A

Seminar report

On

Satrack

Submitted in partial fulfillment of the requirement for the award of degree
Of CSE

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Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

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Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

Preface

I have made this report file on the topic **Satrack ;** I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

CONTENTS

INTRODUCTION

According to the dictionary guidance is the 'process of guiding the path of an object towards a given point, which in general may be moving'. The process of guidance is based on the position and velocity if the target relative to the guided object. The present day ballistic missiles are all guided using the global positioning system or GPS.GPS uses satellites as instruments for sending signals to the missile during flight and to guide it to the target. SATRACK is a system that was developed to provide an evaluation methodology for the guidance system of the ballistic missiles.

This was developed as a comprehensive test and evaluation program to validate the integrated weapons system design for nuclear powered submarines launched ballistic missiles .This is based on the tracking signals received at the missile from the GPS satellites. SATRACK has the ability to receive record, rebroadcast and track the satellite signals.

SATRACK facility also has the great advantage that the whole data obtained from the test flights can be used to obtain a guidance error model. The recorded data along with the simulation data from the models can produce a comprehensive guidance error model. This will result in the solution that is the best flight path for the missile.

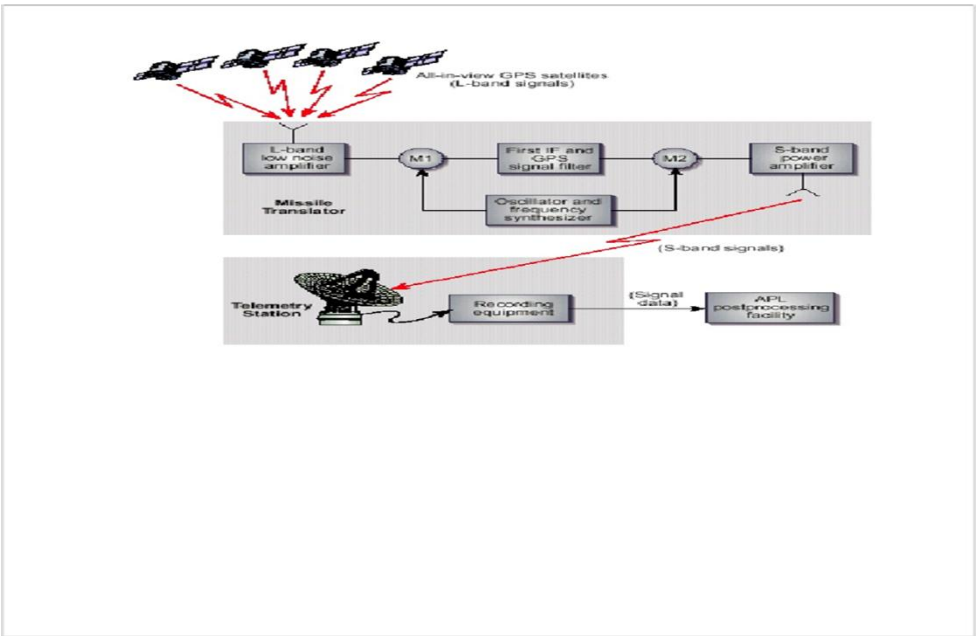
SATRACK GPS SIGNAL

The signals for the GPS satellite navigation are two L-band frequency signals. They can be called L1 and L2.L1 is at 1575.42 MHz and L2 at 1227.60 MHz.The modulations used for these GPS signals are

1. Narrow band clear/acquisition code with 2MHz bandwidth
2. Wide band encrypted P code with 20MHz bandwidth.

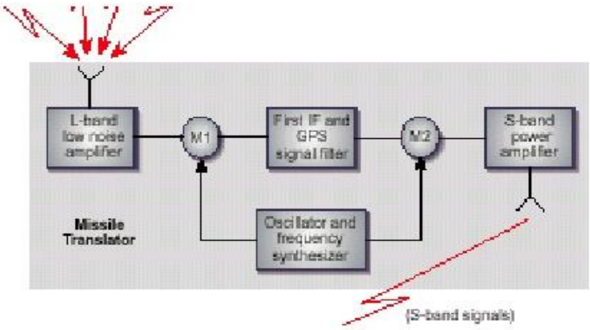
L1 is modulated using the narrow band C/A code only. This signal will give an accuracy of close to a 100m only. L2 is modulated using the P code. This code gives a higher accuracy close to 10m that is why they are encrypted. The parameters that a GPS signal carries are latitude, longitude, altitude and time. The modulations applied to each frequency provide the basis for epoch measurements used to determine the distances to each satellite. Tracking of the dual frequency GPS signals provides a way to correct measurements from the effect of refraction through the ionosphere. An alternate frequency L3 at 1381.05MHz was also used to compensate for the ionospheric effect.

SATRACK CONCEPT



Guidance system evaluation concept of very early weapons systems depended on the impact scoring techniques. This means that the missile was shot and the accuracy was formulated on the scoring or the target destruction. This evaluation method was unacceptable for evaluating the more precise requirements of the latest systems. A new methodology was needed that provided insights into the major error contributors within the flight-test environment. The existing range instrumentation was largely provided by radar systems. they however did not provide the needed accuracy or range in the broad ocean test ranges. The accuracy projections needed to be based on the high confidence understanding of the underlying system parameters. SATRACK was developed with the necessary hardware and telemetry stations.

The figure shows the SATRACK measurement concept. The main parts are the GPS satellites, the missile translator and ground telemetry stations. The missile receives the signals from the GPS satellites. They are translated to another frequency and relayed to the ground telemetry stations. The telemetry station records the data for playback and for post processing. The satellite signals received at the missile are translated to S-band frequencies for the telemetry station using the missile hardware called translatorsground based telemetry station record the data after reception through the antenna after digitising the signals. Some ground sites uses L1 C/A signals to.ground based telemetry station record the data after reception through the antenna after digitising the signals. Some ground sites uses L1 C/A signals to provide real time tracking.uses L1 C/A s



SATRACK GPS TRANSLATOR

This flight hardware is fixed in the missile. The translator receives the GPS signals and they are amplified, shifted to an intermediate frequency, filtered to cover the satellite signal modulation bandwidth, shifted to an output frequency. Then they are amplified for transmission to one or more ground station. The translator does the following

1. Received the satellite signal

2. Translated it to a missile telemetry frequency (S-band)

channels. The user interface is done using windows based PC workstation

SATRACK POST FLIGHT TRACKING AND DATA PROCESSING

This is the most important part of the SATRACK technology3. Rebroadcast the received signal

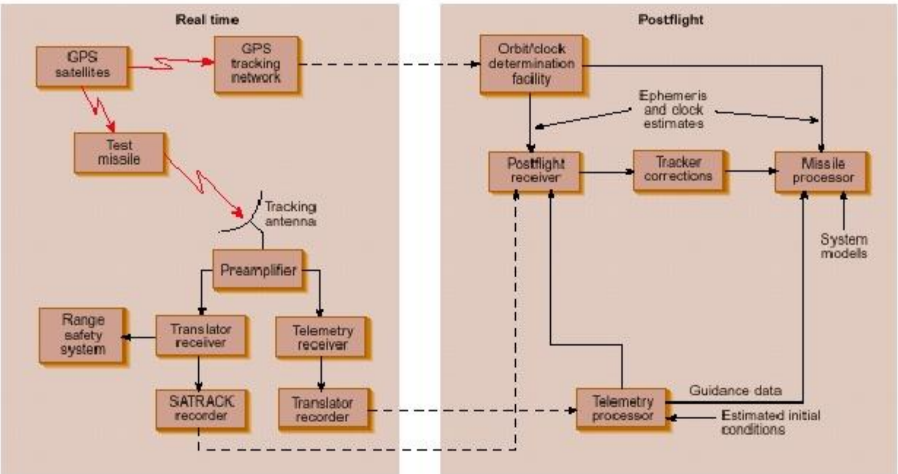
GPS translator are of both Analog and digital types The Analog translators heterodyne the L-band signal to S-band adds a pilot carrier to allow the monitoring of the reference oscillator variations. Both wide and narrow band type of Analog translators are used. Digital translators down-convert the received L-band GPS signal to near base band and digitises it. This digitised data is modulated into an S-band carrier and transmitted to the ground stations.

FIELD SUPPORT EQUIPMENT

SATRACK is the most useful tool because of its post flight processing facility .The ground equipment consists of receiving antenna, data recorder and auxiliary reference timing systems. The equipment receives the translated GPS signal along with other telemetry signals and distributes it to the data recorder. Most ground stations are capable of generating a precise atomic timing standard. The earlier equipments were narrowband recorders that relied on high-speed tape recorders. These gave up to 14 tracks of recording channels with four mega samples per second. The translator processing system was developed for the national missile defence exoatmospheric re-entry intercept subsystem where it served as a real-time GPS processor for range safety as well as data recorder.

PORTABLE GROUND EQUIPMENT

This hardware is used for the post flight processing and tracking of the satellite signals. The SATRACK facility processes the raw data into a time series of range and Doppler measurements for each satellite, and the Kalman filter, which incorporates various corrections and generates a navigation solution for the missile. The system has undergone a lot of redesign and development as the requirements evolved with new type of translators and receivers. The latest system processes the wideband L1/L2 signals dual frequency P-code as required by wide band translators. The system hardware is based on Analog Device SHARC processor. Most of the custom GPS processing hardware is based on field programmable gate arrays [FPGA]. Each board has the ability to track up to eight



BASIC SATRACK CONFIGURATION

FIG 3

For a number of days surrounding the missile flight, GPS signals are received, tracked, and recorded at the GPS tracking sites.

During the missile flight, GPS signals are received by missile, translated in frequency, and transmitted to the surface station(s).

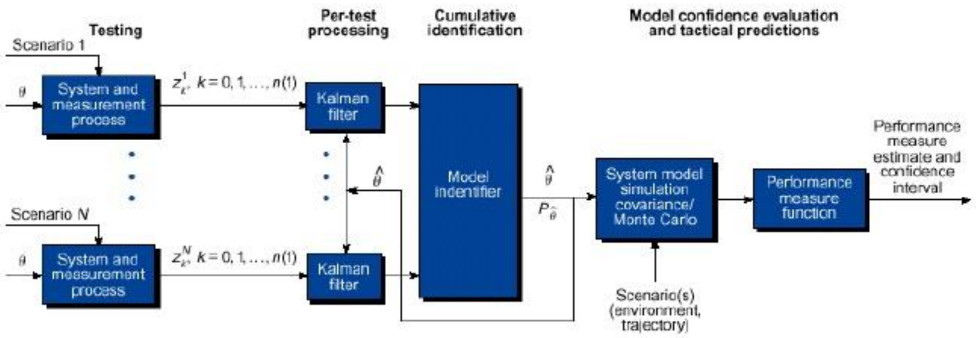
A tracking antenna at the station receives the missile signals, separates the various components and records the data.

The post-flight process uses the recorded data to give satellite ephemeredes clock estimates tracked signal-data from the post-flight receiver, and missile guidance sensor data.

After the signal tracking data are corrected, all the data element and the system models are used by the missile processor to produce the flight test data products.

The figure shows how the post flight tracking facility accomplishes precision tracking of the GPS signals through the playback of the recorded translator signals. High accuracy satellite ephemeredes and the clock estimate covering their span of test flight is obtained. These data along with the processed telemetry data help provide the tracking aids for the post flight receiver and measurement estimates for the missile processor. The translator passes signal for all the satellite in view of the missile antenna and the post flight receiver provides all in view satellite signal tracking. During play back satellite signals are tracked through delay locked loops

For range code modulation and phase locked loops for carrier phase tracking. The post flight processing of the recorded data is used to test the accuracy of the measurements that is to evaluate the guidance system. The concept can explained based on the block diagram given below.

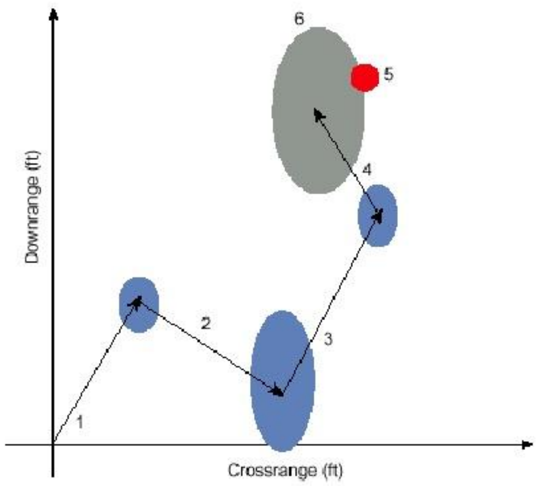


STRATEGIC WEAPONS SYSTEM ACCURACY EVALUATION CONCEPT

FIG 4

The procedure was developed by whish the uncertainties with which we observe a performance as well as the finitude of test programs was translated in to specified confidence in the accuracy parameters being estimated. Information theory provided the basis for developing the algorithms that could quantify the confidence with which accuracy could be estimated. Next performance needed to be known, not just the system level but at the subsystem level also. The accuracy evaluation program had to be able to isolate faults and estimate performance of the subsystems or the various phases of the system. Since the allowable number of test used for the determination of estimates were limited to 10to 20 the instrumentation had to be of high quality to provide the high confidence measurements hence to get good confidence estimates. In addition to this, we also needed to extrapolate the untested condition that is to predict tactical performance with high-quantified confidence from test data.

Data from each accuracy test was analysed using some variant of the Kalman filter. Within these filters are the detailed models of both the system and the instrumentation for each system. The figure depicts how this analysis is accomplished. Given a particular test or scenario measurement, data are collected on the various subsystems. Using rigorous methods, these data are collected with prior information generally developed and maintained by builders of the various parts of the system under test. This prior information is necessary for the single test processing, given the incomplete observability of the error sources. The outputs of the filter provide the basis for understanding particular realizations of system and subsystem behaviour. Analysis results provide insight in to the sources and causes of the inaccuracy. The results of the multiple tests –the outputs of the Kalman filter –serve as the inputs to the cumulative parameter estimation process. All prior information regarding therelative error models is removed o that the estimate accuracy is derived solely



RECONSTRUCTIONS OF SOURCES OF MISSILE IMPACT MISS DISTANCE ERROR

FIG 5

of sources of missile impact miss distance error The graph shows a hypothetical diagram used to allocate contributions to the impact miss. This method is based on projecting each error contributor and its uncertainty into impact domain.

1. first level allocation is at the subsystem level: initial conditions, guidance, and deployment and re-entry

2. second-level allocation provides data for major error groups within each subsystem eg: accelerometers

3. third-level allocation (not given in figure) produces estimates of fundamental error terms of guidance model eg: an accelerometer scale factor.

This process solves the highly non linear equations for the means, variances, and Markov parameters that characterize the overall system accuracy performance. In addition uncertainties in the parameter estimates are calculated so that we have a quantitative measure of our confidence in the solution .The ultimate desired product is system performance under tactical not test conditions. Here we rely heavily on the tactical gravity and weather conditions developed from data and instrumentation. These models along with deterministic simulations of the system are then used to propagate the fundamental model parameter estimates and the uncertainties to the domain of interest-system accuracy at the target.

The carrier phase tracking of the signals provide the critical measurements .The measurements of the GPS signal; phase sense range changes along the line of sight for each signal to a small fraction of the wavelength usually a few millimetres. These measurements which when compared to their values computed from guidance sensor data and satellite position and velocity estimates, provide most of the information. Noise in the measurement of the recovered GPS range code signals is of secondary importance. In essence, the inertial sensors provide high frequency motion information better than the signal processes, the Doppler information senses the systematic errors associated with the inertial sensors and the range data provide an initial condition for all the dynamic measurements. The range noise remaining after the process of smoothing of the noise is smaller than the other bias like uncertainties that set the limit on absolute position accuracy e.g.: the satellite position

The missile and satellite trajectories including stimulated errors for satellite position and clocks were used dot drive the satellite signal generators to produce the simulated GPS signals. These are then passed through digitally controlled phase shifters and time multiplexing switch to emulate the missile GPS antenna network. This is connected to a missile translator hardware simulator that produced the GPS signals at S-band. An S-band antenna hardware simulator produced the outputs, which were recorded by the prototype telemetry station receiver, and the recording equipment .The hardware simulator drivers were conditioned to encompass all anticipated effects including signal refraction through the ionosphere and troposphere. The recorded data were equivalent to the data that would be received from telemetry site.

The post flight processing facility now has all the inputs, GPS ephemeredes, clock files, telemetry data and translated signal data tape. These data are then processed and an estimate of the underlying model errors is produced. In addition, the testing of the post processing system is done

SATRACK MAJOR BREAKTHROUGHS

1. **EVALUATION CAPABILITY FOR CUMULATIVE FLIGHT TEST ACCURACY**
   The limitations of the test geometry prohibit observations of all the errors in any single flight test. Since each test flight provides observations of the underlying system missile guidance error models, the data can be combined from may flight tests. The final cumulative analysis of flight test data produces a guidance error model of the weapons system. It combines observations from each flight to derive a missile guidance model that is both tactically representative and based completely on the flight test data. This model combined with other similarly derived sub system models helps develop planning factors used to assign weapons system targets

2. FULL DIGITAL IMPLEMENTATION

. The full digital implementation is of the Portable ground equipment and processing facility. So, the results are expected to be repeatable. This is a very big improvement over the Analog circuitry such as the Analog PLLs used for carrier- phase tracking loop. In addition, the digital implementation removes the need for periodic hardware calibration that accompanies the analogckt.

3. BATCH MODE PROCESSING

This type of processing allows hardware to operate with software like flexibility. As the pure software system was too slow, hardware that is fully configurable under software control implemented the most computing intensive portions of the process such as signal correlation, generation of local code and carrier signal mixing. It is possible to acquire the signal with virtually no acquisition delay by conducting extensive searches with initial batch of data until all the signal is found.

4.FLEXIBLE ARCHITECTURE RECEIVER

The batch mode processing has been applied to stand alone real time capable receiver called FAR. It retains the essence of batch mode architecture. While maintaining the capability to process the data in real time. FAR is a single channel L1 C/A only receiver with a front-end data storage memory that buffers unto one s of data. It can track up to 16 satellites in real time without any loss from channel multiplexing.

Conclusion

SATRACK is a significant contributor to the successful development of and operational success of the trident weapons system. It provides a unique monitoring function that is critical to the maintenance of strategic weapons systems.

The development and research leading up to this technology has been instrumental in bringing out the latest in GPS receiver, translators, data recorders etc.several special test have been conducted with various combinations of inertial systems, GPS receivers, translators as well as RF/antenna designs. Special tests have demonstrated that accuracy a be achieved to support potential new and extremely demanding tactical strike scenarios.

The development of SATRACK looks forward to the implementation of the Low Cost Missile Test Kit. one other main development from this technology was the development of sophisticated tools for optimal target patterning. Instrumentation, analytic methods, and modelling and the use of limited and expensive flight tests assets were also born out of the SATRACK research

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