A Study on the Tracking Antenna System for Satellite Communication Using Embedded Controller

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Abstract: The tracking antenna system must be always pointed to a satellite for data link among moving vehicles. Especially, for an antenna mounted on a moving vehicle, it needs the stabilized the antenna system. So, software and hardware, signal processing of motion detection sensors, real-time processing of vehicle dynamics, trajectory estimation of satellite, antenna servo mechanism, and tracking algorithm, are unified in the antenna system. The purpose of this paper is to design the embedded tracking antenna control system for satellite communication. The embedded OS(Operating System) based stabilization and tracking algorithm was implemented. The performance of the designed embedded control system was verified by the real satellite communication test.

Keywords: Tracking Antenna System, Embedded OS, Embedded Linux

1. Introduction

The antenna system which is mounted on ships, ground vehicles, and aircraft can continuously track moving vehicles which azimuth and elevation angle are vary continuously. The antenna system must continuously track the moving vehicle to receive data form moving vehicle. There are several tracking methods, such as cross tracking, paramidal tracking, step tracking, and so on [1, 2]. It is important that new needs and short life cycle design are implemented in these embedded controllers. Therefore, more flexible and rapid prototyping design is necessary for open control system. The embedded linux kernel can be optimized, compiled and reconstructed by the user in small size. So, embedded linux can be ported in the small memory space. In this reason, embedded linux is widely used and suitable for open controller design. If the embedded linux based open controller is equipped in control system, there are many merits in controller design. The cost of development will be down and upgrade and maintenance is convenient owing to its open kernel.

By using the relative position information among moving aircraft, UAV and moving ship, more efficient tracking and pointing are possible. It is more efficient that the GPS position information is used for the data link and data communication between ground site and moving aircraft, UAV, and moving ships [3]. Relative position between two sites, the relative direction and altitude can be known. The antenna can point the moving vehicle based on calculation of these relative positions. In this paper, a tracking antenna system installed an embedded linux based embedded controller was designed and tested. By using this embedded controller, tracking and communication performance among moving vehicles was studied. The embedded control system for antenna driver was based on a SA-1110 microprocessor [4, 5, 6].

To verify the performance of the designed embedded controller and antenna system, satellite communication and tracking antenna was designed and tested. The test was performed and analyzed by experiments based on the trajectory information of Arirang satellite.

2. Antenna System

2.1. The Structure of Antenna System

Generally, antenna system is composed of three parts, ACU(Antenna Control Unit), PCU(Pedestal Control Unit), SAP (Stabilized Antenna Pedestal). ACU controls SAP by transferring control command for azimuth and elevation angles of SAP and calculate position of the moving vehicle. In figure 1, general structure of antenna system was represented. SAP is mechanical part that directly controls the azimuth and elevation angle of the antenna for pointing a moving vehicle. PCU controls SAP using azimuth and elevation angle value form ACU.

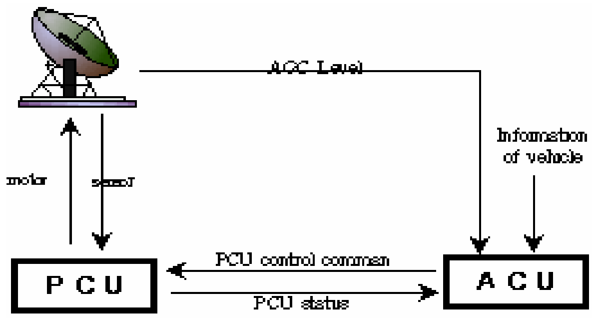

Fig.1. Structure of the antenna system.

2.2. Tracking Method

To track moving vehicle, antenna site position information, GPS signal, and position information of the moving vehicle were used. The relative position was calculated and processed in embedded computer for antenna control. For this antenna control system, an embedded computer equipped with microprocessor was charge of these calculations.

2.3. The Pointing Angle

The geometry of relative pointing between antenna and moving vehicle was represented in figure 2. The coordinate of moving vehicle is consist of altitude φ (center angle is TOA, T is a perpendicular fall point) and latitude λ. Also, the coordinate of the considering point P is consist of altitude l (center angle is POB) and latitude ψ. To clear the figure, the latitude difference between moving vehicle and point P was represented as L. Center angle BOT has value of ς and center angle POT(angle between moving vehicle and point p view form center of mass) is to be ϕ. Put the distance between moving vehicle and point P as R, the distance between moving vehicle and center of earth as r, and the radius of earth as RE, the elevation angle is equal to equation (1) and azimuth angle is equal to equation (2).

$$E = \sin^{-1}\left\{\frac{\cos\phi - \left(\frac{R_E}{r}\right)}{\frac{R}{r}}\right\} \tag{1}$$

$$a = \sin^{-1}\left(\frac{\sin L \cos\varphi}{\sin\phi}\right) \tag{2}$$

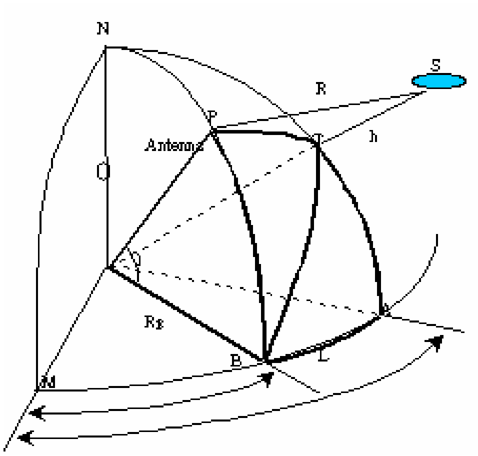

Fig.2. Pointing Geometry of the Antenna.

2.4. The Tracking Antenna System & Tracking Algorithm

A SeaTel 1899 model was used for this experiment. This antenna can stabilize 2-axies tracking and stabilization. Figure 3 represents the shape of 2-axes antenna system. Detailed specification of the antenna was represented in table 1. An embedded control board was used for antenna tracking and data processing. A 32 bit ARM microprocessor, a 16MB flash memory and a SDRAM were equipped in this embedded control board. Operating System was based on embedded linux. For rotation angle sensor, two potentiometers were used and the analog value form this potentiometer was converted by 12bit A/D converter. Two HZ1-90-100A (Systron Donner Inertial Division) MEMS rate sensor were used for rate sensors. This sensor has dynamic range within ±45 °. This range is suitable for antenna motion stabilization (< ±25 °) and motion responses(< ±12°/sec).

Fig.3. Test Antenna System. (SeaTel 1898)

Table 1. Specification of Antenna System. (SeaTel898)

Gain		12.2 GHz (34.4 dB)
Azimuth	Turn Rate	12°/sec
	Turn Range	680°
Full Elevation Range		10°~80°

2.5. Tracking Algorithm

Antenna tracking was performed by using the relative position information, i.e., the GPS relative position information between the antenna and moving vehicle. For this antenna experiment microcomputer equipped embedded controller was used. The overall system construction was shown in figure 4. A flowchart for tracking antenna driving algorithm was represented in figure 5.

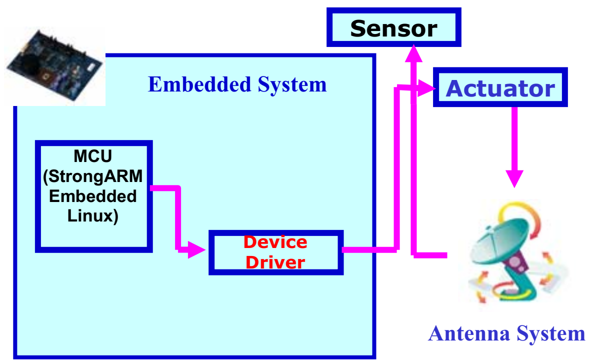

Fig.4. Structure of the Antenna System

2.6. Device Driver Design

Two device drivers were necessary for experiments. A serial device deriver for GPS position signal and a step motor driving device driver for step motor.

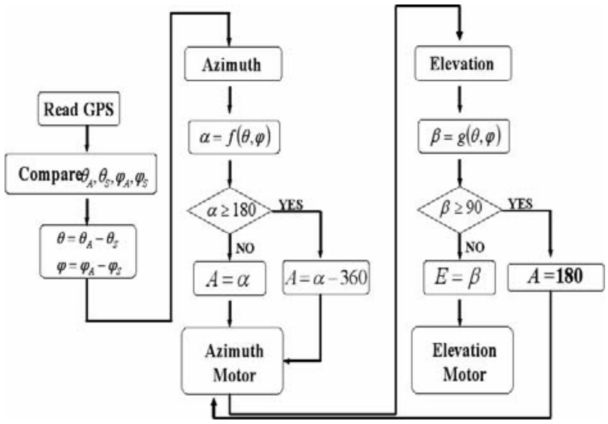

Fig.5. Flowchart of the Tracking Algorithm

2.6.1. Device Driver for GPS Signal

Two parts of device driver, a serial communication port control part and signal analysis part were designed. Because the information from GPS is transfer by RS-232, serial port control part for serial communication and signal processing form the GPS information are separately designed.

2.6.2. Device Driver for Step Motor

The control method for antenna driving step motor was defined. In this paper, the speed control part for motor responsibility and rotational position control part were designed. In fig. 6, the structure of a step motor device driver was represented. The test result of designed device drivers was represented in Fig 7.

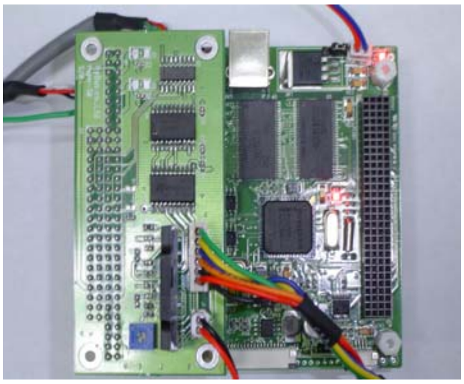

Fig.6. Structure of the Step Motor Device Driver.

3. Antenna Tracking Simulation and Results

These experiments are performed to verify the performance of commercial satellite tracking antenna is also satisfied on this newly designed embedded antenna system. Embedded linux based control and interface system was designed and applied to the embedded controller and antenna tracking system. To drive antenna system and to test designed embedded controller, first criterion trajectory was set and the tracking performance was tested with this trajectory. The trajectory of Arirang satellite was used for this criteria trajectory. Figure 8 illustrates criteria trajectory, longitude and altitude of Arirang satellite.

Figure 9 and 11 show tracking results of embedded controller respectively. Figure 10 and 12 are magnified views of fig. 9 and fig. 10 in first 30 seconds respectively. Around 10 seconds, some errors occur but reasonable tracking performance is satisfied in the whole responses. The performance of designed embedded system is over the target model (SeaTel 1898), 1.5 times more fast response time performance (±12°/sec), the overall performance will be satisfied in spite of including several tasks such as user monitoring interface task and so on.

```
[root@hyper104 /root]$./install
init module, major number : 0
data_motor_open Request for
27 IRQ Success MOTOR detected
********** MOTOR menu **********
* 1.   MOTOR forward              *
* 2.   MOTOR Reverse              *
* 3.   MOTOR Speed Up             *
* 4.   MOTOR Speed Down           *
* 5.   MOTOR STOP                 *
* 6.                              *
* 7.                              *
* 8.                              *
* 9.    TEST THE SYSTEM           *
* 0.    Exit Program              *
**********************************
select the command number : 9
print the result of a 9
NO GPS SIGNAL
(t_a:36.375000t_s:53.452999
p_a:127.355003p_s:144.259995)
(pos:29.270685,alpha:29.270685,
phi:0.362007loop:2)NO GPS SIGNAL
```

Fig.7. A test Scene of the Device Driver

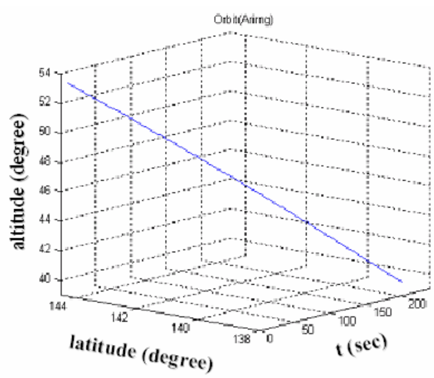

Fig.8. Trajectory of the Ariang Satellite.

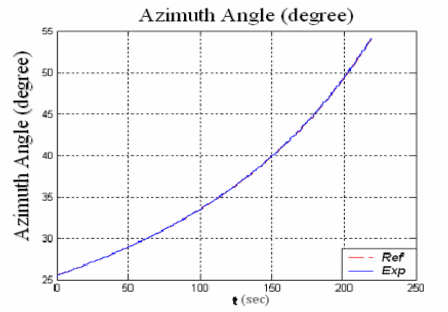

Fig. 9. The Azimuth Angle Response of the Tracking Antenna System

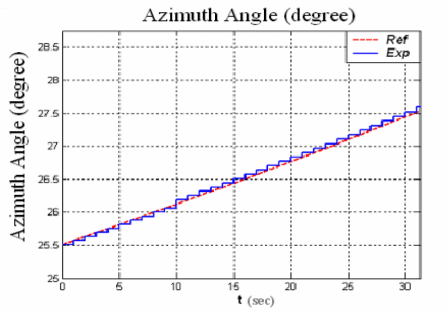

Fig. 10. The Magnified Azimuth Angle Response of the Tracking Antenna System

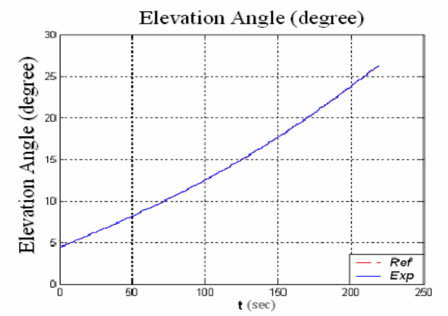

Fig. 11. The Elevation Angle Response of the Tracking Antenna System

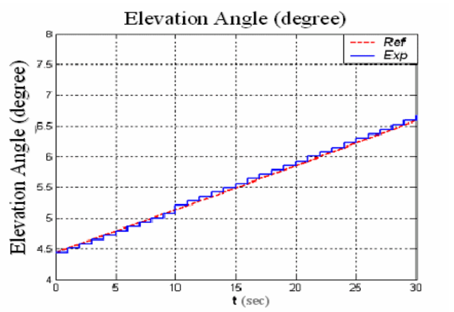

Fig. 12. The Magnified Elevation Angle Response of the Tracking Antenna System

4. Conclusions

An embedded system was designed and applied to a tracking and satellite communication antenna system. This system was tested for Data Link between moving vehicle. Since the merits of embedded linux are open source and adaptability, more flexible system can be reconstructed. These open kernel concept can satisfy the needs for suitable and adjustable controller design in the fields of varying system characteristics and environmental conditions. Results of designed system showed superior performance. The antenna system driven by embedded controller has some calculation error and step motor dynamic error, but the overall performance is reasonable. Further researches must be performed for 3-axes antenna stabilized system. The stabilization algorithm for antenna stabilized system and status monitoring graphical user interface will be also imbedded in this controller.

Acknowledgement

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