PHASED ARRAY FED SINGLE REFLECTOR ANTENNA FOR COMMUNICATION SATELLITES

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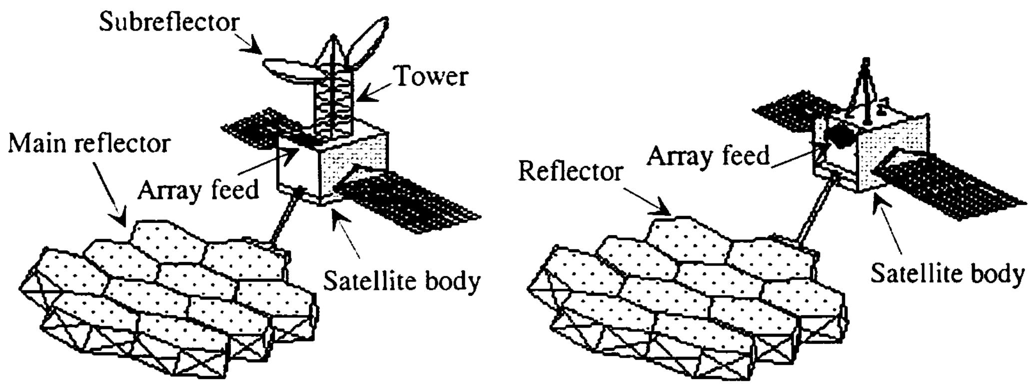
1. Introduction

The need for dozens of beams for a satellite antenna will require active phased array antennas. These antennas can generate high power with small power amplifiers, provide flexible power assignment to an arbitrary beam according to traffic demands, avoid feed losses, and independently reconfigure each beam [1]. Taking into considering the furling/unfurling operation of the satellite antenna, a feasible configuration of a phased array antenna is to combine a large deployable reflector and a rigid phased array feed. This paper describes the configuration of our targeting antenna and new developing technology that enables the construction of an appropriate-sized beam forming network for the antenna. Characteristics of the phased array fed single reflector antenna are shown and the effectiveness of the antenna is demonstrated.

2. Configuration of the antenna system

Satellite reflector antennas over 10 meters in diameter are located on the satellite as in Fig. 1 [2]. The difference between Figs. 1(a) and (b) is the presence of a subreflector. Figure 1(a) has a phased array fed dual reflector antenna known as an imaging reflector antenna [3]. In the electrical design, this antenna can be treated as a direct radiating phased array antenna with expanded dimensions up to the size of the main reflector. It has an advantage in applying various known array design methods. Figure 1(b) has a type of imaging reflector antenna employing a defocused array feed. This configuration is superior in that it alleviates the satellite payload by removing the subreflector and the tower. Although a few variations of this antenna have been reported [4],[5], a design method has not been established. Looking ahead



(a) Dual reflector type (b) Single reflector type

Fig.1 Configuration of satellite and antenna systems

into the next ten years, volume limitations regarding launching vehicles will not be lessened. So, Figure 1(b) becomes a feasible configuration and thus requiring study of the unknown electrical characteristics of this configuration.

A beam forming network (BFN) is a key component in achieving a fully flexible multibeam antenna system. Figure 2 is an assumed BFN for a transmission antenna. The BFN is composed of two stages of dividers and combiners. The RF input signal into port-i is divided into the number of array feed elements. Each divided signal is controlled by an individual phase shifter and its strength is kept constant by compensating for the insertion loss variation due to phase control by an individual attenuator. RF outputs from divider cards are combined

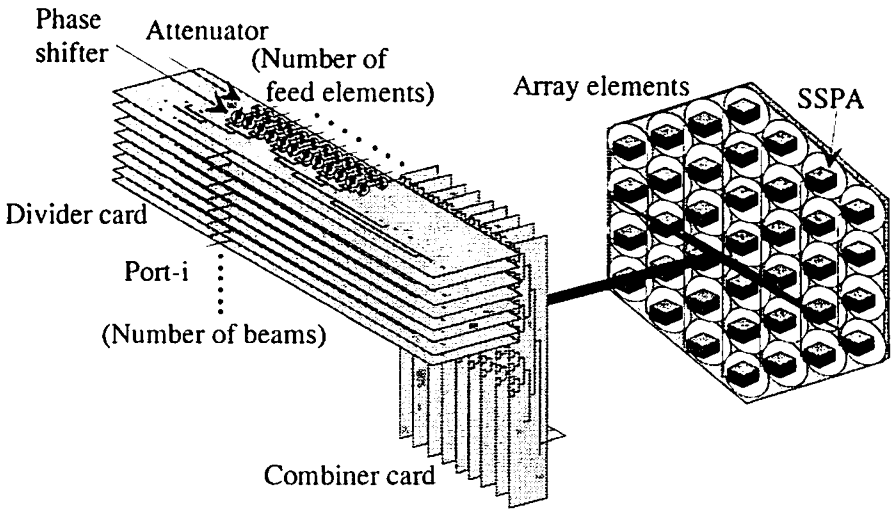


Fig.2 Beam forming network (Transmission)

through combiner cards in each feed element and are inserted to the solid state power amplifier (SSPA). This simple and conventional BFN enables each beam to be formed and directed independently without any limitations. So, this BFN is quite suitable for an array fed reflector antenna requiring a complex excitation coefficient. However, the large-scale circuit with cross points numbering in the thousands prevents miniaturizing the BFN. A monolithic microwave integrated circuit (MMIC) technology may contribute to miniaturizing cards, but the conventional technology has achieved only one function such as a phase shifter on one chip. One of our solutions is to advance the MMIC design method to reduce the number of circuit elements and to achieve a one-chip divider or combiner [6]. This technology is now under development.

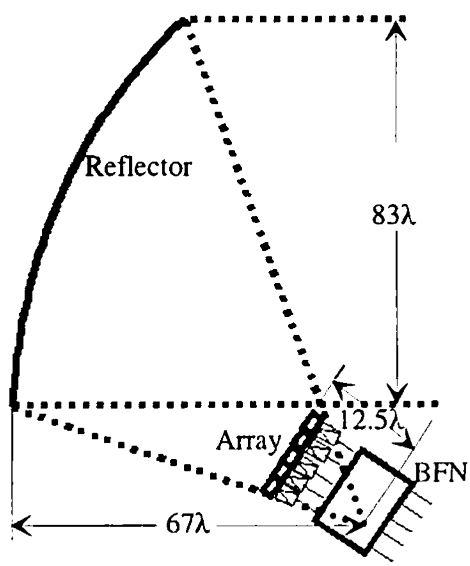
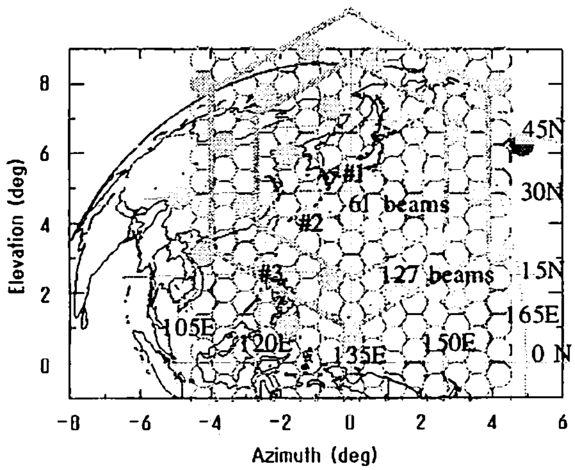


Fig.3 Configuration of the antenna

3. Characteristics of the array fed antenna

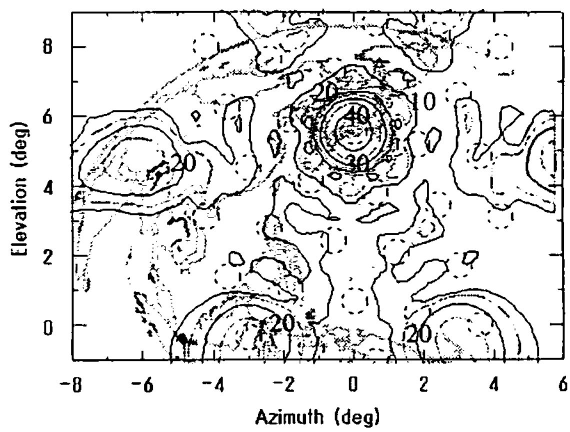
3.1 Antenna configuration

In order to confirm the feasibility of a phased array fed single reflector antenna, we assumed the configuration as shown in figure 3. This is not a well optimized model but only one of a few calculated models is used. The reflector has a diameter of 83λ, a focal length of 67λ and the planar array feed is placed at 12.5λ from the focus to the reflector. Here, λ is a wavelength. The array elements are arranged in a triangle and the spacing of these elements is 1.6λ. The number of feed elements is 61 and each element has a diameter of 1.6λ. In the calculation, these 61 elements were assumed to form a circular aperture and to radiate with a circular polarization.

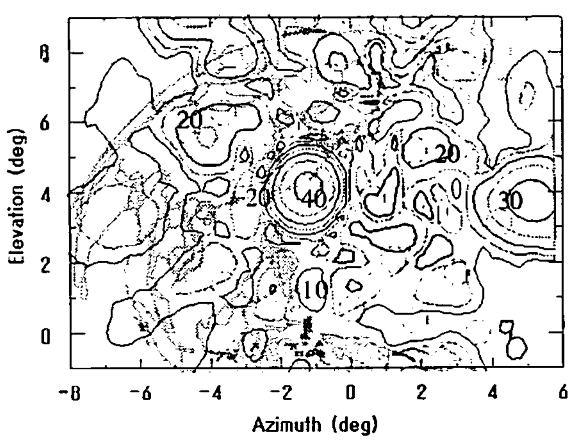


Coverage using the same frequency

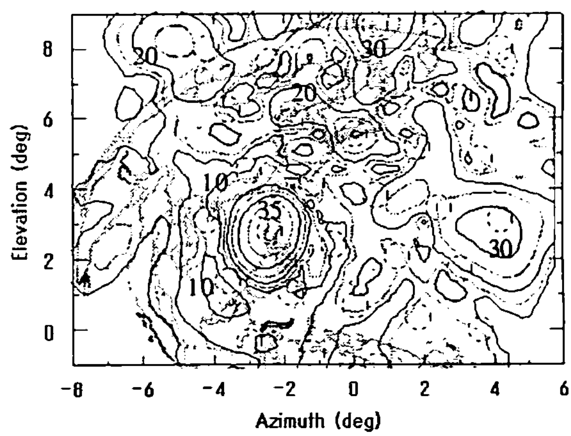
(a) Coverages from the stationary orbit



(b) Contour pattern of #1 beam (boresight beam)



(c) Contour pattern of #2 beam (1.85 deg. scanned)



(d) Contour pattern of #3 beam (3.7 deg. scanned)

Fig.4 Calculated characteristics of the antenna

3.2 Antenna characteristics

Figure 4(a) shows an example of allocated beam coverage on the map viewed from synchronous orbit. Each coverage has a hexagonal footprint, a circumcircle diameter of 0.8 degrees and the spacing is 0.63 degrees. Frequency reuse in seven frequencies is assumed. Figure 4(b) shows a contour pattern of which the beam direction is coincident with the antenna boresight. In calculating the excitation coefficient, an iterative minmax procedure [7] was used which takes into account maximizing the main lobe area gains and minimizing sidelobe levels in six adjacent coverages using the same frequency. The resulting excitation has an amplitude taper of about -12 dB from the center to the peripheral elements. The peak gain of this beam is 43.8 dB and the isolation between the main lobe area gains and the sidelobe levels in adjacent areas using the same frequency is 26.4 dB. Figures 4(c) and (d) show scanned beam patterns synthesized under the same amplitude coefficient constraints with boresight beam #1. These constraints are necessary for SSPAs to operate at a constant level of efficiency. Peak gains for beam #2 and #3 are 42.2 and 39.7 dB, respectively. Isolation for beam #2 is 24.3 dB and that for #3 is 21.1 dB.

These calculated results demonstrate the effectiveness of the phased array fed single reflector antenna as a multibeam antenna or a wide angle scanning beam antenna taking into consideration the elimination of feed losses. Improvement in antenna efficiency especially for scanned beams and suppression of grating lobe levels should be investigated in future research.

4. Conclusion

A phased array fed single reflector antenna which is attractive under limited satellite conditions has been investigated. Achieving this antenna system will be enhanced by decreasing the dimensions of the BFN by advancing the new MMIC design method. The electrical characteristics of the antenna have demonstrated the effectiveness of the antenna as a multibeam antenna or a wide angle scanning beam antenna. Also, this study has clarified the points that need improvement.

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