ULTRA LIGHTWEIGHT, LOW COST, TELEMETRY TRACKING SYSTEM

Arthur Sullivan
Vice President
Electro Magnetic Processes, Inc.
9616 Owensmouth Avenue
Chatsworth, CA 91311

INTRODUCTION

Because of limited budgets, many telemetry applications can not be performed on a real time basis. Consequently, there is a need for a very low cost tracking system. In addition to being inexpensive, the system should be lightweight to minimize building or tower modifications required for installation, and to lower shipping and handling costs.

In order to reduce weight and cost, EMP, Inc. has designed an aerodynamically smooth single axis tracking system with a multimode antenna, constructed almost entirely of graphite and utilizing a minimum number of parts. Using this material, the system will be as strong as a conventional system, but will be one half the weight and will be almost temperature insensitive. Furthermore, with the construction technique selected, considerable savings are realized in fabrication costs.

Additionally, the step -track technique via a microprocessor controller was selected to eliminate the expensive autotracking feed and all the associated electronic circuitry required for high performance angle tracking. Since a single axis tracking system with a multi-mode antenna can cover a wide variety of missions, an elevation tracking axis is not required. In-close and near overhead passes are covered by the low gain antenna. Switching between the antennas is accomplished automatically based on received signal strength.

STEP-TRACK TECHNIQUE

Traditionally, telemetry tracking systems have employed angle error detection and correction techniques for maximizing received signal strength. The common error detection technique utilized a servo feedback mechanism to null the error by driving the antenna boresite axis toward the instrumented vehicle. While these methods are required to derive precise target position data of highly dynamic targets, they are over designed for those systems requiring only maximization of received signal strength. This over kill initiated the development of the “step-track” technique for satellite data acquisition systems. The existing step track positioning principle is to maximize the received signal strength based on some a priori information such as the initial target position and expected target trajectory.

Step-track has been implemented in both hardware and software algorithms, but to date has seen use only in satellite tracking because of a satellite’s predictability, low dynamic target trajectory, and absence of multipath variations. The design/performance analysis of a step-tracking system is statistical in nature, an attempt to predict the probability that the antenna gain reduction as a result of pointing error will be no more than some value given as a design goal. Typically, the algorithm variables are angular step size and stepping frequency. Of these, stepping frequency is usually operator selectable for flexibility in tracking both geo-synchronous and non-synchronous satellites, and the angular step size is usually a fixed angle having a magnitude determined by the antenna directivity and system sensitivity. In a typical application the antenna, once positioned by the operator to maximize signal level, is placed under control of the step-tracking system. The maximum signal level is maintained by periodically moving the antenna some small angle and then memorizing the signal level. The motion is reversed, moving the antenna twice the step angle in the opposite direction and memorizing the signal level. The antenna is then positioned to the angle where the maximum signal level was detected. This sequence is repeated at a step frequency which may typically vary between one cycle every 3 seconds to one cycle per hour depending on target trajectory and multipath variations.

When EMP embarked on a design effort to produce a low cost telemetry tracking system, a microprocessor based controller was being designed as an inexpensive yet extremely powerful method for remotely controlling an antenna positioner. Consequently, for only the modest cost of additional software, step-tracking capability could be added. By limiting the height of the antenna above the mean level of the terrain and by use of digital filtering techniques, multipath effects can be reduced. Preliminary analysis indicates that the system can in fact track targets in such adverse conditions as: 1) multipath signal variations in excess of 13 dB peak-to-peak, 2) target speeds of 250 mph at 10 miles slant range and 3) random signal fading of 8 dB. The 3 sigma gain reduction (relative to ideal) for the above simulation runs was approximately 1.0 dB.

MECHANICAL CONSTRUCTION

Figure 1 is an artist’s rendition of the system now under development. The majority of the structure is constructed of graphite. The antenna reflector is a 4 foot diameter paraboloid made of graphite with aluminum mesh as a reflecting surface and a white gel coat external surface. To reduce wind induced torque a fiber glass paraboloid is used as a radome clam shelled to the reflector with a graphite band. The antenna feed is mounted to the radome eliminating spar supports. When not in the operational mode the antenna free-wheels, reducing wind resistance and minimizing overturning forces. The entire pedestal is constructed of graphite with the exception of the rotating mechanism, drive motor, and data pack. The pedestal access door is finned aluminum which dissipates servo amplifier heat.

Graphite fibers are high performance carbon fibers manufactured by a process involving the conversion of an organic polymer precursor into carbon or graphite with a highly ordered material structure. The fibers comprise extremely fine filament tows which, when bound together by a plastic matrix, provide composite materials with outstanding stiffness and strength to mass ratio.

Graphite or carbon fiber composites are extremely stiff, strong and lightweight, providing specific mehanical performance considerably superior to metals and many other materials used for construction. The stiffness to density ratio and strength to density ratio are 2:1 and 5:1, respectively, compared to aluminum. This means that an epoxy graphite fiber structure having the same material thickness as an aluminum structure will be almost three times as strong and weigh about half as much. Further, the mechanical damping property of the structure is improved by a factor of two.

SYSTEM CONSIDERATIONS

The system will meet the following specifications:

Antenna Type:	4 Ft. Diameter Front Fed Paraboloid	
Feed Type:	Crossed Dipoles	
Frequency:	1435 to 2300 MHz	
Polarization:	RH or LH Circular, Selectable	
Gain:	<u>High Gain Antenna</u>	<u>Low Gain Antenna</u>
	22 dB @ 1485 MHz	10 dB Nominal
	26 dB @ 2250 MHz	
Beamwidth:	12° @ 1485 MHz	65° Nominal
	8° @ 2250 MHz	
Velocity:	12°/Sec.	
Acceleration:	24°/Sec.	
Weight:	90 Pounds	
Temperature Operational:	-20 to +52° C + Solar Heating	
Storage:	-50 to +85° C	
Humidity:	To 100%	
Rain/Snow:	100 mph Wind Driven	
Wind Operational:	75 mph	
Survival:	150 mph	

For a typical airborne tracking application assuming an 8 watt transmitter and a 1 MHz bandwidth, the system would have a range of 150 miles for a 12 dB signal to noise ratio allowing for a 3 dB polarization loss and 13 dB multipath fading loss. Figure 2 is a computer plot showing the coverage of both the high gain and low gain antenna. Figure 2 also shows the maximum amount of multipath modulation for which the system will still be capable of step-tracking. For presentation purposes the multipath modulation curve has been displaced 12 dB. The multipath modulation increases with increased height of the tracking system and with the smoothness of the terrain over which the target is being tracked. The multipath pattern shown corresponds to the tracker being 13 feet above the terrain and the terrain being perfectly smooth sea water. The multipath variation would be less over land and considerably less over a non-smooth terrain, i.e. hills, trees, buildings etc.

The system automatically switches between the high gain and low gain antenna based on signal strength. Under the assumed conditions the system would track a target up to a maximum range of 150 miles at altitudes up to 40,000 feet and also track a near overhead pass.

CONCLUSIONS

The 4 foot diameter graphite tracking system being developed will be suitable for many telemetry tracking applications. The cost of the system will be approximately one half of the cost of a conventional 4 foot single axis tracking system and the weight will be reduced by a factor of 2. The use of the system is restricted to low velocity vehicles such as aircraft or higher velocity vehicles at a distant range. The height of the system above ground is also restricted because of multipath considerations.

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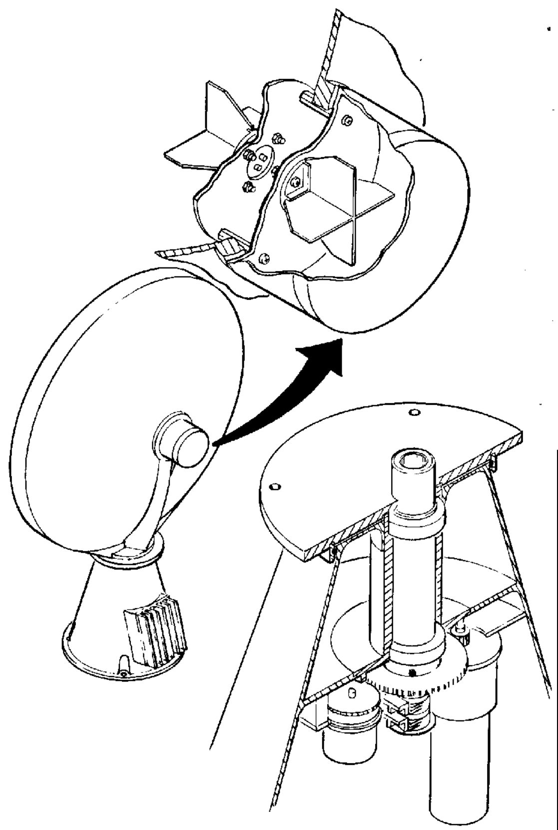

FIGURE 1

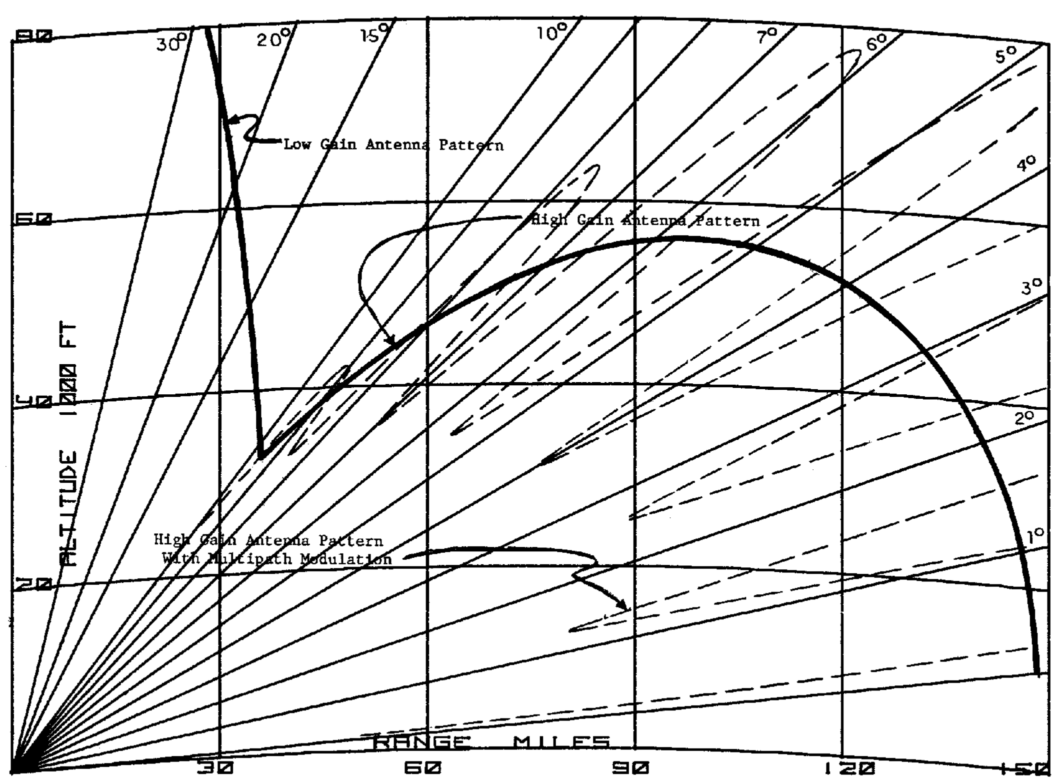

FIGURE 2