SIDEWINDER MISSILE GPS RECEIVER TESTS

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ABSTRACT

The use of Global Positioning System (GPS) receivers as a source to provide Time Space and Position Information (TSPI), and Miss Distance Indication (MDI) data in Test and Evaluation (T&E) applications is being considered. Specifically, GPS receivers are being evaluated to determine their usefulness as a sensor in a Sidewinder missile telemetry system (AN/DKT-80). Initial testing has indicated that position information generated from a GPS receiver can provide significantly better position data than a radar tracking system when using Double Differential error correction techniques. This concept requires a GPS reference station to be located in the general proximity of the Telemetry data-receiving site. Software has been developed that will compare GPS data from the airborne telemetry system to the GPS reference station and display a real-time TSPI solution. This software will also provide MDI information from two different airborne sources that are equipped with GPS receivers (missile and drone). To prove out this concept, a Commercial Off the Shelf (COTS) Commercially/Available (C/A) code GPS receiver was integrated into the AN/DKT-80 Sidewinder telemetry system (TM). A MQM-107 drone was instrumented with the same GPS receiver, as was a ground based reference station. A simple TM was developed for the drone that telemeters only the GPS data. The modified AN/DKT-80 system incorporated an Inertial Measurement Unit (IMU) into the design. Post processing software was developed that will integrate the IMU information with the GPS data so accurate position can be generated if the GPS data was momentarily lost. A missile firing is scheduled for the spring of 1999 to prove this concept.

KEY WORDS

Global Positioning System (GPS), Time, Space, Position Information (TSPI), Miss Distance Indication (MDI), and missile telemetry.

OVERVIEW

A Sidewinder telemetry system is being flown that has a GPS receiver on board. The purpose is to see how the GPS receiver performs in a small missile environment. The data that is of interest is the Time, Space, and Position Information (TSPI) and Miss Distance Indication (MDI). In order to get MDI between the drone and the Sidewinder, the drone needs a GPS receiver so the data can be compared with that of the missile and the MDI data can be calculated. The drone picked for this firing is a MQM-107.

The Sidewinder GPS telemetry system is a modified AN/DKT-80. The system works just like an AN/DKT-80. The encryption key and frequency loading has remained the same. The connector that mates to the guidance and control section (GCS) is also the same. The only difference that is noticeable is the antenna. The antenna is wider than the one on a standard AN/DKT-80. There are two antennas in the band. One is the S-band for the telemetry and the other is tuned for the L1 GPS frequency. In terms of the measurement list, all the parameters that were being monitored in the standard AN/DKT-80 are still being monitored. There are some added signals. They are Pitch, Yaw and GPS receiver data.

The drone telemetry system is a simple telemetry system which only sends the GPS receiver data down to the ground. It replaces the radar altimeter and uses the same housing.

The mission objectives were defined by the Joint Advance Missile Instrumentation (JAMI) program which are to display the GPS TSPI data real time for both the missile and drone for range safety with accuracies of less than 50 meters. The MDI between the drone and missile are to be displayed in real time for scoring with an anticipated accuracy of 3 meters. The post processed data of TSPI and MDI may have accuracies of less than 30 centimeters. Several software packages are being used to do this processing.

A simple diagram showing all the players for this test are shown on Figure 1. Only two satellites are shown to keep the diagram from being too busy. On the day of the test the GPS receivers could be tracking as many as eight satellites. A GPS reference receiver is added to the TM ground station. There are also three PC computers that are added to the ground station. These PCs are used to compute and display the real time TSPI for the missile and drone and the MDI between the missile and drone. How all this comes together is explained in this paper.

The physical differences between the standard AN/DKT-80 and the Sidewinder GPS TM are: the Frequency Select Card has the GPS interface circuitry added, the Motherboard was modified to move the Frequency Select/GPS Card to add room for the GPS receiver, Pitch and Yaw rate sensors were added and a BOA (A Sidewinder improvement program) power distribution board was used to power the added rate sensors. The rate sensors were added to provide a six degree of freedom (DOF) inertial measurement unit so post processing of the data can be done to improve the position update rates. The GPS receiver outputs position updates at 20 Hz

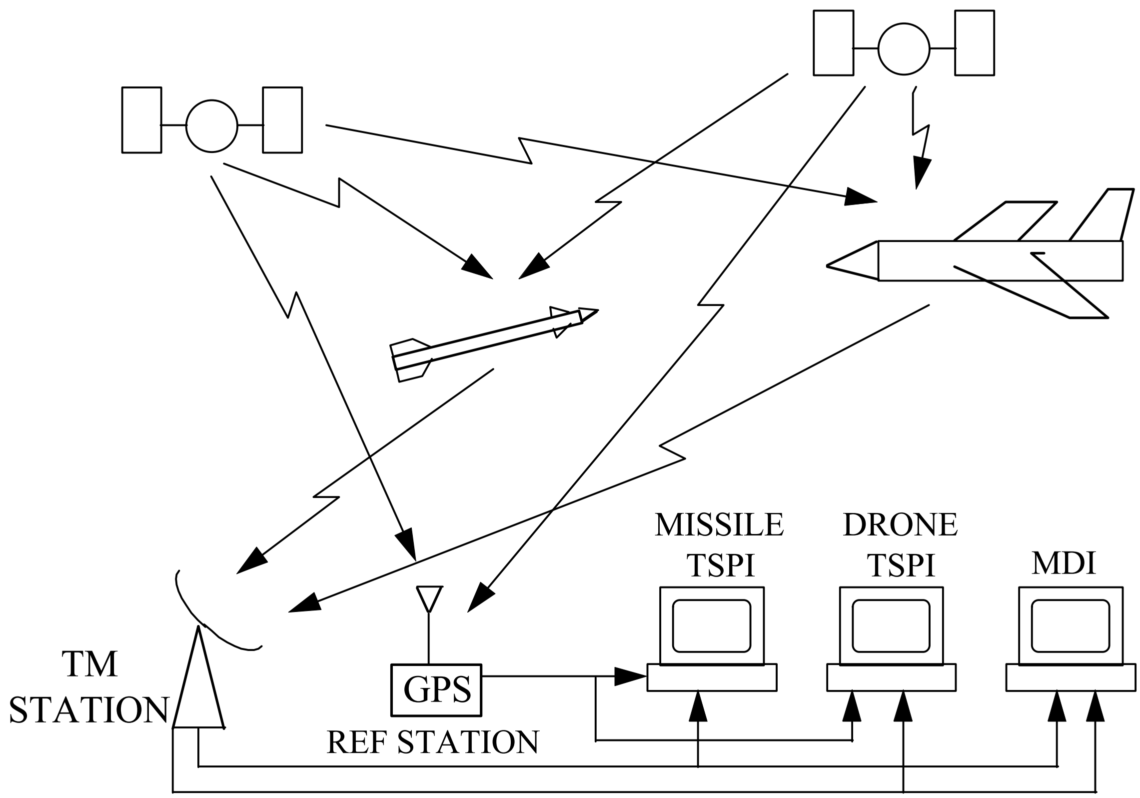

FIGURE 1. Test set up

SIDEWINDER GPS TM

The card cage of the AN/DKT-80 was designed to hold up to five cards but uses four. There are two signal conditioner cards, an encoder card and a Frequency select board that is used to store the transmitter frequency in nonvolatile static random access memory (NOVRAM). The Frequency select card has few components on it so the GPS receiver interface circuitry was added. The interface circuitry consists of a RS-232 interface and a universal asynchronous receiver transmitter (UART) to output the GPS data in parallel. The GPS receiver, a G12 HDMA (High Dynamic Missile Application), plugs into the Frequency Select/GPS interface board as a daughter card. This combination takes up two card slots. All five slots are now used. The pre-amplifier and filter for the G12 are also located on the Frequency Select/GPS interface card. A drawing showing the card layout is shown on Figure 2.

The Ashtech G12 HDMA GPS receiver was chosen for this effort. There are several reasons for this. One is the packaging. It is small enough to fit into the AN/DKT-80. Another is that sled testing was done on the receiver[1]. The environment seen in the sled testing is much harsher than that seen in Sidewinder. The G12 was also used in Vandal and worked very well. The data from the Vandal shot has been very well analyzed and is thought to give centimeter accuracy[2].

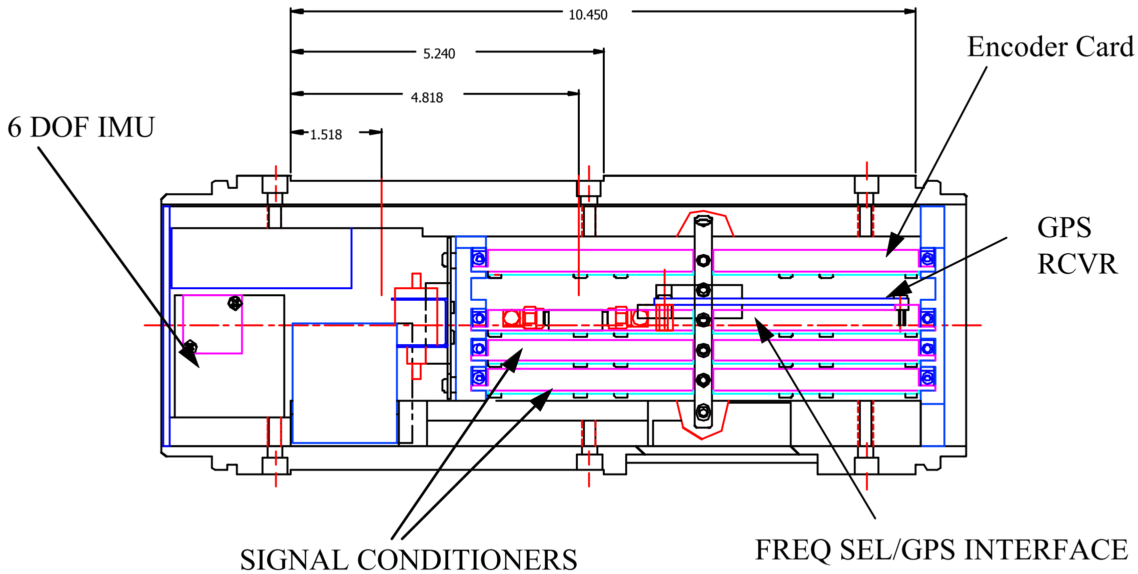

FIGURE 2. Modified AN/DKT-80 telemetry unit

The G12 has two RS-232 ports. Port A is used for telemetry data. Port B is brought out to a service connector located under a hatch in the skin of the missile telemetry system and is used to configure the GPS receiver. A holding battery is used save the receiver configuration. A simple block diagram of how the GPS receiver was integrated into the telemetry unit is shown on Figure 3. The RS-232 from the receiver goes to a microcontroller that acts as a UART. The serial data is converted into a parallel word and tagged with a valid bit where it is read by the encoder and transmitted to the ground.

The antenna is a dual band wrap-around antenna made by Haigh-Farr. The phase center of the GPS antenna was measured and was found to be about an inch and a half aft of the connector and on the surface of the missile. The GPS measurements are made from the phase centers of the antennas. In order to get centimeter accuracy, the phase center needs to be accurately known.

TELEMETRY FORMAT

The telemetry format for the AN/DKT-80 also had to change to accommodate the added rate sensors and GPS data. The bit rate changed from 1 MB/s to 1.25 MB/s. The common word size is 12 bits. The GPS receiver baud rate is 115.2 KBaud with 8 bit words. To handle this rate, the GPS data word is sampled at 20 Ksamples per second. The TM word format is shown on Figure 4. The GPS data takes up the first 8 bits. The 9th bit is a status bit to verify the GPS data word is a new valid word. This is needed because at 20 KSamples per second the data is oversampled and a word will be repeated. Also the data is asynchronous and there is dead time. This bit is cleared once that word has been sent. The next two bits are unused. The last bit is a timing bit. This is the 1 pulse per second output from the GPS receiver. The rising edge indicates when the GPS time has been incremented by a second. This pulse is accurate to about 40 microseconds. The pulse is needed to be able to correlate the GPS data and the IMU data in post processing.

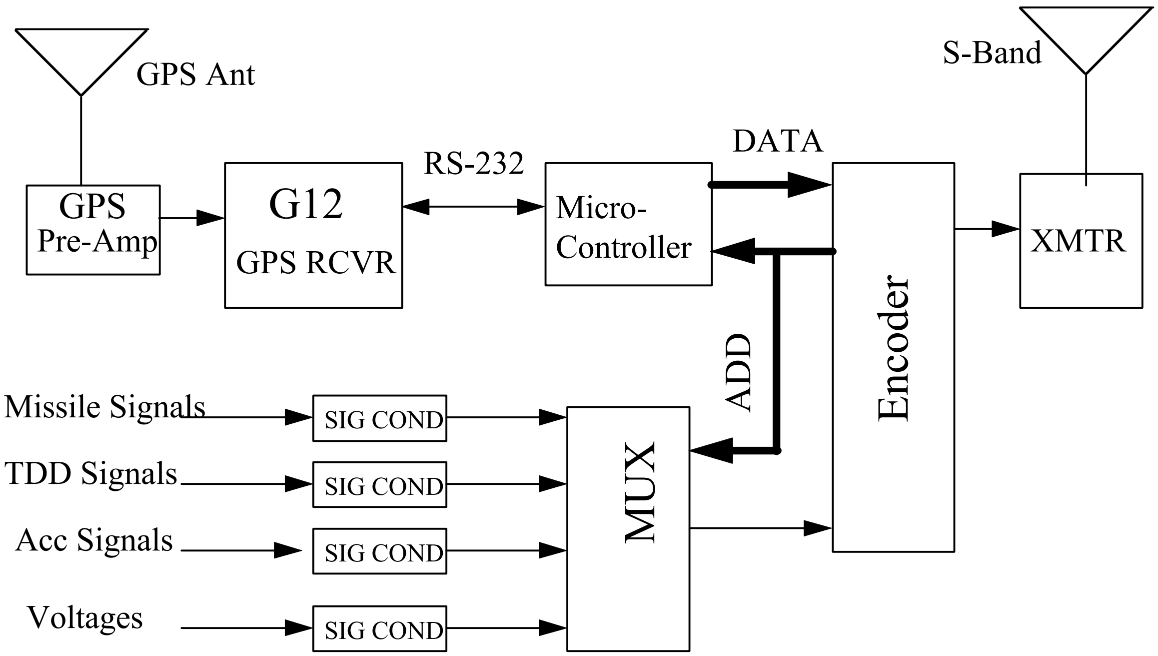

FIGURE 3. Sidewinder GPS TM block diagram

Timing	Spare	Spare	Valid Data	GPS Word							
D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

FIGURE 4. GPS DATA word format

MISSILE GROUND STATION

The firing is scheduled to be done at Tyndall AFB. The missile ground station equipment is shown in Figure 5. The Decom system used at Tyndall is a Loral ADS-550. The main difference in the ground station set-up between a standard AN/DKT-80 and a modified GPS AN/DKT-80 is the need for a parallel to serial box to convert the GPS data back into the RS-232 signal at 115.2 KBaud. The box reverses the process that is done in the missile. This box checks to see if the valid bit is set. If it is set, then it ships it through the UART and is converted back into the RS-232 format that the GPS receiver originally sent. The computer, tied to this box, thinks it is tied directly to the GPS receiver. This was necessary to be able to use COTS software to display the GPS data in real time. The GPS reference receiver is also tied into this computer so it can do the double difference GPS correction, display and archive the missile TSPI data.

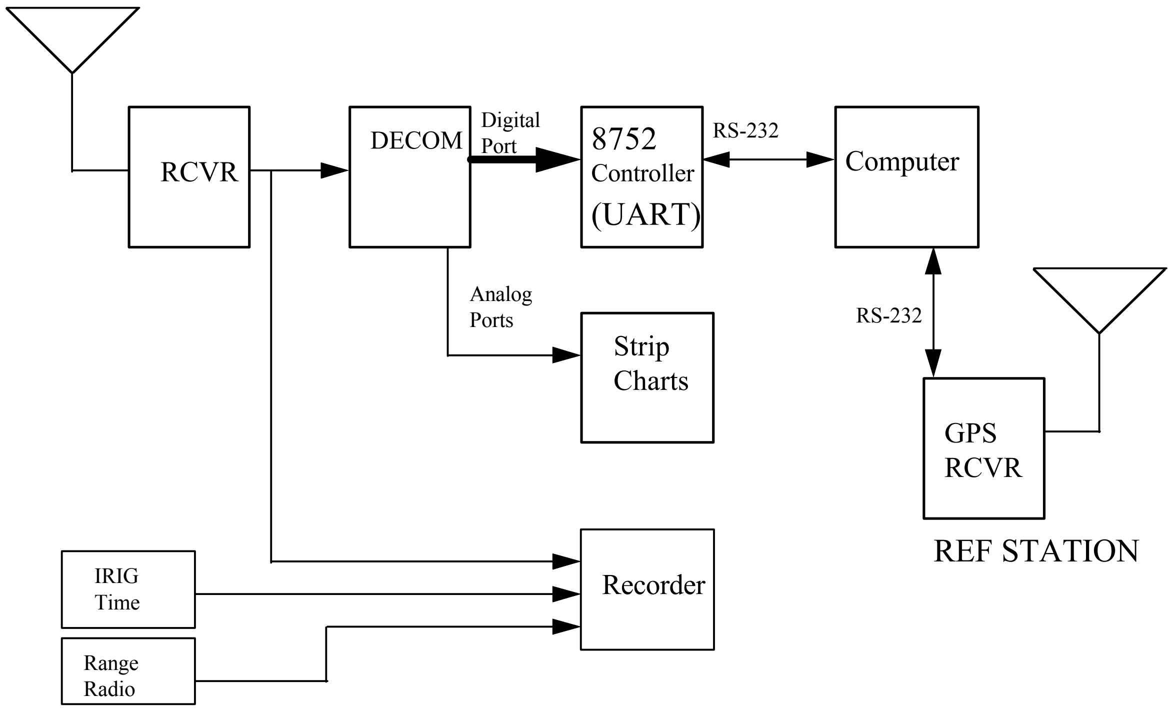

FIGURE 5. Missile ground station block diagram

DRONE GPS TELEMETRY

The GPS telemetry system for the drone is housed in the case of the Radar Altimeter. The drone will not have to be rewired to accommodate the GPS TM. To turn on the GPS TM, the switch on the control panel for the altimeter activates the TM.

The GPS receiver is the same as that used in the missile, an Ashtech G12 HDMA receiver. The receiver outputs the raw code and carrier phase information through a RS-232 communication port at 115.2K baud. The RS-232 data is converted it to Non Return to Zero-Level (NRZ-L) data and then randomized with an IRIG 106-96 approved 15 bit randomizer. This data goes through a 3-pole Bessel pre-mod filter set at .7 times the bit rate and deviates the transmitter with a peak-to-peak deviation of .7 times the bit rate.

The Antenna will be located in the nose of the drone. A dual band 5 inch wrap-around antenna is used. There is an L-band antenna for the GPS receiver and an S-band antenna for the telemetry transmitter. This antenna was designed and built at NAWCWD. It is similar in size to the Haigh-Farr antenna. The antenna is secured in the nose section of the drone by wrapping it around a Styrofoam tube approximately 5 inches in diameter and 12 inches in length. The aluminum foil will be wrapped around the Styrofoam tube helps to provide a ground plane for the antenna. This assembly is then place into the drone nose cone where additional foam is added to fill any voids and to provide a cushion for the drone to land on during recovery. The signals from the GPS satellites are very weak and the receiver needs a pre-amplifier. There is the pre-amplifier for the GPS receiver located in the nose and provides 25 dB of gain. Again the phase center of this antenna had to be measured and was found to be about 2 inches aft of the antenna and on the surface of the 5 inch diameter mounting tube. The drone configuration is shown on Figure 6.

Port B of the GPS receiver is also brought out to the nose cone. This provides access to the receiver when the drone is assembled and allows the receiver to be configured and checked out prior to flight.

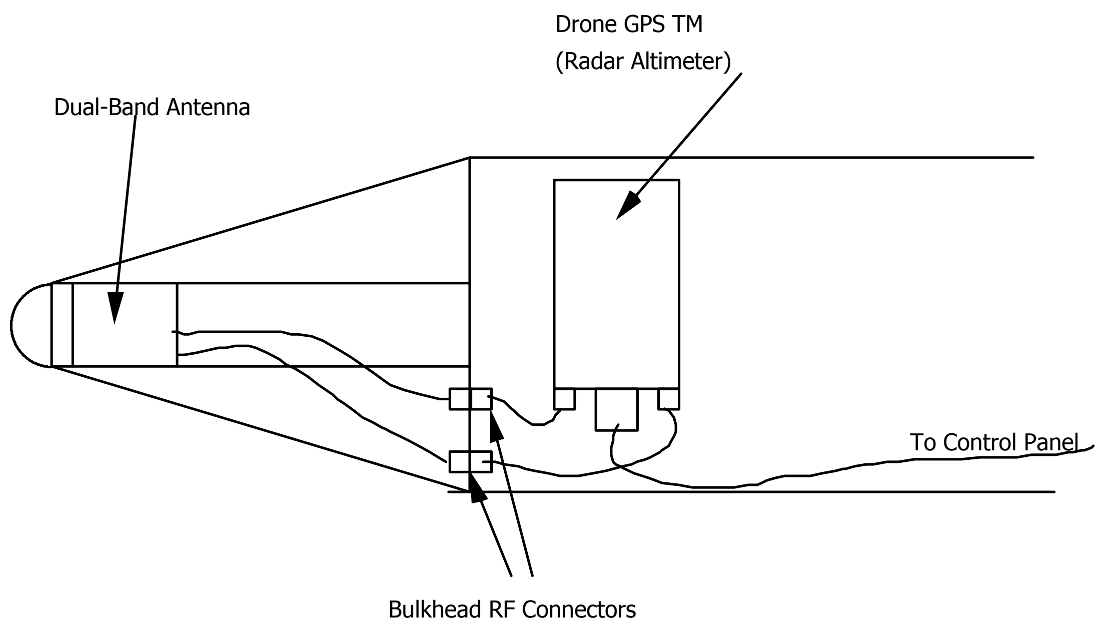

FIGURE 6. Drone GPS layout

DRONE GPS GROUND STATION

The ground station requirements to support the Drone GPS TM is rather minimal. Figure 2 is a block diagram of the ground station set-up. Tyndall will provide a receiver, a tape recorder and a bit sync. The bit sync will derandomize the data stream and create a NRZ-L data stream and 0° clock. The data stream and clock are fed into a box provided by China Lake to convert the NRZ-L data to RS-232. This data is then fed into a PC, along with the reference receiver where the data will be processed, displayed and archived. This will give the real-time TSPI display for the drone.

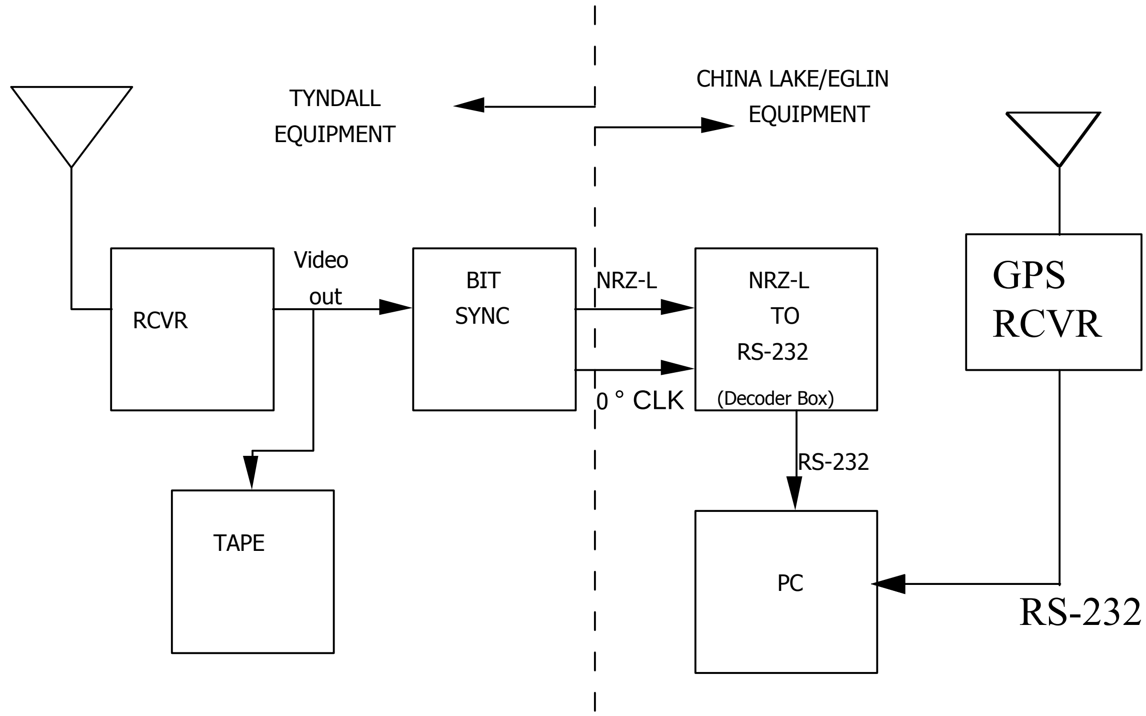

FIGURE 7. Block diagram for the drone GPS ground station

MISS DISTANCE INDICATION (MDI)

The setup for MDI between the missile and drone is shown on Figure 8. The block diagram is a continuation of Figures 5 & 7. From the two respective boxes, the RS-232 data streams are brought into a PC where one of the two streams is treated as the reference receiver. The double difference correction is done on these data streams exactly as it is done for the missile and drone TSPI. This computer then displays, and archives the MDI data.

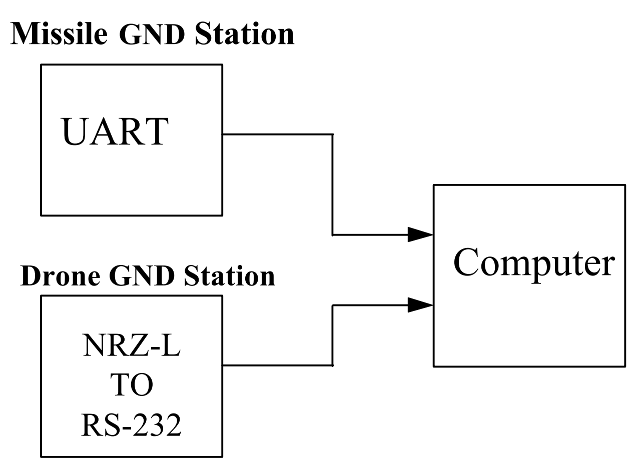

FIGURE 8. MDI set up

SOFTWARE

There are several different software packages that will be used to process the data. There is one for real time processing and a couple of others that will be used to post process the data.

Waypoint is the software that is used for real time processing[3]. The Missile and drone will be outputting pseudorange, carrier phase and doppler information. The receiver will not be outputting its position data. The position data is calculated differentially between the ground station and the missile or drone. This will provide real time TSPI data at 20 Hz for the missile and drone. The miss distance between the missile and drone is done by doing the differential correction between the drone and missile with one used as a moving baseline[4]. This data could be converted to the correct data protocol and sent to the range control center to be displayed in real time as an Independent Tracking Aid (ITA). This could be very useful for the range safety. This integration will not be done at this time but looks as though it will not be difficult to implement.

For post processing there will be two packages used but other software packages may be used later. The Multi-sensor Optimal Smoother Estimating Software (MOSES) is used at Edwards AFB[5]. MOSES takes the GPS data and the IMU data and couples the data together. This will give much higher position update rates for the missile. This should also improve the MDI calculations between the missile and drone. The other package is WADGPS done by the NSWC at Dahlgren[2]. This package was used on the Vandal shot and came up with some very good results. Vandal also uses the G12 GPS receiver.

CONCLUSION

This demonstration project, which is a joint effort between the Air Force and Navy, shows promise that GPS receivers can be used as a sensor in high dynamic missiles and other T&E applications. As an instrument or sensor added to the telemetry, they can provide centimeter accuracy for TSPI. Since GPS is more accurate than radar, this will reduce the need for radar tracking and will allow testing to the done at remote sites.

REFERENCES

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[3] http:// www.waypnt.com

[4] http:// www.waypnt.com/MOVBASE.HTM

[5] http://www.tspi.elan.af.mil/gainr/mosesstat.html