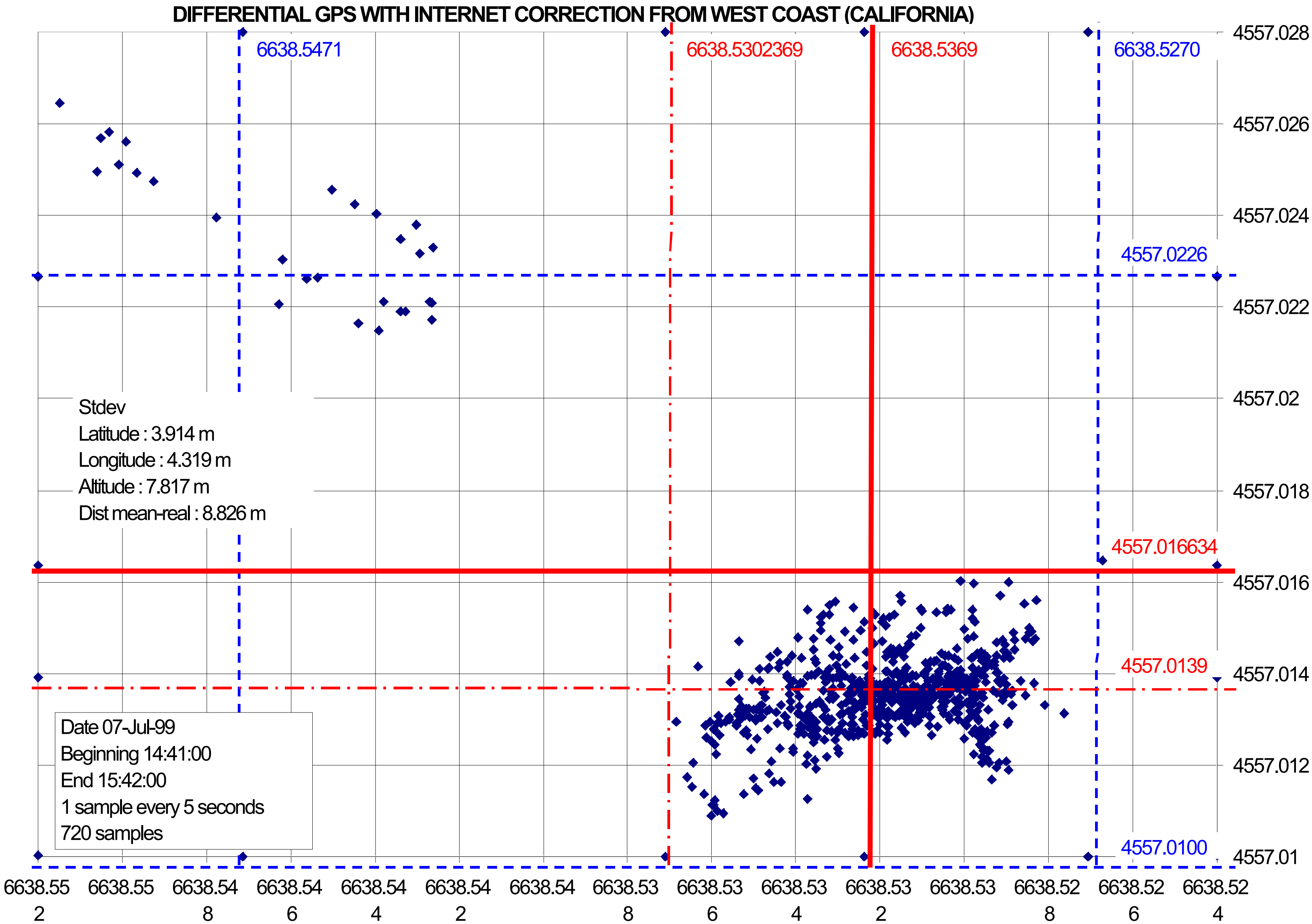
Singleton, J.D. (1992). "Radio" ", *Mc. Graw-Hill Encyclopedia of Science & Technology,* Volume 15, pp. 52-54.

APPENDIX I

SAMPLES OF THE GPS ACCURACY WITH AND WITHOUT DIFFERENTIAL CORRECTIONS


GPS ONLY
Stdev
Latitude : 17.202 m
Longitude : 14.698 m
Altitude : 49.747 m
Dist mean-real : 7.515 m
4557.044162
4557.019543
4557.016634
4556.988530
4557.04
4557.03
4557.02
4557.01
4557
4556.99
4556.98
Date 07-Jul-99
Beginning 12:32:00
End 13:33:00
1 sample every 5 seconds
720 samples
6638.571282
6638.536995
6638.539972
6638.502917
6638.57
6638.56
6638.55
6638.54
6638.53
6638.52
6638.51
6638.5


DIFFERENTIAL GPS WITH MBX-2 CORRECTION
Stdev
Latitude : 1.268 m
Longitude : 0.523 m
Altitude : 1.687 m
Dist mean-real : 0.446 m
Date 07-Jul-99
Beginning 13:36:00
End 14:37:00
1 sample every 5 seconds
720 samples
4557.0185
4557.018396
4557.018
4557.0175
4557.017
4557.016634
4557.0165
4557.016264
4557.016
4557.0155
4557.015
4557.014296
4557.0145
4557.014
6638.538316
6638.536995
6638.537361
6638.535883
6638.539
6638.5385
6638.538
6638.5375
6638.537
6638.5365
6638.536
6638.5355
6638.535
6638.5345


DIFFERENTIAL GPS WITH INTERNET CORRECTION FROM WEST COAST (CALIFORNIA)
6638.5471
6638.5302369
6638.5369
6638.5270
4557.0226
4557.016634
4557.0139
4557.0100
4557.028
4557.026
4557.024
4557.022
4557.02
4557.018
4557.016
4557.014
4557.012
4557.01
Stdev
Latitude : 3.914 m
Longitude : 4.319 m
Altitude : 7.817 m
Dist mean-real : 8.826 m
Date 07-Jul-99
Beginning 14:41:00
End 15:42:00
1 sample every 5 seconds
720 samples
6638.552
6638.55
6638.548
6638.546
6638.544
6638.542
6638.54
6638.538
6638.536
6638.534
6638.532
6638.53
6638.528
6638.526
6638.524

APPENDIX II
DGPS RADIO BEACON LISTING FOR NORTH AMERICA

Updated March 3, 1999. New information regarding DGPS radiobeacons listing are **bolded** and *italicized*
You can also find the others parts of the wolrd on: http://www.csi-dgps.com/dgps/

BROADCAST SITE	FREQ (kHz)	MSK RATE (bps)	LATITUDE	LONGITUDE	REF. ID	STATION ID	FIELD STRENGTH	OPERATIONAL STATUS
Canada								
Alert Bay	309.0	200	50° 35.0' N	126° 55.0' W	300, 301	909	75µV/m@450 km	On-line
Amphitrite Point	315.0	200	48° 55.0' N	125° 32.0' W	302, 303	908	75µV/m@350 km	On-line
Bassano, AB **	325.0	200	50° 47' 27" N	112° 27' 07" W	005, 006	-	70µV/m@70 NM	On-line
Cape Norman, NF	310.0	200	51° 29' 55" N	55° 49' 28" W	342, 343	944	75µV/m@350 km	On-line
Cape Race	315.0	200	46° 45.0' N	53° 10.0' W	338, 339	940	75µV/m@525 km	On-line
Cape Ray, NF	290.0	200	47° 34' 02" N	W 59° 09' 36" W	340, 341	941	75µV/m@350 km	On-line
Cardinal, ON	306.0	200	44° 47' 20" N	75° 25' 21" W	308, 309	919	75µV/m@300 km	On-line
Fox Island, NS	307.0	200	45° 19' N	61° 04' W	336, 337	934	75µV/m@300 km	On-line
Lauzon, QC	309.0	200	46° 48' 45" N	71° 09' 33" W	316, 317	927	75µV/m@330 km	On-line
Moisie, QC	313.0	200	50 12.0' N	66 07.0' W	320, 321	925	75µV/m@300 km	On-line
Partridge Island, NB	295.0	200	45° 14' 12.82' N	66° 03'13.68' W	326, 327	939	75µV/m@300 km	On-line
Point Escuminac, NB	319.0	200	47° 04' N	64° 47' W	332, 333	936	75µV/m@300 km	On-line
Richmond, BC	320.0	200	49° 19' 50" N	123° 15' 48" W	304, 305	902	75µV/m@300 km	On-line
Rigolet, NF	299.0	200	54° 15.0' N	58° 30.0' W	344, 345	947	75µV/m@350 km	On-line
Rivière-du-Loup, QC	300.0	200	47° 45.0' N	69° 36.0' W	318, 319	926	75µV/m@300 km	On-line
Sandspit, BC	300.0	200	53° 14.0' N	131° 48.0' W	306, 307	906	75µV/m@350 km	On-line
St. Jean Richelieu, QC	296.0	200	45° 19.0 N	73° 18.0 W	312, 313	929	75µV/m@330 km	On-line
Trios-Rivières, QC	321.0	200	46° 23.0 N	72° 27.0 W	314	928	-	On-line
Watrous, SK **	321.0	200	51° 40' 42" N	105° 26' 49" W	001, 002	-	70µV/m@125 NM	On-line
Western Head, NS	312.0	200	43° 59' 21" N	64° 39' 44" W	334, 335	935	50µV/m@90 NM	On-line
Wiarton, ON	286.0	200	44° 44' 51" N	81° 06' 44" W	310, 311	918	75µV/m@250 km	On-line
Winnipeg, MB **	312.0	200	49° 50' 12" N	97° 30' 43" W	003, 004	-	70µV/m@170 km	On-line
United States of America								
Alexandria, VA	305.0	100	38° 45.18" N	77° 07.69' W	40, 41	820	75µV/m@35 NM	On-line, Test Station
Alma (St. Paul), MN	317.0	200	44° 18.23' N	91° 54.19' W	158, 159	864	100µV/m@150 SM	On-line
Annette Island, AK	323.0	100	55° 04.14' N	131° 35.97' W	278, 279	889	75µV/m@170 NM	On-line
Appleton, WA	300.0	100	45° 46.55' N	121° 19.34' W	172, 173	871	100µV/m@170 SM	On-line
Aransas Pass, TX	304.0	100	27° 50.30' N	97° 03.53' W	32, 33	816	75µV/m@180 NM	On-line
Brunswick, ME	316.0	100	43° 53.38' N	69° 56.79' W	0, 1	800	75µV/m@115 NM	On-line
Cape Canaveral, FL	289.0	100	28° 27.59' N	80° 32.59' W	18, 19	809	75µV/m@200 NM	On-line
Cape Henlopen, DE	298.0	200	38° 46.60' N	75° 05.26' W	10, 11	805	75µV/m@180 NM	On-line
Cape Henry, VA	289.0	100	36° 55.62' N	76° 00.38' W	12, 13	806	75µV/m@130 NM	On-line
Cape Hinchinbrook, AK	292.0	100	60° 14.30' N	146° 38.80' W	288, 289	894	75µV/m@ 120 NM	On-line
Cape Mendocino, CA	292.0	100	40° 26.50' N	124° 23.77' W	270, 271	885	75µV/m@180 NM	On-line
Charleston, SC	298.0	100	32° 45.45' N	79° 50.57' W	16, 17	808	75µV/m@150 NM	On-line
Chatham, MA	325.0	200	41° 40.27' N	69° 57.00' W	4, 5	802	100µV/m@95 NM	On-line
Cheboygan, MI	292.0	200	45° 39.20' N	84° 27.93' W	112, 113	836	100µV/m@110 SM	On-line
Chico, CA	***318.0***	***-***	***39° 25.80' N***	***121° 36.00' W***	***256, 257***	***878***	***75µV/m@ - NM***	***On-line, Test Mode***
Clark, SD	***309.0***	***100***	***44° 55.8' N***	***97° 57.6' W***	***146, 14***	***850***	***75µV/m@250 SM***	***On-line, Test Mode***

Cold Bay, AK	289.0	100	55° 11.41' N	162° 42.42' W	296, 297	838	75µV/m@180 NM	On-line
Detroit, MI	319.0	200	42° 17.84' N	83° 05.71' W	116, 117	838	100µV/m@100 SM	On-line
Egmont Key, FL	312.0	200	27° 36.02' N	82° 45.61' W	24, 25	812	75µV/m@210 NM	On-line
English Turn, LA	293.0	200	29° 52.73' N	89° 56.50' W	28, 29	814	100µV/m@170 NM	On-line
Ft. Macon, NC	294.0	100	34° 41.84' N	76° 40.98' W	14, 15	807	75µV/m@130 NM	On-line
Ft. Stevens, OR	287.0	100	46° 12.29' N	123° 57.36' W	272, 273	886	75µV/m@180 NM	On-line
Galveston, TX	296.0	100	29° 19.79' N	94° 44.20' W	30, 31	815	75µV/m@180 NM	On-line
Gustavus, AK	288.0	100	58° 25.04' N	135° 41.83' W	284, 285	892	75µV/m@170 NM	On-line
Hackleburg, AL	***325.0***	***200***	***34° 16.8' N***	***87° 51.6' W***	***50, 51***	***825***	***100µV/m@ - NM***	***Under Construction***
Hartsville, TN	***317.0***	***100***	***36° 21.3' N***	***86° 5.5' W***	***144, 145***	***858***	***75µV/m@ - NM***	***Under Construction***
Isabella, PR	295.0	100	18° 27.77' N	67° 04.01' W	34, 35	817	75µV/m@125 NM	On-line
Kansas City, MO	305.0	200	39° 07.04' N	95° 24.53' W	164, 165	867	100µV/m@100 NM	On-line
Kenai, AK	310.0	100	60° 40.50' N	151° 21.00' W	292, 293	896	75µV/m@170 NM	On-line
Key West, FL	286.0	100	24° 34.94' N	81°39.18' W	22, 23	811	75µV/m@110 NM	On-line
Kodiak, AK	313.0	100	57° 37.06' N	152° 11.60' W	294, 295	897	75µV/m@180 NM	On-line
Kokole Pt., HI	300.0	200	21° 59.00' N	159° 45.48' W	260, 261	880	100µV/m@300 NM	On-line
Louisville, KY	290.0	200	38° 00.60' N	85° 17.90' W	168, 169	869	100µV/m@150 SM	On-line
Memphis, TN	310.0	200	35° 27.94' N	90° 12.34' W	152, 153	861	100µV/m@115 SM	On-line
Miami, FL	322.0	100	25° 43.96' N	80° 09.61' W	20, 21	810	75µV/m@75 NM	On-line
Miller's Ferry, AL	320.0	200	32° 05.43' N	87° 23.53' W	160, 161	865	100µV/m@150 SM	On-line
Milwaukee, WI	297.0	100	43° 00.15' N	87° 53.30' W	106, 107	833	75µV/m@140 SM	On-line
Mobile Point, AL	300.0	100	30° 13.65' N	88° 01.44' W	26, 27	813	75µV/m@170 NM	On-line
Moriches, NY	***293.0***	***100***	***40° 47.37' N***	***72° 44.77' W***	***6, 7***	***803***	***75µV/m@130 NM***	***On-line (Was Montauk Pt.)***
Neebish Island, MI	309.0	200	46° 19.28' N	84° 09.04' W	110, 111	835	100µV/m@60 SM	On-line
Omaha, NE	298.0	200	41° 46.70' N	95° 54.66' W	166, 167	868	100µV/m@150 SM	On-line
Onondaga, MI	***296.0***	***200***	***42° 47.8' N***	***84° 27.6' W***	***98, 99***	***840***	***100µV/m@ - NM***	***Under Construction***
Penobscot, ME	***290.0***	***200***	***44° 33.0' N***	***68° 46.20' W***	***44, 45***	***799***	***75µV/m@65 SM***	***On-line***
Pigeon Point, CA	287.0	100	37° 11.22' N	122° 23.39' W	266, 267	883	75µV/m@180 NM	On-line
Point Arguello, CA	321.0	100	34° 34.72' N	120° 38.61' W	264, 265	882	75µV/m@180 NM	On-line
Point Blunt, CA	310.0	200	37° 51.18' N	122° 25.13' W	268, 269	884	100µV/m@60 NM	On-line
Point Loma, CA	302.0	100	32° 39.92' N	117° 14.58' W	262, 263	881	75µV/m@180 NM	On-line
Portsmouth Harbor, NH	288.0	100	43° 04.25' N	70° 42.59' W	2, 3	801	75µV/m@100 NM	On-line
Potato Point, AK	298.0	100	61° 03.40' N	146° 41.80' W	290, 291	895	75µV@100 NM	On-line
Reedy Point, DE	***309.0***	***200***	***39° 33.68' N***	***75° 34.19' W***	***170, 171***	***870***	***100µV/m@70 SM***	***On-line, Test Mode***
Robinson Pt., WA	323.0	200	47° 23.25' N	122° 22.48' W	274, 275	887	100µV/m@60 NM	On-line
Rock Island, IA	311.0	200	42° 00.74' N	90° 13.54' W	156, 157	863	100µV/m@150 SM	On-line
Saginaw Bay, MI	301.0	100	43° 37.71' N	80° 50.26' W	114, 115	837	75µV/m@85 SM	On-line
Sallisaw, OK	299.0	200	35° 22.00' N	94° 49.00' W	162, 163	866	100µV/m@161 SM	On-line
Sandy Hook, NJ	286.0	200	40° 28.28' N	74° 00.69' W	8, 9	804	100µV/m@100 NM	On-line
Savannah Beach, GA	319.0	100	32° 8.40' N	81° 42.00' W	36, 37	818	75µV/m@185 SM	On-line
St. Louis, MO	322.0	200	38° 36.66' N	89° 45.52' W	154, 155	862	100µV/m@115 NM	On-line
Sturgeon Bay, WI	322.0	100	44° 47.72' N	87° 18.85' W	104, 105	832	75µV/m@110 SM	On-line
Upolu Point, HI	286.0	100	20° 14.75' N	155° 53.02' W	258, 259	879	75µV/m@170 NM	On-line
Upper Keweenaw, WI	298.0	100	47° 13.62' N	88° 37.45' W	102, 103	831	75µV/m@130 SM	On-line
Vicksburg, MS	313.0	200	32° 19.88' N	90° 55.18' W	150, 151	860	100µV/m@115 SM	On-line
Whidbey Island, WA	302.0	100	48° 18.76' N	122° 41.76' W	276, 277	888	75µV/m@90 NM	On-line

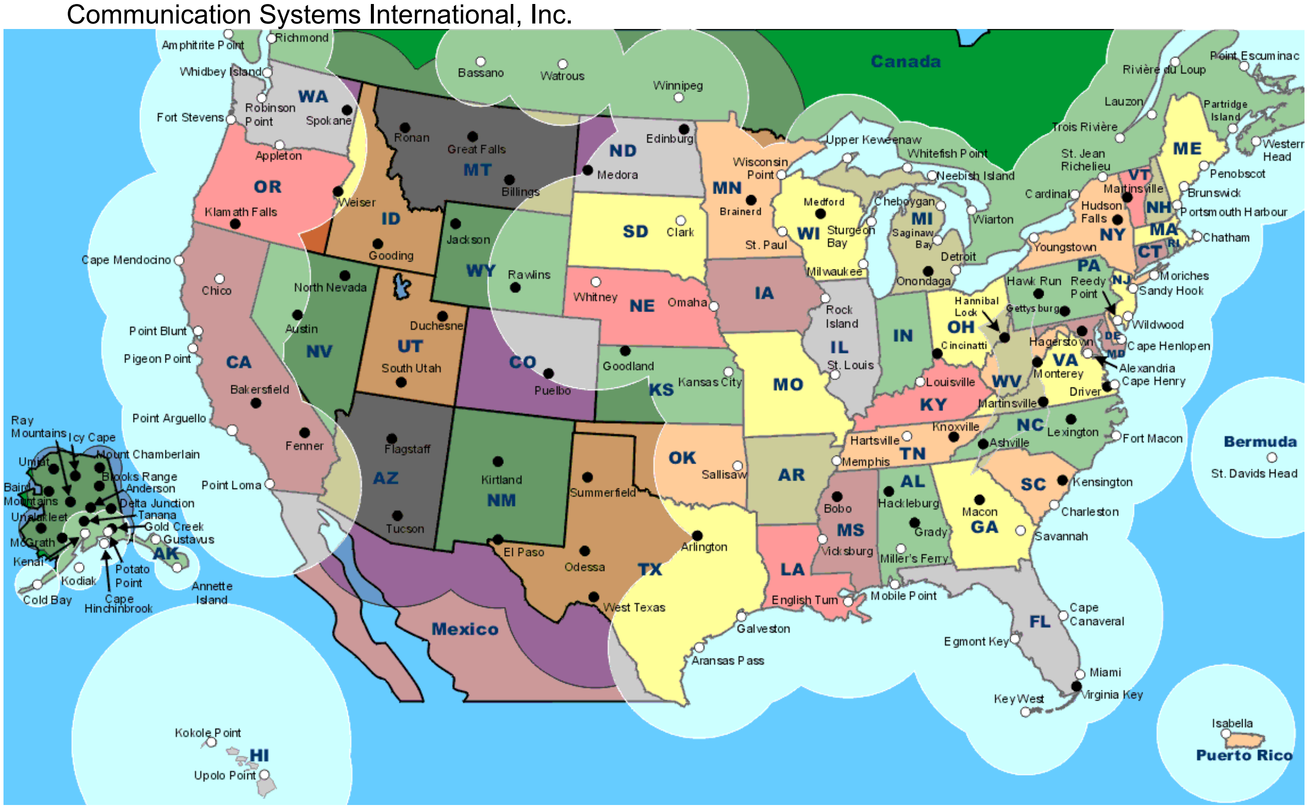
Whitefish Point, MI	318.0	100	46° 46.27' N	84° 57.48' W	108, 109	834	75µV/m@80 SM	On-line
Whitney, NE	310.0	200	43° 44.00' N	103° 19.00' W	148, 149	859	75µV/m@280 SM	On-line
Wildwood, NJ	301.0	200	38° 57.10' N	74° 51.57' W	38, 39	111	75µV/m@75 NM	On-line
Wisconsin Point, WI	296.0	100	46° 42.30' N	92° 00.91' W	100, 101	830	75µV/m@40 SM	On-line
Youngstown, NY	322.0	100	43° 13.87' N	78° 58.20' W	118, 119	839	75µV/m@150 SM	On-line

Information Sources

- List of Radionavigation services, DGNSS Reference and Transmitting Stations in the Maritime Radionavigation (Radiobeacons) Band (283.5-325 kHz Region 1; 285-325 kHz Regions 2 and 3), International Association of Lighthouse Authorities, Issue 5 - July 1997
- DGPS Broadcast Site Status & Operation Specifications, dgpssts.txt at www.navcen.uscg.mil
- Canadian Coast Guard Radiobeacon DGPS Station Status
- Australian Maritime Safety Authority, Navigational Services
- MENAS (Middle East Navigation Aids Service) Notice To Mariners No. 16/97
- GPS World Newsletter, October 10, 1997
- Ministèrio Da Marinha, Centro de Sinalização Náutica e Reparos Almirante Moraes Rego

** CSI Proprietary Encrypted Signal
*** GPS receiver must be maintained with the WGS-84 datum. Resulting position information using São Marcos (Brazil) radiobeacon is given in the Córrego Alegre datum (used on Brazilian nautical charts)

Brendon Cook, Product Manager, bcook@csi-dgps.com
Communication Systems International, Inc.



Umiat
Icy Cape
Mount Chamberlain
USA
Brooks Range
Anderson
Ray
Mountains
Delta Junction
Gold Creek
YK
Potato Point
Gustavus
NWT
Annette
Island
Sandspit
BC
Alert Bay
AB
SK
MN
ON
QC
Amphritite
Point
Richmond
Bassano
Watrous
Winnipeg
Whidbey Island
Robinson
Point
Spokane
Ronan
Great Falls
Ft. Stevens
Appleton
Billings
Medora
Edinburg
Wisconsin
Point
Upper
Keweenaw
Whitefish
Point
Neebish
Cheboygan
Wiarton
Brainerd
Medford
Sturgeon
Bay
Weiser
Jackson
USA
Clark
St. Paul
Saginaw
Bay
Klamath Falls
Rawlins
Whitney
Gooding
Omaha
Milwaukee
Detroit
Cape Mendocino
Rock Island
Onondaga
Hawk Run
Rigolet
Cape Norman
NF
Cape
Race
Cape Ray
Moisie
Point
Escuminac
Rivière du loupe
PEI
NB
NS
Fox Island
Lauzon
Partridge
Island
Trios Rivière
St. Jean
Richelieu
Western
Head
Penobscot
Cardinal
Martinsville
Brunswick
Portsmouth
Harbour
Hudson
Falls
Youngstown
Moriches
Sandy Hook
Reedy
Point
Wildwood
Cape Henlopen

APPENDIX III

COMMAND REFERENCE CARD AND HEALTH COUNTER FOR PACKET CONTROLLERS

Version 1.1.6D6

PacComm
3652 W.Cypress St.
Tampa, FL 33607-4916
(813) 874-2980

Health Feature

Twenty five counters, all of them 16 bits wide, are provided to monitor a number of parameters in the packet controller. They are ALWAYS initialized to 0000 on power up or RESTART.

ASYFRERR	Asynchronous Framing Error. Incremented when a receive framing error is detected on the serial port IC.
ASYQOVER	Asynchronous Overflow Error. Incremented each time a character was received by the serial port IC but not accepted by the firmware.
ASYRXOVR	Asynchronous Received Overflow Error. Increases when the software doesn't service the asynchronous receive in time. Indicates data from the user to the packet controller is being dropped.
BBFAILED	Battery Backed RSM Failure. Counts number of time bbRAM checksum was in error.
DIGISENT	Digipeated Frames Sent. Each frame digipeated by this packet controller causes the counter to increase.
HOVRERR	HDLC Overrun Error. Increases when HDLC receiver is not serviced rapidly enough and data is lost.
HUNDRERR	HDLC Underrun Error. Increases when HDLC transmitter is not serviced rapidly enough and frames are aborted.
PMSCONN	PMS Connections. Increments once for each connection established with MYPCALL.
RCVDFRMR	Received Frame Rejections. Increases when Frame reject frames are received from a connected station.
RCVDIFRA	Received Frames. Increases for each reception of I-frame from a connected.
RCVDREJ	Received Reject Frames. Increases for each reception of a REJect frame from a connected station.
RCVDSABM	Received SABM Frames. Each received SABM frame addressed to the packet controller causes this counter to be increased by one.
RCVDRNR	Received RNR frames. Counts the number of received Receiver Not Ready (RNR) frames. Incremented each time the connected station sends a RNR because it cannot take any more frames.
RXABORT	Received Aborts. Counts the number of received Abort Signals. Abort signals are generated by the HDLC chip, not the AX.25 firmware. Abort means, in effect, a cancel frame signal.
RXCOUNT	Received frame count. Increases when any frame is received with good CRC (or any CRC if PASSAll is turned on)
RXERRORS	Received Errors. Increments each time a received frame is thrown out due to it being too short, suffering overrun(s), or it having a bad CRC. Latter occurs only when CRC checking is enable (i.e. PASSAll is OFF). This counter will often increment in the presence of noise.
RXLENERR	Received Length Error. Received detected a frame less than 15 bytes in length.
RXRESYNC	Received Resynchronization counter. Increments each time a difference between the received packet length and the buffer data length has been detected, causing buffer resynchronization.
SENTFRMR	Frame Rejects Sent. Increments for each Frame Reject frame transmitted.
SENTIFRA	Information Frames Sent. Increases by one for each I-frame sent.
SENTREJ	The number of Frame Reject Sent. Whenever a REJect frame is transmitted, this counter is incremented.
SENTRNR	The number of Received Not Ready (RNR) frames sent. RNR frames are sent when the packet controller is unable to accept any more frames, usually due to flow control by the computer.
TXCOUNT	Frame Transmitted Counter. Incremented whenever a frame is correctly transmitted.
TXQOVFLW	Transmit Queue Overflow. Counts how many times frames were discarded because the outgoing frame queue was too small
TXTMO	Transmitter timeouts. Counts the number of HDLC transmitter timeouts.

Command reference card

Upper case/bold portion of command is the shortest useable form
Call string = call #1 [-n] [via call #2 [-n] [call # [-n] …. [call #9 [-n]]]
Default values are in bold face type or parenthesis
[1] not on all models [2] export models [3] Personal message System

Command	**Argument**	**Description**
3rdparty [3]	**ON** | OFf	Allow PMS messages to other than Sysop
8bitconv	ON | **OF**f	Pass or strip high-order bit in CONV mode
ADrdisp	ON | **OF**f	Display addresses for monitored frames
AMonth	ON | **OF**f	Select alphabetic or numeric month in the date
AUTOFwd	ON | **OF**f	Enable automatic forwarding of PMS messages
AUtolf	**ON** | OFf	Send Linefeed, <LF>, to terminal after each <CR>
AWlen	n = 7-**8**	Number of bits in each byte sent to the terminal
Ax2512v2	**ON** | OFf	Select ver 2.0 (ON) or 1.0 of AX.25 protocol
AXDelay	n = **0**-180	Extra key-up delay for voice rptr (n*0.1 sec)
AXHang	n = **0**-20	Voice Repeater hang time (n*0.1 sec)
BAud [1]	none	Set terminal and radio baud rates
BBSmsgs	ON | **OF**f	Alter message display for BBS applications
Beacon	**E** | A n = **0**-250	Beacon timing/mode (Every | After) (n*10 sec)
BKondel	**ON** | OFf	Select (ON) backspace or delete for DEL key
BReak	**ON** | OFf	Enable response to break signal
BText	text	Text to be send as beacon (max 120 chars)
BUdlist	ON | **OF**f	Treat LCALLS as the only stations to monitor
CALibra [1]	none	Enable calibrate mode for the built-in modem

CALSet [1]	n = **0**-65335	Sets parameters for CAL "LED counter"
CANline	n = $00-$7F	($18 ^X) Sets Cancel-line character
CANPac	n = $00-$7F	($19 ^X) Sets Cancel-packet character
CBell	ON | **OF**f	Enable (ON) connect bell on terminal
CHeck	n = 0-250	(30) Connection check time (n*10 sec)
CLKadj	n = **0**-65335	Real time clock adjustment (slows clock)
CLKSet [3]	**ON** | OFf	Enable clock setting by BBS connection
CMdtime	n = 0-255	(1) Sets the transparent mode timeout value
CMSg	ON | **OF**f	Enable the connect message function
CMSGDisc	ON | **OF**f	Enable forced disconnected after Connect Msg
COMmand	n = $00-$7F	($03 ^C) Set Conv to cmd mode entry char
CONMode	**CONV** | TR	Mode to enter when connection occurs
Connect	Call string	Open a connection via optional repeaters
CONOk	**ON** | OFf	Enable accepting connection
CONPerm	ON | **OF**f	Select temporary or permanent connection
CONStamp	ON | **OF**f	Print date and time on connect messages
CONVers	none	enter CONV mode from CMD mode (alt = **K**)
CPactime	ON | **OF**f	Enable CONV mode timed packet dispatch
CR	**ON** | OFf	Select appending a <CR> to each data packet
CRAfter	ON | **OF**f	Add <CR> after monitored frame and printer
CStatus	none	Display the status of all streams
CText	text	Connect message Text (120 Chars)
CWid [2]	**E** | A n = **0**-250	CWID frequency/mode (E |A) (n*100 sec)
CWIdtext [2]	text	Up to 32 alphanumeric characters for CWID
CWLen [2]	n = 1-9	(6) Set CWID wpm (9=13, 6=20, 3=40)
DAytime	yymmddhhmm	Set or display date and time
DAYUsa	**ON** | OFf [2=OFf]	Date format mm/dd/yy (ON) or dd-mm-yy
DELete	ON | **OF**f	Select BS char: BS ($08) (OFF) or DEL ($7F)
DIGipeat	**ON** | OFf	Enable (ON) the Digipeater function
Disconnect	none	Teardown connection on current stream
DISPlay	A,B,C,H,I,L,M,P,T	Display all or selected parameters
DWait	n = 0-250	(16) Extra digipeater delay (n*10 msec)
Echo	**ON** | OFf	Echo characters typed on keyboard
EDithdr [3]	to call, @ call	Edit PMS 'to' or '@BBS' callsigns
EScape	ON | **OF**f	Set ESC character ($1B) (OFF) or ($24) (ON)
FIrmrnr	ON | **OF**f	Reduce frequent polling of busy packet station
Flow	**ON** | OFf	Inhibit output to terminal while user is typing
FOrward [3]	Msg #	Cause PMS Msg # to be reverse forwarded
FNPms [3]	<callsign>	[via callsign #2] Force PMS forwarding via node
FPms [3]	<callsign>	[via callsign #2] Force PMS forwarding
FRack	n = 1-15	(3) Set time to wait for packet ack
FUlldup	ON | **OF**f	Select simplex or duplex mode
HEaderli	ON | **OF**f	Header and text on the same/separate lines
HEALled	ON | **OF**f	Normal/software test by CON + STA LEDs
HId	ON | **OF**f	Enable ID packet every 9,5 minutes
HOMebbs [3]	Callsign	Callsign of 'home BBS' serving your PMS
Id	none	Send ID packet (UI frame VIA UNproto path)
K	none	Alternative form of the CONV command
KIll [3]	n	Kill (delete) message number n from PMS
KILONFWD [3]	**ON** |OFf	Kill (delete) PMS messages after forwarding
KISs	ON | **OF**f	Select KISS mode. Must follow by RESTART
KM [3]	none	Kill all PMS messages addressed to my callsign
LCAlls	Call # 1-8	Callsigns to receive or ignore (see BUDLIST)
LCok	**ON** | OFf	Convert lower to UPPER case (async)
LCStream	**ON** | OFf	Allow STREAM ID char to be lower case
LFadd	ON | **OF**f	Add line Feed to each <CR> sent to terminal
LFIgnore	ON | **OF**f	Filter imbedded linefeeds in received data
List [3]	none	List the ten most recent PMS messages
LOGonmsg [3]	**ON** | OFf	Enable standard PMS logon message
MAll	**ON** | OFf	Monitor connected frames and UI-frames
MAXframe [1]	n = 1-7	(4) Number of outstanding frames allowed
MCOM	ON | **OF**f	Display data/all (CON/DIS/UA/DM) frames
MCon	ON | **OF**f	Monitor UI-frames while connected
MFilter	n = **$00**- $7F	Four chars to purge from monitored data
MHClear	none	Clear the Calls Heard list
MHeard	none	Show calls heard and date/time (if clock set)
MIne [3]	none	List the messages to/from PMS callsign
MNonax25	ON | **OF**f	Set ON and set PID OFf to monitor nodes
Monitor	**ON** | OFf	Monitor on – see BUD, MALL, MCON, MST

<table>
<tr><td>**MR**pt</td><td>**ON** | OFf</td><td>Display monitored digipeater paths</td></tr>
<tr><td>**MSGH**dr [3]</td><td>**ON** | OFf</td><td>Add message header to forwarded messages</td></tr>
<tr><td>**MS**tamp</td><td>ON | **OF**f</td><td>Select time stamping of monitored frames</td></tr>
<tr><td>**MYA**lias</td><td>call [-n]</td><td>(none) Alternate callsign (for digipeater use)</td></tr>
<tr><td>**MY**call</td><td>call [-n]</td><td>(NOCALL) Station callsign for ID and linking</td></tr>
<tr><td>**MYP**call</td><td>call [-n]</td><td>(none) PMS callsign (different than MYcall)</td></tr>
<tr><td>**NE**wmode</td><td>**ON** | OFf</td><td>Select timing and method off changing modes</td></tr>
<tr><td>**NO**mode</td><td>ON | **OF**f</td><td>Allow explicit mode change only</td></tr>
<tr><td>**NU**cr</td><td>ON | **OF**f</td><td>Select sending NULLS ($00) after a <CR></td></tr>
<tr><td>**NUL**f</td><td>ON | **OF**f</td><td>Select sending NULLS ($00) after a <LF></td></tr>
<tr><td>**NULL**s</td><td>n = **0**-30</td><td>Nr of nulls sent if NUCR or NULF enable</td></tr>
<tr><td>**P**aclen [1]</td><td>n = 0-255</td><td>(128) Number of bytes of data in a frame</td></tr>
<tr><td>**PACT**ime</td><td>E | A n = 0-250</td><td>(A 10) TRANS mode timer (n*100ms)</td></tr>
<tr><td>**PAR**ity</td><td>n = **0**-3</td><td>Serial parity: 0/2 = none, 1 = odd, 3 = even</td></tr>
<tr><td>**PAS**s</td><td>n = $00-$7F</td><td>($16 ^V) Sets the value of the PASS char</td></tr>
<tr><td>**PASSA**ll</td><td>ON | **OF**f</td><td>Displays frames with valid CRC or all frames</td></tr>
<tr><td>**PE**rsit</td><td>n</td><td>(127) Set threshold for retry probably</td></tr>
<tr><td>**PI**dcheck</td><td>ON | **OF**f</td><td>Select all protocol ID or PID F0-see MNonax25</td></tr>
<tr><td>**PM**s [3]</td><td>ON | **OF**f</td><td>Enable Personal Message System</td></tr>
<tr><td>**PO**rt</td><td>1 | **2**</td><td>Set radio port, modem tones, baud rate</td></tr>
<tr><td>**PP**ersist</td><td>ON | **OF**f</td><td>Select PERSISTANCE or FRACK timing</td></tr>
<tr><td>**PPR**int [1] [3]</td><td>Msg # (s)</td><td>Print PMS message(s) via printer port</td></tr>
<tr><td>**PRA**utolf [1]</td><td>**ON** | OFf</td><td>Add line feed to each <CR> sent to printer</td></tr>
<tr><td>**PR**int [1]</td><td>**ON** | OFf</td><td>Enable printer port operation</td></tr>
<tr><td>**PRPA**ge [1]</td><td>**ON** | OFf</td><td>Enable control of printer pagination</td></tr>
<tr><td>**PRPD**isc [1]</td><td>**ON** | OFf</td><td>Send Form feed char upon disconnect</td></tr>
<tr><td>**PRPG**ln [1]</td><td>n = 1-99</td><td>(60) Nr of lines per page if PRPAGE is ON</td></tr>
<tr><td>**PRTTO**ff [1]</td><td>n = $00-$7F</td><td>($0F ^O) Disable print char (if PRTTgl ON)</td></tr>
<tr><td>**PRTTON** [1]</td><td>n = $00-$7F</td><td>($10 ^O) Enable print char (if PRTTgl ON)</td></tr>
<tr><td>**PRTT**gl [1]</td><td>**ON** | OFf</td><td>Set print control via PRTTON/PRTTOFF</td></tr>
<tr><td>**PRTU**ifra [1]</td><td>**ON** | OFf</td><td>Send monitored frames to printer port</td></tr>
<tr><td>**R**ead [3]</td><td>#</td><td>Display PMS message # on operator’s terminal</td></tr>
<tr><td>**REC**onnect</td><td>Call string</td><td>Reestablished a connection via a new path</td></tr>
<tr><td>**RED**isplay</td><td>n = $00-$7F</td><td>($12 ^R) Set character to print the input buffer</td></tr>
<tr><td>**REMS**ysop</td><td>ON | **OF**f</td><td>Enable Sysop functions for remote operator</td></tr>
<tr><td>**RESET**</td><td>none</td><td>Reset TNC and set bbRAM to default parameters</td></tr>
<tr><td>**RES**ptime [1]</td><td>n = **0**-250</td><td>Select the delay for sending an ACK (n*100ms)</td></tr>
<tr><td>**RESTART**</td><td>none</td><td>Reset TNC saving user supplied parameters</td></tr>
<tr><td>**RE**try</td><td>n = 0-15</td><td>(10) Max number of retry (0 = infinity)</td></tr>
<tr><td>**RX**block</td><td>ON | **OF**f</td><td>Format TNC data for computer processing</td></tr>
<tr><td>**S**creenln</td><td>n = **0**-255</td><td>Select line length (screen width) for terminal</td></tr>
<tr><td>**SEND** [3]</td><td>callsign</td><td>Enter a message to <callsign> in PMS</td></tr>
<tr><td>**SP** [3]</td><td>callsign</td><td>Enter a private message to <callsign> in PMS</td></tr>
<tr><td>**SR** [3]</td><td>Msg #</td><td>Enter a reply message to callsign of Msg # in PMS</td></tr>
<tr><td>**ST** [3]</td><td>callsign</td><td>Enter a ‘TRAFFIC’ message to <callsign> in PMS</td></tr>
<tr><td>**SE**ndpac</td><td>n = $00-$7F</td><td>($0D CR) Select the character which send frame</td></tr>
<tr><td>**SL**ottime</td><td>n</td><td>(1) Set PPERSIST priority in accessing channel</td></tr>
<tr><td>**SO**ftdcd [1]</td><td>**ON** | OFf</td><td>elect DCD from software algorithm or hardware</td></tr>
<tr><td>**STA**rt</td><td>n = $00-$7F</td><td>($11 ^Q) Set XON char for data ***to*** the terminal</td></tr>
<tr><td>**STAT**us</td><td>none</td><td>Query connection and frame ack status</td></tr>
<tr><td>**STE**xt [3]</td><td>text</td><td>PMS custom sign-on message text (max 80 chars)</td></tr>
<tr><td>**STO**p</td><td>n = $00-$7F</td><td>($13 ^S) Set XOff char for data ***to*** the terminal</td></tr>
<tr><td>**STREAMC**a</td><td>ON | **OF**f</td><td>Select showing the callsign after stream id</td></tr>
<tr><td>**STREAMD**bl</td><td>ON | **OF**f</td><td>Print the stream switch char once/twice (| | A)</td></tr>
<tr><td>**STR**eamsw</td><td>n = $00-$FF</td><td>($7C |) Set the character to use to change stream</td></tr>
<tr><td>**TRAC**e</td><td>ON | **OF**f</td><td>Select the hexadecimal trace mode</td></tr>
<tr><td>**T**rans</td><td>none</td><td>Place the TNC in transparent mode</td></tr>
<tr><td>**TRF**low</td><td>ON | **OF**f</td><td>Enable Flow control to the TNC (TRANS mode)</td></tr>
<tr><td>**TXU**ifram</td><td>**ON** | OFf</td><td>Enable sending UI-frames in CONVERSE mode</td></tr>
<tr><td>**U**nproto</td><td>Call string</td><td>(CQ) Path and address to send UI-frames</td></tr>
<tr><td>**US**ers</td><td>n = 0-10</td><td>(1) Set the number of stream (connections)</td></tr>
<tr><td>**V**ersion</td><td>none</td><td>Displays sign-on banner</td></tr>
<tr><td>**X**flow</td><td>**ON** | OFf</td><td>XON/XOFF flow control enabled vs. hardware</td></tr>
<tr><td>**XM**itok</td><td>**ON** | OFf</td><td>Allow the transmitter to be keyed</td></tr>
<tr><td>**XO**ff</td><td>n = $00-$7F</td><td>($13 ^S) Set the char to stop data from terminal</td></tr>
<tr><td>**XON**</td><td>n = $00-$7F</td><td>($11 ^Q)Set the char to start data from terminal</td></tr>
</table>

APPENDIX IV
SETTINGS

Normal Settings

Mobile part

Transmitter: MAXON radio with PacComm TNC (Terminal Node Controller).
Antenna: Antenex Mobile, NGP, 2.4dB,radiator:30 _ inches
Frequency: 173.635 MHz
TNC settings:

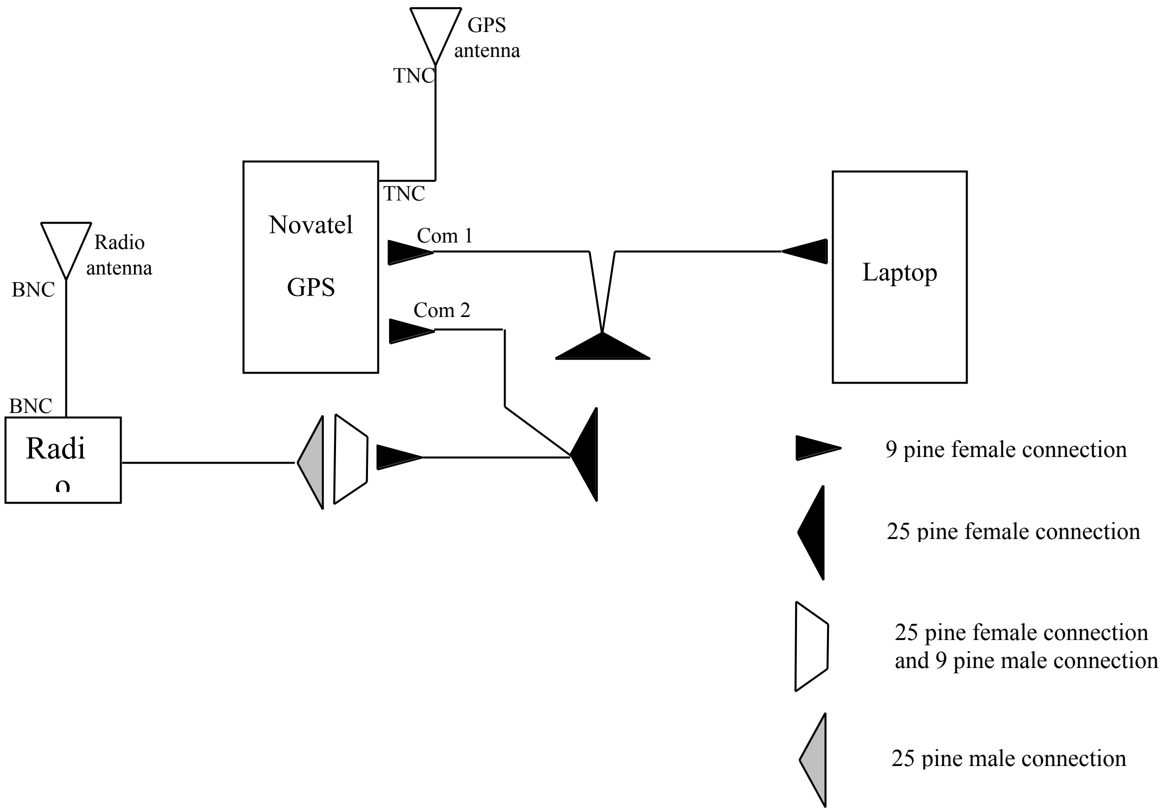
PacComm ULTRAMINIATURE
Wireless Modem
AX.25 Level 2 Version 2.0
Features:
PRINTER PORT
SILENT
SMR TRUNKING
CWID
Release P2.6A April 2, 1991-32K
Ram
Checksum $18
display
8bitconv OFF
ADrdisp ON
AMonth OFF
ASyrxovr 0
ASYFrerr 0
ASYQover 0
AUtolf ON
AWlen 8
Ax25l2v2 OFF
AXDelay 0
AXHang 0
BBfailed 0
BSmsgs OFF
Beacon EVERY 0
BKondel ON
BReak ON
BText
BUdlist OFF
CANline $18
CANPac $19
CBell OFF
CHeck 30
CLKadj 0
CMdtime 1
CMSg OFF
CMSGDisc OFF
COMmand $03
CONMode CONVERSE
Link state is: DISCONNECTED
CONOk ON
CONPerm OFF
CONStamp OFF
CPactime OFF
CR OFF
CRAfter ON
CText
CWid EVERY 0
CWLen 6
CWIDText
DATalog OFF
DATAMode ON
DAYUsa ON
DELete OFF
DIGipeat ON
DIGISent 0
DWait 0
Echo OFF
EScape OFF
Flow ON
FRack 3
FUlldup ON
Group OFF
HEaderli OFF
HEALled OFF
HId OFF
HOvrerr 0
HUndrerr 0
LCAlls
LCok ON
LCStream ON
LFadd OFF
LFIgnore ON
MAll ON
MAStermn AA
MAXframe 4
MCOM OFF
MCon OFF
MFilter $00
Monitor ON
MRpt ON
MStamp OFF
MTRans OFF
MYAlias WIDE
MYcall UNBRM1-9
NEwmode OFF
NOmode ON
NUcr OFF
NULf OFF
NULLs 0
Paclen 128
PACTime AFTER 10
PARity 0
PASs $16
PASSAll OFF
PErsist 127
PIdcheck OFF
PPersist OFF
PRAUtolf ON
PRint ON
PRPAge ON
PRPDisc ON
PRPGln 60
PRTTON $10
PRTTOFf $0F
PRTTgl ON
PRTUifra OFF
RCVDFrmr 0
RCVDIfra 0
RCVDRej 0
RCVDSabm 0
RCVDRNr 0
RXAbort 2350
RXLenerr 0
RXResync 0
REDispla $12
REMoteio OFF
RESptime 0
REtry 10
RXblock OFF
RXCount 0
RXErrors 0
Screenln 0
SEndpac $0D
SENTFrmr 0
SENTIfra 0
SENTRej 0
SENTRNR 0
SIlent OFF
SLottime 1
STArt $11
STATus $00
STOp $13
STReamsw $02
STREMx OFF
STREMCal OFF
TRACe OFF
TRFlow OFF
TRIes 0
TRMax 3
TRSEnse OFF
TRSTyle OFF
TRUnk OFF
TXCount 0
TXdelay 30
TXFlow OFF
TXQovflw 0
TXTmo 0
TXUifram ON
Unproto GPS
USers 1
Wdogsecs 0
Xflow ON
XMitok ON
XOff $13
XON $1

GPS receiver: Novatel RT20 receiver

Settings: Com1 plug to Laptop with Winsat running to program the receiver
log com2,GPGGA,ontime,10,0

COM1 9600,N,8,1,N,OFF
COM2 9600,N,8,1,N,OFF
OEM card : PC port : **COM2**
OEM port : COM1
Baud rate : 9600
Parity : None
Data Bits : 8
Stop Bits : 1
Flow Control : None

Connections settings:



Fix part

Transmitter: KENWOOD radio with PacComm TNC (Terminal Node Controller).
Frequency: 172.635 MHz
Antenna: Antenex Mobile, NGP, 2.4dB,radiator:30 _ inches
TNC settings:

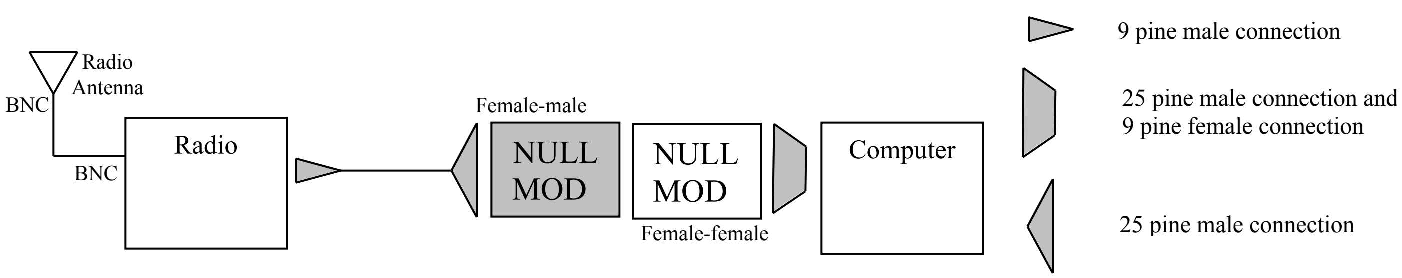
PacComm ULTRAMINIATURE
Wireless Modem
AX.25 Level 2 Version 2.0
Features:
PRINTER PORT
SILENT
SMR TRUNKING
CWID
Release P2.6A April 2, 1991 - 32K
Ram
Checksum $18
display
8bitconv ON
ADrdisp ON

AMonth OFF
ASyrxovr 0
ASYFrerr 0
ASYQover 0
AUtolf ON
AWlen 8
Ax25l2v2 OFF
AXDelay 0
AXHang 0
BBfailed 0
BBSmsgs ON
Beacon EVERY 0
BKondel ON
BReak ON

BText
BUdlist OFF
CANline $18
CANPac $19
CBell OFF
CHeck 30
CLKadj 0
CMdtime 1
CMSg OFF
CMSGDisc OFF
COMmand $03
CONMode CONVERSE
Link state is: DISCONNECTED
CONOk ON

CONPerm OFF
CONStamp OFF
CPactime OFF
CR OFF
CRAfter ON
CText
CWid EVERY 0
CWLen 6
CWIDText
DATalog OFF
DATAMode ON
DAYUsa ON
DELete OFF
DIGipeat ON
DIGISent 0
DWait 0
Echo OFF
EScape OFF
Flow OFF
FRack 3
FUlldup OFF
Group OFF
HEaderli OFF
HEALled OFF
HId OFF
HOvrerr 0
HUndrerr 0
LCAlls
LCok ON
LCStream ON
LFadd OFF
LFIgnore ON
MAll ON
MAStermn AA
MAXframe 4
MCOM OFF
MCon OFF
MFilter $00
Monitor ON
MRpt ON
MStamp OFF
MTRans OFF
MYAlias
MYcall UNBBAS
NEwmode OFF
NOmode ON
NUcr OFF
NULf OFF
NULLs 0
Paclen 128
PACTime AFTER 10
PARity 0
PASs $16
PASSAll OFF
PErsist 127
PIdcheck OFF
PPersist OFF
PRAUtolf ON
PRint ON
PRPAge ON
PRPDisc ON
PRPGln 60
PRTTON $10
PRTTOFf $0F
PRTTgl ON
PRTUifra OFF
RCVDFrmr 0
RCVDIfra 0
RCVDRej 0
RCVDSabm 0
RCVDRNr 0
RXAbort 1
RXLenerr 0
RXResync 0
REDispla $12
REMoteio OFF
RESptime 0
REtry 10
RXblock OFF
RXCount 0
RXErrors 0
Screenln 0
SEndpac $0D
SENTFrmr 0
SENTIfra 0
SENTRej 0
SENTRNR 0
SIlent OFF
SLottime 1
STArt $11
STATus $00
STOp $13
STReamsw $02
STREMx OFF
STREMCal OFF
TRACe OFF
TRFlow OFF
TRIes 0
TRMax 3
TRSEnse OFF
TRSTyle OFF
TRUnk OFF
TXCount 1
TXdelay 30
TXFlow OFF
TXQovflw 0
TXTmo 0
TXUifram ON
Unproto APW228
USers 1
Wdogsecs 0
Xflow ON
XMitok ON
XOff $13
XON $11

Connections settings:



DGPS settings

Mobile part

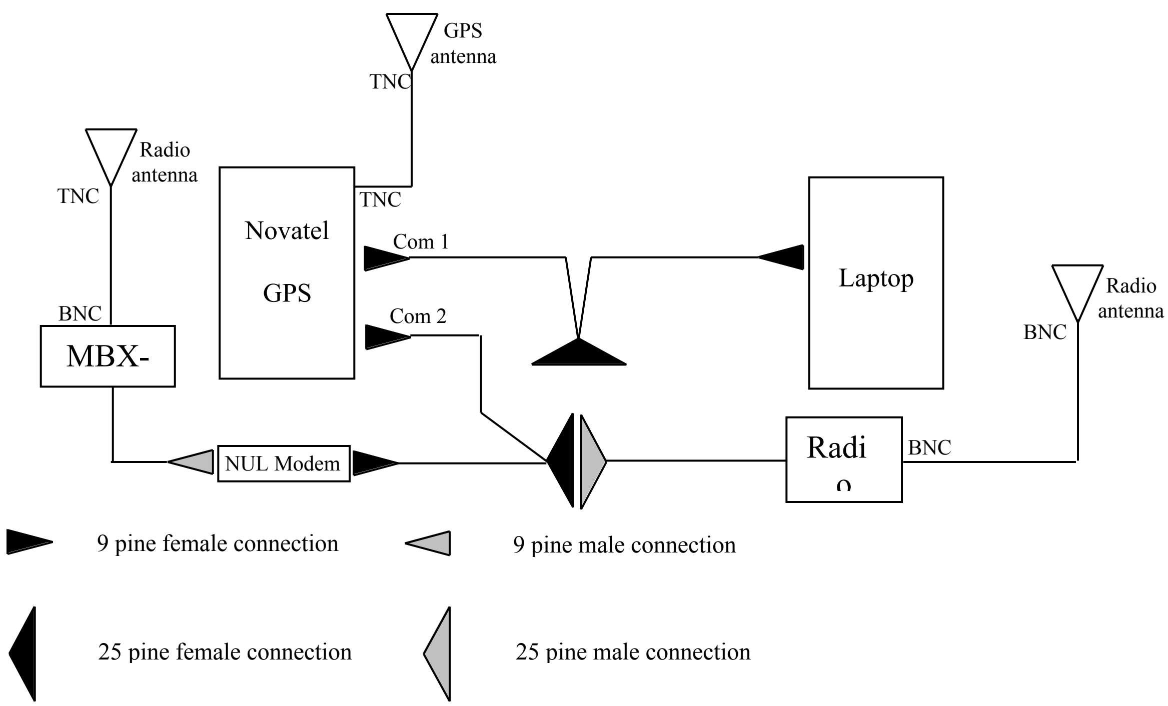
Transmitter: MAXON radio with PacComm TNC (Terminal Node Controller). The TNC settings are the same as for the normal settings
GPS receiver: Novatel RT20 receiver

Settings: Com1 plug to Laptop with Winsat running to program the receiver

log com2,GPGGA,ontime,10,0
accept com2,RTCM
COM1 9600,N,8,1,N,OFF
COM2 9600,N,8,1,N,OFF
OEM card : PC port : **COM2**
OEM port : COM1
Baud rate : 9600
Parity : None
Data Bits : 8
Stop Bits : 1
Flow Control : None

MBX-2: receiver for the coast guard GPS corrections
Antenna: Loop Antenna
Settings : frequency : 295 kHz
Beacon Name : BX 326 242
I/O input : None
I/O Baud rate : 9600 bauds

Connections settings :



Fix part

Same as for Normal settings

APPENDIX V

RESULT OF THE EXPERIMENT ON JUNE THE 22

When a line is passed it means that there was a lost of data between the transmitter and the receiver. The […] symbol means that there were no changes in the data between the two sentences

```
cmd:cmd:UNBRM1-9>GPS:Invalid Command Option
UNBRM1-9>GPS:Com2>
[…]
UNBRM1-9>GPS:Invalid Command Option
UNBRM1-9>GPS:Com2>
UNBRM1-9>GPS:fAB@N~eI_B@}^BRj\Lx|□P^JP{GI`pMBYGTp]iGNglWU^
UNBRM1-9>GPS:fAB@kAjz`^@}FImUbsGU@ybycDxv_Ol}fxdOb~ofXQhjh
[…]
UNBRM1-9>GPS:Y~}□q~oPcOI|wI``w|oh□XYB~x|q}\t[s~~o]XTYUIN\gP[Bp{Djjjy
UNBRM1-9>GPS:Y~}□q~O^cuwcDTPAKCPb□DSjQGCNBF@Y}~{o]x|LuHN\oPWDpS{UUUc
UNBRM1-9>GPS:$GPGGA,134136.5,4557.0323597,N,06638.5145144,W,1,05,1.7,90.05,M,,,,*10
UNBRM1-9>GPS:$GPGGA,134138.0,4557.0318990,N,06638.5149714,W,1,05,1.7,89.72,M,,,,*1F
[…]
UNBRM1-9>GPS:$GPGGA,134548.0,4557.0185932,N,06638.5448977,W,1,05,1.7,54.07,M,,,,*1F
UNBRM1-9>GPS:$GPGGA,134556.5,,,,,0,04,28.1,,,,,,*6C
UNBRM1-9>GPS:$GPGGA,134556.5,,,,,0,04,28.1,,,,,,*6C
UNBRM1-9>GPS:$GPGGA,134556.5,,,,,0,03,28.1,,,,,,*6B
UNBRM1-9>GPS:$GPGGA,134628.0,4556.9931286,N,06638.5653636,W,1,04,2.8,54.40,M,,,,*1D
UNBRM1-9>GPS:$GPGGA,134638.0,4556.9927567,N,06638.5659330,W,1,04,2.8,48.69,M,,,,*1C
UNBRM1-9>GPS:$GPGGA,134648.0,4556.9925203,N,06638.5666990,W,1,04,2.8,44.73,M,,,,*17
UNBRM1-9>GPS:$GPGGA,134658.0,4556.9925888,N,06638.5673254,W,1,04,2.8,41.57,M,,,,*1B
UNBRM1-9>GPS:$GPGGA,134708.0,4556.9929324,N,06638.5686066,W,1,04,2.8,38.03,M,,,,*18
UNBRM1-9>GPS:$GPGGA,134718.0,4556.9922501,N,06638.5705768,W,1,04,2.8,32.97,M,,,,*17
UNBRM1-9>GPS:$GPGGA,134728.0,4556.9914731,N,06638.5717575,W,1,04,2.8,32.33,M,,,,*13
UNBRM1-9>GPS:$GPGGA,134738.0,4556.9910040,N,06638.5722149,W,1,04,2.8,32.22,M,,,,*1A
UNBRM1-9>GPS:$GPGGA,134748.0,4556.9901003,N,06638.5724663,W,1,04,2.8,32.72,M,,,,*16
UNBRM1-9>GPS:$GPGGA,134758.0,4556.9905640,N,06638.5723531,W,1,04,2.8,34.07,M,,,,*15
UNBRM1-9>GPS:$GPGGA,134808.0,4556.9907418,N,06638.5727370,W,1,04,2.8,36.45,M,,,,*11
UNBRM1-9>GPS:$GPGGA,134818.0,4556.9919251,N,06638.5722602,W,1,04,2.8,37.66,M,,,,*11
UNBRM1-9>GPS:$GPGGA,134828.0,4556.9857578,N,06638.5571319,W,1,04,2.8,39.23,M,,,,*11
UNBRM1-9>GPS:$GPGGA,134830.0,,,,,0,04,12.7,,,,,,*6B
UNBRM1-9>GPS:$GPGGA,134829.0,,,,,0,04,12.7,,,,,,*63
UNBRM1-9>GPS:$GPGGA,134857.0,4557.0338653,N,06638.5481727,W,1,05,1.7,35.04,M,,,,*1A
UNBRM1-9>GPS:$GPGGA,134907.0,4557.0637865,N,06638.5254408,W,1,05,1.7,20.04,M,,,,*1B
UNBRM1-9>GPS:$GPGGA,134917.0,4557.0461014,N,06638.4830328,W,1,05,1.7,20.85,M,,,,*10
UNBRM1-9>GPS:$GPGGA,134927.0,4556.9994468,N,06638.4200902,W,1,05,1.7,20.48,M,,,,*19
UNBRM1-9>GPS:$GPGGA,134930.0,,,,,0,04,10.5,,,,,,*6A
UNBRM1-9>GPS:$GPGGA,134930.0,,,,,0,04,10.5,,,,,,*6A
UNBRM1-9>GPS:$GPGGA,134930.0,,,,,0,04,10.5,,,,,,*6A
UNBRM1-9>GPS:$GPGGA,135004.0,,,,,0,04,9.6,,,,,,*5E
UNBRM1-9>GPS:$GPGGA,135004.0,,,,,0,04,9.6,,,,,,*5E
UNBRM1-9>GPS:$GPGGA,135004.0,,,,,0,03,9.6,,,,,,*59
UNBRM1-9>GPS:$GPGGA,135037.0,4556.7810828,N,06638.6317456,W,1,04,2.3,122.76,M,,,,*2A
UNBRM1-9>GPS:$GPGGA,135047.0,4556.7254879,N,06638.6787186,W,1,05,2.0,123.84,M,,,,*28
UNBRM1-9>GPS:$GPGGA,135055.5,,,,,0,04,8.6,,,,,,*5E
UNBRM1-9>GPS:$GPGGA,135055.5,,,,,0,04,8.6,,,,,,*5E
UNBRM1-9>GPS:$GPGGA,135055.5,,,,,0,04,8.6,,,,,,*5E
UNBRM1-9>GPS:$GPGGA,135127.0,4556.5391236,N,06638.7553065,W,1,05,2.0,91.45,M,,,,*17
UNBRM1-9>GPS:$GPGGA,135137.0,4556.5257391,N,06638.7516090,W,1,06,1.4,63.58,M,,,,*1F
UNBRM1-9>GPS:$GPGGA,135207.0,4556.3772955,N,06638.8318141,W,1,05,2.0,46.74,M,,,,*1E
UNBRM1-9>GPS:$GPGGA,135217.0,4556.3150150,N,06638.8849987,W,1,06,1.4,40.91,M,,,,*10

UNBRM1-9>GPS:$GPGGA,135257.0,4556.1885215,N,06639.1932357,W,1,06,1.4,39.10,M,,,,*10
UNBRM1-9>GPS:$GPGGA,135347.0,4556.3477451,N,06639.4309432,W,1,06,1.4,21.40,M,,,,*1A
[…]
UNBRM1-9>GPS:$GPGGA,140417.0,4559.4421364,N,06638.4039587,W,1,08,1.1,78.31,M,,,,*1F
UNBRM1-9>GPS:$GPGGA,140427.0,4559.4542570,N,06638.5753762,W,1,07,1.3,120.48,M,,,,*27

UNBRM1-9>GPS:$GPGGA,140447.0,4559.4330604,N,06638.9046169,W,1,07,1.3,85.80,M,,,,*1A

UNBRM1-9>GPS:$GPGGA,140537.0,4559.5155233,N,06639.0708330,W,1,07,1.3,-0.84,M,,,,*03
UNBRM1-9>GPS:$GPGGA,140547.0,4559.5213164,N,06639.0698215,W,1,08,1.1,16.79,M,,,,*1F
UNBRM1-9>GPS:$GPGGA,140557.0,4559.5200524,N,06639.0688772,W,1,08,1.1,8.29,M,,,,*23
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```
UNBRM1-9>GPS:$GPGGA,140607.0,4559.5200774,N,06639.0678941,W,1,08,1.1,6.39,M,,,,*2C
UNBRM1-9>GPS:$GPGGA,140617.0,4559.5195069,N,06639.0666021,W,1,08,1.1,3.30,M,,,,*25
UNBRM1-9>GPS:$GPGGA,140627.0,4559.5194495,N,06639.0657651,W,1,08,1.1,1.82,M,,,,*28
UNBRM1-9>GPS:$GPGGA,140637.0,4559.5195785,N,06639.0657013,W,1,08,1.1,3.40,M,,,,*26
UNBRM1-9>GPS:$GPGGA,140647.0,4559.5191112,N,06639.0650275,W,1,08,1.1,5.12,M,,,,*29
UNBRM1-9>GPS:$GPGGA,140657.0,4559.5196365,N,06639.0637221,W,1,08,1.1,7.37,M,,,,*28
UNBRM1-9>GPS:$GPGGA,140707.0,4559.5281416,N,06639.0717930,W,1,08,1.1,11.05,M,,,,*14
UNBRM1-9>GPS:$GPGGA,140717.0,4559.5428795,N,06639.0994984,W,1,06,1.4,46.15,M,,,,*1A
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UNBRM1-9>GPS:$GPGGA,140757.0,4559.5749026,N,06638.9644545,W,1,08,1.1,47.88,M,,,,*10

UNBRM1-9>GPS:$GPGGA,140957.0,4600.3646880,N,06638.2590762,W,1,08,1.2,49.43,M,,,,*11

UNBRM1-9>GPS:$GPGGA,141017.0,4600.4945772,N,06638.1531277,W,1,07,1.3,51.82,M,,,,*17

UNBRM1-9>GPS:$GPGGA,141047.0,4600.7036626,N,06637.9797780,W,1,07,1.3,28.10,M,,,,*1D

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UNBRM1-9>GPS:$GPGGA,141157.0,4600.6461320,N,06637.8328256,W,1,06,1.4,21.33,M,,,,*18
UNBRM1-9>GPS:$GPGGA,141207.0,4600.5496289,N,06637.8361851,W,1,06,1.4,15.49,M,,,,*1D

UNBRM1-9>GPS:$GPGGA,141227.0,4600.3306545,N,06637.8469637,W,1,06,1.4,16.02,M,,,,*1D
UNBRM1-9>GPS:$GPGGA,141237.0,4600.2206838,N,06637.8541578,W,1,05,2.0,-2.74,M,,,,*05
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UNBRM1-9>GPS:$GPGGA,141307.0,4559.9107103,N,06637.8710764,W,1,06,1.4,16.80,M,,,,*1E
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UNBRM1-9>GPS:$GPGGA,141337.0,4559.6330188,N,06637.8962855,W,1,05,2.0,8.67,M,,,,*23
UNBRM1-9>GPS:$GPGGA,141347.0,4559.5603025,N,06637.9025345,W,1,05,2.0,10.47,M,,,,*1E

UNBRM1-9>GPS:$GPGGA,141407.0,4559.4196581,N,06637.9109484,W,1,07,1.3,43.64,M,,,,*1C
[…]
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UNBRM1-9>GPS:$GPGGA,141927.0,4557.6149603,N,06637.5230679,W,1,05,1.8,94.99,M,,,,*10

UNBRM1-9>GPS:$GPGGA,141947.0,4557.4568768,N,06637.4426629,W,1,07,1.3,86.32,M,,,,*11
UNBRM1-9>GPS:$GPGGA,141957.0,4557.3843134,N,06637.4155353,W,1,08,1.2,67.65,M,,,,*16
UNBRM1-9>GPS:$GPGGA,142017.0,4557.2717690,N,06637.4058543,W,1,07,1.3,87.66,M,,,,*16
UNBRM1-9>GPS:$GPGGA,142027.0,4557.2368305,N,06637.4128927,W,1,07,1.3,83.73,M,,,,*18
UNBRM1-9>GPS:$GPGGA,142037.0,4557.1828476,N,06637.4180487,W,1,07,1.3,82.01,M,,,,*17
UNBRM1-9>GPS:$GPGGA,142047.0,4557.1096019,N,06637.4131310,W,1,07,1.4,47.28,M,,,,*16
UNBRM1-9>GPS:$GPGGA,142057.0,4557.0176027,N,06637.4161864,W,1,08,1.2,49.80,M,,,,*1C
UNBRM1-9>GPS:$GPGGA,142107.0,4556.9480720,N,06637.3720625,W,1,08,1.2,56.54,M,,,,*14
UNBRM1-9>GPS:$GPGGA,142117.0,4556.9038266,N,06637.3530687,W,1,06,1.4,46.79,M,,,,*18
UNBRM1-9>GPS:$GPGGA,142127.0,4556.8837258,N,06637.3237210,W,1,07,1.3,17.37,M,,,,*12
UNBRM1-9>GPS:$GPGGA,142137.0,4556.8837796,N,06637.3090093,W,1,04,3.4,57.93,M,,,,*1E
UNBRM1-9>GPS:$GPGGA,142147.0,4556.8353921,N,06637.2465661,W,1,08,1.2,33.55,M,,,,*16
UNBRM1-9>GPS:$GPGGA,142157.0,4556.7652830,N,06637.1904860,W,1,06,1.4,30.44,M,,,,*10
UNBRM1-9>GPS:$GPGGA,142207.0,4556.7114087,N,06637.0823685,W,1,09,1.1,1.23,M,,,,*2E
UNBRM1-9>GPS:$GPGGA,142217.0,4556.6414453,N,06637.0515508,W,1,06,1.3,-28.05,M,,,,*37
UNBRM1-9>GPS:$GPGGA,142227.0,4556.6145256,N,06637.0667554,W,1,09,1.1,12.22,M,,,,*15
UNBRM1-9>GPS:$GPGGA,142237.0,4556.6052440,N,06637.0760279,W,1,09,1.1,8.01,M,,,,*26
UNBRM1-9>GPS:$GPGGA,142247.0,4556.5744906,N,06637.1165853,W,1,08,1.2,32.28,M,,,,*1D
UNBRM1-9>GPS:$GPGGA,142257.0,4556.5583040,N,06637.2057011,W,1,09,1.1,6.23,M,,,,*2D
UNBRM1-9>GPS:$GPGGA,142307.0,4556.5247505,N,06637.3203595,W,1,09,1.1,7.26,M,,,,*2D

UNBRM1-9>GPS:$GPGGA,142327.0,4556.4659876,N,06637.5806113,W,1,09,1.1,58.29,M,,,,*1A
UNBRM1-9>GPS:$GPGGA,142337.0,4556.4132624,N,06637.7058158,W,1,09,1.1,16.42,M,,,,*11
UNBRM1-9>GPS:$GPGGA,142347.0,4556.3757693,N,06637.8371631,W,1,09,1.1,20.35,M,,,,*12
UNBRM1-9>GPS:$GPGGA,142357.0,4556.3768171,N,06637.9358933,W,1,09,1.1,30.35,M,,,,*12

UNBRM1-9>GPS:$GPGGA,142417.0,4556.4240255,N,06638.0367343,W,1,09,1.1,16.19,M,,,,*11
UNBRM1-9>GPS:$GPGGA,142427.0,4556.4894750,N,06638.0242009,W,1,05,2.0,-51.70,M,,,,*35
[…]
UNBRM1-9>GPS:$GPGGA,142717.0,4557.0254937,N,06638.5260169,W,1,07,1.5,18.86,M,,,,*16
UNBRM1-9>GPS:$GPGGA,142727.0,4557.0512694,N,06638.5224339,W,1,07,1.5,-16.30,M,,,,*3F
```

APPENDIX VI

TRACK OF THE EXPERIMENT ON JUNE THE 22

Scale: 1/50,000

APPENDIX VII
RESULT OF THE EXPERIMENT ON JULY THE 15

```
cmd:convUNBRM1-9>GPS:fAB@Nj`iZI`|Cc□WYzWNHCrFvL|AiTKqjlKH\ffs\p~yQH□MQ~□_xCCE□JAP
UNBRM1-9>GPS:fAB@kUoZeUa|_ct}[jWE@bKOBsG~oZYKdlyvCXmpcpnyi□m\_D@dG@qXLx~[
[...]
UNBRM1-9>GPS:Y~}□TjJnZx_□gR{mYzWMhwXGgL|A~imWXS[H\Uda|q~yYXJAzF@`GJpJr~~M
UNBRM1-9>GPS:$GPGGA,143019.5,4557.0215549,N,06638.5310242,W,2,08,1.2,24.21,M,,,3,0327*2B
[...]
UNBRM1-9>GPS:$GPGGA,143637.0,4556.9110838,N,06638.5561971,W,2,04,2.8,29.13,M,,,3,0327*23
UNBRM1-9>GPS:$GPGGA,143637.0,,,,,0,02,2.8,,,,,,*5A
UNBRM1-9>GPS:$GPGGA,143647.0,4556.8533410,N,06638.5980312,W,2,04,2.4,46.89,M,,,3,0327*2C
[...]
UNBRM1-9>GPS:$GPGGA,143747.0,4556.5485333,N,06638.7804014,W,2,06,1.4,93.88,M,,,3,0327*28
143752.0
UNBRM1-9>GPS:$GPGGA,143757.0,4556.5603389,N,06638.8246243,W,2,06,1.4,97.07,M,,,3,0327*24
143802.0
UNBRM1-9>GPS:$GPGGA,143807.0,4556.5842847,N,06638.8794364,W,2,06,1.4,94.55,M,,,3,0327*26
[...]
UNBRM1-9>GPS:$GPGGA,143832.0,4556.6415558,N,06638.8778639,W,2,05,2.2,94.06,M,,,18,0327*1B
UNBRM1-9>GPS:$GPGGA,143836.0,,,,,0,04,99.9,,,,,,*60
UNBRM1-9>GPS:$GPGGA,143841.5,,,,,0,04,99.9,,,,,,*65
UNBRM1-9>GPS:$GPGGA,143847.0,4556.7055134,N,06638.7991203,W,2,05,2.2,66.69,M,,,3,0327*23
[...]
UNBRM1-9>GPS:$GPGGA,144402.0,4556.8957597,N,06639.8886913,W,2,07,1.1,101.24,M,,,3,0327*18
144407.0
UNBRM1-9>GPS:$GPGGA,144412.0,4556.9472909,N,06639.8460972,W,2,08,0.9,94.37,M,,,3,0327*23
144417.0,144422.0
UNBRM1-9>GPS:$GPGGA,144427.0,4557.0430401,N,06639.7659576,W,2,08,0.9,81.64,M,,,10,0327*11
144432.0
UNBRM1-9>GPS:$GPGGA,144437.0,4557.1130510,N,06639.7086456,W,2,08,0.9,70.82,M,,,20,0327*17
[...]
UNBRM1-9>GPS:$GPGGA,144512.0,4557.3007482,N,06639.5316290,W,2,07,1.2,31.35,M,,,5,0327*23
UNBRM1-9>GPS:$GPGGA,144516.5,,,,,0,04,5.1,,,,,,*50
UNBRM1-9>GPS:$GPGGA,144522.0,4557.2615082,N,06639.4837352,W,2,06,1.3,32.79,M,,,15,0327*1C
[...]
UNBRM1-9>GPS:$GPGGA,144602.0,4557.1090481,N,06639.2420961,W,2,06,1.7,78.64,M,,,55,0327*16
UNBRM1-9>GPS:$GPGGA,144604.5,,,,,0,02,1.7,,,,,,*54
UNBRM1-9>GPS:$GPGGA,144610.5,,,,,0,04,11.3,,,,,,*62
UNBRM1-9>GPS:$GPGGA,144617.0,4557.0839294,N,06639.1869475,W,2,04,11.3,37.21,M,,,3,0327*1E
[...]
UNBRM1-9>GPS:$GPGGA,144717.0,4557.4011356,N,06638.9585171,W,2,06,1.3,11.16,M,,,5,0327*24
                                                    144722.0
UNBRM1-9>GPS:$GPGGA,144727.0,4557.4309033,N,06639.0269065,W,2,06,1.3,10.38,M,,,4,0327*28
[...]
UNBRM1-9>GPS:$GPGGA,144822.0,4557.5331857,N,06639.2666664,W,2,06,1.7,11.53,M,,,4,0327*24
                                                    144822.0
UNBRM1-9>GPS:$GPGGA,144832.0,4557.5574391,N,06639.3208812,W,2,06,1.7,10.14,M,,,3,0327*24
[...]
UNBRM1-9>GPS:$GPGGA,144907.0,4557.6060497,N,06639.2979227,W,2,07,1.1,9.91,M,,,8,0327*18
                                                    144912.0
UNBRM1-9>GPS:$GPGGA,144917.0,4557.6543494,N,06639.2570186,W,2,08,0.9,7.86,M,,,18,0327*2C
[...]
UNBRM1-9>GPS:$GPGGA,145242.0,4557.6691314,N,06638.5148124,W,2,04,2.9,8.39,M,,,4,0327*1C
UNBRM1-9>GPS:$GPGGA,145245.0,,,,,0,03,2.9,,,,,,*5D
UNBRM1-9>GPS:$GPGGA,145252.0,4557.6489844,N,06638.4623865,W,2,04,4.5,11.11,M,,,3,0327*20
[...]
UNBRM1-9>GPS:$GPGGA,145352.0,4557.5914666,N,06638.3304303,W,2,07,1.0,10.10,M,,,3,0327*2A
                                                    145357.0
UNBRM1-9>GPS:$GPGGA,145402.0,4557.5624404,N,06638.2591219,W,2,06,1.3,9.04,M,,,3,0327*1C
[...]
UNBRM1-9>GPS:$GPGGA,145852.0,4557.6270847,N,06638.4089026,W,2,08,1.1,10.50,M,,,3,0327*29
                                                    145857.0
UNBRM1-9>GPS:$GPGGA,145902.0,4557.6463284,N,06638.4553676,W,2,07,1.1,10.06,M,,,12,0327*11
[...]
UNBRM1-9>GPS:$GPGGA,145957.0,4557.6783101,N,06638.5309845,W,2,05,2.0,7.36,M,,,6,0327*14
                                              150002.0,150007.0
UNBRM1-9>GPS:$GPGGA,150012.0,4557.7061318,N,06638.5991206,W,2,06,1.5,8.11,M,,,21,0327*24
[...]
UNBRM1-9>GPS:$GPGGA,150047.0,4557.7185238,N,06638.6234282,W,2,07,1.1,11.38,M,,,6,0327*24
                                                    150052.0
UNBRM1-9>GPS:$GPGGA,150057.0,4557.7292890,N,06638.6481136,W,2,08,0.9,10.66,M,,,3,0327*25
```

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UNBRM1-9>GPS:$GPGGA,150102.0,4557.7402839,N,06638.6745622,W,2,07,1.1,9.86,M,,,7,0327*15
UNBRM1-9>GPS:$GPGGA,150107.0,4557.7524370,N,06638.7046694,W,2,07,1.1,10.59,M,,,7,0327*21
                                        150112.0
UNBRM1-9>GPS:$GPGGA,150117.0,4557.7764243,N,06638.7571114,W,2,08,1.1,9.75,M,,,3,0327*14
[...]
UNBRM1-9>GPS:$GPGGA,150157.0,4557.9598531,N,06638.6307443,W,2,08,1.1,17.94,M,,,5,0327*2A
                                        150202.0
UNBRM1-9>GPS:$GPGGA,150207.0,4558.0314069,N,06638.5957153,W,2,08,1.1,19.06,M,,,4,0327*2C
[...]
UNBRM1-9>GPS:$GPGGA,150552.0,4559.4742303,N,06638.6395630,W,2,08,1.1,53.16,M,,,3,0327*2B
                                        150557.0
UNBRM1-9>GPS:$GPGGA,150602.0,4559.4598780,N,06638.7924770,W,2,09,0.9,44.79,M,,,3,0327*24
                                        1500607.0
UNBRM1-9>GPS:$GPGGA,150612.0,4559.4403693,N,06638.9433746,W,2,09,0.9,37.62,M,,,3,0327*2B
UNBRM1-9>GPS:$GPGGA,150617.0,4559.4312038,N,06639.0153810,W,2,09,0.9,33.58,M,,,4,0327*23
                    Problem of reinitilisation of all the system at brookside mall
UNBRM1>CQ:
UNBRM1>CQ:Com2>fAB@Nh{IXt
[...]
UNBRM1>CQ:Y~}□TxviZm^CzAppZjW□_lEJsLxJQog□R[_I@In\pMQRnXHvE□K[~kmx|{□w
UNBRM1>CQ:$GPGGA,151144.0,4559.4916826,N,06639.9068955,W,2,07,1.3,21.27,M
UNBRM1>CQ:,,,14,0327*15
[...]
UNBRM1>CQ:$GPGGA,151302.0,4559.4904985,N,06639.9067169,W,2,07,1.3,20.24,M
UNBRM1>CQ:,,,3,0327*22
151307.0,151312.0,151317.0,151322.0
UNBRM1>CQ:$GPGGA,151331.0,4559.4910605,N,06639.9066056,W,2,07,1.3,21.16,M
UNBRM1>CQ:,,,3,0327*2C
[...]
UNBRM1>CQ:$GPGGA,151737.0,4559.4915757,N,06639.9064119,W,2,07,1.3,19.44,M
UNBRM1>CQ:,,,3,0327*29
                                        151742.0
UNBRM1>CQ:$GPGGA,151747.0,4559.4913915,N,06639.9063729,W,2,07,1.3,20.31,M
UNBRM1>CQ:,,,3,0327*2A
UNBRM1>CQ:$GPGGA,151752.0,4559.4911748,N,06639.9063129,W,2,07,1.3,20.46,M
UNBRM1>CQ:,,,3,0327*2C
UNBRM1>CQ:$GPGGA,151757.0,4559.4910003,N,06639.9062706,W,2,07,1.3,20.46,M
UNBRM1>CQ:,,,3,0327*2A
UNBRM1>CQ:$GPGGA,151802.0,4559.4909336,N,06639.9065579,W,2,07,1.3,21.26,M
                                     Fnd of 151802.0
UNBRM1>CQ:$GPGGA,151807.0,4559.4907850,N,06639.9065310,W,2,07,1.3,20.63,M
UNBRM1>CQ:,,,3,0327*2B
UNBRM1>CQ:$GPGGA,151812.0,4559.4906340,N,06639.9066052,W,2,07,1.3,20.12,M
UNBRM1>CQ:,,,3,0327*24
UNBRM1>CQ:$GPGGA,151817.0,4559.4906484,N,06639.9068288,W,2,07,1.3,20.09,M
UNBRM1>CQ:,,,4,0327*28
                   First problem of deconnection between laptop and GPS receiver
UNBRM1>CQ:
UNBRM1>CQ:Com2>fAB@N||i\u^□_Az`[jWTpD~cuLxJZpD^_[CI`dYJoOQR}Pn|}kKkjjm
[...]
UNBRM1>CQ:Y~}□T|[nZLY`P{|`~□wG[qRonfzu[yFCOCpnbaw{Otf}UpgwwHSdtsXkc@M{
UNBRM1>CQ:$GPGGA,152223.5,4559.4908288,N,06639.9064308,W,2,08,1.0,22.02,M
UNBRM1>CQ:,,,3,0327*20
[...]
UNBRM1>CQ:$GPGGA,152233.0,4559.4906449,N,06639.9065250,W,2,08,1.0,20.83,M
UNBRM1>CQ:,,,3,0327*27
                                  Beginning of 152237.0
UNBRM1>CQ:,,,3,0327*23
                                  Beginning of 152242.0
UNBRM1>CQ:,,,4,0327*25
                                  Beginning of 152247.0
UNBRM1>CQ:,,,3,0327*27
                             152252.0,152257.0,152302.0
UNBRM1>CQ:$GPGGA,152308.0,4559.4959552,N,06639.8988210,W,2,08,1.0,20.22,M
UNBRM1>CQ:,,,5,0327*2D
UNBRM1>CQ:$GPGGA,152313.0,4559.4947209,N,06639.9065612,W,2,08,1.0,20.69,M
UNBRM1>CQ:,,,10,0327*17
                                  Beginning of 152318.0
UNBRM1>CQ:,,,3,0327*28
```

UNBRM1>CQ:$GPGGA,152323.0,4559.4875504,N,06639.9386546,W,2,08,1.0,20.66,M
UNBRM1>CQ:,,,3,0327*2F
[...]
UNBRM1>CQ:$GPGGA,152338.0,4559.4463679,N,06639.9358265,W,2,07,1.1,21.53,M
End of 152338.0
UNBRM1>CQ:$GPGGA,152342.0,4559.4258613,N,06639.9308390,W,2,07,1.1,21.48,M
UNBRM1>CQ:,,,3,0327*20
[...]
UNBRM1>CQ:$GPGGA,152402.0,4559.3944863,N,06640.0997590,W,2,09,0.9,23.18,M
UNBRM1>CQ:,,,3,0327*26
Beginning of 152407.0
UNBRM1>CQ:,,,3,0327*26
UNBRM1>CQ:$GPGGA,152412.0,4559.3834536,N,06640.2362625,W,2,09,0.9,22.07,M
UNBRM1>CQ:,,,8,0327*27
[...]
UNBRM1>CQ:$GPGGA,152422.0,4559.3616887,N,06640.3822598,W,2,09,0.9,18.45,M
UNBRM1>CQ:,,,18,0327*18
Beginning of 152427.0
UNBRM1>CQ:,,,3,0327*20
152432.0
UNBRM1>CQ:$GPGGA,152437.0,4559.3042954,N,06640.5934347,W,2,09,0.9,15.51,M
UNBRM1>CQ:,,,3,0327*22
Beginning of 152442.0
UNBRM1>CQ:,,,4,0327*29
Beginning of 152447.0
NBRM1>CQ:,,,3,0327*2C
UNBRM1>CQ:$GPGGA,152452.0,4559.2459107,N,06640.8056442,W,2,09,0.9,13.74,M
End of 152452.0
152457.0,152502.0
UNBRM1>CQ:$GPGGA,152507.0,4559.1870661,N,06641.0187578,W,2,09,0.9,13.82,M
UNBRM1>CQ:,,,3,0327*24
[...]
UNBRM1>CQ:$GPGGA,152527.0,4559.1053590,N,06641.3009578,W,2,09,0.9,15.02,M
UNBRM1>CQ:,,,3,0327*28
152537.0
UNBRM1>CQ:$GPGGA,152537.0,4559.0502609,N,06641.4337130,W,2,09,0.9,16.13,M
UNBRM1>CQ:,,,3,0327*28
[...]
UNBRM1>CQ:$GPGGA,152602.0,4558.8802269,N,06641.7124656,W,2,09,0.9,19.34,M
UNBRM1>CQ:,,,3,0327*25
152607.0,152612.0
UNBRM1>CQ:$GPGGA,152617.0,4558.7820802,N,06641.8490867,W,2,09,0.9,17.66,M
UNBRM1>CQ:,,,3,0327*29
[...]
UNBRM1>CQ:$GPGGA,152642.0,4558.7187122,N,06641.8749688,W,2,09,0.9,16.27,M
UNBRM1>CQ:,,,3,0327*2A
152647.0
UNBRM1>CQ:$GPGGA,152652.0,4558.7131062,N,06641.7874978,W,2,07,1.1,17.56,M
UNBRM1>CQ:,,,3,0327*2D
Beginning of 152657.0
UNBRM1>CQ:,,,3,0327*26
Beginning of 152702.0
UNBRM1>CQ:,,,5,0327*2F
UNBRM1>CQ:$GPGGA,152707.0,4558.7249092,N,06641.6193324,W,2,09,0.9,18.14,M
End of 152707.0
UNBRM1>CQ:$GPGGA,152712.0,4558.7259931,N,06641.5647627,W,2,09,0.9,18.84,M
End of 152712.0
UNBRM1>CQ:$GPGGA,152717.0,4558.7198739,N,06641.5108421,W,2,08,1.0,18.99,M
UNBRM1>CQ:,,,3,0327*24
UNBRM1>CQ:$GPGGA,152722.0,4558.7126108,N,06641.4540264,W,2,07,1.1,19.09,M
UNBRM1>CQ:,,,7,0327*20
152727.0
UNBRM1>CQ:$GPGGA,152732.0,4558.6968719,N,06641.3386107,W,2,08,1.0,17.30,M
UNBRM1>CQ:,,,12,0327*18
[...]
UNBRM1>CQ:$GPGGA,152812.0,4558.6598801,N,06640.8602077,W,2,09,0.9,14.43,M
UNBRM1>CQ:,,,11,0327*18
152817.0
UNBRM1>CQ:$GPGGA,152822.0,4558.6589020,N,06640.7365452,W,2,08,1.0,12.80,M

```
UNBRM1>CQ:,,,3,0327*2B
[...]
UNBRM1>CQ:$GPGGA,152847.0,4558.7439945,N,06640.4985585,W,2,08,1.0,5.71,M,
UNBRM1>CQ:,,3,0327*1D
                    Second problem of deconnection between laptop and GPS receiver
UNBRM1>CQ:
UNBRM1>CQ:
UNBRM1>CQ:
UNBRM1>CQ:Com2>$GPGGA,153232.0,4558.8049740,N,06640.3566131,W,2,06,2.6,12
UNBRM1>CQ:.12,M,,,3,0327*26
UNBRM1>CQ:$GPGGA,153237.0,4558.8032723,N,06640.3544763,W,2,07,1.4,20.01,M
UNBRM1>CQ:,,,3,0327*28
[...]
UNBRM1>CQ:$GPGGA,153337.0,4558.8047787,N,06640.3536894,W,2,07,1.4,15.50,M
UNBRM1>CQ:,,,3,0327*25
                    Beginning of 153342.0
UNBRM1>CQ:,,,3,0327*24
UNBRM1>CQ:$GPGGA,153347.0,4558.7872482,N,06640.3406084,W,2,07,1.4,13.84,M
UNBRM1>CQ:,,,3,0327*21
UNBRM1>CQ:$GPGGA,153352.0,4558.7799299,N,06640.3426087,W,2,07,1.4,14.21,M
                    End of 153352.0
UNBRM1>CQ:$GPGGA,153357.0,4558.7852422,N,06640.3369300,W,2,08,1.1,13.25,M
UNBRM1>CQ:,,,4,0327*2F
                    Beginning of 153402.0
UNBRM1>CQ:,,,9,0327*25
UNBRM1>CQ:$GPGGA,153407.0,4558.8070304,N,06640.3583738,W,2,06,1.5,63.73,M
UNBRM1>CQ:,,,3,0327*2D
                    153412.0
UNBRM1>CQ:$GPGGA,153417.0,4558.8402069,N,06640.3381686,W,2,06,1.7,15.45,M
UNBRM1>CQ:,,,4,0327*24
                    Beginning of 153422.0
UNBRM1>CQ:,,,4,0327*2B
                    Beginning of 153427.0
UNBRM1>CQ:,,,4,0327*24
                    153432.0
UNBRM1>CQ:$GPGGA,153437.0,4558.9334741,N,06640.1698278,W,2,08,1.0,14.18,M
                    End of 153437.0
UNBRM1>CQ:$GPGGA,153442.0,4558.9580540,N,06640.1188284,W,2,09,0.9,13.76,M
UNBRM1>CQ:,,,3,0327*2E
UNBRM1>CQ:$GPGGA,153447.0,4558.9797942,N,06640.0623894,W,2,09,0.9,14.80,M
                    End of 153447.0;153452.0
UNBRM1>CQ:$GPGGA,153457.0,4559.0223360,N,06639.9500258,W,2,08,1.0,13.07,M
UNBRM1>CQ:,,,5,0327*22
                    Beginning of 153502.0
UNBRM1>CQ:,,,6,0327*26
                    Third problem of deconnection between laptop and GPS receiver
UNBRM1>CQ:
UNBRM1>CQ:cmd:
UNBRM1>CQ:
UNBRM1>CQ:Com2>$GPGGA,153827.0,4558.9466888,N,06639.7451504,W,2,09,0.9,6.
UNBRM1>CQ:03,M,,,31,0327*20
UNBRM1>CQ:$GPGGA,153832.0,4558.9457118,N,06639.7451308,W,2,09,0.9,4.71,M,
UNBRM1>CQ:,,36,0327*2C
[...]
UNBRM1>CQ:$GPGGA,153947.0,4558.8924424,N,06639.6659289,W,2,08,1.1,16.77,M
UNBRM1>CQ:,,,3,0327*25
                    Beginning of 153952.0
UNBRM1>CQ:,,,3,0327*2E
[...]
UNBRM1>CQ:$GPGGA,154007.0,4558.8196944,N,06639.5110029,W,2,08,1.1,13.51,M
UNBRM1>CQ:,,,3,0327*25
                    Fourth problem of deconnection between laptop and GPS receiver
UNBRM1>CQ:
UNBRM1>CQ:Com2>$GPGGA,154218.0,4558.7080374,N,06639.2646542,W,2,08,1.1,10
UNBRM1>CQ:.77,M,,,3,0327*25
UNBRM1>CQ:$GPGGA,154222.0,4558.7080926,N,06639.2647168,W,2,08,1.1,10.75,M
UNBRM1>CQ:,,,3,0327*2E
[...]
UNBRM1>CQ:$GPGGA,154457.0,4558.5511457,N,06638.8632802,W,2,09,0.9,14.57,M
```

UNBRM1>CQ:,,,15,0327*16
154502.0
UNBRM1>CQ:$GPGGA,154507.0,4558.5232448,N,06638.7740296,W,2,06,1.3,12.37,M
UNBRM1>CQ:,,,4,0327*2D
[...]
UNBRM1>CQ:$GPGGA,154607.0,4558.3705308,N,06638.3011481,W,2,08,1.1,10.48,M
UNBRM1>CQ:,,,6,0327*29
154612.0
UNBRM1>CQ:$GPGGA,154617.0,4558.3310870,N,06638.2146463,W,2,06,1.3,7.11,M,
UNBRM1>CQ:,,3,0327*11
[...]
UNBRM1>CQ:$GPGGA,154652.0,4558.2255791,N,06638.0233989,W,2,08,1.1,8.81,M,
UNBRM1>CQ:,,23,0327*23
Fifth problem of deconnection between laptop and GPS receiver, tape the connection
UNBRM1>CQ:
UNBRM1>CQ:Com2>fAB@NiAIY~^□FFa□[jk^o^N@BRVUU\
[…]
UNBRM1>CQ:fAB@NiqBYv^□fEY@dUTaPYq□hmijjF
UNBRM1>CQ:
UNBRM1>CQ:
UNBRM1>CQ:Com2>$GPGGA,155054.0,4558.1635323,N,06637.9464552,W,2,06,1.3,14
UNBRM1>CQ:.09,M,,,3,0327*25
UNBRM1>CQ:$GPGGA,155057.0,4558.1631678,N,06637.9468160,W,2,06,1.3,13.71,M
UNBRM1>CQ:,,,3,0327*28
[...]
UNBRM1>CQ:$GPGGA,160357.0,4558.1715187,N,06637.9452333,W,2,08,1.1,10.86,M
UNBRM1>CQ:,,,4,0327*20
Beginning 160407.0
UNBRM1>CQ:,,,9,0327*28
[...]
UNBRM1>CQ:$GPGGA,160442.0,4557.9869766,N,06637.6868700,W,2,07,1.3,11.93,M
UNBRM1>CQ:,,,2,0327*29
Beginning of 160442.0
UNBRM1>CQ:,,,2,0327*2A
UNBRM1>CQ:$GPGGA,160452.0,4557.9194437,N,06637.6389454,W,2,07,1.3,11.71,M
End of160452.0
UNBRM1>CQ:$GPGGA,160457.0,4557.8849011,N,06637.6158628,W,2,07,1.3,11.23,M
UNBRM1>CQ:,,,2,0327*23
Beginning of 160502.0
UNBRM1>CQ:,,,6,0327*2F
[...]
UNBRM1>CQ:$GPGGA,160627.0,4557.2660356,N,06637.3857972,W,2,08,1.1,10.47,M
UNBRM1>CQ:,,,2,0327*24
Beginning of 160632.0
UNBRM1>CQ:,,2,0327*13
[...]
UNBRM1>CQ:$GPGGA,160917.0,4557.1818292,N,06635.8446189,W,2,08,1.1,31.61,M
UNBRM1>CQ:,,,3,0327*2C
Beginning of 160922.0
UNBRM1>CQ:,,,5,0327*25
[...]
UNBRM1>CQ:$GPGGA,161112.0,4557.1890668,N,06634.2526596,W,2,08,1.1,101.36,
UNBRM1>CQ:M,,,3,0327*17
Beginning of 161117.0
UNBRM1>CQ:M,,,3,0327*14
Beginning of 161122.0
UNBRM1>CQ:M,,,3,0327*1F
161127.0
UNBRM1>CQ:$GPGGA,161132.0,4557.2454381,N,06633.9549241,W,2,08,1.1,96.22,M
UNBRM1>CQ:,,,4,0327*25
UNBRM1>CQ:$GPGGA,161137.0,4557.2608861,N,06633.8779276,W,2,08,1.1,96.39,M
UNBRM1>CQ:,,,3,0327*2F
161142.0,161147.0,161152.0,161157.0,161202.0
UNBRM1>CQ:$GPGGA,161207.0,4557.3983873,N,06633.4671827,W,2,08,1.1,97.20,M
End of 161207.0
UNBRM1>CQ:$GPGGA,161212.0,4557.4138082,N,06633.3957098,W,2,08,1.1,98.71,M
UNBRM1>CQ:,,,3,0327*25
Beginning of 161217.0
UNBRM1>CQ:,,,3,0327*29

161222.0,161227.0,161232.0
UNBRM1>CQ:$GPGGA,161237.0,4557.5188806,N,06633.0308547,W,2,08,1.1,99.14,M
UNBRM1>CQ:,,,3,0327*22
Beginning of 161242.0
UNBRM1>CQ:,,,3,0327*26
Beginning of 161247.0
UNBRM1>CQ:,,,13,0327*13
Messages between 161252.0 and 162702.0 are missing
UNBRM1>CQ:$GPGGA,162707.0,4557.8242161,N,06631.8327719,W,2,07,1.4,99.84,M
End of 162707.0
UNBRM1>CQ:$GPGGA,162717.0,4557.8252219,N,06631.9923000,W,2,08,1.1,98.61,M
UNBRM1>CQ:,,,3,0327*26
Beginning of 162722.0
UNBRM1>CQ:,,,3,0327*28
Beginning of 162727.0
UNBRM1>CQ:,,,3,0327*2C
Beginning of 162732.0
UNBRM1>CQ:,,,3,0327*2F
162737.0,162742.0,162747.0,162752.0,162752.0,162802.0,162807.0,162812.0,162817.0
UNBRM1>CQ:$GPGGA,162822.0,4557.5336826,N,06632.9976913,W,2,08,1.1,98.85,M
UNBRM1>CQ:,,,3,0327*25
162827.0,162832.0
UNBRM1>CQ:$GPGGA,162837.0,4557.4474689,N,06633.2318190,W,2,08,1.1,99.64,M
UNBRM1>CQ:,,,6,0327*2A
162842.0
UNBRM1>CQ:$GPGGA,162847.0,4557.4140618,N,06633.4041471,W,2,08,1.1,99.70,M
End of 162847.0;162852.0
UNBRM1>CQ:$GPGGA,162857.0,4557.3662211,N,06633.5669510,W,2,08,1.1,96.84,M
UNBRM1>CQ:,,,3,0327*28
Beginning of 162902.0
UNBRM1>CQ:,,,3,0327*2E
162907.0,162912.0
UNBRM1>CQ:$GPGGA,162917.0,4557.2593997,N,06633.8959223,W,2,08,1.1,95.24,M
End of 162917.0;162922.0
UNBRM1>CQ:$GPGGA,162927.0,4557.2248938,N,06634.0642008,W,2,08,1.1,98.39,M
UNBRM1>CQ:,,,3,0327*23
Beginning of 162932.0
UNBRM1>CQ:M,,,3,0327*13
[...]
UNBRM1>CQ:$GPGGA,163107.0,4557.1676082,N,06635.5165190,W,2,07,1.4,40.60,M
UNBRM1>CQ:,,,42,0327*1A
Beginning of 163112.0
UNBRM1>CQ:,,,4,0327*22
Beginning of 163117.0
UNBRM1>CQ:,,,9,0327*2C
UNBRM1>CQ:$GPGGA,163122.0,4557.1784486,N,06635.7141219,W,2,08,1.1,39.32,M
UNBRM1>CQ:,,,14,0327*17
UNBRM1>CQ:$GPGGA,163125.0,,,,,0,03,3.3,,,,,,*57
UNBRM1>CQ:$GPGGA,163132.0,4557.1842605,N,06635.8378299,W,2,06,1.9,31.63,M
UNBRM1>CQ:,,,3,0327*29
[...]
UNBRM1>CQ:$GPGGA,163232.0,4557.0783782,N,06636.0200950,W,2,08,1.1,27.91,M
UNBRM1>CQ:,,,21,0327*10
163237.0
UNBRM1>CQ:$GPGGA,163242.0,4557.0035036,N,06636.1113812,W,2,08,1.1,23.30,M
UNBRM1>CQ:,,,31,0327*1C
[...]
UNBRM1>CQ:$GPGGA,163257.0,4556.9186825,N,06636.3074797,W,2,08,1.1,10.90,M
UNBRM1>CQ:,,,46,0327*19
Beginning of 163302.0
UNBRM1>CQ:,,51,0327*25
UNBRM1>CQ:$GPGGA,163307.0,4556.8619687,N,06636.4403772,W,2,08,1.1,5.71,M,
UNBRM1>CQ:,,56,0327*29
UNBRM1>CQ:$GPGGA,163310.0,,,,,0,03,2.0,,,,,,*51
[…] (3)
UNBRM1>CQ:$GPGGA,163310.0,,,,,0,03,2.0,,,,,,*51
UNBRM1>CQ:$GPGGA,163337.0,4556.7412809,N,06636.8141033,W,2,06,2.0,10.31,M
UNBRM1>CQ:,,,4,0327*22
[...]

UNBRM1>CQ:$GPGGA,163357.0,4556.7764185,N,06637.0539151,W,2,08,1.1,9.80,M,
UNBRM1>CQ:,,3,0327*15
163402.0
UNBRM1>CQ:$GPGGA,163407.0,4556.7605060,N,06637.0806970,W,2,08,1.1,9.53,M,
UNBRM1>CQ:,,8,0327*14
[...]
UNBRM1>CQ:$GPGGA,163517.0,4556.5026078,N,06637.4574818,W,2,08,1.1,27.49,M
UNBRM1>CQ:,,,3,0327*27
UNBRM1>CQ:$GPGGA,163521.5,,,,,0,03,1.6,,,,,,*55
UNBRM1>CQ:$GPGGA,163527.0,4556.4676284,N,06637.5835811,W,2,08,1.1,32.37,M
UNBRM1>CQ:,,,4,0327*2D
[...]
UNBRM1>CQ:$GPGGA,163607.0,4556.4013240,N,06638.0005868,W,2,09,1.1,44.29,M
UNBRM1>CQ:,,,3,0327*26
Beginning of 163612.0
UNBRM1>CQ:,,,3,0327*29
UNBRM1>CQ:$GPGGA,163617.0,4556.4177427,N,06638.0509859,W,2,06,2.0,44.00,M
UNBRM1>CQ:,,,3,0327*2E
Beginning of 163622.0
UNBRM1>CQ:,,,5,0327*21
UNBRM1>CQ:$GPGGA,163627.0,4556.4644754,N,06638.0390082,W,2,06,2.2,35.71,M
UNBRM1>CQ:,,,4,0327*20
Beginning of 163632.0
UNBRM1>CQ:,,,9,0327*2A
Beginning of 163637.0
UNBRM1>CQ:,,,7,0327*27
[...]
UNBRM1>CQ:$GPGGA,163702.0,4556.7383392,N,06638.1319640,W,2,06,2.2,9.64,M,
End of 163702.0
UNBRM1>CQ:$GPGGA,163707.0,4556.7753485,N,06638.1650705,W,2,06,2.2,11.85,M
UNBRM1>CQ:,,,3,0327*22
[...]
UNBRM1>CQ:$GPGGA,164012.0,4557.4841009,N,06638.6155365,W,2,05,4.3,9.20,M,
UNBRM1>CQ:,,4,0327*1A
Beginning of 164017.0
UNBRM1>CQ:,,3,0327*17
UNBRM1>CQ:$GPGGA,164021.5,,,,,0,04,65.7,,,,,,*63
UNBRM1>CQ:$GPGGA,164027.0,4557.5213240,N,06638.6888524,W,2,05,5.0,5.84,M,
UNBRM1>CQ:,,2,0327*13
[...]
UNBRM1>CQ:$GPGGA,164107.0,4557.6022960,N,06638.9001121,W,2,06,2.1,9.20,M,
UNBRM1>CQ:,,9,0327*11
Beginning of 164112.0
UNBRM1>CQ:,,14,0327*21
[...]
UNBRM1>CQ:$GPGGA,164227.0,4557.6922256,N,06639.2284032,W,2,07,1.4,10.21,M
UNBRM1>CQ:,,,2,0327*24
Beginning of 164237.0
UNBRM1>CQ:,,,7,0327*22
[...]
UNBRM1>CQ:$GPGGA,164552.0,4557.1130319,N,06639.1635390,W,2,06,2.3,38.89,M
UNBRM1>CQ:,,,6,0327*28
164557.0
UNBRM1>CQ:$GPGGA,164602.0,4557.0551921,N,06639.2138545,W,2,07,2.2,45.94,M
UNBRM1>CQ:,,,3,0327*29
[...]
UNBRM1>CQ:$GPGGA,165232.0,4557.0199435,N,06638.5278192,W,2,07,1.5,24.83,M
UNBRM1>CQ:,,,3,0327*2D

APPENDIX VIII

TRACK OF THE EXPERIMENT ON JULY THE 15

Scale: 1/20,000