MOBILE TRACKING SYSTEM
"MOTION ON THE OCEAN" TEST

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ABSTRACT

The Transportable Range Augmentation and Control System (TRACS), Mobile Telemetry System (MTS), is a versatile system capable of supporting anywhere when called upon. The MTS is designed to operate anywhere on land. It is unknown how the system will perform on a floating platform without a stabilizing gimbal. The operation of a tracking system at sea generally require the use of a three-axis pedestal. The MTS is a two-axis pedestal. This paper is a report on how the MTS responds to simulated ocean-motion. Testing the system on a body of water is very expensive, especially out in the desert. The MTS was tested in the desert area of Las Cruces, New Mexico in the parking lot of EMI Technologies, prime contractor, using two forklifts to simulate ship motion in the pitch and yaw planes. The location is perfect for crossover dynamics tests. The tests conducted were for the purpose of determining if the MTS could auto-track a moving signal in space while it also moves due to "simulated ocean swells" that increase the generated tracking error signal levels in an opposite or in addition to the ones generated from the space vehicle. There is no gyroscopic correction. Successful results of the tests could preclude the use of a gyroscopically stabilized gimbaled platform necessary to keep the tracking system steady for auto-tracking a target during "6 degrees of freedom" disturbances. Several thousand dollars can be saved if the concept can be proven.

KEY WORDS
Gimbal, gyroscopic correction, autotrack, tracking errors, pitch and yaw plane movements, autotrack threshold setting, slave track, and memory track.

INTRODUCTION

A major difference between a Telemetry Tracking System (TTS) and a RADAR is in the objectives. RADAR yields position data of the space object while a TTS main objective is to receive the vehicle telemetry data for demodulation. RADAR operates in a frequency band much higher than a TTS and has an extremely narrow beamwidth. The beamwidth is

measured in mils (17.3 mils/degree). A TTS measures the beamwidth in degrees. RADAR determines XYZ position from the azimuth and elevation angles to the object. The accuracy is based on several factors. Two of the factors are stability and location. It must be located on level ground or on a gyroscopically stabilized gimbaled platform.
A Mobile Telemetry System (MTS) can be located on uneven ground. The main concern is to receive a signal in a much broader beamwidth. It can afford more "sloppiness" in the servo subsystem. The target dynamics and the platform "6 degrees of freedom" in the pitch and yaw planes must be within the MTS tracking specifications. Also, the MTS must have sufficient torque margin to resist wind loading.

The parameters affecting the auto-track mode for a TTS are the antenna beamwidth, first sidelobes levels, error gradient linearity, (az/el) cross-talk, servo stability, dynamic error, the amount of backlash, system velocity and acceleration, and the auto-track threshold setting. The auto-track mode is where the antenna rotation is based on tracking errors generated by the space position differences between the space vehicle telemetry antenna and the receive system.

The discussion that follows explains how the MTS utilizes the above parameters and under the "rocking" motion of the trailer, proves it can operate in the autotrack mode for three different scenarios. The discussion then introduces the three tests conducted.
The MTS is "rocked" up and down by two forklifts for three different tests attempting to autotrack three different objects. The first object is the sun with an elevation angle of 42^0. The second object is a Landsat satellite, with the MTS maximum elevation angle of 45^0 at its point of closest approach. The third object is a transmitter radiating at S-Band, located on top of an automobile. The Satellite Track Test lasted 15 minutes. The last test involves a vehicle traveling along Interstate-25 at 55 MPH.

DISCUSSION

Mobile Telemetry System (MTS)

The pedestal and Antenna Control Unit (8360) is a Scientific Atlanta elevation over azimuth -axis system with an 8-foot parabolic antenna. The pedestal trailer is 164 in.(L) by 96 in.(W) by 36 in.(H) and extremely stable. This part of the MTS is referred to as the Mobile Telemetry Antenna Pedestal (MTAPS). The recording and relaying sections of the system are referred to as the Telemetry Receiving System (TRS) and are in a separate shelter from the MTAPS. The electronics shelter sits upon a 6 x 4 vehicle that has its own 35 KW Power Generator, making the system self-sufficient. The shelter and power generator can be removed from the vehicle and placed on the floating platform.

TRACKING SYSTEM PARAMETERS

The antenna efficiency is 54% with a gain of 32 dB. The low noise amplifier, (LNA) has a noise figure of 0.8 dB that allows the System Sensitivity to be high. The f/d is 0.5 to enhance the tracking error resolution and thereby minimizing Elevation/Azimuth crosstalk. Azimuth/elevation crosstalk is where a legitimate error signal in one axis has been developed and an error is indicated in the other axis which did not generate an error. This type of problem is investigated in the tests below. The MTS is capable of operating from 1415 MHz to 1540 MHz, 1710 to 1850 MHz , and 2200 to 2400 MHz. The beamwidth is 3.9 degrees from 2200 MHz to 2300 MHz, where the measurements were made. The tracking error gradient is 0.9 volt/degree up to +/- 2^0 for all three operating bands in both axis. The servo subsystem is a type 2 with three Ka's capability. The maximum velocity and acceleration is 30 deg/sec and 30 deg/sec/sec. The position servo bandwidth filters are designated as LOW, MEDIUM, and HIGH. The MEDIUM filter has a lead-lag filter for stability, fast response, and accuracy. It uses a two torque motor configuration for both azimuth and elevation with an integral tachometer. The servomotors are connected to a bull gear through a 800:1 gear box. The two motors are torque - biased to prevent gear backlash. The system uses a resolver accurate to .006 degrees, static error . Tracking errors such as velocity lag errors are compensated in real-time by the resolver that is mechanically connected to the axis shafts. The fact that the servo is Type 2 allows the acceleration error to stay within the 0.6 degree servo error limit as long as the movement does not exceed 30 deg/sec/sec. It has slip rings instead of cable wrap to enable it to rotate continuously without reaching any antenna pedestal azimuth travel limits. The system can be operated remotely or from a local computer within the MTS shelter. The smart 3860 Antenna Control Unit (ACU) has three backup tracking modes in addition to autotrack and position modes. It has a rate mode (used sparingly), memory track (up to 15 seconds, variable), and slave mode. The ACU can select the slave mode after a preset memory track time has expired and there is still no autotrack. It is smart because it can select the slave radar track mode if it detects that the radar sending it tracking data is also in autotrack.

TESTING

Vehicle and Transmitter

A portable transmitter with an omni-directional stub antenna was located on top of an automobile. See Figure 1.0. The transmitter radiated an S- Band frequency without modulation. The signal level was controlled by several attenuators. The tests were conducted using strong and weak signal levels to see how the MTS would respond to jerking moves in the presence of multipath and high winds (winds were 25 to 40 MPH) as the vehicle traveled along Interstate-25. The vehicle speed was limited to 55 MPH. At this speed, the crossover velocity of the antenna was 10^0 / sec. The minimum distance was approximately 500 feet at the crossover point and the maximum distance 2 miles in one direction and 1 mile in the other. The azimuth movement was from 234^0 to 116^0 with the elevation averaging 0^0.

Forklift Movement

Figure 2.0 is a photograph of one of the two forklifts used to raise and lower the antenna-pedestal trailer during the sun track test. The forklift movement was fast for one set of tests and slow for other tests to simulate platform movement on the ocean. Inside the shelter you could not tell where you were but could "sense" the illusion of the movement if you kept your eyes on the video monitor. (A camera is mounted on the side of the antenna). The elevation digital readout indicator showed that the antenna was moving up and down (pitch plane) as much as 8^0 . There were jerking movements in azimuth (yaw plane) of 2 degrees. The signal level indicator on the tracking receivers and ACU showed the signal level fluctuating as the antenna moved.

RESULTS

Test 1.0 Transmitter on roof of vehicle: No trailer movement

This test involved tracking the transmitter on top of the vehicle as the vehicle traveled along I-25 at 55 MPH. The MTS was able to track the vehicle without any problems with a signal strength of 40-45 dB. The MTS performed as expected even with heavy traffic that included a semi-trailer passing the vehicle and shading the antenna. Figure 3.a is a recording of the signal strength without any trailer movement.

Test 2.0 Transmitter on roof of vehicle: Strong Signal in a high multipath environment

The tracking threshold was set at +20 dB above the noise floor to compensate for signal level fluctuations as the antenna was moved up and down. Initially, the received signal level was approximately +60 dB. The movement of the vehicle with the transmitter generated the tracking errors that you normally see when you track a space vehicle. The movement of the trailer generated additional tracking error amplitudes randomly in both axis. At this point the servo did not know if the correction to the tracking error was all from the space vehicle. The servo generated enough torque to rotate the antenna and keep the system in the autotrack mode in both axis. Due to the high multipath environment the antenna had a very hard time maintaining autotrack.

Test 3.0 Transmitter on roof of vehicle: Weak Signal in a high multipath environment

With a lower signal level of 40 dB, the multipath conditions were not as destructive. Figure 3.b shows a steady signal level. The MTS remained in the autotrack mode throughout the test as long as the signal level was above the autotrack threshold. The autotrack threshold was purposely raised to allow the system to break lock and enter memory track. With the trailer moving, the antenna followed the source in memory track and re-entered autotrack as soon as the threshold level was lowered. The biggest surprise was that the antenna saw the signal and maintained autotrack even as it rotated in front of the forklift! The system never experienced el/az crosstalk problems.

Test 4.0: Track Satellite

This test consisted of both azimuth and elevation motion due to the satellite. The forklift motion added to the tracking error amplitudes for the elevation and azimuth servo systems. These errors combined with the generated tracking errors from the satellite. The maximum signal level never got above +25 dB at the point of nearest approach. The signal level at initial acquisition over the horizon was below +5 dB. This meant the tracking threshold was set at +2 dB. On movements where the signal level was below this setting, the system would lose autotrack and enter memory track for a preset value of 10 seconds. The loss of signal was due to the antenna moving up and down. The signal level would return above the autotrack threshold before the system would complete memory track and re-acquire in the autotrack mode.

Test 5.0: Sun Track

The photograph shows the antenna tracking the sun in the autotrack mode. Figure 4.0 is a photograph of the 8360 Antenna Controller showing that the system is in autotrack at an elevation angle of 42^0 at 1019 hours. This test was very similar to Test 4.0. The antenna would "zero in" on the sun and enter the autotrack mode when the autotrack threshold was set above the maximum signal received from the sun. With the wide beamwidth of 3.9^0 the antenna movement caused by the forklift motion was not enough to prevent the system from maintaining autotrack.

CONCLUSION

Although the main movement to simulate ocean motion in the desert was up and down from two planes, the trailer was able to simulate pitch and yaw movements by using two forklifts. The MTS demonstrated it is capable of operating in the autotrack mode in both azimuth and elevation for strong and weak signals while being "rocked". The MTS did not experience any crosstalk problems. The strong signals generated more multipath interference from all of the metal in the surrounding area. This condition could exist from water reflections if the signal is very close. This problem has been resolved by adding a 5k potentiometer between the receiver AGC output and the input to the 3860 Antenna Control Unit. The potentiometer adjusts the incoming signal level up to 17 dB. The computer can be used to make threshold adjustments rapidly. With such a wide antenna beamwidth, and, since we do not generate position data, a gyroscopically stabilized gimbaled platform is not necessary.

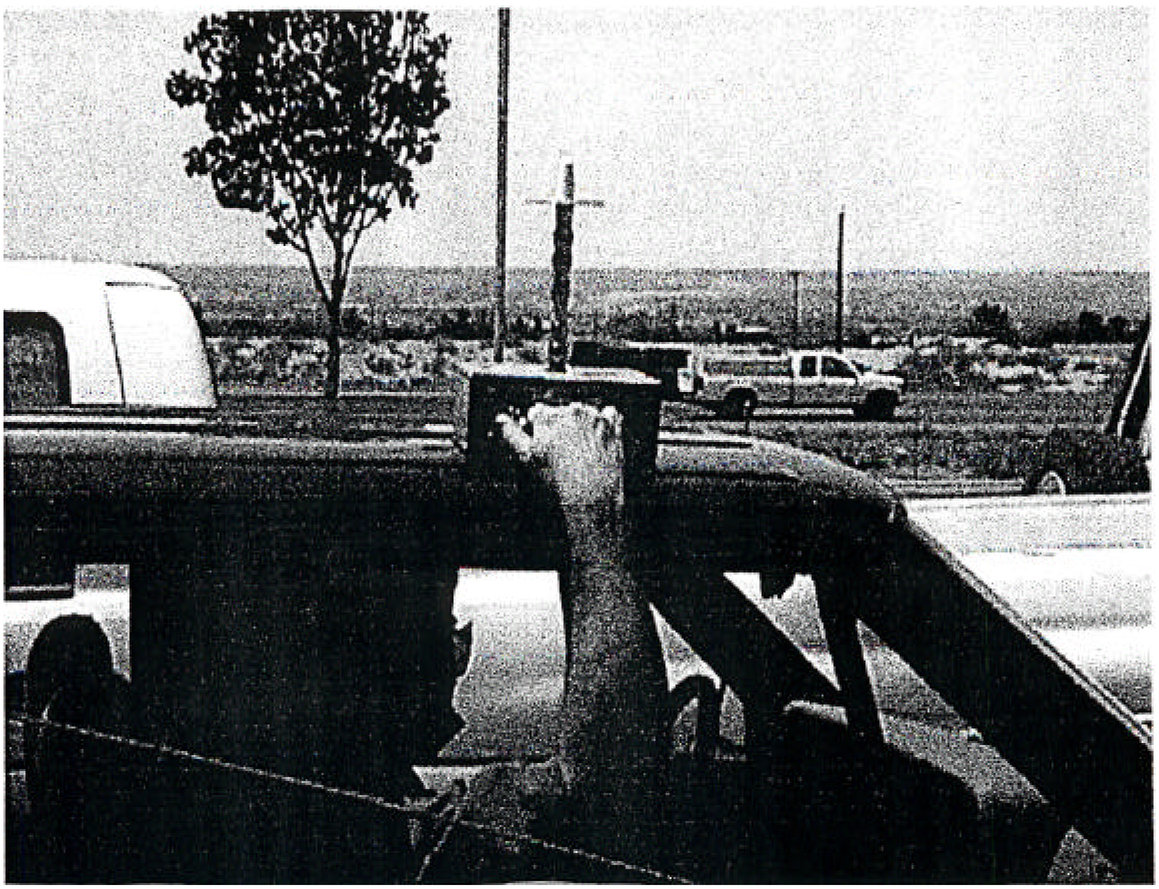

Figure 1.0 One watt portable transmitter radiating at 2250.5 MHz using an omni-directional antenna.

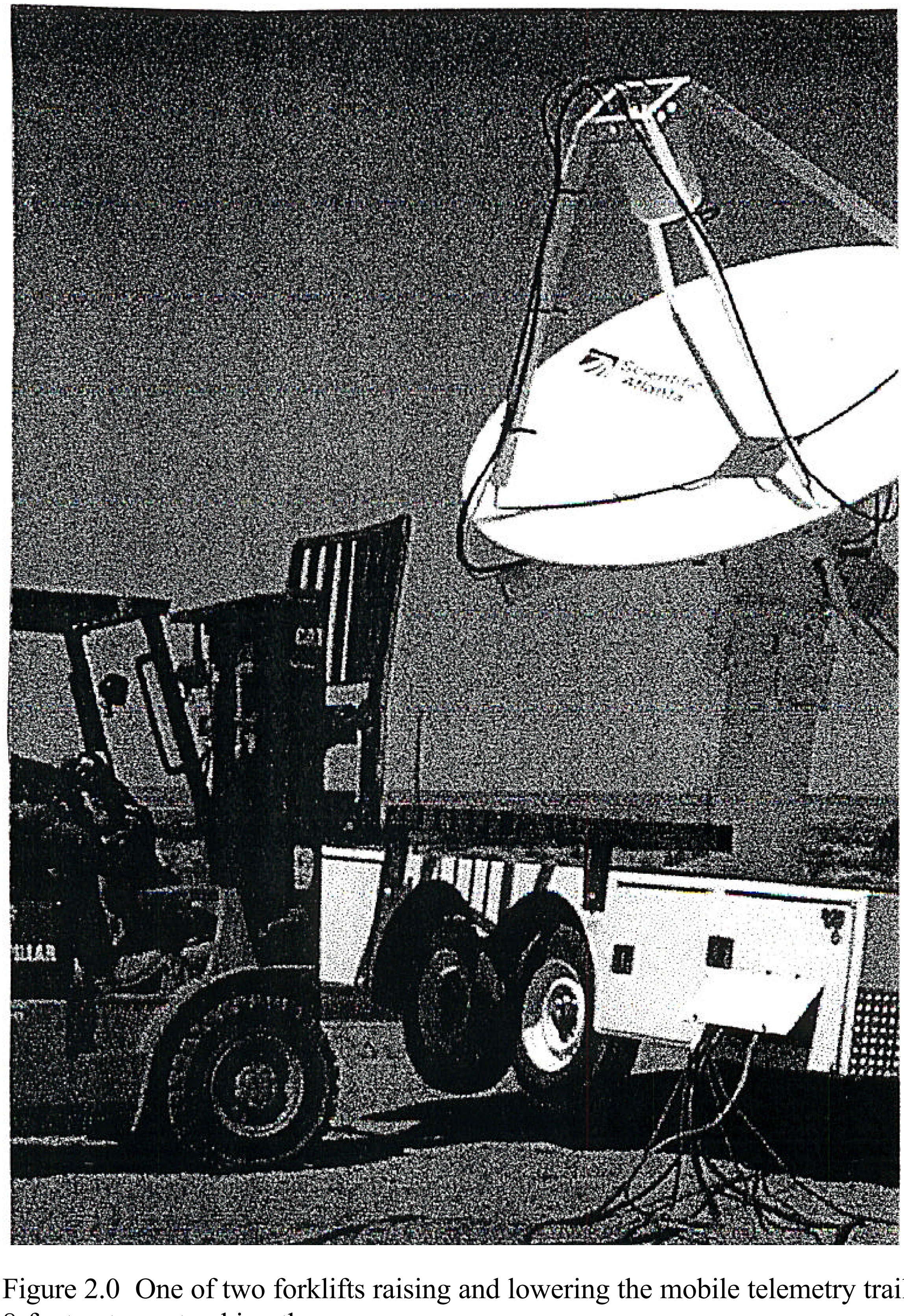

Figure 2.0 One of two forklifts raising and lowering the mobile telemetry trailer with the 8-foot antenna tracking the sun.

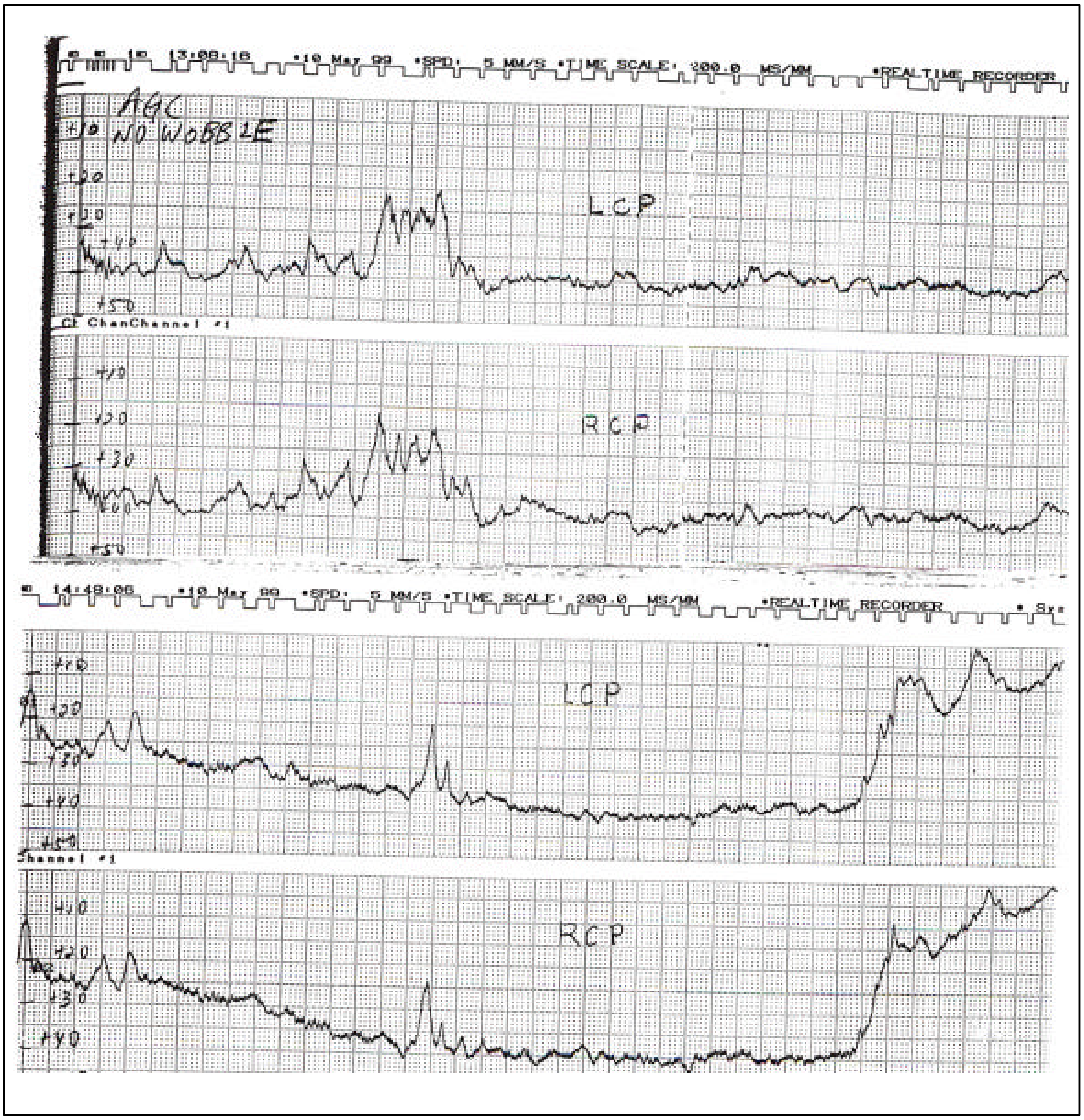

Figure 3.a and 3.b The top two AGC traces show the signal level for the vehicle test without forklift action. The bottom traces show the signal level for the vechicle test with forklift action. The MTS was in the autotrack mode for both tests.

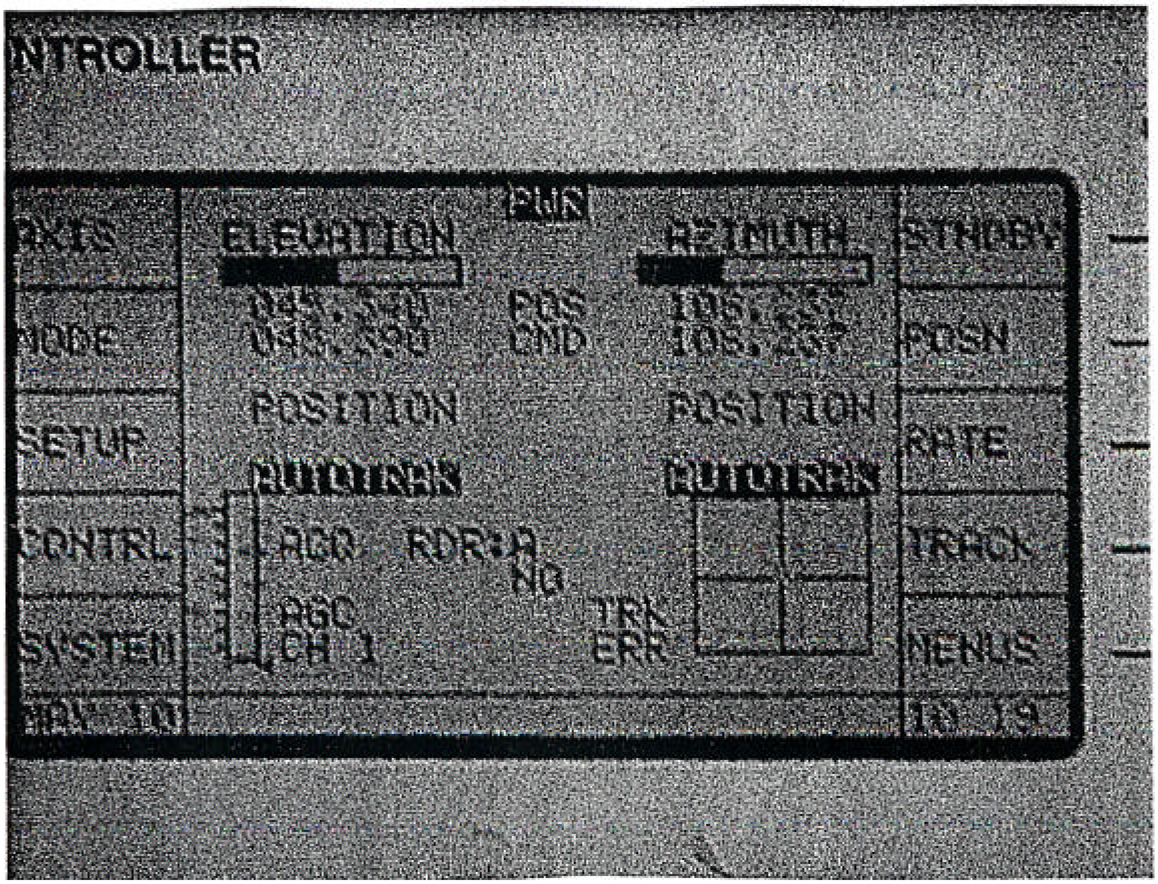

Figure 4.0 Antenna Control Unit. SA 8360, showing the MTS in the autotrack mode during the Sun Track Test.

ACKNOWLEDGEMENT

I would like to thank and acknowledge the following personnel for their contribution to the tests.

Mr. Joe Alvarez, President of Electro-Magnetic Inference Technologies, (EMI), and prime contractor for the MTS. Mr. Alvarez proposed the tests and provided his facilities at EMI in Las Cruces, New Mexico.

Mr. Joe Granados, Electronics Engineer, EMI. Mr. Granados coordinated the testing and provided the forklift operators.

Mr. Mark Bielcik, Mr. Mario Telles, EMI, forklift operators. The tests could not have been done without their expert forklift operation.

Mr. Mike Winstead, Ms. Angela Ferrara, and Mr. Richard Fuentes, Electronic Engineers from WSMR, NM, Telemetry Branch. This is a group of dedicated engineers that work with me and continuously demonstrate their engineering abilities. I could not have done the above test without their support.