MULTI-STAGE DISPERSED AMPLIFIER ARRANGEMENT METHOD FOR ACTIVE ARRAY ANTENNAS

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1. Introduction

In recent years, as circuit technology for high frequency bands has developed and the amount of information transmitted over wireless systems has increased, investigations of communication systems that employ higher than quasi-millimeter and millimeter wave frequency bands have been actively pursued. Furthermore, development of mobile communications systems based on wide-area satellites has progressed [1]. In these systems, in order to make the equipment more portable, a planar antenna is used because it has a low profile, is lightweight, and compact. However, as the frequency increases, the loss of the feeding circuit increases resulting in lowered efficiency and an excessively bulky antenna. On the other hand, an active antenna configuration integrating an antenna and active devices is one candidate, although this configuration is mainly used with radar [2],[3]. It is difficult to apply this configuration towards communications, especially for mobile terminals when considering equipment complexity and power consumption. A simple active antenna configuration must be developed that has a low power consumption while it suppresses the side lobes to reduce interference to other systems.

This paper proposes a multi-stage dispersed amplifier arrangement method (MS-DAAM) for active array antennas that decreases the number of times active devices are mounted using active antenna technology employing spatial power combining and multi-stage amplifiers. The transmission active array antennas of the proposed antenna configuration establish a flexible excitation distribution to suppress the side lobes by connecting multi-stage amplifiers. The reception active array antennas of the proposed antenna configuration achieve a low noise figure (NF) and do not affect the active device configuration for transmission.

2. Concept of MS-DAAM

The concept behind this proposed antenna configuration is shown in Fig. 1. The figure shows an example application of the configuration to a microstrip antenna fed through a via hole. The feeding circuit for transmission is shown in Fig. 2, and the feeding circuit for reception is shown in Fig. 3. For the sake of simplicity, the impedance conversion circuit in the feeding circuit is omitted in the figure. This configuration comprises a feeding circuit that controls the excitation distribution by inserting an amplifier in the distribution circuit output in a tournament feeding circuit in series and changes the number of insertions from a common terminal to every block of an array antenna. The conventional method for determining the excitation condition of an active array antenna that is used to improve the side lobe characteristics is described in [4]. However, there are no reports concerning the implementability of the excitation distribution using a multi-stage configuration employing amplifiers that have the same characteristics as one another with an actual planar antenna feeding circuit. Variations in the characteristics due to the individual differences are suppressed to the minimum extent by using amplifiers that have the same characteristics. Moreover, a low-noise reception amplifier can use the density difference in the transmission amplifier configuration, and can establish a configuration that achieves uniform low NF characteristics, without changing the arrangement of the transmission amplifier. The features of this proposed antenna configuration are described below.

(1) The number of devices is decreased by consolidating the number of amplifiers in the configuration.
(2) The output power of each amplifier is reduced and the design of the spatial power combining array is simplified for heat dissipation.
(3) The side lobe characteristics are improved by the excitation distribution obtained from the multi-

stage configuration of the transmission amplifier.

(4) Simple design of the active devices is achieved by reducing the gain of the amplifier per stage, and minimizing the variations of the array characteristics by using only the same type of amplifier.

(5) Maximum directive gain is obtained for reception because the feeding circuits have the uniform amplitude and phase as a result of separating the transmission and reception functions of the configuration. This is accomplished by utilizing the difference between the transmission and reception amplifier configurations.

3. Design of MS-DAAM

Figure 4 shows the number of amplifiers elements required in each amplifier stage and maximum number of amplifier stage in number of elements. The indicated number of amplifiers is the minimum number required to obtain amplifier stage. Even if the number of elements increases, the minimum number of amplifies does not change. When one amplifier is arranged between the branch circuits, the maximum number of amplifier connections is 2(N-1) elements in a $2^N X 2^N$ configuration. Because the composition uses a 2N piece branch circuit, the position of the second amplifier stage can only be at the input terminal with the configuration $(2^N X 2^N)$ / 16. In addition, the amplifier after the third stage can be arranged into the antenna-element feeding section for every branch. For the sake of simplicity, a square amplitude distribution is assumed here, however, if the suppression of the side lobes is the priority then a circular amplitude distribution is more appropriate. When making a Chebyshev distribution into an ideal distribution, the minimum amplifier gain obtained from the elements in a square amplitude distribution and the maximum amplifier gain obtained from the elements of four angles in circular amplitude distribution. The amplitude distribution using the Chebyshev distribution of N elements from a center is set to A_{chev} (N).

$$20\log\left(\frac{1}{A_{chev}(2^{N-1})}\right) \le G\times(2(N-1)-1) \le 20\log\left(\frac{1}{\left(A_{chev}(2^{N-1})\right)^2}\right) \quad (1)$$

Figure 5 shows the relation between the directive gain of the proposed antenna and the side lobe level characteristics based on the number of elements. From aforementioned Formula (1), the amplifier gain of 5 dB and four stages maximum and element spacing of 0.8 λ_0 were used for the calculated value of Fig. 5 from the conditions currently assumed. A Chebyshev distribution and the results are compared and the results are shown not to be inferior. Figure 6 shows that the degree of directive-gain degradation from this configuration is small compared to other arrays that have the uniform amplitude and phase. Moreover, form the viewpoint of side lobe suppression, this configuration is effective for 16 elements or more. Figure 6 shows the value of NF with respect to the position of the receiver amplifier as a unit line loss parameter in order to determine the amplifier configuration for the receiver mounted in the minimized configuration. In addition, the low noise amplifier assumed here has a large gain and a sufficiently small NF. The degree of NF degradation by the line connected to the latter part is disregarded. When the number of elements that comprise a sub-array is large, the total feeding line loss from a radiation element to a first stage amplifier is increased.

4. Application of MS-DAAM to 8X8 element active array antennas

An 8X8 element array with the element spacing of 0.8 λ_0 is used as an example to verify the design described in the preceding section. λ_0 is free space wavelength. The comparison results of the directive gain to amplifier gain and the side lobe level are shown in Fig. 7 and Fig. 8, respectively, for each amplifier stage when considering the 8X8 element array. These figures show that the beamwidth is spread and the directive gain deteriorated, thus a large amplifier gain is used. Moreover, an effective effect cannot be planned as a result, even if it increases the amplifier gain by more than 5 dB, although it is effective when increasing the amplifier gain to 5 dB. Figure 9 shows the radiation pattern. This figure shows that the side lobes can be suppressed. In order to maintain a low NF of two or less as shown in Fig. 6, a reception-amplifier configuration with 16 elements is required when line loss estimate is 0.13 dB per λ_0. In this paper, the position of the reception amplifier is determined based on the conditions of the location that does not overlap the transmission amplifier. An example of this is shown in Fig. 3. Therefore, an array antenna design is achieved that exhibits good side lobe characteristics without the need for changing the conventional array design. The validity of this technique was confirmed based on these figures.

5. Conclusion

This paper proposed multi-stage dispersed amplifier arrangement method for active array antennas that have both a transmission unit and reception unit. The transmission portion of this configuration suppressed the side lobes without using an unequal power distribution circuit to obtain the amplitude distribution for the feeding circuit by changing the number of amplifier stages to connect every element. The reception portion showed that it was possible to position the amplifier such that it can obtain the maximum directive gain and achieve a low NF. It is cleared that the number of amplifier stages in which the realization when constituting $2^N X 2^N$, and the amplifier gain at that time. And it is cleared that changes in the characteristics based on the gain of the used amplifiers, and the number of stages of the amplifiers to connect. For an 8X8 element configuration, it was shown from the viewpoint of side lobe suppression and directive gain degradation that the optimum number of stages and the optimum gain of the amplifiers are four stages and 5 dB, respectively.

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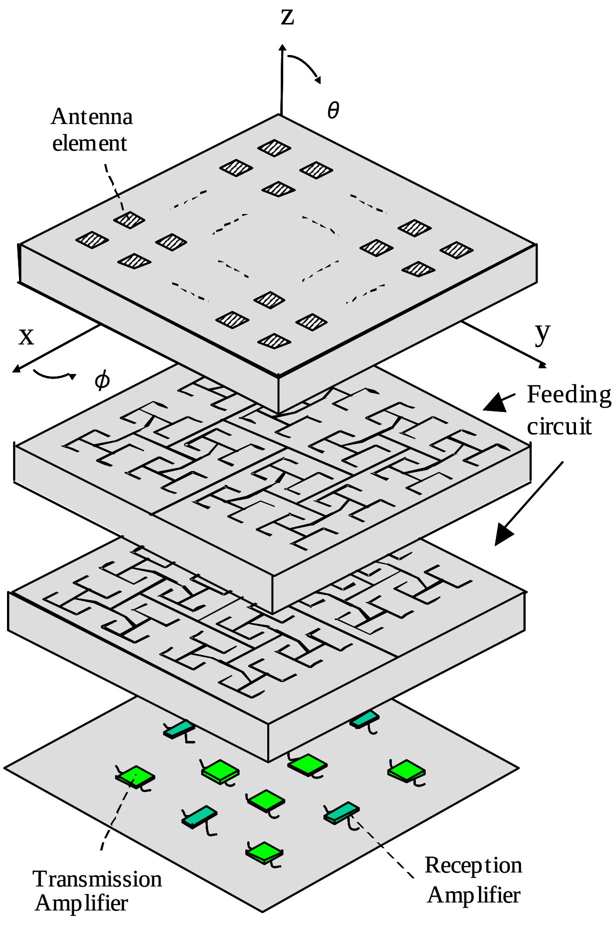

Fig. 1 Proposed configuration

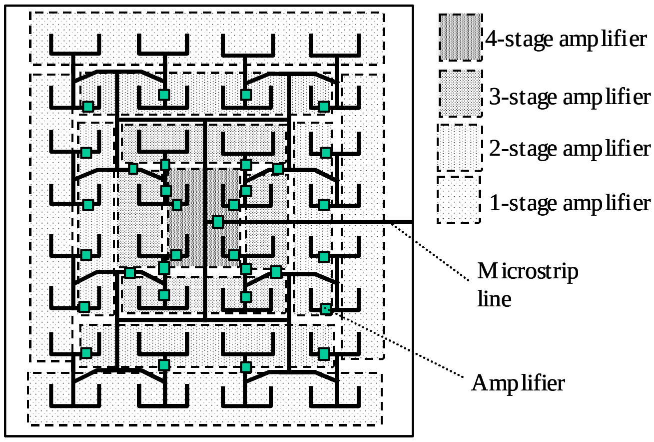

Fig. 2 Transmitter circuit

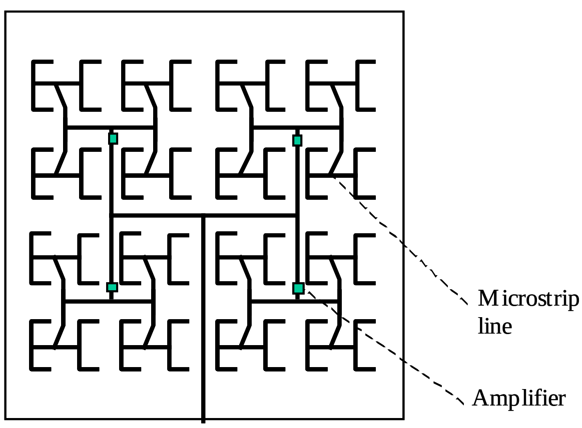

Fig. 3 Receiver circuit

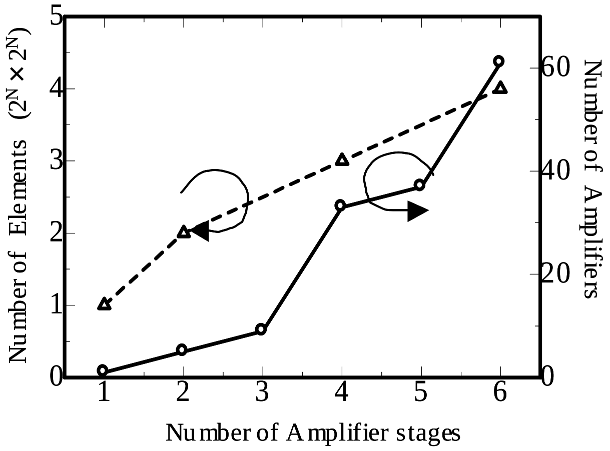

Fig. 4 Numbers of amplifiers and elements VS. the number of amplifier stages

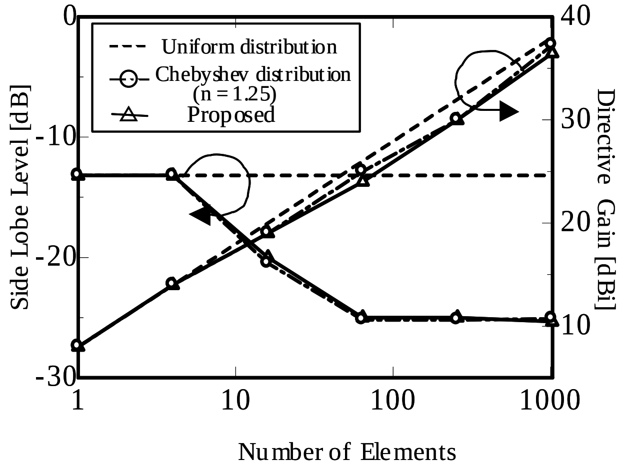

Fig. 5 Side lobe level and directive gain VS. the number of elements

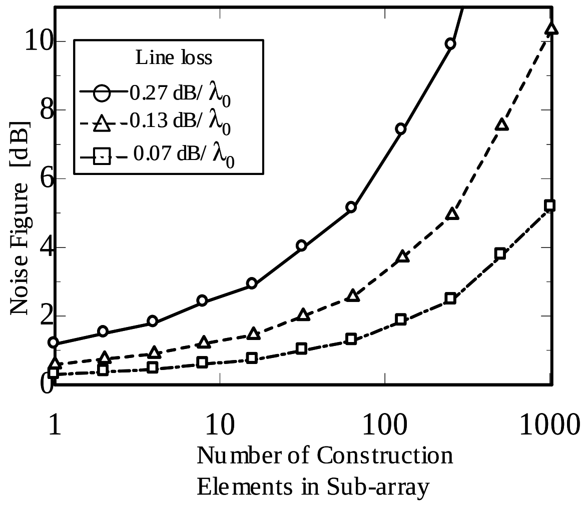

Fig. 6 NF VS. the number of construction elements in a sub-array

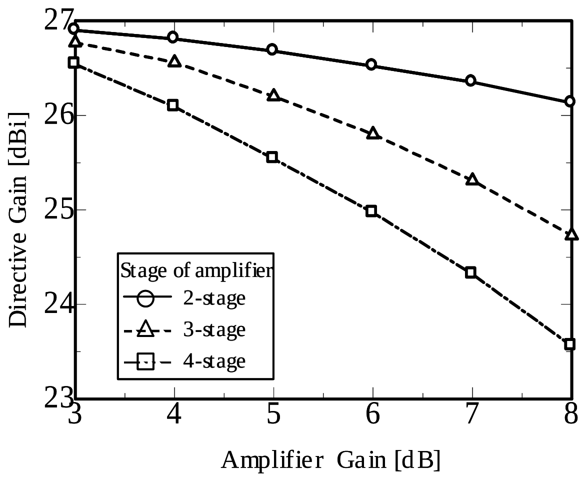

Fig. 7 Directive gain VS. amplifier gain

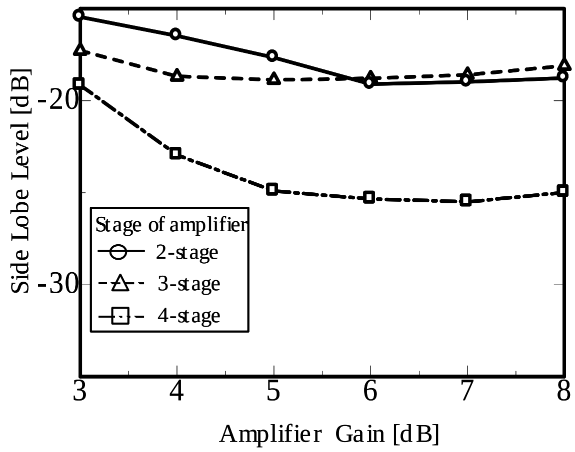

Fig. 8 Side lobe level VS. amplifier gain

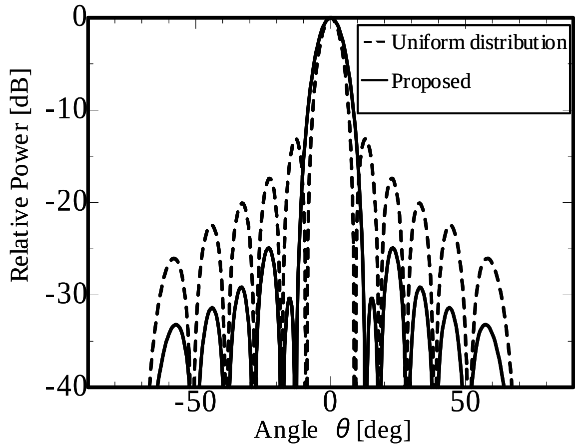

Fig. 9 Comparison of radiation patterns of uniform distribution and proposed configuration