DBF ANTENNA SYSTEM FOR HAPS(High Altitude Platform Station)

Bon-Jun Ku, Jong-Min Park, and Do-Seob Ahn

Broadband Wireless Communication Technology Department,

ETRI-Radio & Broadcasting Research Laboratory 161 Gajong-dong, Yusong-gu, Daejon,

305-350, Korea, Tel: +82-42-860-5719, Fax: +82-42-860-5740
E-mail : bjkoo@etri.re.kr

ABSTRACT

The minimum requirements of the parameters such as the amplitude and phase distribution errors on an antenna aperture are obtained by using the statistical simulation method. The comparison of the analogue beamfomer and the digital beamformer for HAPS(High Altitude Platform Station) is presented. Then the appropriate antenna type is considered to generate the circular polarization.

INTRODUCTION

HAPS (High Altitude Platform Station) is a new infrastructure utilizing the airship for providing the broadband fixed and mobile communication, broadcasting, and remote sensing and control, etc. The airship would be fixed at the altitude of about 20 km with the station keeping range within 1km in radius.

The airship has the multibeam antenna to generate a number of beams on the service area. In S band, it is useful to adopt a multibeam active phased array antenna (APAA) with high directivity. In each channel of the APAA, microw ave amplifier (HPA in transmitting channel or LNA in receiving one) and ADC, or DAC, are placed. Antenna beams must have a high electromagnetic isolation. This leads a rigid limitation on off-axis antenna radiation. Especially low side lobe level (SLL) would be required when Code Division Multiple Access (CDMA) standard is used.

To satisfy these requirements and to design the antenna with low SLL in accordance with WRC 2000 Resolution, it is necessary to realize a certain taper amplitude distribution in the antenna aperture with adequate accuracy. Due to fabrication errors and dispersion of microwave amplifier parameters, array elements are not absolutely identical. This causes random errors in amplitude-and-phase distribution over antenna aperture. In order to reduce the influence of fabrication errors as well as amplifier dispersion, a calibration procedure of array antenna should be performed. The overall accuracy of amplitude-and-phase aperture distribution is determined by a quantization in phase shifters, and by quality of applying calibration method.

Antenna multibeam radiation pattern can be realized by means of analog or digital beam former. For example, Butler matrix is a well known analogous beam former. In order to implement a weighted summation of analog signals from many array elements for each of many beams, such a beam former represents a network of interlaced microwave devices. In this system, it is necessary to process complex gain values of array elements with high accuracy (amplitude errors should be less than 0.2 dB and phase errors should be less than 1.5° in order to suppress the side lobes of the HAPS antenna). Analogue beam former could not provide this accuracy because of imperfection of mentioned microwave devices (due to reflections and insertion loss). The only way is to use digital beam forming (DBF). In this case, signals from the array radiators are converted directly to a digital form and translated to the digital signal processor where all the antenna beams are formed independently.

In this paper, statistical simulation is performed to get the requirement of amplitude and phase errors in antenna aperture and the appropriate antenna type is proposed for HAPS in IMT-2000 frequency bands.

REQUIREMENTS

To obtain the radiation beam pattern with respect to amplitude and phase distribution errors on an aperture, the random parameters to consider both is added into the basic equation of antenna beam pattern as shown from (1) to (4),

$$K_p = \left| f(u_x, u_y) \sum_{m=1}^{M} \sum_{n=1}^{N} E_{mnp} \exp\left[i \left(kx_{mn} u_x + ky_{mn} u_y - P_{mnp} \right) \right] \right|^2 \Big/ K_{p\max} \quad (1)$$

$$K_{p\max} = MN \sum_{m=1}^{M} \sum_{n=1}^{N} E_{mnp}^2 \quad (2)$$

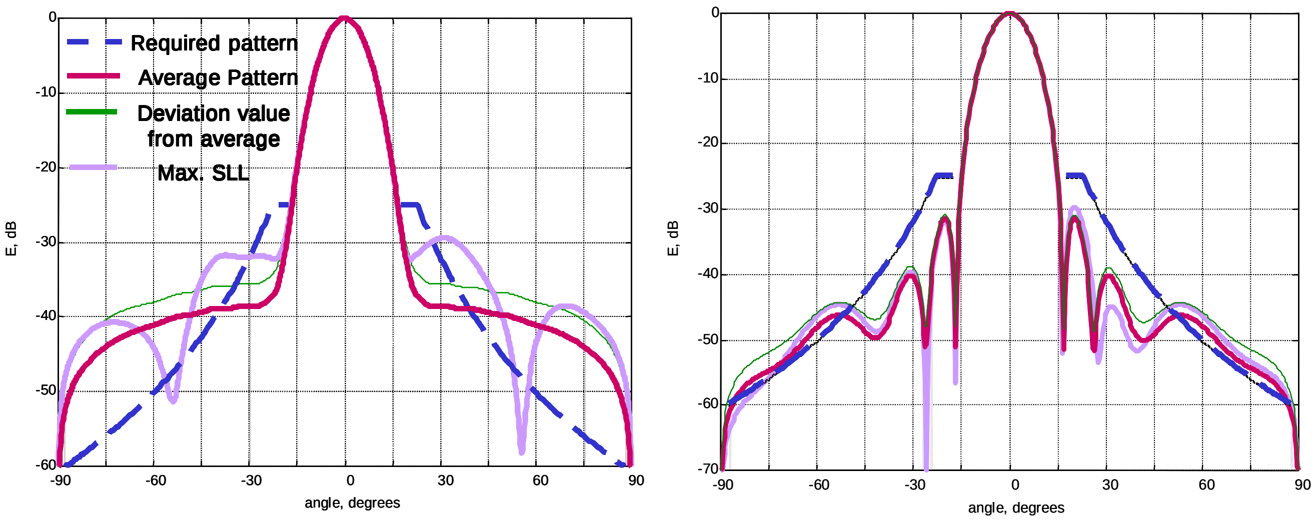
$$E_{mnp} = E'_{mnp} 10^{\left(\alpha - 2\alpha\mu_{mnp}\right)/20} \quad (3)$$

$$\Psi_{mnp} = -\Phi \quad + 2\Phi \quad \varepsilon_{mnp} \quad (4)$$

where $f(u_x , u_y)$ is the element radiation pattern, M is a total number of radiators in the row (or total number of the columns in the array), N is a total number of radiators in the column (or total number of the rows in the array), $u_x = sin\theta \cos\varphi$, $u_y = sin\theta \sin\varphi$. E_{mnp} is the amplitude of the element in *m-th* column and *n-th* row for the *p-th* output of the BFN, P_{mnp} is the phase shift in the *mn-th* element for the *p-th* output of the BFN, $P_{mnp} = kx_{mn}u_{px0} + ky_{mn}u_{py0} - \Psi_{mnp}$, $u_{px0} = sin\theta_0 \cos\varphi_0$, $u_{py0} = sin\theta_0 \sin\varphi_0$. θ_0 and φ_0 are the steering angles in elevation and azimuth, x_{mn} and y_{mn} are the coordinates of the radiator, and $x_{mn} = (m-1)d_x$, $y_{mn} = (n-1)d_y$,$d_x (d_y)$ is the interelement spacing along the axis. E'_{mnp} is determined by the taper amplitude distribution, Ψ_{mnp} is the phase error of the *p-th* channel, Φ is the maximum phase error, degrees, α is the maximum amplitude error, dB, μ_{mnp} and ε_{mnp} are the values produced independently by a generator of pseudo-random numbers within the interval [0,1]. $k = 2\pi/\lambda$ is the wavenumber.

The considered antenna parameters is that the antenna gain is 23 dBi and the number of elements is 73 on hexagonal lattices of circular aperture. In the case of the analogue beamformer, the minimum errors for the amplitude and phase distribution are assumed as 0.5 dB and 10 degree respectively. Actually the errors would be higher than the assumption but here the minimum value as the assumption is applied. In spite of the minimum errors in analogue beamformer, the sidelobe level of radiation beam pattern is over the specification. In the case of digital beamformer, α=0.2 dB and

Φ=1.5 degree is assumed. From the results, the minimum requirements for the amplitude and phase distribution would be below α=0.2 dB and Φ=1.5 degree to satisfy the specification of radiation beam pattern for HAPS.

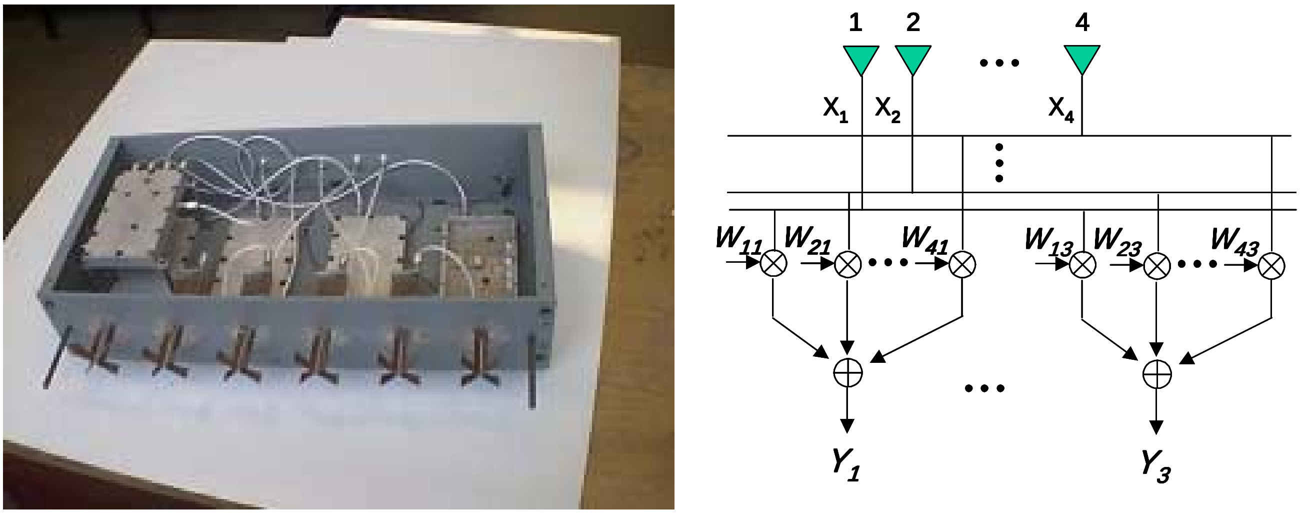


(a) Analogue beamformer case(α=0.5 dB, Φ=10 degree) (b) Digital beamformer case(α=0.2 dB, Φ=1.5 degree)

Fig. 1. Comparison of radiation beam patterns between the analogue and digital beamformer

EXPERIMENTAL MODEL

Cross dipole microstrip antenna type, which has the simple radiating element and feeding structure of quadrature hybrid to achieve the circular polarization, is considered and designed to measure its radiation beam pattern. In the case of digital processors, 4 channels are linearly assembled as the sub-DBF system of 73 channels as shown in Fig. 2.



(a) 4 elements RF block (RF=2.425 GHz, IF=21.4 MHz) (b) 4 channel and 3 beam digital beamformer

Fig. 2. Comparison of radiation beam patterns between the analogue and digital beamformer

The radiation beam pattern is measured and the results for the central beam and two beams with angle deflections of ±20° are shown in Fig. 3.

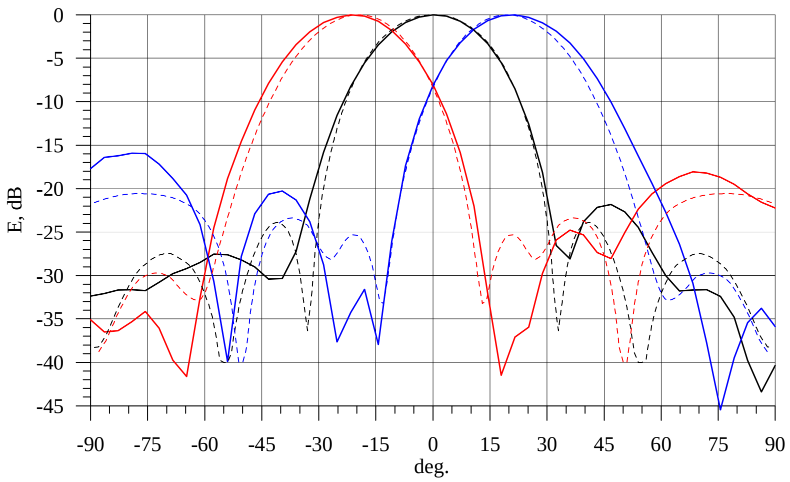


Fig. 3. The radiation patterns for the central beam and two beams with angle deflections ±20°
(solid lines correspond to the measured patterns, dashed lines to the calculated ones)

CONCLUSIONS

The statistic numerical algorithm is proposed to obtain the requirements to the amplitude and phase error on an antenna aperture and the radiation beam pattern is simulated from the value of the random amplitude and phase errors. From the results, it is found that the only way to meet the requirement of the sidelobe level is to use digital beam forming (DBF). The considered model is a simplified prototype of more complicated multielement APAA which should be developed for the stratospheric communication system.

REFERENCES

[1] ITU-R Resolution 221, “Use of high altitude platform stations providing IMT-2000 in the bands 1885-1980MHz, 2010-2025MHz and 2110-2170MHz in Region 1 and 3 and 1885-1980MHz and 2110-2160MHz in Region 2,” 2000.

[2] R. J. Mailloux. "Phased Array Antennas Handbook", *Artech House*, *Inc*., 1994.

[3] Digital Beamforming in Wireless Communications, J. L. Litva, T. K.-Y. Lo, Artech House, Boston, London, 1996.

[4] An Experimental S-Band Digital Beamforming Antenna, L. Peterson, M. Danesting and U. Sjostom, Sweeden Defence Research Establishment, 1997.

[5] A Digital Beamforming Processor For Multiple Beam Antennas. J. L. Langston, K. Hinman, Texas Instruments and Electronics Group, P.O. Box 869305, M/S 8513, Plano, Texas 75086.