High Coupling Radiating Element Using Impedance Transform Stub for Microstrip Comb-Line Antennas in the Millimeter-Wave Band

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***Abstract* – A novel high coupling radiating elements using an impedance transform stub are developed for microstrip comb-line antennas. In the design of low-sidelobe microstrip comb-line antennas with small numbers of element, array element with large coupling of the antenna around the input port is required. The radiating edge impedance of the rectangular microstrip antenna is transformed to adequate low impedance around the input port by the impedance transform stub. Then, high coupling is achieved. The coupling power is controlled from 6 % to 70 %. The performance of low-sidelobe 6-elements comb-line antenna with our proposed high coupling radiating element using impedance transform stub was demonstrated in this paper.**

***Index Terms* — Array antenna, microstrip antenna, millimeter wave.**

I. Introduction

Many kinds of automotive radars have been developed in the millimeter-wave band [1], [2]. Microstrip antennas are superior candidates when radar sensors are used extensively in vehicles due to their advantages of low cost and low profile. On the other hand, feeding loss due to transmission loss of microstrip lines is a significant problem in array feeding. So, microstrip array antennas are suitable for relatively low gain applications. Microstrip comb-line antennas are more effective for relatively low loss compared to ordinary parallel feeding microstrip array antennas since feeding loss is smaller [3],[4]. In the conventional microstrip comb-line antennas, the radiating elements are shaped in rectangular. Coupling power (which is a ratio of radiating power divided by input power) is controlled by the width of the element. In the design of travelling-wave array antennas for required aperture distributions, the width of the element increases gradually toward the termination to control the coupling of the element. In the design of arrays whose number of elements is small, large coupling is required for each element, because radiation power assignment to each element is large. Consequently, cross polarization radiates significantly from wide radiating element. The upper limit of the coupling power from the wide radiating element is still low. As a previous work, radiating element with high coupling power was studied [5]. However, it needs severe tolerance of the chemical pattern etching. Therefore, we propose a novel and simple radiating element using impedance transform stub to achieve high coupling power.

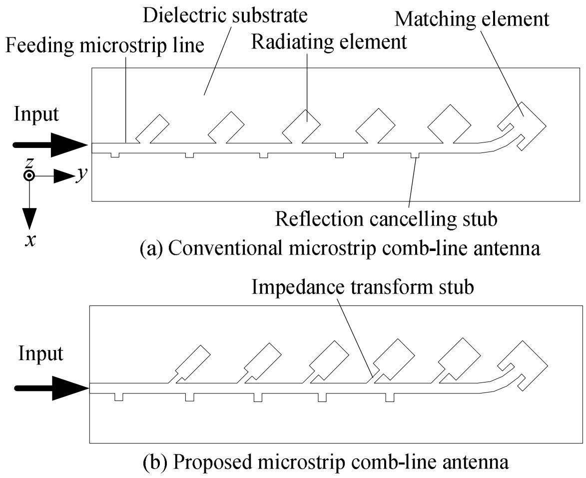

Fig. 1. Microstrip comb-line antenna.

6-elements microstrip comb-line antennas are designed with conventional radiating elements, and with our proposed high coupling radiating elements at 76.5 GHz. Simulated performances have been demonstrated.

II. Configuration

A microstrip comb-line antenna is composed of several rectangular radiating elements directly attached to a straight feeding microstrip line printed on a dielectric substrate with back ground plane, as shown in Fig. 1.(a). All the radiating elements are inclined 45 degree from the feeding line for the polarization requirement of the automotive radar systems. The element spacing is approximately one guided wavelength so that all the elements are excited in phase. The dielectric material of the substrate is PTFE (thickness=0.127 mm, relative dielectric constant εr = 2.2, and loss tangent $\tan\delta = 0.001$). The width of the feeding microstrip line Wf is 0.37 mm and the characteristic impedance is 50 Ω.

We propose a radiating element using impedance transform stub as shown in Fig. 1. (b). and Fig. 2. The radiating element is connected to the feeding line via the impedance transform stub (width Ws = 0.2 mm, length Ls = approximately ¼ guided wavelength) whose characteristic impedance is 72 Ω. The edge impedance of the radiating element becomes

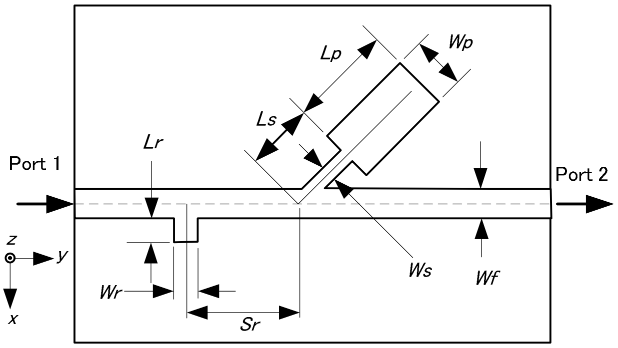

Fig. 2. Simulation model of high coupling element.

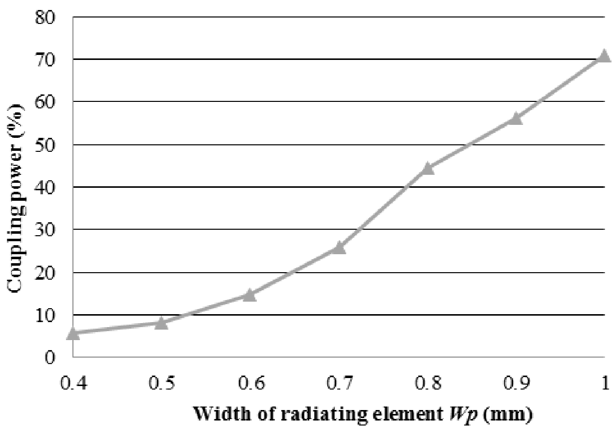

Fig. 3. Coupling powers in variation of *Wp*.

more low value and large coupling could be done.

Coupling power is calculated for each element width *Wp* from the scattering parameters S_{11} and S_{21} obtained by electromagnetic simulation of a single element, that is

$$C = (1 - |S_{11}|^2 - |S_{21}|^2) \times 100 \quad (1)$$

The coupling powers in variation of *Wp* are shown in Fig. 3. In this calculation, the coupling power is controlled from 6 % to 70 %.

III. Antenna Design

2 types of 6-elemets microstrip comb-line antennas were designed as shown in Fig. 1. (a). and Fig. 1. (b). in order to investigate the performance of the proposed high coupling radiating element. In array design, the target is a -20 dB Taylor distribution with $\bar{n} = 2$. Amplitudes of each radiating element and coupling powers of each element are shown in Table 1. Large coupling power is required for each element, because radiation power assignment to each element is large. In the design of conventional microstrip comb-line antenna, required radiation power assignment is not achieved due to the upper limit of the coupling power. However, in the design of our proposed microstrip comb-line antenna, necessary amplitude distribution is achieved. Simulated radiation patters are shown in Fig. 4.

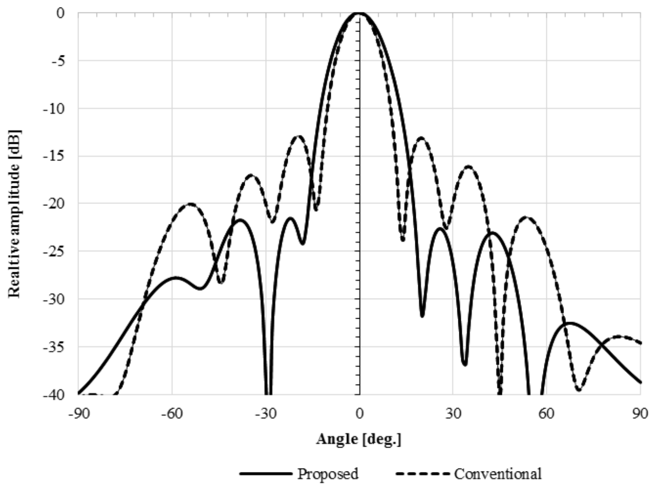

Fig. 4. Radiation pattern in the *yz*-plane of 6-elemets comb-line antennas at a frequency of 76.5 GHz.

TABLE I
Required Amplitude Distribution and Coupling Power.

Element No. from the Port 1	Amplitude	Coupling power (%)
1	0.5531	8
2	0.7766	17.2
3	1	34.4
4	1	52.4
5	0.7766	66.3
6	0.5531	100

IV. Conclusion

High coupling radiating elements for microstrip comb-line antenna were developed using impedance transform stub in the millimeter-wave band. The configuration of high coupling element was proposed in this paper. The low-sidelobe 6-elements comb-line antennas are demonstrated.

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