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L-band Circular Active Phased Array Antenna

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Abstract

An L-band circular phased array antenna has been developed. Features of this antenna, and a design technique of deciding a set of weights for the circular array for realizing the required sidelobe level, are described. Further, measured antenna patterns are also presented.

1. Introduction

Recently, phased array antennas employing electronic beam scanning, have been widely employed. This is because compact and high-performance semiconductor devices are becoming available at relatively low prices owing to the remarkable development of semiconductor technology. However, the phased array antenna is still more expensive than conventional antennas with high-power transmitters, so conventional antennas are also used depending on the requirements of each application.

As a typical case of the phased array antenna, the circular phased array antenna has notable features of scanning beams in azimuth direction electronically, free from scanning loss and beam skew. Therefore, the circular phased array antenna can search and track to any direction at any moment. On the other hand, both scanning loss and beam skew cannot be eliminated in case of planar phased array antenna. So the implementation of the circular phased array antenna is in progress in such applications as wide-angle and omnidirectional search and track. Circular phased array antennas have a large loss in feeding lines due to the complexity of the network, so they are suitable for active operation.

2. Outline of the Antenna

Figure 1 shows L-band circular phased array antennas developed with and without radome. Each column array employs honeycomb sandwich structure and two rectangular patch antennas to provide light weight and thin thickness. Generally the patch antenna has narrow band characteristic, however, the developed antenna realized bandwidth as much as 6%. Figure 2 shows a schematic diagram of this antenna. 1/3 of the total aperture is excited to form a beam when transmitting (TX), and is selected to form two beams, Σ/Δ, simultaneously when receiving (RX). And beam scanning is achieved by switching the aperture using a set of SP3T switches.

When transmitting, an exciter signal is distributed through a divider to T/R modules. The distributed RF signal is fed to a phase shifter, a power amplifier (PA), and to variable attenuator (ATT) for weighting to form a beam in the T/R module. And the output RF signal is fed to the antenna element. When receiving, a signal from the antenna element is fed to a low noise amplifier (LNA), a phase shifter, and divided into two signals by the divider. The divided signals (Σ/Δ) are weighted in each distribution depending on specific distributions for beam shape design, by the variable ATT and $0/\pi$ switchable phase shifter ($0/\pi$ PS). Finally, signals from all the T/R modules are synthesized by the combiner. The quantization LSB of the variable ATTs, above mentioned, are 3 dB when transmitting and are 1 dB when receiving.

3. Design

The designed sidelobe level of the L-band circular phased array antenna is -20 dB when transmitting and -22 dB when receiving. In an active phased array antenna, the thinning method is commonly used for sidelobe suppression when transmitting. Because the thinning method is not effective for arrays having small number of antenna elements, the amplitude weighting is only effective for this circular antenna. First of all, the use of an A-class amplifier for amplitude weighting, in which the output power is proportional to the input power, is considered. But A-class amplifier is not a good selection, because of a large amount of amplitude and phase errors between T/R modules. These errors make sidelobe level higher. Instead of the A-class amplifier, the variable ATT is adopted for Taylor weighting as shown in Figure 3.

In this case, the trade-off design is required to optimize the quantization LSB. The bigger the quantization LSB is, the more compact the size of T/R module is. The smaller the quantization LSB is, the lower the sidelobe level is. When transmitting, because of large power, the variable ATT, in which several fixed ATT are switched depending on weights, is generally used. When receiving, a small variable ATT is available. In this antenna, through the trade-off of these factors, and by the error distribution table shown in Table 1, we selected 3 dB of quantization LSB for the variable ATT when transmitting and 1 dB of quantization LSB when receiving. Due to the error distribution, the sidelobe level cannot be suppressed effectively if 1 dB or less of quantization LSB is used. Figure 4 shows the weights when receiving.

For the same reason, 5 bits phase shifter is selected.

4. Antenna Pattern

Figure 5 shows the measured TX antenna pattern. A sidelobe level of -25 dB is obtained. Figure 6 shows the measured RX antenna pattern. Σ/Δ patterns are shown. -23 dB of sidelobe level for Σ pattern is obtained.

5. Conclusion

The outline of the L-band circular active phased array antenna developed and, particularly an example of design technique taking errors into consideration, has been described. The antenna patterns of this antenna are -25 dB of sidelobe level when transmitting and -23 dB of sidelobe level when receiving. The validity of this design technique has been indicated.

Reference

M.Sato, et al. : "Cylindrical Active Phased Array Antenna", IEICE TRANS. COMMUN., VOL.E76-B,NO.10,1993,pp1243-1248

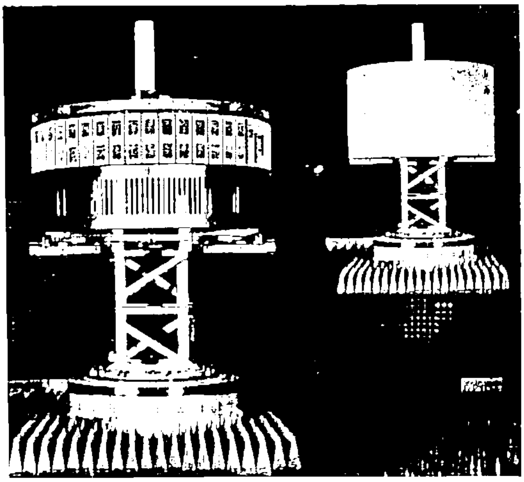


Fig.1 L-band Circular Active Phased Array Antenna

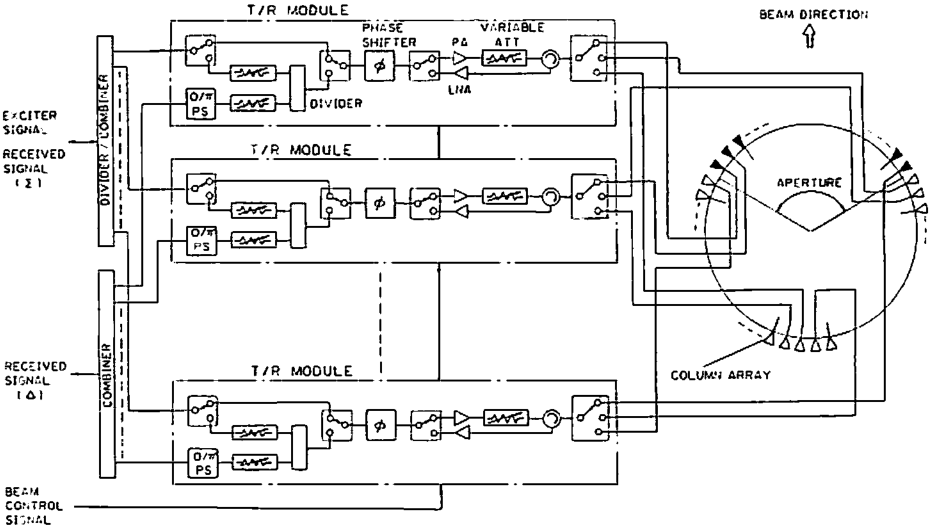


Fig.2 Antenna System Diagram

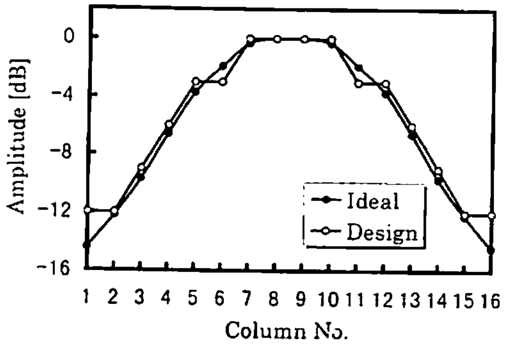
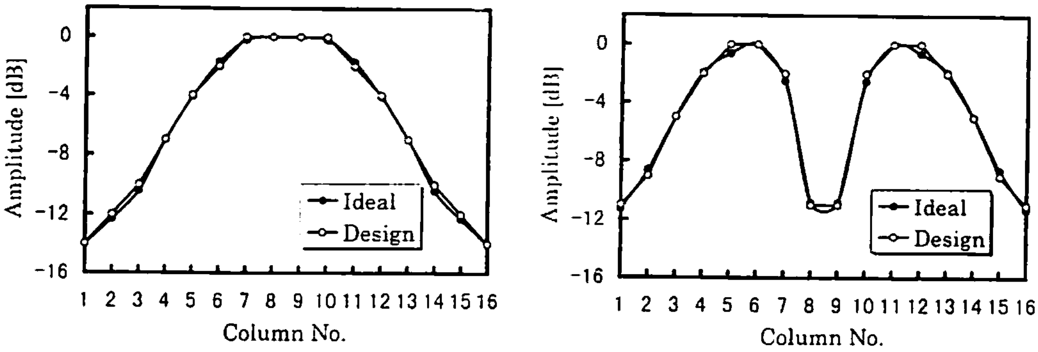


Fig.3 Weight Data (TX)



(a) Weight Data for Σ pattern (b) Weight Data for Δ pattern

Fig.4 Weight Data (RX)

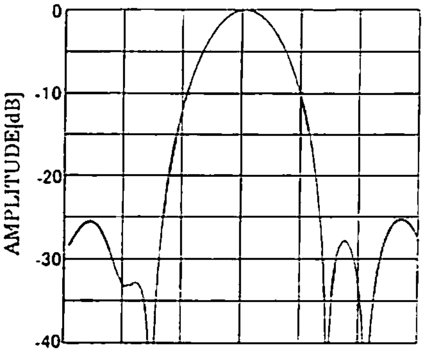


Fig.5 TX pattern

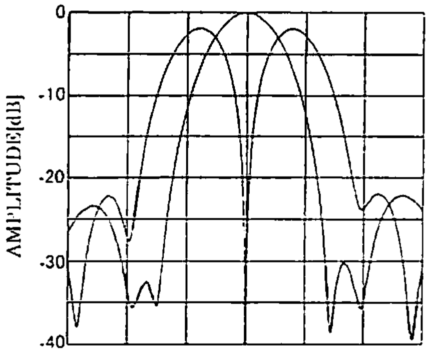


Fig.6 RX pattern

Table 1 Error Distribution

	Error (TX)		Error (RX)	
	Amplitude	Phase	Amplitude	Phase
Quantization Error	±1.5dB 0.87dBrms	±5.6° 3.3° rms	±0.5dB 0.29dBrm	±5.6° 3.3° rms
Others	0.4dBrms	8.3° rms	0.4dBrms	7.8° rms
TOTAL	0.96dBrms	9.0° rms	0.49dBrms	8.5° rms