A study on radiation pattern of DBF antenna with bit number restriction

Yu Ito[1,2], Amane Miura[2], Teruaki Orikasa[2], Norio Komiyama[3] and Hajime Fukuchi[1]
[1] Faculty of Aerospace Engineering, Tokyo Metropolitan University, 6-6 Asahigaoka, Hino, Tokyo, 191-0065 Japan
[2] National Institute of Information and Communications Technology,
4-2-1 Nukui-Kitamachi, Koganei, Tokyo 184-8795 Japan
[3]AXIS Corporation, 2-24-5 Higashitokorozawa, Tokorozawa, Saitama, 359-0021 Japan

***Abstract* –This paper describes an experimental study on the performance limitation of Digital Beam Former (DBF) antenna caused by bit number restriction. The study focuses on the evaluation of the relationship between radiation pattern of DBF antenna and quantization bit number of A/D converter. Two experiments were performed by using a prototype RX DBF/Digital Channelizer (DBF/DC). At first, we evaluated DBF/DC input-output (I/O) linearity and dynamic range characteristics, and it is confirmed that the bit number restriction function of the RX DBF/DC properly works. Then, we measured the radiation pattern of the 16-element array antenna integrated with the RX DBF/DC. It was observed that the radiation patterns with small bit number (6bit) were distorted compared with those with high bit number (8bit) for both one-element antenna and 16-element array. From these observations, we confirmed that bit number restriction affects the performance of DBF antenna.**

***Index Terms* — Array antenna, Satellite communication, Digital beam former, DBF, A/D converter**

I. INTRODUCTION

NICT has conducted R&D on Satellite/Terrestrial Integrated Mobile Communication System (STICS). In this system approximately 100 high-gain multibeams were needed to cover the Japan islands and the Exclusive Economic Zone (EEZ) [1]. The communication system onboard the satellite in STICS employs DBF/DC, which has functions to reallocate beam pointing arbitrarily and change the bandwidth corresponded to each beam [2].

The DBF is key technology for the satellite antenna. In the design of DBF antenna in which digital and analog (IF-RF) devices are integrated, it is important to understand the characteristics of DBF and its effect for the performance of the antenna such as the radiation pattern. An important parameter of DBF is quantization bit number of A/D converter. Therefore, we conducted an experimental study on the performance limitation of DBF antenna caused by bit number restriction.

II. A LINEARITY CONFIRMATION OF THE RX DBF/DC

A prototype RX DBF/DC was applied for the experimental study. At first, we evaluated the I/O linearity characteristics of the DBF/DC which has a function to restrict quantization bit number of A/D converter. Fig.1 shows the block diagram of the RX DBF/DC. The bit number can be changed by 2bit step: 14, 12, 10, 8 and 6 bit.

The linearity confirmation experiments were carried out for one port of the 16-port of the RX DBF/DC. Fig.2 shows the results for each bit number. Wide linear range was observed for high quantization bit number: 14 and 12 bit. In contrast, when the quantization bit number is low (10, 8, and 6 bit), linearity range is small and the nonlinear transition level shifts about 12 dB step. This trend agrees with the theory that 1 bit reduction of bit number reduces 6dB of the dynamic range. From this examination, it is confirmed that the bit number restriction function of the RX DBF/DC properly works.

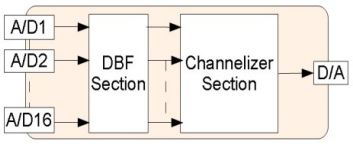


Fig. 1 Block diagram of RX DBF/DC.

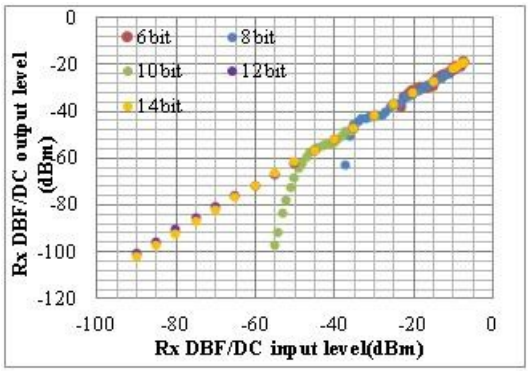


Fig. 2 RX DBF/DC I/O characteristics vs. bit number.

III. ANTENNA RADIATION PATTERN MEASUREMENT WITH BIT NUMBER RESTRICTION

We measured the radiation pattern with bit number restriction, and confirmed the relationship between the results of RX DBF/DC I/O linearity characteristic confirmation and the antenna radiation pattern measurements.

To measure radiation pattern, we applied planar Near-Field Measurement(NFM). Fig.3 shows the NFM facility and experimental antenna. The 16-element array antenna receives the signal from the probe antenna. Measured frequency was around 2GHz. Each output signal from the element antenna was connected to each port of the RX DBF/DC via diplexer, attenuator and low noise converter. The RX DBF/DC input power is adjustable by changing an attenuatar before the probe antenna.

A. One element antenna measurement

To evaluate the effect of bit number restriction, we measured the radiation pattern of the one element antenna. The DBF coefficient indicates excitation amplitude and phase of the element antenna. To measure radiation pattern of one element antenna, we set the DBF coefficients as minimum amplitude level except for one element antenna. Figs.4 (a)(b) show the measured near-field pattern of one element antenna on x-axis with bit number of 8 bit and 6 bit, respectively.The plot on top of each figure is the near-field pattern when the input level of the RX DBF/DC is maximum and within the linear range of the RX DBF/DC (the RX DBF/DC input power was -10dBm as shown in Fig.2). Other plots in each figure indicate the near-field patterns with adding 3 dB attenuation step by step for the input level of the RX DBF/DC.

For the bit number of 8 bit (Fig.4(a)), all the measured near-field patterns show similar pattern, which indicates the linearlity of the RX DBF/DC. However, for the bit number of 6 bit (Fig.4(b)) different result was observed. Under -30dBm, radiation patterns are distorted and the measured level decreased rapidly with adding attenuation. This trend corresponds to the result of the linearity confirmation as shown in the section II. This result would be due to the dynamic range reduction caused by restricting bit number.

B. 16-element array antenna measurement

In this section, we evaluates effects of bit number restriction on the far-field radiation pattern of 16-element array. Array antenna parameter are; array distribution: triangular, element spacing: 150mm, measured frequency: 2GHz, DBF coefficient: identical amplitude and phase for all the elements.

Fig.5 shows the far-field radiation pattern for 16-element array antenna. The each port input level of the RX DBF/DC corresponds to the near-field pattern of the one element antenna which is 4th plot from the top in Fig.4.

Pattern with 8 bit(blue line) agrees well with the calculated ideal pattern (black line). On the other hand, sidelobe pattern with 6 bit (red line) is distorted compared with calculated ideal pattern. From this observation, we confirmed that bit number restriction of the RX DBF/DC affects the far-field pattern of the DBF antenna.

IV. CONCLUSION

In this paper, an experimental study on the performance limitation of DBF antenna caused by bit number restriction was described. At first, we evaluated DBF/DC input-output (I/O) linearity and dynamic range characteristics, and it is confirmed that the bit number restriction function of the RX DBF/DC properly works. Then, we measured the radiation pattern of the 16-element array antenna integrated with the RX DBF/DC by using the near-field measurement system. Nonlinear characteristics, which is distortion of near-field patterns, was observed in one-element antenna measurement when bit number is restricted to 6 bit. It is due to the dynamic range reduction caused by bit number restriction of the RX DBF/DC. In consequence, sidelobe pattern of 16-element array is distorted when bit number is restricted to 6 bit. From these observations, we confirmed that quantization bit number restriction affects the performance of DBF antenna.

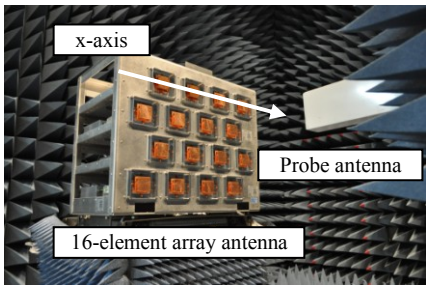
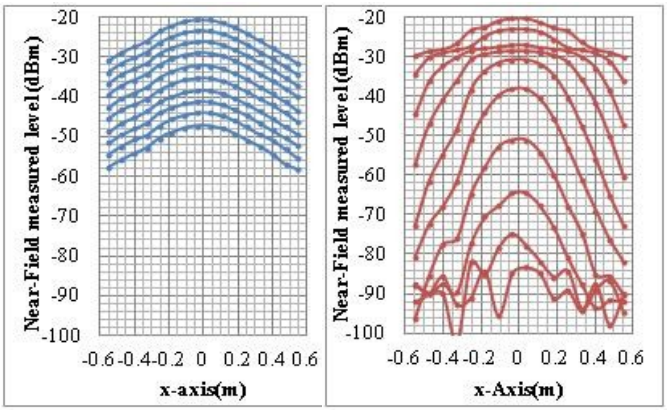


Fig. 3 The NFM facility and experimental antenna



(a) Bit number: 8bit (b) Bit number: 6bit

Fig.4 Measured near-field patterns for one-element antenna.

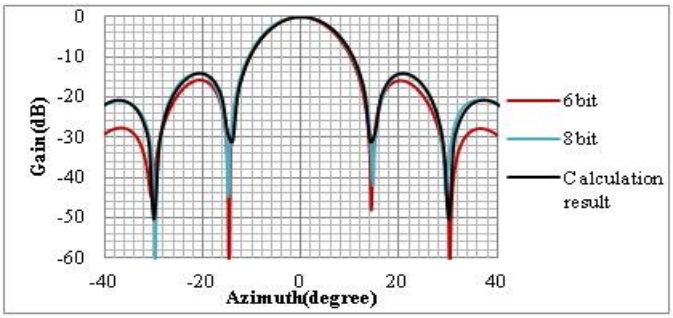


Fig.5 Measured far-field patterns for 16-element array.

REFERENCES

[1] Y. Fujino et al., "Experimental study for DBF and channelizer for Satellite/Terrestrial Integrated mobile Communication System," International Symposium on Antennas and Propagation (*ISAP)*, pp. 720 - 723, Nagoya, Japan, Oct. 2012.

[2] Yu Ito et al., "Development and performance test of DBF/Channelizer for STICS", Technical Report of IEICE, vol. 113, no. 258, SAT2013-35, pp. 27-32, Oct. 2013.