Variable step size tracking algorithm for the VICTS antenna

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Abstract. A variable step size tracking algorithm for the Variably Inclined Continuous Transverse Stub (VICTS) Antenna for Ku-band fixed-satellite service is proposed. The traditional step tracking algorithm is improved by using and the simulation analysis of the VICTS antenna to get the apposite step size. And the feasibility and superiority of the algorithm are verified by the failure rate of locking the satellite. The proposed algorithm provides a feasible method for the VICTS antenna servo system to achieve satellite communication on the move (SOTM).

1. Introduction
With the rapid development of technology and the urgent demands of social advance, the research of satellite communications has lasted some years at some institutes and colleges. VICTS antenna has the features of high gain and less adjacent interference [1], besides VICTS antenna controls the beam pointing by rotating the different functional layers (see Figure 1) which means the beam scanning of VICTS antenna is only achieved by one-dimensional mechanical rotation [2]. Those features are beneficial to VICTS antenna achieve satellite communication on the move.

![Diagram of VICTS antenna layers](image)

Figure 1. Schematic representation of VICTS antenna.

In the satellite communication on the move system, stable tracking is the critical technique for this system. There are four common tracking methods which are suitable for this system: conical scanning tacking, mono-pulse tracking, step tracking and program tracking [3]. Among them, due to the unique structure of the VICTS antenna, conical scanning tracking and mono-pulse tracking aren’t applicable for the VICTS antenna. Meanwhile, program tracking is easy to be affected by external environment and apparatus which may result in the terrible tracking accuracy even tracking failure. Step tracking also has the defects of low tracking accuracy or tracking speed, so we need to find out an apposite tracking strategy which can improve the VICTS antenna performance.
In this paper, we proposed an algorithm which improves tracking accuracy and tracking speed of the VICTS antenna. The algorithm used the relation of azimuth angle and elevation angle with the relative rotation angle between elevation scanning layer and azimuth scanning layer to get the step size to improve the tracking accuracy and tracking speed.

2. Variable step size tracking algorithm

2.1. Step tracking
Step tracking is a tracking pattern which searches the maximum value of received signal intensity by the rotation in azimuth plane and elevation plane with a stable angle [4]. The step tracking determined the step direction based on received signal intensity from the beacon receiver. The functional block diagram of step tracking is shown in Figure 2.

![Functional block diagram of step tracking](image)

As a traditional step tracking pattern with stable step size, it couldn’t keep the tracking accuracy and tracking speed at the optimal value simultaneously. When the step size is bigger, it has a faster tracking speed and lower accuracy. When the step size is smaller, it has higher tracking accuracy and slower tracking speed. For the better performance of the VICTS antenna, we demand an algorithm which can improve the tracking accuracy and tracking speed at the same time.

2.2. Simulation Analysis of the VICTS antenna
To getting the relation between θ(elevation angle) and Φ(azimuth angle) and γ(the relative rotation angle between elevation scanning layer and azimuth scanning layer) , we use CST(3D electromagnetic simulation software) to obtain the θ、Φ and γ of the far-field pattern(see Figure 3).

![2D far-field pattern](image)
According to the database from the simulation results, we fitted the relation curve of $\theta$, $\Phi$, and $\gamma$ (see Figure 4). Known from Figure 4, there is not a simple linear relation between $\theta$, $\Phi$, and $\gamma$. The curve provides us with the theoretical basis of the variable step size tracking algorithm. We can calculate the apposite step size by the slope of the relation curve. For example, we ought to select a larger step size during the step tracking process (such as $0.3^\circ$ when $\theta$ is at $31.98^\circ$), and obviously a smaller step size is more suitable for the step tracking process (such as $0.1^\circ$ when $\theta$ is at $62^\circ$).

**Figure 4.** The results of the angular position of beam.

### 2.3. Tracking process

Based on the above research works and the unique beam steering principle of VIC TS antenna, we proposed a variable step size tracking algorithm for the VIC TS antenna. To achieve the SOTM system, we should calculate the beam parameters at current position, then calculate the step size of tracking algorithm based on Figure 4, finally control the elevation scanning layer and azimuth scanning layer to track the satellite with the selected step size. The flowchart of the algorithm is shown in Figure 5.

**Figure 5.** The flowchart of the step tracking algorithm.
Due to the unique structure of the VICTS antenna, the step tracking has a complicated process. The rotation of elevation scanning layer can realize the elevation angle scanning, besides the azimuth scanning can be realized by rotating the elevation scanning layer and the azimuth scanning layer with the same angle. At the beginning of step tracking, we control the motor to rotate the elevation scanning layer with the selected step size for tracking the satellite on the elevation plane, besides the azimuth angle is also changing in the elevation angle step tracking process. For better tracking performance of the VICTS antenna, we should drive the elevation scanning layer and the azimuth scanning layer to rotate at same angle simultaneously to revise the azimuth angle after the elevation angle step tracking process.

3. Algorithm verification
We implement the algorithm with the coding on control board of the VICTS antenna servo control system, and then put the VICTS antenna on the swaying platform that can control the frequency and amplitude of oscillation which imitates the motion of the VICTS antenna on the carrier (see Figure 6). We demodulate the received satellite TV signal, and then determine whether the tracking algorithm improves the performance of the VICTS antenna based on the failure rate of television signal. The failure rate represents the ratio of the time of received television signal can’t be demodulated and the whole time of receiving television signal.

![Figure 6. The picture of algorithm verification.](image)

The failure rate of television signal by applying proposed algorithm is shown in Table 1 compared with the failure rate by applying the traditional algorithm under different posture changes. The traditional algorithm used the fixed step size under a different elevation angle. Instead, the proposed algorithm applied the variable step size based the different elevation angle. It is obvious that the failure rate of applying proposed algorithm is lower than the traditional algorithm under different posture changes. The proposed algorithm is verified.

| Elevation angle | Posture changes | Failure rate (traditional) | Failure rate (proposed) |
|-----------------|-----------------|---------------------------|-------------------------|
| 10 2°/5s        |                 | 7%                        | 1%                      |
| 10 3°/5s        |                 | 9%                        | 3%                      |
| 10 4°/5s        |                 | 12%                       | 6%                      |
| 20 2°/5s        |                 | 9%                        | 4%                      |
| 20 3°/5s        |                 | 11%                       | 7%                      |
| 20 4°/5s        |                 | 15%                       | 11%                     |
| 30 2°/5s        |                 | 10%                       | 6%                      |
| 30 3°/5s        |                 | 13%                       | 9%                      |
| 30 4°/5s        |                 | 15%                       | 13%                     |
4. Conclusions
In this paper, we proposed a variable step size tracking algorithm of the VICTS antenna. The traditional step tracking algorithm and the simulation analysis of the VICTS antenna are used to get the apposite step size and the tracking algorithm. The feasibility and optimization of the algorithm is verified by the failure rate of locking the satellite. It is shown that better performance is achieved by using the proposed algorithm.

References
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