A MULTI-LAYERED MICROSTRIP ARRAY ANTENNA

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1.INTRODUCTION

Mobile satellite communications can provide wide-spread services which connect various users such as in airplanes, ships and cars. Following the growth of mobile satellite communications, there has been considerable interest in the technological development of mobile antennas[1]. A low profile and an electrical beam scanning function are required for these antennas. Recently, it has been considered to utilize active phased array antennas with monolithic microwave integrated circuit (MMIC) devices[2,3] for mobile satellite communications. By using MMIC modules, (a) electrical beam scanning, (b) solid state power amplifiers and (c) phase and amplitude weightings for optimum performance, are realized with compact array feed systems.

Concerning the antenna element, a slot-coupled microstrip antenna fed by triplate lines is suitable for mobile array antennas because of its thin structure[4,5]. Furthermore, this type antenna matches multi-layered structures and can have individual transmitting and receiving feed lines. This type antenna is effective when the antenna is used simultaneously for transmitting and receiving, because high isolation is expected between transmitting and receiving, and the band-pass filter can be built easily.

The authors have been developing a 16-element active phased array antenna, whose transmitting and receiving bands are 1.6 GHz and 1.5 GHz, respectively. The beam scanning range is up to 60 degrees from boresight. This paper first reports about the array configuration study. Then proposes a multi-layered microstrip antenna element which is a suitable structure for the active phased array, and indicates the experimental characteristics of the antenna element.

2.ARRAY CONFIGURATION

Table 1 shows the requirements for the array antenna. Figure 1 illustrates the array configuration. The antenna element radiation patterns and the spacing between elements are important factors which must be taken into consideration to obtain high gain while a beam is scanned.

With regard to the element, two types of arrays are considered to generate circular polarization. One is an array whose elements are circularly polarized. The other is an array in which circular polarization is synthesized by linearly polarized elements. In Fig. 2, a circular polarization element array (CP-array) is compared with a linear polarization element array (LP-array) in terms of the array gain, while the beam is scanned. In this figure, element antenna patterns are assumed to be ideal cosine patterns. From this numerical result, a CP-array is superior to an LP-array, particularly when the beam scan angle is large. The LP-array gain is lower, because the array generates cross polarization. Also, it is clear that the CP-array with about $\cos^1\theta$ pattern elements has maximum gain when the beam scan angle is 60 degrees.

Figure 3 shows the relation between the gain and the element spacing. In order to build the array in small size and attain high gain, it is required to use the CP-array with $\cos^1\theta$ elements and to set the element spacing at about 0.5λ (λ is wavelength).

3.ANTENNA ELEMENT

A slot-coupled microstrip antenna, fed by triplate lines, is suitable for use as an antenna element for a multi-layered structure array. The authors propose a multi-layered microstrip antenna, which is composed of a pile of transmitting and receiving slot-coupled microstrip antennas. This paper reports experimental results of basic characteristics of the antenna.

Figure 4 shows a multi-layered microstrip antenna. This antenna consists of six dielectric substrates. The upper three layers build the transmittig antenna, and the lower three layers build the receiving antenna. Each antenna is excited by a slot, which is fed by a triplate line. This structure has the following features.

(A) Hybrids and/or power dividers for circular polarization excitation can be built in triplate line structures.
(B) Low feed line insertion loss is realized.
(C) High isolation level is expected because the transmitting antenna and the receiving antenna are built separately.

In order to investigate characteristics for this antenna, a linear polarized multi-layer antenna element was developed.

Figure 5 indicates the resonant frequency characteristics. The resonant frequency can be determined by choosing suitable slot length and microstrip antenna radius. It is also possible to slightly regulate the resonant frequency by changing the slot width.

Figure 6 shows an example of experimental return loss results. A 1/4 wavelength transformer and a stub are used for the matching purpose. Figure 7 presents the mutual coupling between the transmitting and receiving ports. When two slots are set perpendicularly, about 30 dB islolation level is attained.

Figure 8 shows the radiation patterns for this antenna. E-plane and H-plane patterns resemble each other. Approximating each antenna pattern with $\cos^n\theta$, n is equal to 0.9 for the transmitting antenna and 1.3 for the receiving antenna, respectively. This performance satisfies the gain requirement for the phased array to be developed.

4.SUMMARY

Numerical analysis results indicate that an array, consisting of circularly polarized elements, obtains higher gain than a linear polarization element array, as the beam is scanned. In order to realize the highest gain in the condition that the beam scanning is in the range of 60 degrees, it is required that the element spacing is 0.5λ and that the element patterns are approximately $\cos^1\theta$. Also, the authors proposed the multi-layered microstrip antenna and indicated that good performance was realized experimentally. Next, the authors intend to develop circularly polarized elements and then build 16-element active phased array antennas.

REFERENCES

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Table 1 Requirements

Frequency(receive) (transmit)	1535.0-1542.5 MHz 1636.5-1644.5 MHz
Array antenna gain	More than 12.5 dBi
Polarization	Right-hand circular
Beam scanning range	60 degrees
V S W R	Less than 2.0
Isolation level	More than 30 dB

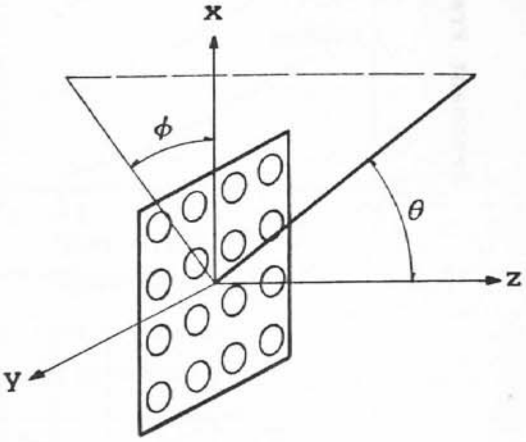


Fig. 1 Array Configulation

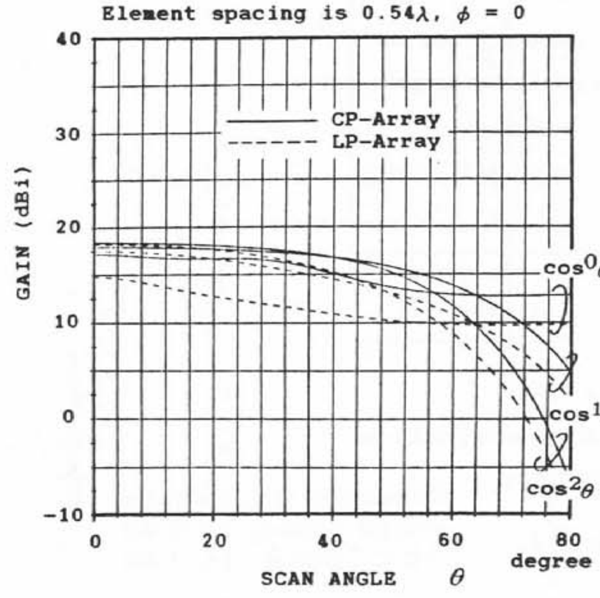


Fig.2 Gain vs. scan angle

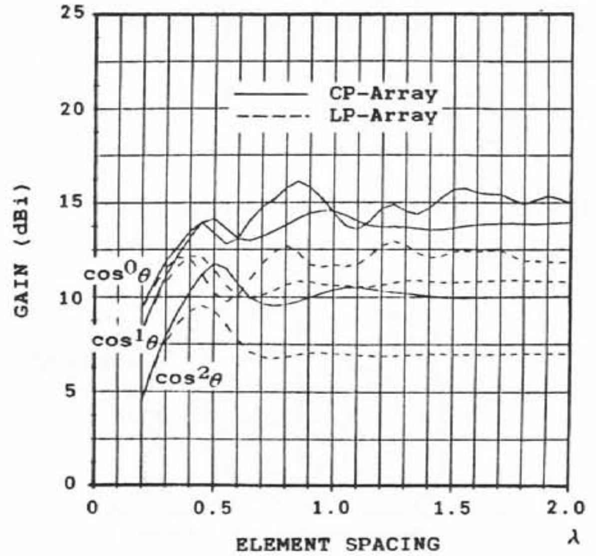


Fig.3 Gain vs. element spacing

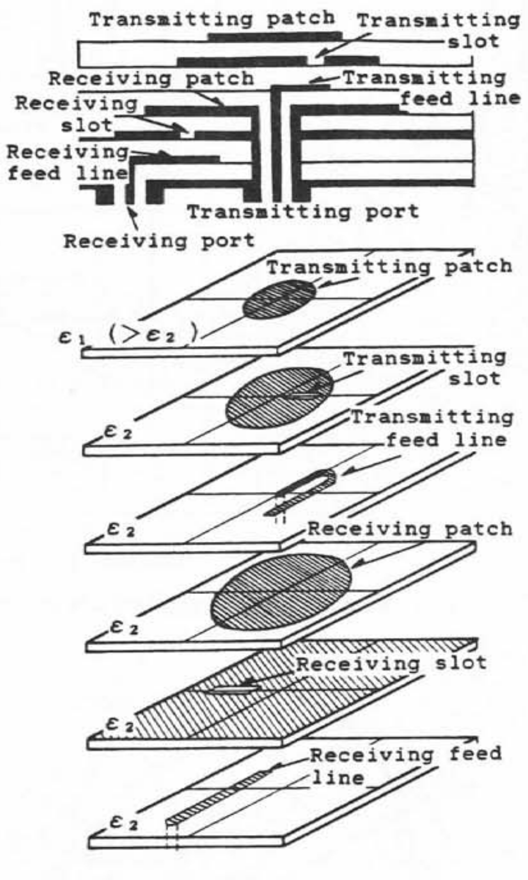


Fig.4 Multi-layered microstrip antenna

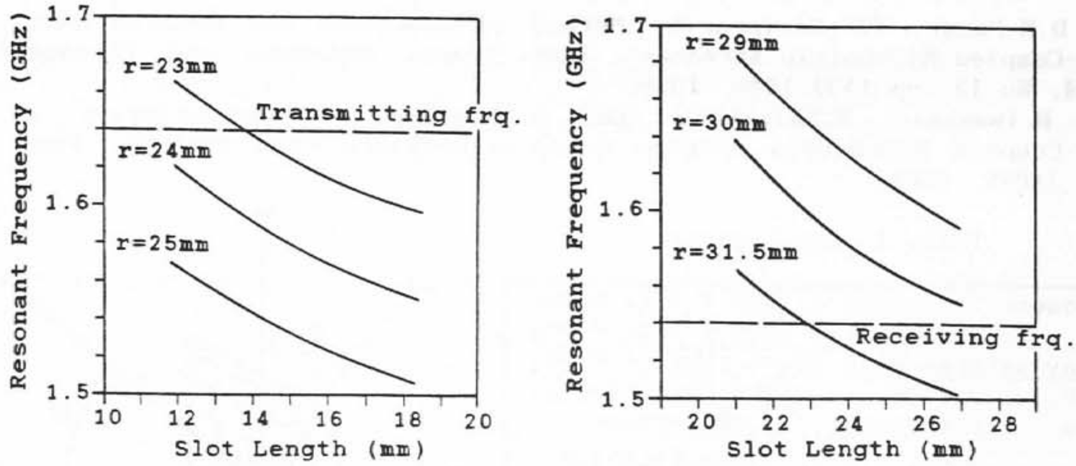


Fig.5 Resonant Frequency characteristics

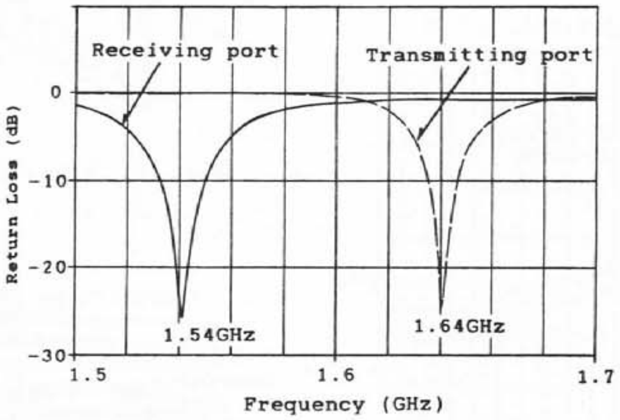
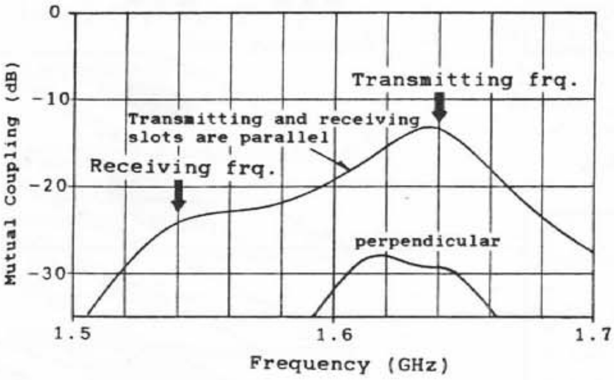


Fig.6 Reflection characteristics



[Transmitting antenna]
Patch radius 23.0 mm
Slot length 14.0 mm

[Receiving antenna]
Patch radius 32.0 mm
Slot length 22.0 mm

Fig.7 Coupling between transmitting and receiving ports

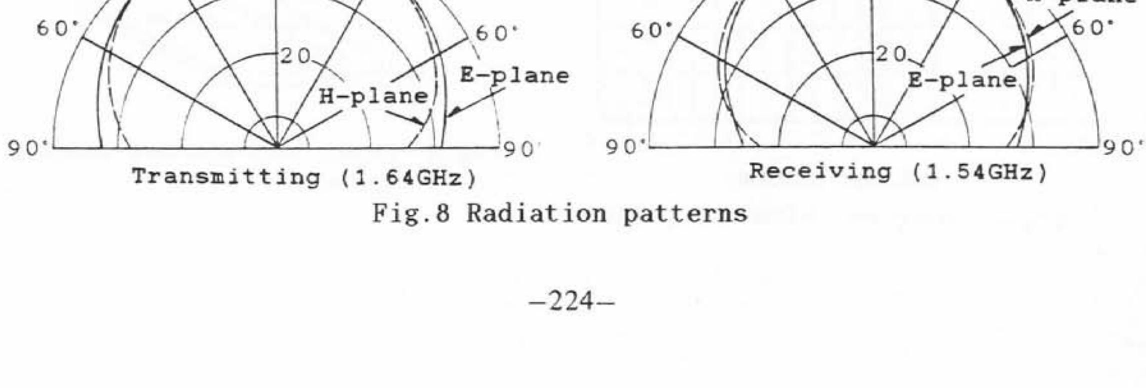


Fig.8 Radiation patterns