A High-gain Array Antenna Available for One-dimensional Beamforming at V-band

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We propose an array antenna using liquid crystal polymer (LCP). The antenna works between 57 and 71 GHz. In order to achieve a wide beamforming range in the horizontal direction and a relatively high gain for each antenna element, a sub-array antenna consisting of four patches arranged in a row is used. Each sub-array antenna is fed from the center in order to prevent the radiation direction from changing with frequency. The layer structure consists of wiring layer, ground, antenna layer, and parasitic antenna layer from the bottom. S11 is less about -10 dB and the gain is higher than 9 dBi from 57 to 71 GHz.

1. Introduction

In recent years, the demand for wireless communication has been increasing due to the increased communication capacity such as video streaming serves and new use of IoT and V2X. In order to meet the increasing demand for wireless communications, millimeter-wave communication that can use wider frequency bands is being developed for practical use. The available frequency band of the V band has been expanded from 57 - 66 GHz to 57 - 71 GHz[1)], and it makes V band communication more attractive because the longer distance communication became possible.

High signal noise ratio (SNR) and wide band are required for high speed communication. Though the millimeter wave band is wide band, the SNR tends to be low because the transmission loss is high. Therefore, the gain is increased by narrowing the radiation direction. To increase the radiation gain, an aperture antenna such as a parabolic antenna or an array antenna in which a plurality of antennas are arranged is used. Recently, array antenna is often used because it uses less space than the aperture plane antenna, and because it is easy to electrically control the narrowed radiation direction [2)].

This work is an array antenna capable of one-dimensional beamforming in V-band band. To achieve a relatively high gain, a subarray antenna consisting of four patches arranged in a row is used. A four-conductor-layer substrate of a liquid crystal polymer (LCP) is used, and the layer constitution is composed of a wiring layer, a ground, an antenna layer and a parasitic antenna layer from the bottom. A patch antenna is used, and power is supplied by a microstrip separated from ground under the patch. In order to prevent the change of the radiation direction by the frequency, each subarray antenna is fed from the center. An array antenna operating at 57 - 71 GHz was developed, and the S11 was about -10 dB and the gain was about 9 dB at 57 - 71 GHz.

2. Array antenna

A phased array antenna which makes the maximum scanning angle θ_0 possible is considered. As shown in figure 1, a one-dimensional antenna is arranged at equal intervals d. When the phase difference between adjacent elements is φ ($0 \leqq \varphi < \pi$) and the wavelength λ of the radio wave, the main beam direction is perpendicular to the equal phase plane.

$$d \cdot sin\theta_0 = \lambda \frac{\varphi}{2\pi} \quad (1)$$

In addition, the beam by the equal phase plane made by the phase difference (2π-φ) between adjacent elements is called the grating lobe, and the angle θ_1 of the grating lobe is

$$d \cdot sin\theta_1 = \lambda\left(1 - \frac{\varphi}{2\pi}\right) \quad (2)$$

When using a phased array antenna, we need to prevent generation of a strong beam in an unnecessary direction. Therefore, the condition that the antenna interval d, (2) is not satisfied such that the grating lobe does not appear is obtained. The absence of θ_1 when the beam is directed at θ_0

$$d < \lambda\left(1 - \frac{\varphi}{2\pi}\right) \quad (3)$$

from (1) and (3).

$$d < \frac{\lambda}{1 + sin\theta_0} \quad (4)$$

Then, the condition of the antenna interval d is obtained. Since all bands used must be filled, λ uses the smallest wavelength.

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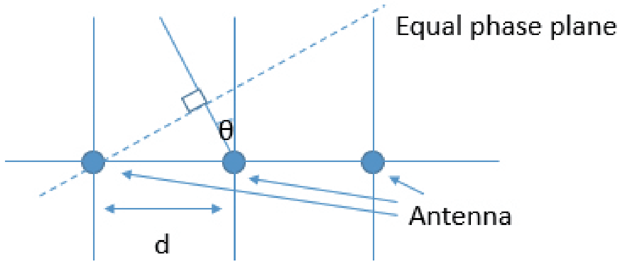

Fig. 1 Phased array antenna.

3. Simulation

The target of this development is ± 45 ° scanning of the vertical polarization in the horizontal direction, and the vertical coverage is about ± 10 ° antenna. Therefore, subarray antennas of 4 (vertical) × 1 (horizontal) arranged at the interval of 2.47 mm or less in the horizontal direction from (4) were examined. Fig. 2 shows the configuration of this antenna. This antenna consists of four layers: a feeder layer, a ground conductor layer, an antenna layer, and a parasitic antenna layer. From the feeder layer to the antenna layer, it is electromagnetically coupled through the aperture of the ground layer, and it does not conduct DC. By arranging the dielectric with high rigidity on the antenna, the following are aimed: Security of the flatness and wideband by weakening the confinement between antenna and ground conductor. Fig. 3 shows S11 and the radiation gain in the zenith direction.

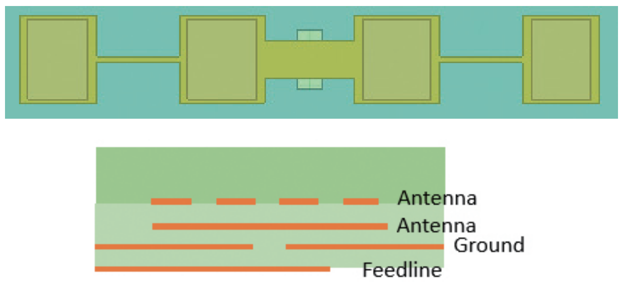

Fig.2 Configuration of antenna (top) top view (bottom) side view.

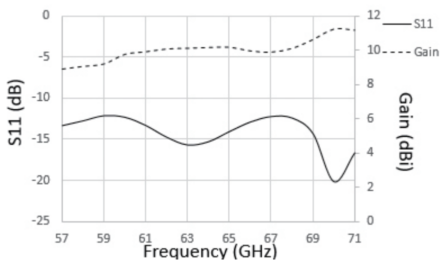

Fig.3. Simulation result of S11 and gain.

4. Measurement result

The antenna was measured using a probe. Since the radiation direction is on the opposite side of the feed line surface to which the probe is applied, it is impossible to measure by placing the antenna substrate on the probe station. Therefore, as shown in figure 4, a probe setup obtained by hollowing out the antenna portion of the antenna substrate was prepared and measured. The TRL calibration[3)] is used to set the reference point near the antenna feed point. Since the measuring instrument was available up to 67 GHz and from 60 GHz, the measurement was carried out by dividing into two. Fig 5 shows the measurement results of S11. Though there was some variation, it became about -10 dB at 57 - 71 GHz. The measurement results of the radiation gain in the zenith direction are shown in figure 6. The gain was about 9 dBi.

5. Conclusion

Millimeter-wave antennas are required to have high gain and wide band. A broadband antenna operating at 57 - 71 GHz has been developed using an LCP substrate. By arranging these antennas, high gain and horizontal beamforming is possible and this antenna which operates at 57 – 71 GHz makes high speed radio communication possible.

Reference

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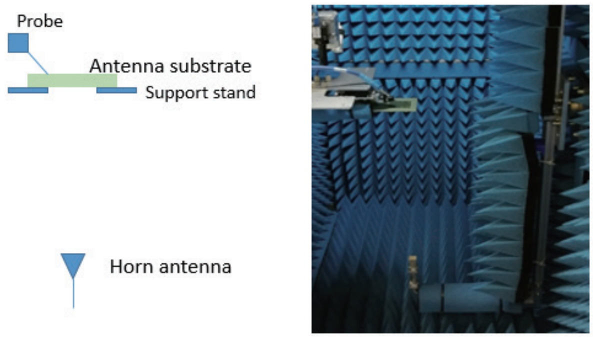

Fig.4 Measurement set-up.

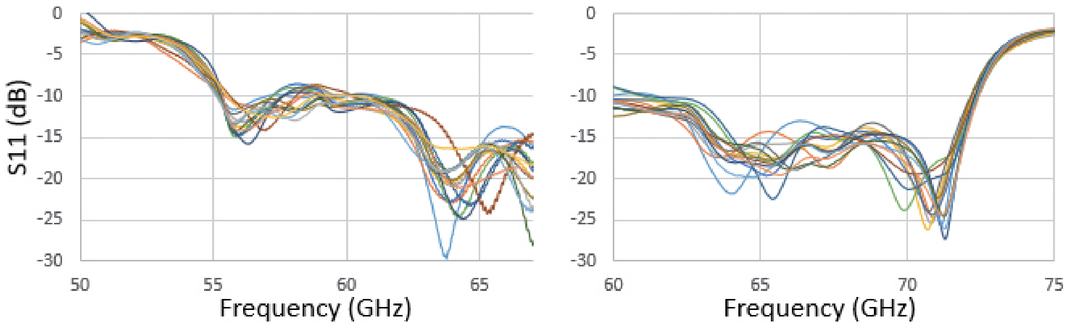

Fig.5 Measurement result of S11.

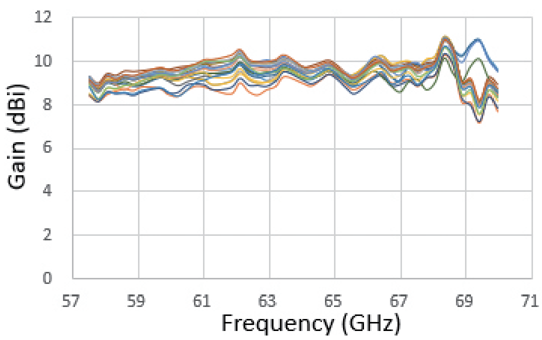

Fig.6 Measurement result of radiation gain.