Antenna Array Feed of Minimum Power Consumption by Adopting the Optimum Amplifier Selection

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1. Introduction

In recent years, multibeam satellite systems with hundreds of spot beams have been developed and studied [1,2]. A Multibeam satellite system realizes adaptive frequency allocation for efficient frequency reuse, and has the flexibility to control traffic in communication. Generally, most multibeam satellite systems use an array-fed reflector antenna. When natural disasters (earthquake, flood, tsunami, etc.) happen, the communications traffics concentrate at the area because many people use cellular phones and access to the Internet. The corresponding beam to the area requires the highest output power opperation in the emergency case. The amplifiers consist of the beam is operated at the required output power (ROP) in the emergency case. Generally, all amplifiers have the same maximum output power (MOP) corresponding to the gate width. However, not all the amplifiers require the same power as the MOP. Because the ROP of amplifier is different for each antenna element. The amplifier whose MOP is much higher than the ROP has low efficiency. To minimize power consumption of array-fed element, we need to design optimal selection of MOP of amplifiers. Also, in practice design, only a few kinds of amplifiers with different MOP could be used.

In this paper, to minimize the power consumption of array-fed element, we propose the method how to select the MOP for each amplifier of antenna element of array antenna system.

2. Proposed Method

Figure 1 shows the flow chart of the proposed method. Figure 2 shows the power consumption and required output power (ROP) of each element. Figure 3 shows the definition of the estimation function. First, as shown in Figure 2, the ROP of an amplifier at each element is derived by calculating amplitude distribution of aperture corresponding to each beam and summing up all of it. The estimated the power consumption of each element is derived by using the pre-calculated table between an output power to efficiency [3]. When all system bandwidth are assigned to a certain beam, the output power of the corresponding element will have the maximum value. We define the total power consumption as the one when identical bandwidth will be assigned to all beams. Second, as shown in Figure 3, the order of the element is sorted by the corresponding power consumption, where horizontal line of Figure 3 shows element number and N is total number of element. Third, the approximate power consumption function g(x) {x=1,…,N} is obtained by polynomial approximation. At last, the area surrounded by dash line is calculated, corresponding to a certain amplifier selection as $g(n_1)$, $g(n_2)$, … , and $g(n_{m-1})$. Multiplying the power consumption of amplifier by the number of element assigned the amplifier gives the area surrounded by dash line. Therefore, when the total area is minimized, the power consumption of array-fed element minimizes and antenna/amplifier combination is obtained.

From Figure 3, we define the function of the total power consumption as

$$S = n_1 g(n_1) + \sum_{m=2}^{M} (n_m - n_{m-1}) g(n_m) \qquad (1)$$

where g(x) is the power consumption of the element number x. M is the number of amplifiers which have different maximum output power, n_m is number of element of power consumption $g(n_m)$. By differentiating equation (1) with respect to n_m, the following equation is obtained.

$$\frac{\partial S}{\partial n_m} = g(n_m) + (n_m - n_{m-1})\frac{\partial g(n_m)}{\partial n_m} - g(n_{m+1}) \qquad (2)$$

Equation (2) must be zero to minimize equation (1). Therefore

$$g(n_m) + (n_m - n_{m-1})\frac{\partial g(n_m)}{\partial n_m} = g(n_{m+1}) \qquad (3)$$

By solving equation (3) for n_m, we obtain n_m for all m, to minimize estimation function. Therefore, we can assign the maximum output power (MOP) of each amplifier as the optimum selection.

3. Simulation Result

We evaluate the proposed method using computer simulation. Table 1 describes the parameter for computer simulation. The total power consumption of array-fed element is given by

$$P_{dc} = \sum_{x=1}^{N} \frac{P(x)}{\eta(P(x), m)} \qquad (4)$$

where P_{dc} is the total power consumption of array-fed element, P(x) is the output power of element number x , η is the power efficiency of amplifier whose number is m , the output power is P(x).

Figure 4 shows the performance of power consumption of array-fed element for a certain assigned bandwidth per beam. In this example, four amplifiers which have different output power, corresponding to their gate width, are assumed. The degree of polynomial approximation is set to three. When the assigned bandwidth per beam is 1MHz, the total power consumption by proposed method is 3.35kW. For the conventional selection in which all the amplifiers has identical MOP as $g(n_M)$, the total power consumption is10.28kW. For the ideal selection in which all the amplifier has optimal MOP as $g(n_i)$ and N=M, the total power consumption is 2.38kW. Compared to conventional amplifier selection, the proposed method reduces the total power consumption up to about 70%. Compared to the ideal selection, the proposed method suppresses the total power consumption only up to 1.2 times.

4. Conclusion

We have proposed the method of optimization of selection of amplifier which has the different MOP to achieve the minimum total power consumption of array-fed element. The proposed method can reduce the power consumption of array-fed element compared to the conventional amplifier selection with identical gate width. Also by our simplifying the process, the estimation of the total power consumption can be taken in to account at the first system design.

Table 1: Parameter for simulation

Antenna type	Reflect antenna with array-fed element
Total number of element	73
Total number of beam	70
Number of element per beam	1〜14
Bandwidth of satellite communication system	20MHz

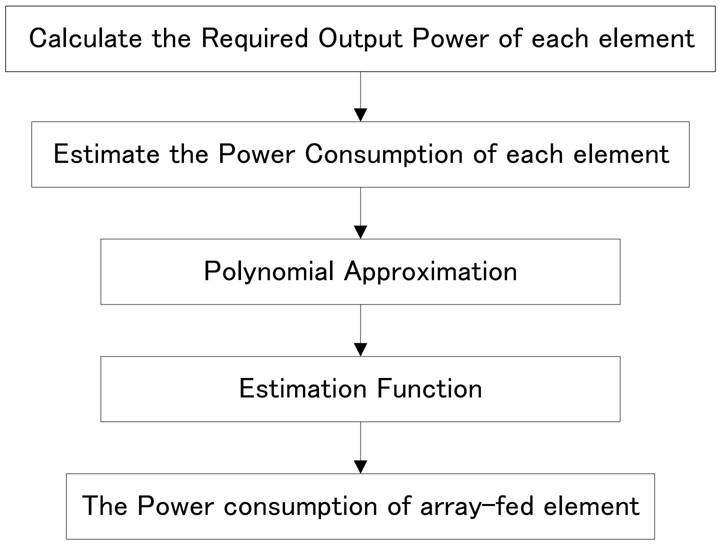

Figure 1: Flow Chart of Proposed method

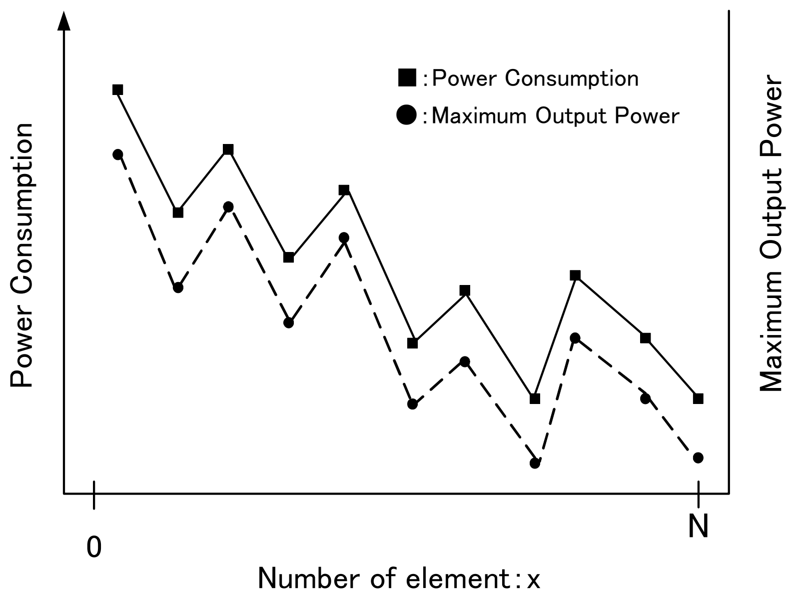

Figure 2: Power Consumption and Maximum Output Power of each element

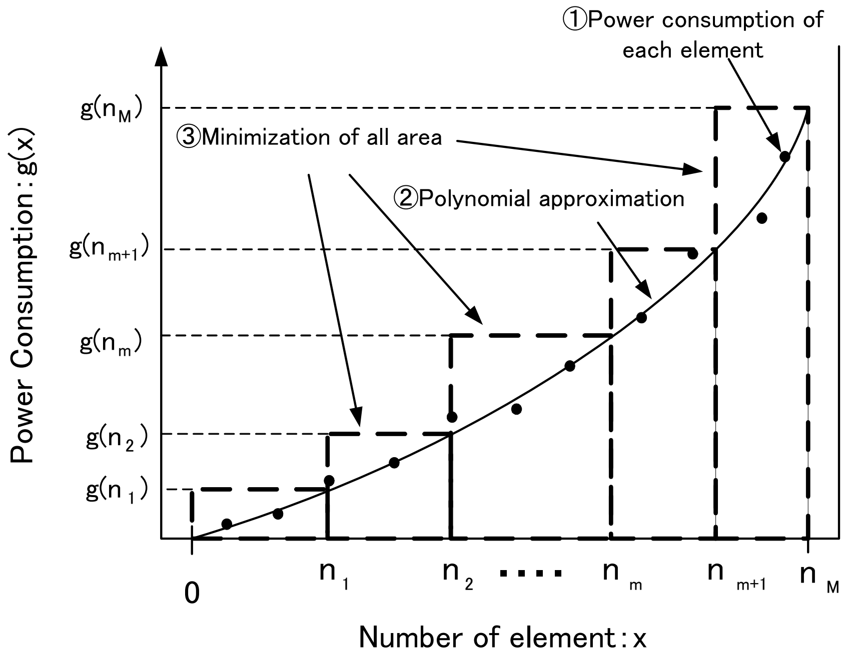

Figure 3: The definition of Estimation Function

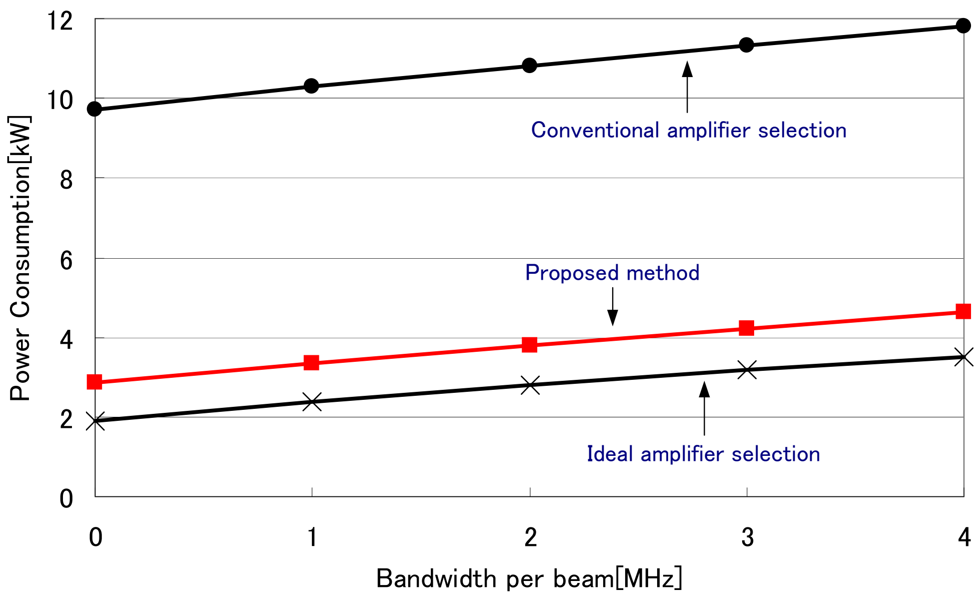

Figure 4: Simulation result

References

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