LOW SIDELOBE MILLIMETER-WAVE MICROSTRIP ARRAY ANTENNA RADIATION-CONTROLLED BY MODIFICATION OF FEEDING-LINE WIDTH

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1 Introduction

Millimeter-wave antennas have been developed for applications of broadband high-speed wireless communication systems and automotive radar systems. Microstrip comb line array antennas are more advantageous than other millimeter-wave antennas at the viewpoints of low-profie and low-cost. A comb line feeding structure is effective for relatively low loss compared with other ordinary microstrip patch array antennas since feeding loss is smaller[1][2]. Extremely low radiating elements and high accuracy of radiation control are required in the design of Taylor distribution for low-sidelobe radiation pattern such as lower than -30 dB. Radiation from the array elements has been controlled only by modifcation of the element width in the conventional comb line array antennas. However, it is difficult to realize small radiation in the millimeter-wave band since the width of the element is limited wider than 0.1 mm in etching process. We propose the way to extend the design freedom of radiation control of the array element in this paper. Radiation from the element depends on the ratio between the widths of radiating element and transmission line. Radiation from the element can be reduced by using a wide feeding line as well as narrow elements. A linear array antenna with 27 radiating elements is developed in this work. Measured performance is evaluated and applicability is confrmed in the millimeter-wave band.

2 Configuration

A microstrip comb line array antenna is composed of several rectangular radiating elements directly attached to a straight feeding microstrip line printed on a dielectric substrate with a ground plane as is shown in Fig.1. The radiating elements are inclined 45 degrees from the feeding microstrip line for the polarization requirement of the automotive radar systems. Radiation from the elements can be controlled only by the width $W_{\rm n}$ of the elements where $L_{\rm n}$ is the resonant length. In order to realize low-sidelobe array, elements with extremely low radiation is required around the input port where high input power flows in the feeding line. Then, we propose to extend a width $B_{\rm n}$ of the feeding line for small radiation from the elements.

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The feeding line width is changed at the connection of the radiating elements without impedance transformer to prevent discontinuities on the feeding line. The radiating elements are arranged on the both sides of the feeding line, which forms interleave arrangement. Element spacing d_n is approximately a half guide wavelength so that all the elements are exicited in phase. An ordinary patch antenna for a matching element is connected at the termination of the feeding line in order to radiate all the residual power.

3 Design

Radiation from the element is investigated by using the elctromagnetic simulator of the finite element method. Figure 2 shows a simulated model for one element. The dielectric material of the substrate is Teflon (thickness $t = 0.127$ mm, relative dielectric constant $\varepsilon_r = 2.2$ and loss tangent $\tan\delta = 0.001$). Figure 3 shows radiation power from the element depending on the element width W_n and feeding line width B_n. Radiation is reduced to 1.4 % in minimum with decreasing of W_n to 0.1 mm. However, radiation of 0.5 % is possible by using a wide feeding line where $B_\mathrm{n} = 1.0$ mm. As results of element analysis and array design, the geometrical parameters are determined to achieve the required aperture distributions of amplitude and phase for the sidelobe lower than -30 dB as is shown in Fig.4. B_0 and B_1 are 1.0 mm. It is reduced by 0.1 mm to 0.3 mm of the eighth element. It is 0.3 mm constant from the eighth element to the 26th element. The element spacing d_n is determined taking phase perturbation of each element into account.

4 Experiments

Figure 5 shows a photograph of the developed antenna. An impedance transformer is used at the input port to change the width of the wide feeding microstrip line to that of an ordinary input microstrip line. Figure 6 shows radiation pattern in the yz-plane at 76.0 GHz. A few degrees beam tilting is adopted to improve the reflection characteristics. Low sidelobe of -24.3 dB is observed in the measured results. However, it is still 5.7 dB higher than the calculation. Measured aperture distributions of phase and amplitude are shown in Fig.7 (a) and (b), respectively. Some errors are observed where the feeding line width B_n is modified. Error of amplitude near the input port affects to the radiation from the elements around the termination due to the traveling wave excitation, which causes rapid decrease of amplitude observed in the second half of the array. All these errors of amplitude and phase distribution cause the degradation of the radiation pattern. Figure 8 shows measured frequency dependency of reflection coefficient. Reflection coefficient is -10.9 dB at the design frequency of 76.5 GHz.

5 Conclusion

The low sidelobe microstrip array antenna is developed in the millimeter-wave band. Wide variety of radiation from the element is achieved by modification of feeding line width. Sidelobe level -24.3 dB is obtained in the experiments.

References

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[2] H.Iizuka, T.Watababe, K.Sato and K.Nishikawa, "Millimeter-Wave Microstrip Array Antenna For Automotive Radars," IEICE Trans. Commun., Vol.E86-B, No.9, pp.2728–2738, Sept. 2003.

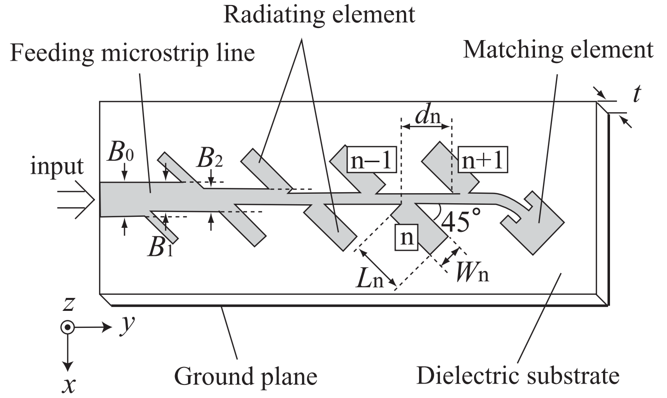


Fig.1 Microstrip comb line array antenna

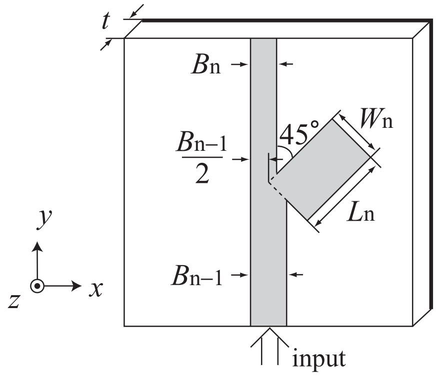


Fig.2 Simulated model

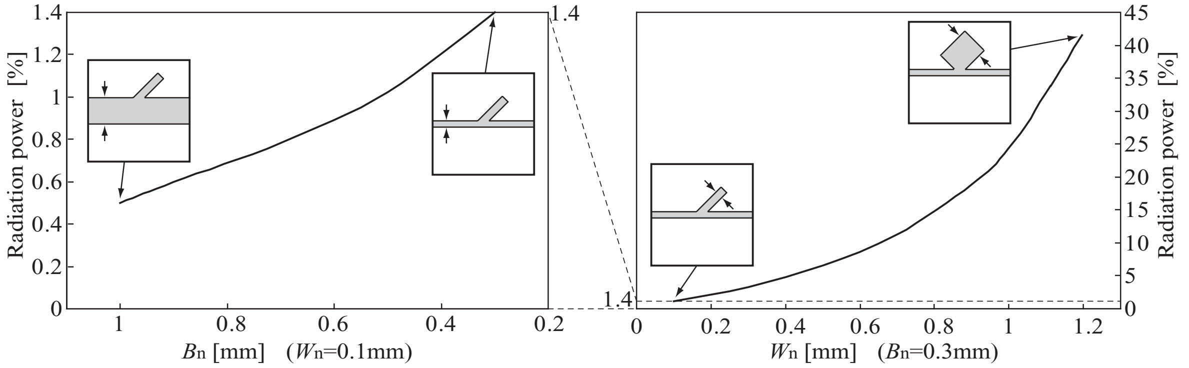


Fig.3 Radiation power depending on W_n and B_n

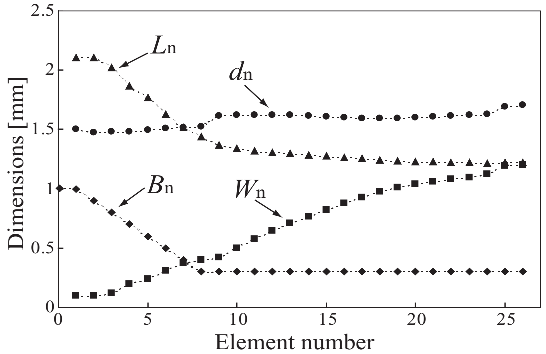


Fig.4 Geometrical parameters of all the radiating elements

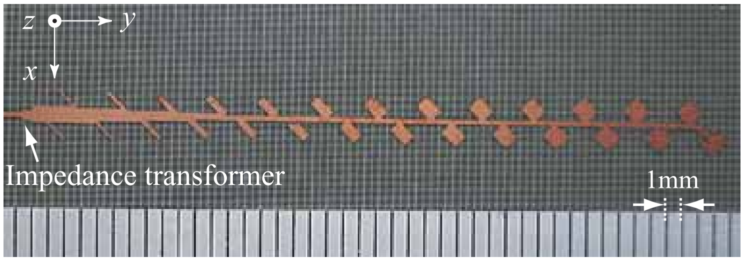


Fig.5 Photograph of the developed antenna

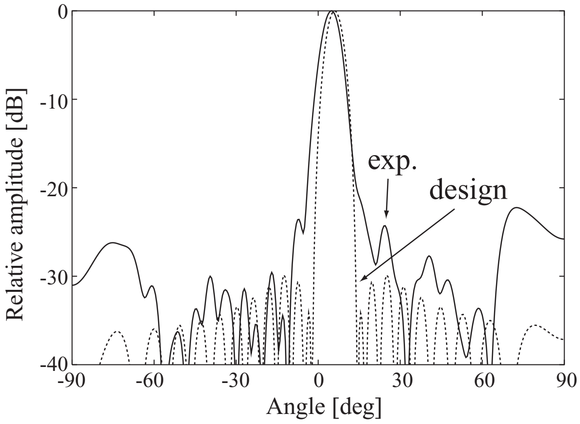


Fig.6 Radiation pattren in the *yz*-plane

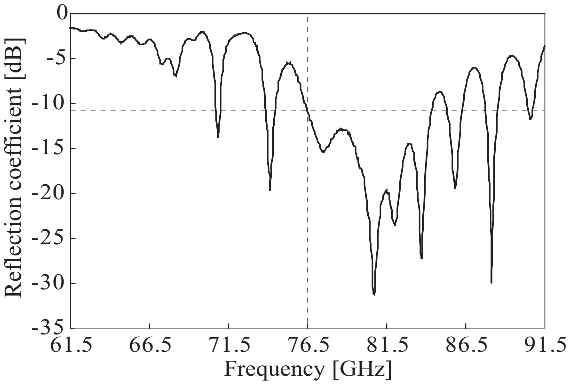
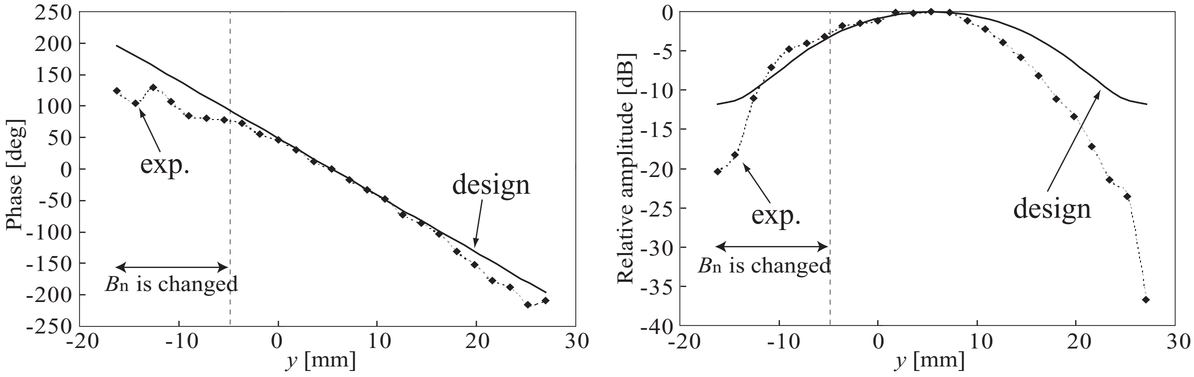


Fig.8 Measured reflection coefficient



(a) Phase distribution

(b) Amplitude distribution

Fig.7 Phase and amplitude distributions on the aperture