

GPS-TRAK*
LOW COST ALTERNATIVE TO AUTO-TRACKING
USING GPS AND MULTIMODE
SINGLE AXIS ANTENNA TECHNIQUES

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ABSTRACT

The GPS Satellite System provides precise determination of time, space, and position of aerospace (airborne) vehicles during flight and flight test situations. The cost of "GPS" equipment has been decreasing dramatically -- a phenomenon similar to that which was experienced with "hand held" calculators 20 years or so ago. By the use of a multigain (and beam) antenna and GPS, a very low cost single axis system can be utilized for reception of telemetry and at the same time to provide accurate position, velocity, and acceleration information concerning the airborne vehicle.

INTRODUCTION

In the early days of telemetry, tracking was not required since the frequency allocation for telemetry was in the P-Band frequency range. Space attenuation was low enough and bandwidths narrow enough so that omnidirectional antennas could be used to complete a datalink. How simple life was for the engineer in those days!

In the early 1960s the Government moved the frequency allocation for telemetry into the L- & S-Band frequency ranges. With the increased space attenuation and higher bandwidths required for the data, automatic tracking systems were required for the majority of flight testing of airborne vehicles. By the end of the 1960s the majority of

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antenna ranges in the United States were equipped with very expensive two axis telemetry tracking antenna systems. Early in the 1970s it was evident that a need existed for a small, self-contained, single axis tracking system which would fit in a small vehicle for transportation and, most importantly, fit the limited budgets that existed for many of the testing requirements. A simple single axis tracking antenna consisting of a fan-beam, four-dipole array was developed and the first two systems were purchased by Patuxent River for flight testing. These systems sold for \$25,000 each including a bandpass filter and a tunnel-diode preamplifier. Because of cost and versatility, these systems described by Sullivan (1) became very popular on many of the flight test ranges around the world in addition to their ideal suitability for shipboard missile tracking.

By the late 1970s, the majority of requirements, except for shipboard missile tracking, required more gain than was practically achievable with the dipole array type single axis tracking system. Several companies began producing six-foot reflector type, single axis tracking systems in order to satisfy these gain requirements. In order to achieve higher elevation angles, a cosecant squared antenna system was used to broaden the elevation beamwidth. The disadvantage of the beam shaping was an overall gain reduction of approximately 3 dB. This disadvantage was eliminated by the use of a dual beam single axis tracking antenna; Sullivan (2). With the dual beam approach, it was easy to cover a large percentage of the tracking requirements with a lower cost single axis system. The dual beam antenna usually afforded adequate elevation coverage for antennas as large as 6 feet in diameter. Since the low gain and high gain antennas were required to autotrack, there was an additional expense using the dual beam approach. This increase, however, was far outweighed by the elimination of the elevation axis. To increase the gain by going to a multibeam (more than two beams) system the cost of tracking increased enough so that it was not much more expensive to go to a two axis system. Throughout the 1980s many of the ranges were using the dual beam, single axis tracking antenna approach as an economical measure to fulfill their testing requirements.

By the late 1980s, the Global Positioning System (GPS) was coming of age and affording low cost position data. The basic GPS approach, in comparison with other positional systems, was described by Hoefener, Beech and Wartenberg (3). The integration of the GPS data with telemetry data has been described by Wells (4).

With the beginning of the 1990s, GPS is indeed here to stay. GPS low cost receivers are available for less than \$1,000 and offer position accuracies of less than 100 meters. It is now a simple matter for a ground station to receive position, time, velocity, and acceleration data from airborne vehicles. The space positioning data can be combined with the telemetry for flight testing as discussed by Wells (4). It would also be a simple matter to take the space position data and transmit it on a voice system between the airborne vehicle and the ground station by way of omnidirectional antennas. The time is now to

combine GPS with multimode single axis antenna systems. The reduced budgets which will be experienced throughout the next few years necessitate the use of this technique wherever possible. Since most of the existing two axis tracking systems are of the order of 8 to 10 feet in diameter, this technique could be used for the majority of tracking requirements. When it is not possible to use a GPS receiver in the tracked vehicle, as in the case of missile tracking, a GPS translator can be used. The use of translated GPS has been discussed by Wells (5).

SYSTEM DESCRIPTION

There are many types of autotracking systems used today for tracking airborne vehicles for the reception of telemetry data. For tracking geo-stationary satellites in an inclined orbit, step track and program track are used for cost effectiveness. Program track is really a misnomer since the system is being positioned from a priori ephemeris data. The system outlined herein will be called GPS-Trak. This name is a little more appropriate since the positioning is done by the use of real time rather than a priori positioning data.

Figure 1 is a block diagram of a GPS-Trak system. The antenna system consists of a two or three beam single axis antenna mounted on an azimuth rotator. The RF signal from the antenna is amplified and fed to the receiver. The TM output of the receiver (which contains the GPS derived target coordinate data) is fed to the data processing sub system. The target coordinate data is fed to the personal computer (PC). The coordinates of the ground receiving antenna system are stored in the PC. The PC calculates the azimuth angle and range of the target. The azimuth servo command is fed to the ground receiving antenna. Based on the computed range the beam switching command is fed to the ground receiving antenna system. Azimuth data is fed back to the PC.

For target acquisition the broad beam of the dual antenna system or the intermediate beam of the tri antenna system is used. The system is scanned in azimuth at maximum velocity until the signal from the target is detected. Immediately upon detection of the signal the antenna system is switched to the appropriate beam and azimuth track is accomplished by positioning commands from the PC. If the signal were lost during a mission, the system would continue to move in azimuth at the rate of track when the signal was lost. If the signal was not reacquired in a predetermined time (usually 5 to 10 seconds), the system would automatically revert to the target acquisition mode.

There are three major cost drivers in conventional two axis telemetry tracking systems: the pedestal, the antenna control unit (ACU), and the tracking feed. With the GPS-Trak approach the pedestal cost, which is usually the largest cost of any component in a tracking system, is reduced by a factor of two (or more). This reduction is of the order of \$20,000 to \$100,000 based on system size. With GPS-Trak the expensive microprocessor

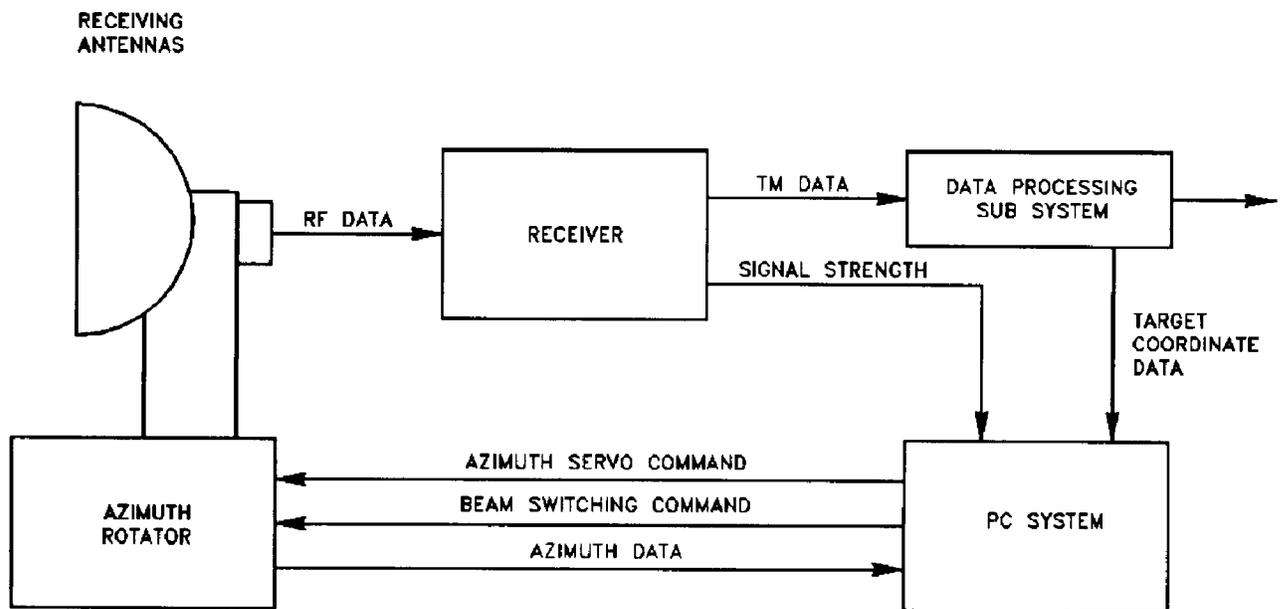


Figure 1: GPS-Trak Block Diagram

ACU is replaced with a simple low cost PC. This is a reduction in the cost of the control system by a factor of at least 3, resulting in a cost saving of approximately \$20,000. While the lowest cost driver is the tracking feed, the difference between a two axis tracking and a nontracking feed is a factor of approximately 100. The nontracking approach would easily save \$20,000 in the feed cost.

Two examples will be used to show the versatility and performance which can be achieved from the GPS-Trak approach. Although there is no such thing as a typical mission, assumptions will be made for these examples which should cover a broad range of requirements. A frequency of 2300 MHZ will be assumed. Since this is at the high end of the telemetry band, it is the worst-case condition for high altitude tracking with a single axis system. The broader beamwidths at the lower frequencies decrease the problem. It is assumed the system will be used for aircraft tracking. An effective isotropic radiated power (EIRP) of 10 watts is assumed. To allow for maximum versatility, a 10 MHZ IF bandwidth is assumed. Again to keep system cost down, a polarization loss of 3 dB is assumed. This way the linearly polarized aircraft antenna will be tracked using circular polarization on the ground thereby eliminating the additional cost of polarization diversity. For versatility a fade margin of 3 dB is assumed. This would correspond to flight testing over a relatively rough terrain or a terrain with considerable vegetation. For tracking over water or smooth land, detailed multipath effects would have to be taken into consideration; Chandler (6). The increased multipath would only decrease the low angle range capability. An antenna height of 60 feet is used which would be required for long ranges because of line of sight considerations. All the assumptions used are listed in Table I.

Table I

Assumptions for Examples of GPS-Trak	
Frequency	2300 MHz
EIRP (Aircraft Tracking)	10 Watts
IF Bandwidth (Worst-case)	10 MHz
Polarization	3 dB
C/N Ratio	13 dB
Fade Margin	3 dB
Antenna Height	60 Feet

The first example is for a 6-foot dual mode single axis GPS-Trak antenna. (Figure 2 illustrates the range and elevation performance of the high gain and low gain antenna.) The 6-foot high gain antenna is tipped 3° in elevation to afford higher altitude coverage. A 3-element cup dipole array is used as a low gain antenna. The 3-element was used to increase the maximum altitude capability of the system. This plot shows that for the assumed conditions tracking to ranges of 150 miles and at altitudes of 40,000 feet can easily be achieved. One can easily envision that the high gain antenna could be tipped less with some sacrifice in altitude coverage but yielding a large increase in range. The 6-foot GPS-Trak system would yield comparable performance to a two axis system at a considerable cost reduction. The system could also output space positioning data to a high degree of accuracy. Range radars would not be required for flight testing with the use of GPS-Trak and differential GPS. An heuristic evaluation of reliability indicates an improvement of an order of magnitude with a corresponding increase in maintainability.

Figure 3 is a similar example of a GPS-Trak system configured for long range operation. The system uses a tri mode antenna. The high gain antenna is a 10-foot newtonian-fed reflector illuminated by a single crossed dipole. The intermediate antenna is a newtonian-fed one meter antenna; and the low gain antenna is a single cupped dipole element. Figure 3 is a plot of the range versus altitude of the tri mode GPS antenna. For the assumptions made the antenna has a range of 350 miles at altitudes in excess of 40,000 feet. Initial acquisition would be accomplished with the one meter antenna. After acquisition the antenna would be switched in accordance with the range of the tracked vehicle. For ranges of greater than 125 miles, the high gain antenna would be used. For ranges between 25-125 miles, the intermediate gain antenna would be used. And for in-close operation and overhead passes, the low gain antenna would be used. Switching would be performed automatically by the PC ACU based on the range of the airborne vehicle.

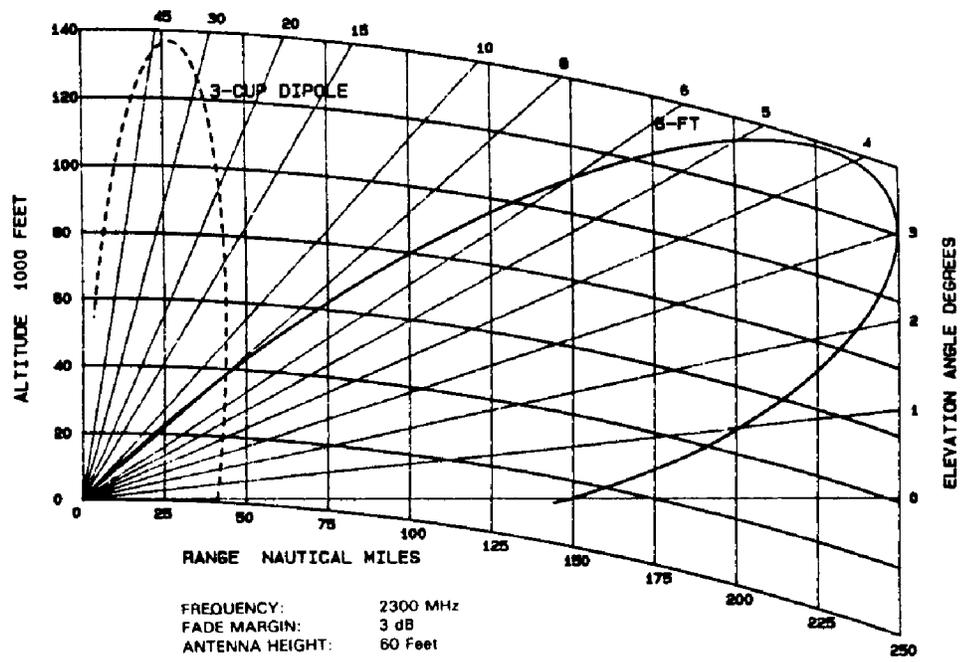


Figure 2: Range and Altitude of Dual Mode Antenna

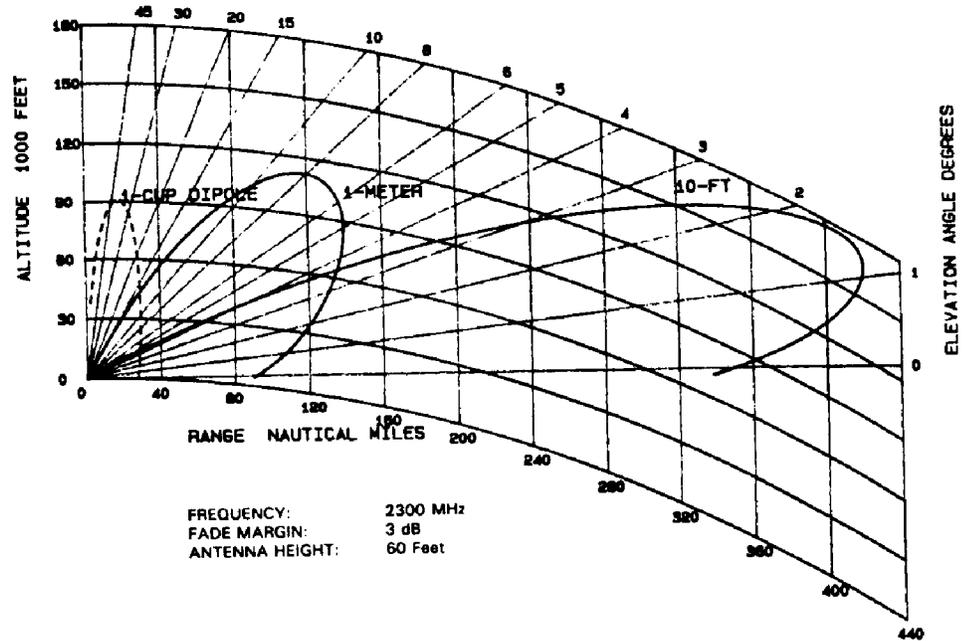


Figure 3: Range and Altitude of Tri Mode Antenna

CONCLUSIONS

With the advent of worldwide operational GPS, a low cost, highly reliable alternate to conventional two axis telemetry autotracking systems is available. GPS-Trak is the ultimate in simplicity and the lowest cost system available for tracking airborne vehicles.

Cost is 30% to 40% of the cost of a conventional two axis autotracking system. Reliability is increased by an order of magnitude. Real time space positioning data is an added bonus. By the use of more sophisticated GPS techniques such as differential GPS, a low cost, highly portable test range is now achievable at a savings of millions of dollars (radars and optical trackers can be eliminated). The per year maintenance costs of a system is reduced drastically.

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