Design Of Millimeter-Wave Series-fed Array Antenna with Loop Elements

Yuichi Kashino [1], Hiroyuki Uno[1], Junji Sato[2]
[1]Panasonic System Networks R&D Lab. Co., Ltd. , Kanazawa-shi, Japan
[2]Panasonic Corporation, R&D Division, 600 Saedo-cho, Tsuzuki-ku, Yokohama City 224-8539, Japan

***Abstract* – We propose the array antenna with the loop elements for millimeter-wave bands. Our proposed antenna is composed of the loop elements and the patch elements on the dielectric substrate. This antenna is realized low loss by composing the series-fed array antenna. In this paper, we design the series-fed array antenna with the loop elements. Moreover the radiation patterns of the fabricated array antenna are measured between 77 and 81 GHz. As a result of the measurement, the antenna gain is 20.5 - 21.5 dBi and the sidelobe level is below -15 dB.**

***Index Terms* — Millimeter-wave, Array antenna, Microstrip antenna, Loop element.**

I. Introduction

Millimeter-Wave antennas have been developed for various applications such as the short-range wireless communication systems and the automotive radar systems [1], [2]. The microstrip antennas are more advantageous than other antenna in terms of low profile and low cost [3]. On the other hand, the feeding loss of the microstrip line is a significant problem for the feeding of the array antenna. The series-fed method is effective for relatively low loss in comparison with the parallel-fed method. Furthermore, low sidelobe level is required in order to prevent false detection for the automotive radar systems. In this paper, we propose the series-fed array antenna which can realize high gain and low sidelobe level at 77 - 81 GHz. In Chapter 2, the structure and the design approach of the proposed antenna is shown. In Chapter 3, the measured results of the fabricated antenna are shown.

II. Structure of The Proposed Array Antenna

The proposed array antenna is composed of the loop elements and the patch elements on the dielectric substrate as shown Fig. 1. The dielectric substrate has the area of 29.05 × 6 mm and the thickness of 0.388 mm, and its relative dielectric constant and loss tangent are 3.3 and 0.0085 at 79 GHz, respectively. The dielectric substrate is constructed of three layers as shown in Fig. 2, and the thickness between layers is as follow: t_{12} = 0.070 λ_0 (0.265 mm), t_{23} = 0.016 λ_0 (0.06 mm), where λ_0 is the free space wavelength at 79 GHz. The thickness of the conductive layer is as follow: t_1 = 0.006 λ_0 (0.024 mm), t_2 = 0.004 λ_0 (0.015 mm), t_3 = 0.006 λ_0 (0.024 mm). The input power is fed to the array antenna by using the through hole from the feeding line of the layer 3.

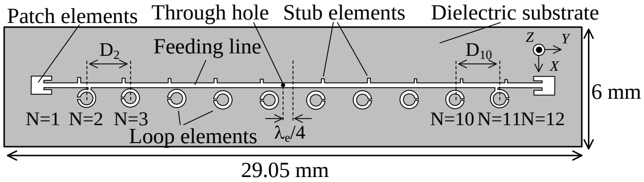

Fig. 1 Overall view of array antenna.

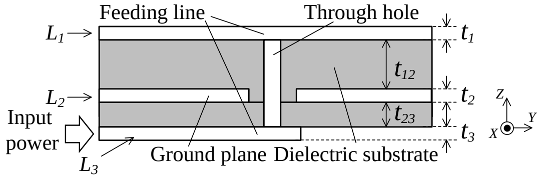

Fig. 2 Cross-section view of array antenna.

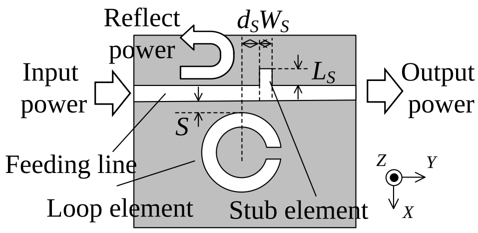

Fig. 3 Close up of loop element.

Figure 3 shows the loop element of the proposed antenna. The length of the loop element is approximately one effective wavelength (= λ_e). The +Y direction side of the loop element is cut out in order to realize the linear polarization of the Y direction. The loop element is excited by an electromagnetic coupling with the microstrip line. The radiation power from each loop element is determined by the distance *S*, and is calculated by subtracting both the output power and reflection power from the input power.

The stub element is formed by the projecting pattern on the feeding line in order to achieve the impedance matching. The stub element length L_S, the stub element width W_S, and the distance d_S from the center position of the loop element are determined to cancel the wave reflected from the loop element.

Table 1 shows the relative amplitude and radiation coefficient of each loop element, where the radiation coefficient is the ratio of the radiation power to the input power. The radiation coefficient is set to the small value as

Table 1 Relative amplitude and radiation coefficient.

Element number	Relative amplitude [dB]	Radiation coefficient [%]
1, 12	-8	100
2, 11	-4.4	67.9
3, 10	-4.4	38.9
4, 9	-1.9	39.4
5, 8	0	36.6
6, 7	0	25.6

Table 2 Design parameters of array antenna.

Element number	Distance S [ ]	Length L_S [ ]	Distance d_S [ ]
2, 11	0.022 λ_0	0.050 λ_0	0.090 λ_0
3, 10	0.021 λ_0	0.061 λ_0	0.090 λ_0
4, 9	0.021 λ_0	0.061 λ_0	0.090 λ_0
5, 8	0.024 λ_0	0.061 λ_0	0.092 λ_0
6, 7	0.037 λ_0	0.050 λ_0	0.092 λ_0

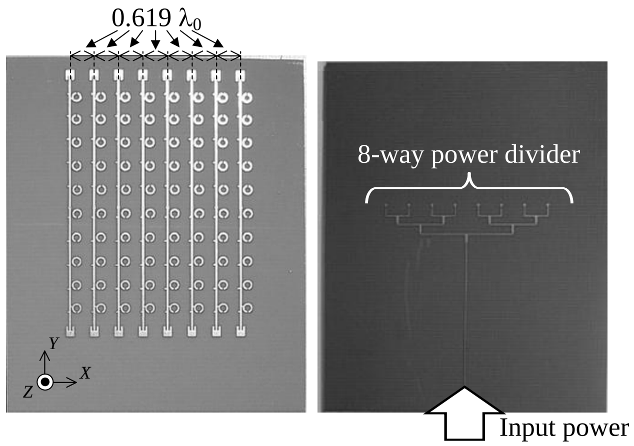

Fig. 4 Photograph of the fabricated array antenna.

the distance between the position of the loop element and the center of the array increases, its range is 25.6 % - 67.9 %. By setting the radiation coefficient shown in Table 1, the array antenna with Taylor distribution can be designed.

Table 2 shows the distance S, the stub element length L_S, and the distance d_S of each loop element. All stub element width W_S are 0.026 λ_0. The element number 2 and 11 is directly connected to the feeding line for the realization of the high radiation coefficient. The element spacing D_N is approximately one effective wavelength, and the distance between the through hole and the center of the array is $\lambda_e/4$ so that all the elements are excited in phase. The feeding line is terminated by arranging the patch elements to radiate all the residual power in the feeding line.

III. Results of Measurement

Figure 4 shows the fabricated array antenna, which is designed at the operating frequency of 77-81 GHz. The fabricated antenna consists of eight branches fed from the microstrip 8-way power divider. The distance between the each branch is 0.619 λ_0. The 8-way power divider loss is omitted for the measurement of the gain.

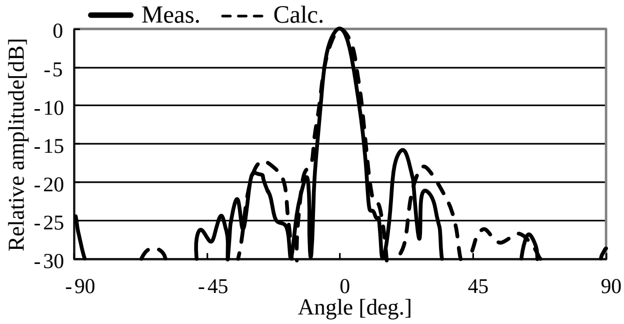

Fig. 5 Calculated and measured radiation patterns.

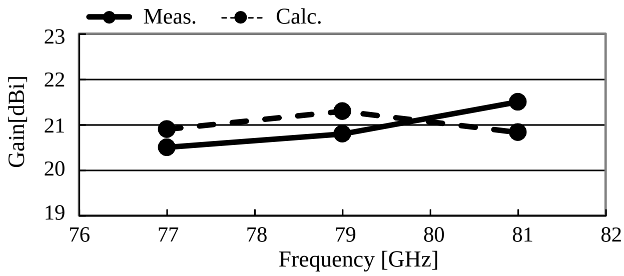

Fig. 6 Gain of fabricated array antenna as a function of frequency.

The measured radiation patterns at 79 GHz are shown in Fig. 5. The measured radiation patterns are almost in agreement with the calculated radiation patterns. In Fig. 5, the sidelobe level of the measured radiation pattern is –15.9 dB. Figure 6 shows the gain of the fabricated array antenna as a function of frequency. In Fig. 6, the gain is 20.5-21.5 dBi between 77-81 GHz.

IV. Conclusion

We have proposed high gain and low sidelobe array antenna with the loop elements. Moreover, the radiation patterns of the fabricated array antenna are measured. It is observed that the radiation patterns in the measurement are in agreement with that in the calculation. The measured gain and sidelobe level of the antenna are 20.5-21.5 dBi and below –15 dB, respectively.

References

[1] T. Ito, Y. Tsutsumi, S. Obayashi, H. Shoki, T. Morooka., “Radiation Pattern Measurement System for mm-Wave Antenna Fed by Contact Probe”, *EuMC 2009*, pp.1543-1546, Sep.-Oct. 2009.

[2] W. Li, S. Glisic, J. Borngraeber, W. Winkler, and J. C. Scheytt “A single-ended fully integrated SiGe 77/79 GHz receiver for automotive radar,” *IEEEJ. Solid-State Circuits*, vol. 43, no. 9, pp. 1897-1908, Sep. 2008.

[3] K. Sakakibara, S. Sugawa, N. Kikuma, and H. Hirayama, “Millimeter-wave microstrip array antenna with matching-circuit-integrated radiating-elements for travelling-wave excitation,” *in Proc. 4th Eur. Conf. Antenna Propag.*, Barcelona, Spain, Apr. 15, 2010.