FREQUENCY SCAN ERROR CORRECTION FOR TRACKING BEAM

Soon Ik Jeon*, Haeng Sook Ro*, Seong Ho Son*, Seung Hyeub Oh**

*ETRI Advanced Radio Technology Dept., Daejeon, 305-350, Korea

**Department of Electronics, Chungnam University, 305-764

sijeon@etri.re.kr

ABSTRACT

To design active phased array antenna with tracking beam and main beam using different frequencies each other, beam direction error by frequency scan effect is serious at large aperture antenna with narrow beam width. In this paper, an effective frequency scan error correction method is introduced. To prove it, the method was implemented at an X-band phased array antenna system with large aperture of 35dBi gain for satellite communications. At the antenna's beam steering test, its direction error without correction was 2.5° offsets between two beams at 35° scan angles and the edge of frequency difference that was 6.7% bandwidth. However, after the proposed correction, the error was improved as 0.1° offset that was only from quantized digital phase error of the system.

1. Introduction

The frequency scan effect is sometimes effective at phased array antennas for radar systems.[1] However, if there is communication antenna with main beam and tracking beam using different frequencies for each other, it will be undesirable and serious. In this paper, the phased array antenna system for satellite communications, that has phase control structure of two series levels, is considered. The number of phase control for the second level can be less than the first level's. The each array phase for tracking beam is sum values of the first level phase and second level phase. With the structure, the tracking beam can be rotating around its main beam.[2] However, at the case, the different frequency loading at each level will make unwanted beam direction error at the second level that is for the tracking beam if the system bandwidth is wide enough to make it. In this case, the system that has 6.7% bandwidth was considered. .

To avoid this error, the simple way is using its separated parallel phase control level for each beam, but its increasing system cost should be considered for the way because the same number of phase control at each level is required.[3][4] The proposed method in this paper is compensation of phase difference calculated from frequency difference between main beam target frequency and tracking beam target frequency at the second series beam level. For its practical implementation, the fast computation algorithm is needed for the fast rotated tracking beam forming at the limited computing power of the processor. Instead of conventional phase calculation from theta and phi values, this method uses u-plane and v-plane values to solve the problem.

2. Idea and Concept

A single electronic beam phase is controlled with independent phase control codes with respect to the respective component frequencies, and in this case, the frequency applied to the first beam cannot be used for a method for generating a plurality of beams with respective different frequencies, and the respective frequencies used to the second or greater beams cannot be applied to the propagation delay phase calculation equation (1) simply.

$$kMd\sin\theta_o \qquad (1)$$

where k is propagation constant, M is the number of the array, d is element distance, θ_o is scan angle. The directional difference according to the prior art frequency difference reduces the antenna's satellite tracking gain and increases satellite-tracking errors, and accordingly, the antenna gain cannot be effectively guaranteed and the satellite communication quality greatly worsens.

A method for correcting the directional difference compensation from frequency scan error is using a second array unit for performing phase shifting on the output value phase-shifted by the first array unit on the basis of a second phase delay control value for compensating for the phase delay difference according to a second beam frequency shifted through the first array unit, and generating second beams. The wrong second beam directional angle, θ_S, can be found from equation (2).

$$k_R \sin\theta_o = k_S \sin\theta_S \qquad (2)$$

where k_R is for the first beam, k_S is for the second beam, θ_S is the wrong second beam directional angle. The wanted second beam correction angle generated by adding the second beam directional error angle to the second beam angle squinted from the target angle is found from the result. Finally the correcting factor is applied to the second array phase control value on the u-plane coordinate axis with respect to the array position.

Regarding the v-plane coordinate axis, the second array phase control value can be calculated through the same way. To assign them to the second array phase shifter is done simultaneously.

3. Implementation and Test

To prove the proposed correction method, its correction algorithm was programmed at the practical phased array antenna system that had phase control structure of two series levels. In the system, each array phase for tracking beam was calculated as sum values of the first level phase and second level phase. The system was designed to have large aperture of 35dBi gain. Its steering angle range was ±35°, and frequency bandwidth was 6.7% enough to make serious frequency scan error at its edge.

The system was fabricated that is shown on Figure 1. The program that had the proposed correction algorithm was loaded in its tracking and beam steering processor. The antenna system was tested using near field measurement system. The measured tracking patterns are shown on Figure 2 and 3. The picture shows the proposed correction method makes the error angles move to almost zero offset from target direction of 35°after correction.

4. Error Correction Effect

As mentioned, the present method relates to an electronic active phase control array antenna for satellite communications. More specifically, the present method relates to an electronic active phase control array antenna, a method for compensating for direction differences at the antenna, and a satellite tracking system and method using the antenna so as to resolve direction differences generated between two beams with different frequencies in the case of applying an electronic active phase control array antenna having two beams to broadband radio transmission and receiving methods.

From the test result of beam direction offset measurement under different frequency offsets and different scan angles, its direction error without correction was none if their frequency difference was not or scan angle was normal direction from aperture. However, its error was maximum value of 2.5° at the steering edge of 35° and frequency difference edge. When the half power beam width of 2.2° was considered for the test system, the value was enough to make the tracking beam have wrong direction that was shown on Figure 2 already. Offset errors for different frequency offsets at each scan angles are shown in Figure 4, and offset errors for different scan angles at each frequency offset are shown in Figure 5 before applying correction method.

After the correction the error was changed to 0.1°. The value is estimated from its quantized error from digital phase shifters. The results after phase compensation, those are shown in Figure 6 and 7 prove its error correction effect clearly.

5. Conclusion

The frequency scan effect for multi-beam antenna system with series phase control levels doesn't make any difficulty to avoid them if the proposed method is used. In this paper, it is proved by practical system test after its design and fabrication. At the test of X-band satellite communications antenna system with 35dBi gain, its direction offsets error was corrected to 0.1° from 2.5 ° at 35° scan angle edge and the edge of its frequency difference.

The series phase control level structure with less number phase control and this proposed error correction method at multi-beam antennas will have give advantage as simple structure and better performance than the conventional structure without correction.

References

[1] Richard C. Johnson, Henry Jasik, *Antenna Engineering Handbook*, McGraw-Hill, New York, 1984.

[2] Soon-Ik Jeon, et al.,"A New Active Phased Array Antenna for Mobile Direct Broadcasting Satellite Reception,," *IEEE Trans. on Broadcasting*, vol. 46, no. 1, pp. 34-40, March 2000.

[3] Robert J Mailloux, *Phased Array Antenna Handbook*, Artech House, Boston 1994

[4] R. C. Hansen, *Phased Array ANTENNAS*, New York: John Willy & Sons, 1998.

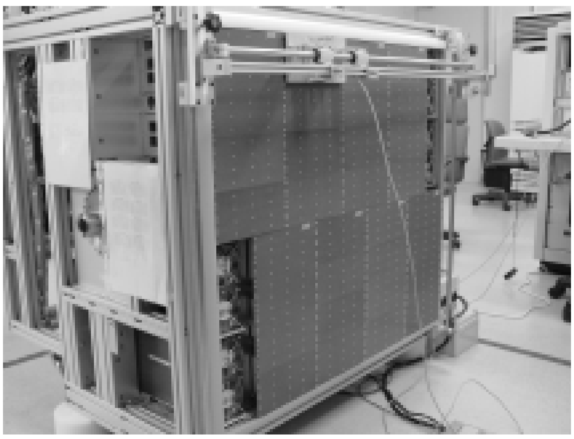

Fig. 1. The antenna system that the idea for frequency scan error correction is implemented and tested on

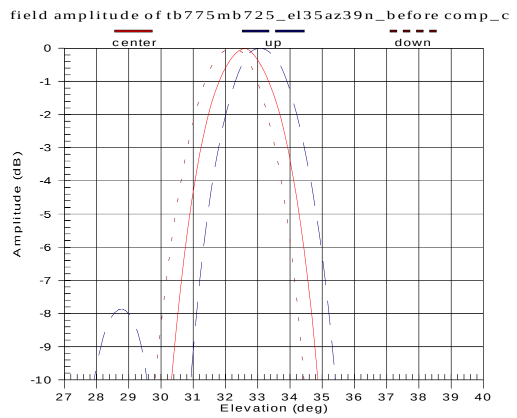

Fig. 2. Three tracking beam patterns (center/up/ down) with frequency scan error from 35° scan angles before correction

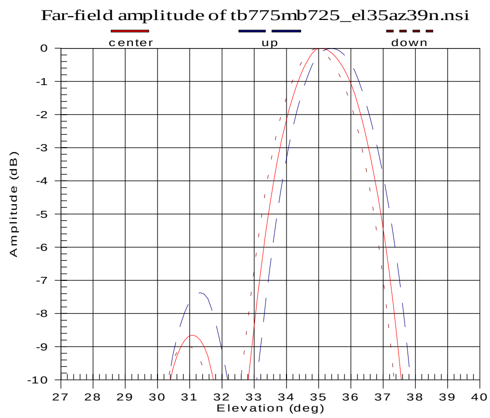

Fig. 3. Three tracking beam patterns (center/up/ down) without frequency scan error at 35° scan angles after correction.

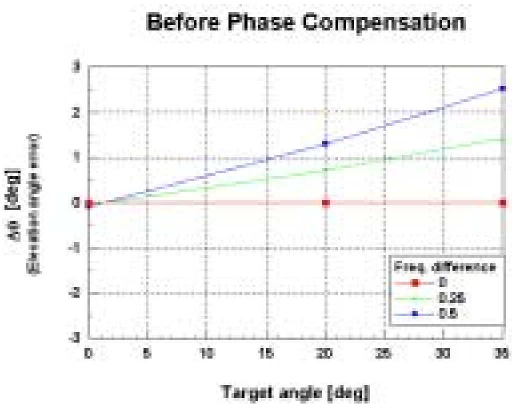

Fig. 4. Offset errors for different frequency offsets at each scan angles before correction

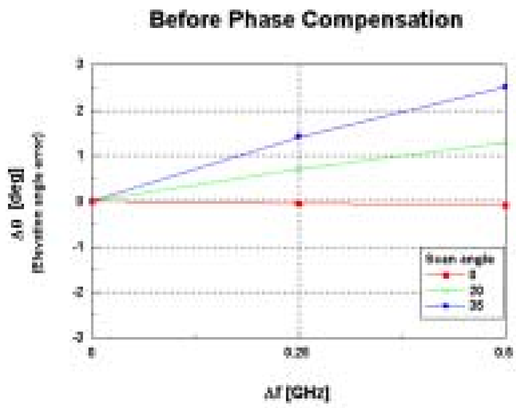

Fig. 5. Offset errors for different scan angles at each frequency offset before correction

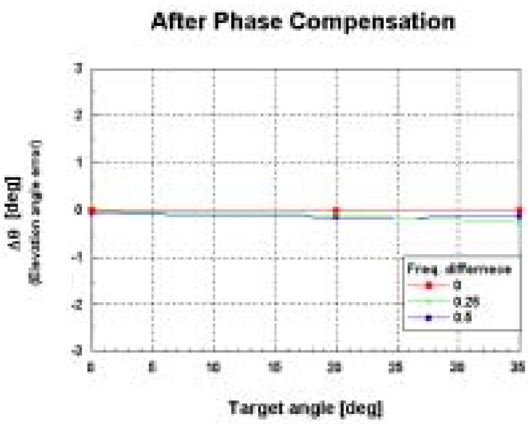

Fig. 4. Offset errors for different frequency offsets at each scan angles before correction

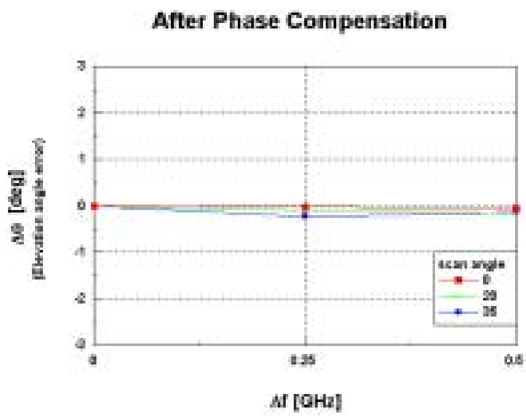

Fig. 5. Offset errors for different scan angles at each frequency offset before correction