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Low-Sidelobe Design of Microstrip Comb-Line Antennas for Beam-Tilting in Perpendicular Plane to Feeding Line

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***Abstract* - We proposed a novel beam switching antenna system which is composed of multiple microstrip comb-line antennas with different beam directions in the perpendicular plane to the feeding line. We applied aperture Taylor distribution in perpendicular plane to the feeding line of microstrip comb-line antenna to reduce sidelobe level. All dimensions of radiating elements are optimized in this design. Sidelobe levels for various beam tilting angles are evaluated in this paper.**

***Index Terms* — microstrip antenna, array antenna, millimeter-wave, beam tilting, Taylor distribution**

I. INTRODUCTION

Various types of beam switching antennas have been developed in millimeter-wave band. Beam switching systems using multi-beam antennas can be obtained by using Butler Matrix, Blass circuit, dielectric lens or Rotman lens. However, the feeding circuit with complicated structure occupies large area in the system. Thus, we propose a quite simple beam switching antenna system which is composed of muliple microstrip comb-line antennas (MSCLAs) with different beam directions in the perpendicular plane to the feeding line. To establish the low-sidelobe design for beam-tilting, aperture Taylor distribution is applied to the comb-line antennas with beam tilting design in this paper. Beam scanning performances and sidelobe levels (SLLs) for various beam tilting angles are evaluated by electromagnetic simulation.

II. CONFIGURATION

Multiple microstrip comb-line antennas with different beam directions are arranged to cover the wide azimuth angle. Five-beam switching microstrip comb-line antenna is shown in Fig. 1. A MSCLA is composed of three lines of comb-line antennas and five MSCLAs with different beam directions are connected to an RF switch, which results in a kind of a simple beam scanning antenna. Five beams of MSCLAs are assigned to five directions with 25-degree intervals to cover ±50 degrees from the broadside. A MSCLA is composed of several rectangular radiating elements directly attached to a straight feeding microstrip line printed on a dielectric substrate (Teflon, thickness t = 0.127 mm, relative dielectric constant ε_r = 2.2 and loss tangent tan δ = 0.001) with a backed ground plane.

To suppress reflections from radiating elements, we have proposed rectangular slit structure shown in Fig. 2. The radiating elements are attached on the both sides of the feeding line, which forms interleave arrangement. Reflection characteristic of the array depends on synthesizing of reflections from all the elements. Radiations excited by the reflections affect radiation pattern significantly. Therefore, a slit is attached for each radiating element. Since reflections from radiating elements and from slits are canceled out of phase in each element, reflection characteristics are independent on any beam directions, consequently [1]. In the beam tilting for $-\theta$ direction, the slit locations on both sides of the feeding line for reflection cancelling interfere. Therefore, only one slit is located to suppress the reflection from two radiating elements on the both sides.

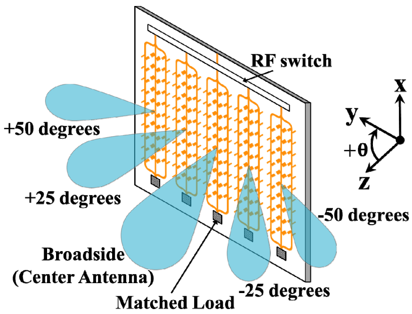

Fig. 1 : Five channel beam-swiching antenna using microstrip comb-line antennas

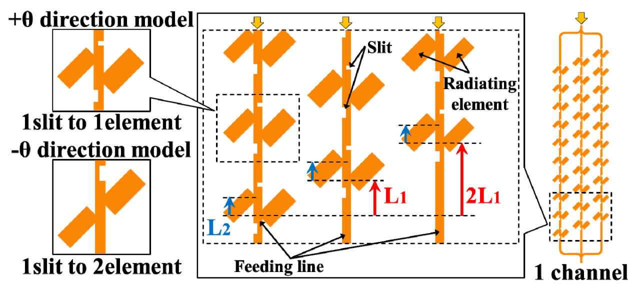

Fig. 2 : Beam tilting design of the microstrip comb-line antenna in perpendicular plane to feeding line

III. BEAM-TILTING AND LOW-SIDELOBE DESIGN

The radiating elements are attached on the both sides of the microstrip lines. Therefore, six elements are arranged in the perpendicular plane to three feeding lines. The beam directions are controlled by excitation phases of the six elements. To obtain the required phase of element excitation, the connection points of radiating elements on the microstrip line are designed [2]. Changing the connection point of the first element L1 and the element spacing L2 in the same feeding line, it is possible to provide independent phases not only to feeding lines but also to both sides on the feeding lines. Then, the radiation patterns formed by array factors of the two-element array connected to the same feeding line and three-element array of the three feeding lines. Thus, optimizing the excitation phases to shift the null, each antenna was designed for minimizing the peak levels of second and third sidelobes.

To reduce the first sidelobe level in the perpendicular plane to the feeding lines, we provided the different radiations from six non-uniform arranged elements for Taylor distribution as shown in Fig. 3. First, the powers to middle and both end lines are assigned by 45.4% and 27.3%, respectively. Then, in the middle feeding line, identical radiating elements are connected on the both sides. On the other hand, on the both end lines, different coupling amounts are provided to the elements connected to both sides of the same feeding line. On the both end lines, the width of the elements on both end lines is designed to obtain coupling amount of 44.6% for outer elements and 55.4% for inner elements. Consequently, the radiations from the elements are controlled to obtain Taylor distribution on the aperture.

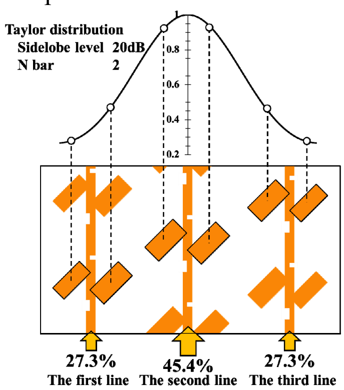

Fig.3 : Element design according to Taylor distribution

IV. ELECTROMAGNETIC SIMULATION

50 degrees beam tilting is challenging target of this design. Therefore, the antennas with different beams of 0, 30, 40, and 50 degrees are designed, and the performances are analyzed by electromagnetic simulation. The analysis model is shown in Fig. 4. Ten identical elements are connected to one side of the feeding line, thus totally twenty elements are connected alternately to both sides of one of the feeding lines. The simulated radiation patterns normalized by the peak levels of their peak levels are shown in Fig. 5. In tilting the main beam to the wide angle, the gain of the main lobe is reduced and the SLL is increased by the element radiation pattern. By minimizing the maximum second and third SLL, the first SLLs of the antenna with different beams of 30, 40, and 50 degrees is −14.0dB, −13.5dB, and −10.5dB, respectively. Concerning the antenna designed for 50 degrees, third SLL is −9.0dB and this is the maximum value. Similarly, controlling the position of the null, the first SLL of the antenna with different beams of −30, −40, and −50 degrees is −14.3dB, −13.1dB, and −8.6dB, respectively.

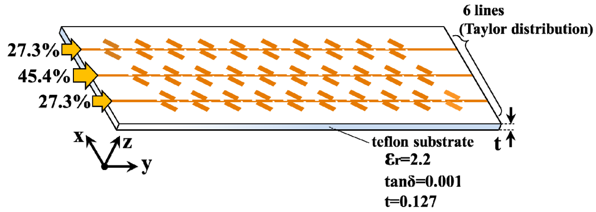

Fig. 4 : Analysis model

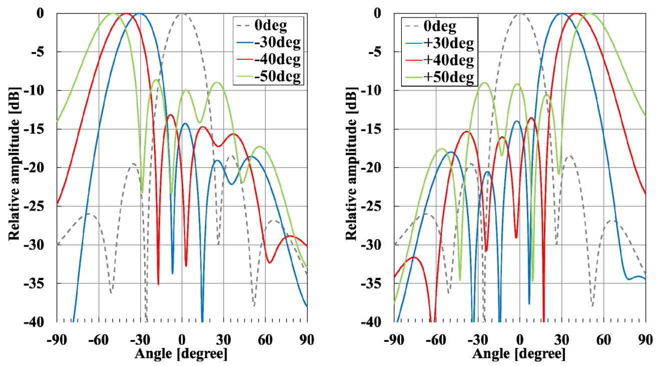

Fig. 5 : Simulated radiation patterns

V. CONCLUSION

Aperture Taylor distribution is applied to MSCLA in the perpendicular plane to the feeding line to reduce SLLs. Beam tilting design up to 50 degrees was achieved and sidelobe level was lower than −8.6dB. We confirmed the design feasibility of the antenna with 50 degrees beam tilting by the electromagnetic simulation.

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