1B3-5

Design of Microstrip Antennas fed by Four-Microstrip-port Waveguide Transition with Slot Radiators

#Daiki Kawase[1], Kunio Sakakibara[1], Kazuyuki Seo[2],
Nobuyoshi Kikuma[1] and ,Hiroshi Hirayama[1]
[1]Department of Computer Science and Engineering, Nagoya Institute of Technology
Gokiso-cho, Showa-ku, Nagoya, 466-8555, Japan
Email:sakaki@nitech.ac.jp
[2]Development 2nd Department, Nippon Pillar Packing Co., Ltd.
541-1, Aza-Uchiba Shimouchigami, Sanda, Hyogo, 532-0022, Japan
E-mail: kazuyuki.seo@pillar.co.jp

1. Introduction

Millimeter-wave antennas have been developed for various applications such as broadband highspeed wireless communication systems and automotive radar systems. Microstrip antennas are more advantageous than other millimeter-wave antennas at the viewpoints of low profile and low cost. On the other hand, feeding loss due to transmission loss of microstrip line is significant problem in array feeding. So, microstrip array antennas are suitable for relatively low gain applications such as a subarray of digital beam forming (DBF) systems. A comb-line feeding system is effective at the point of relatively low loss compared with other microstrip patch array antennas (MSA) fed by parallel or ordinary series feeding [1]. A travelling wave array antenna has a significant problem that gain is degraded due to beam shift in frequency changes when the array antenna is fed from one end of the feeding line. A center feeding microstrip comb-line antenna (MSCLA) is one of the solutions to reduce the gain degradation due to frequency change [2]. However, a blank area exists at the center above the microstrip-to-waveguide transition in the aperture radiation distribution, which causes elevation of sidelobe level (SLL). To fill the radiation source in the blank area, we designed four-microstrip-port waveguide transition with slot radiators. We proposed a center feeding 2 x 2 MSA and a 2-line 6-element MSCLA fed by the transition in this paper. We compared the simulated radiation patterns of the antennas fed by the transitions with slot radiators and without slot radiators in the computer analysis.

2. Microstrip antennas fed by proposed transition

To verify the effect of the four-microstrip-port waveguide transition with slot radiators in the center feeding microstrip antennas with different aperture size, a 2 x 2 MSA and a 2-line 6-element MSCLA are developed in this work. The proposed antennas are shown in Figs. 1(a) and (b). In the 2 x 2 MSA, a co-planer feeding microstrip patch antenna is connected to each port of the four-microstrip-port waveguide transition with slot radiators. The 2 x 2 MSA is designed for uniform aperture distribution. In the 2-line 6-element MSCLA, the 6-element comb-line antennas [3] are connected to four output ports of the transition. The 2-line 6-element MSCLA is designed for Taylor aperture distribution (SLL=-20dB). The coupling powers for the slots on the transition are designed to be 33.3 % and 12.8 %, respectively. The spacing between the transition and the antenna connected to each port is designed to excite the slot and the antennas in phase.

3. Four microstrip-port waveguide transition with slot radiators

A four microstrip-port waveguide transitions with slot radiators are designed for feeding circuit of the microstrip antennas. The configuration is shown in Fig. 2. A single layer dielectric substrate is attached to the waveguide open end (WR-12, 3.1mm x 1.55mm). Two microstrip lines are inserted into the waveguide short on the upper plane of the dielectric substrate from both broad walls. A matching patch is located in the aperture on the lower plane of the substrate. The electric field at the end of the waveguide excites the matching patch and couples to the microstrip lines. Consequently, the power transmits from the waveguide to the output microstrip lines. By connecting two branch microstrip lines to two output lines, four-port transition is realized. Arranging two slot radiators obliquely on the waveguide short, the transition possesses the radiation function of 45-degree polarization [4]. The coupling power of the slot radiators is controlled by the slot length Ls . The reflection and transmission characteristics, when the length Ls of slot is 1.2mm, are shown in Fig. 3. Reflection coefficient at the designed frequency of 76.5 GHz was -30dB. The control range of coupling power of the transition is shown in Fig. 4. When the slot length Ls is longer, coupling power is larger. The control range of coupling power by slot radiators is from 2.2 to 45.1 ％

4. Simulated performance

The 2 x 2 MSA and the 2-line 6-element MSCLA with the four-microstrip-port waveguide transition with slot radiators are evaluated by electromagnetic simulator of HFSS. We compared radiation patterns of antennas fed by the transition with slot radiators and without slot radiators. The required coupling power of slots in 2 x 2 MSA is 33.3 ％ to realize uniform aperture distribution, and that in 2-line 6-element MSCLA is 12.8 ％ for Taylor distribution (SLL=-20dB). The radiation patterns are shown in Fig. 5 and Fig. 6 respectively. The SLL without slot radiators is -2.65dB. The SLL is reduced to -10.6dB due to the slot radiators. On the other hand for MSCLA, the SLL -11.7dB without slot radiators is reduced to -19.7dB due to the slot radiators. The proposed antennas can be designed for sidelobe level to be lower than the antenna without slot radiators.

5. Conclusions

To fill in the blank area over the aperture of the center feeding MSCLA, the four-microstrip-port waveguide transition with slot radiators is proposed and is designed in the millimeter wave band. The control range of coupling power from the transition is from 2.2 ％ to 45.1 %. To verify the effect of the proposed transition with slot radiators in the center feeding microstrip antennas with different aperture size, the 2 x 2 MSA and the 2-line 6-element MSCLA are designed. Comparing the performance of the antennas with and without slot radiators, the effect of the transition with slots is confirmed.

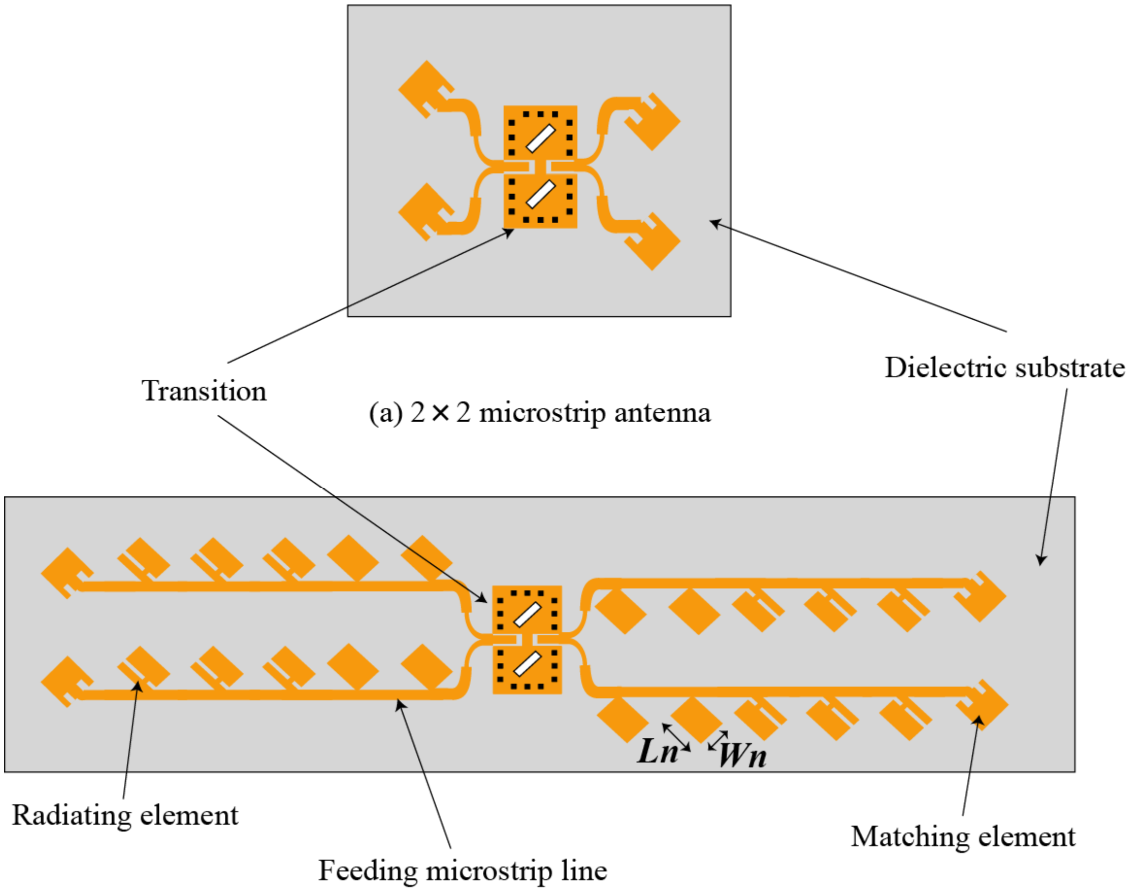
References

[1] J. R. James, and P. H. hall, "Handbook of Microstrip Antennas,"IEE ElectromagneticWaves Seriesvol.2, London, UK, Peter Peregrinus Ltd., 1989.

[2] A. Kunita, K. Sakakibara, and N. Kikuma, "Measured Performance of Center-fed Microstrip Comb-Line Antenna in Millimeter-Wave, "IEICE National Conference, September . 2009.

[3] K. Sakakibara, S. Sugawa, and N. Kikuma, "Millimeter-Wave Microstrip Array Antenna with Matching-Circuit-Integrated Radiating-Elements for Travelling-Wave Excitation, "2010 Proceeding of the Fourth Conference on Antenna and Propagation (EuCAP), pp. 1-5, April. 2010.

[4] K. Seo, K. Sakakibara, and N. Kikuma, "Transition from Waveguide to Two Microstrip Lines withSlot Radiators in the Millimeter-Wave Band, "IEICE Trans. on Commun., vol. E94-B, no. 5, pp.1184-1193, May. 2011.



(a) 2 × 2 microstrip antenna

(b) 2-line 6-element microstrip comb-line antenna

Figure1: Microstrip antennas fed by transition with slot radiators

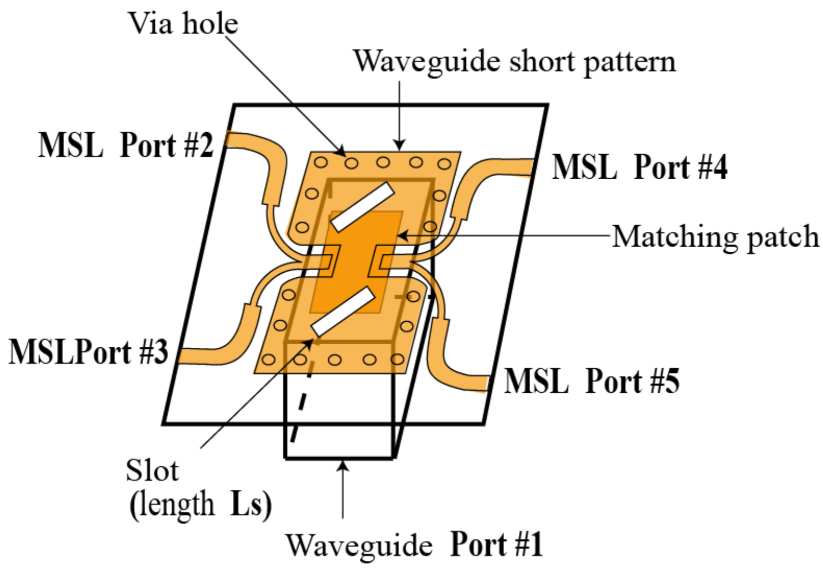


Figure2: Four-port waveguide-to-microstrip line (WG-MSL) transition with slot radiators

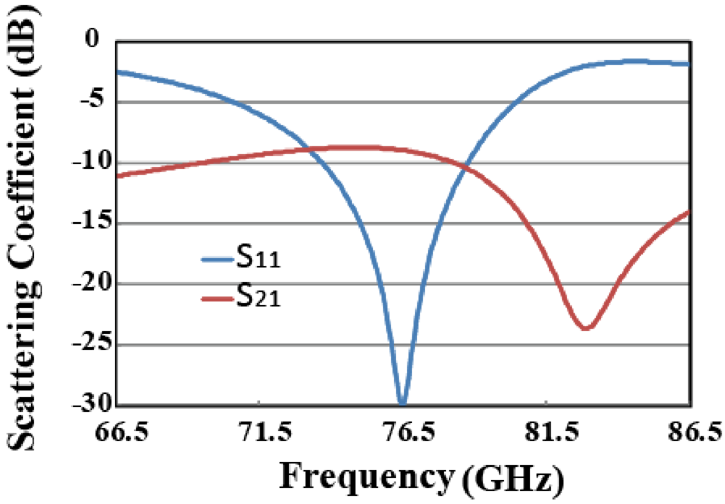


Figure3: The reflection and transmission characteristics (Ls=1.2mm)

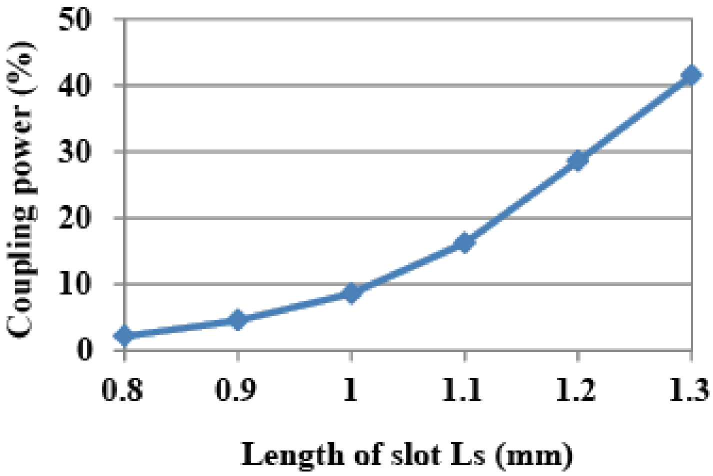


Figure4: Control range of coupling power for transition with slot radiators

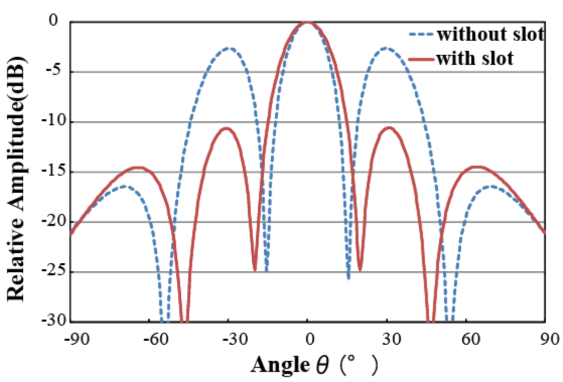


Figure5: Radiation patterns (2 x 2 antennas)

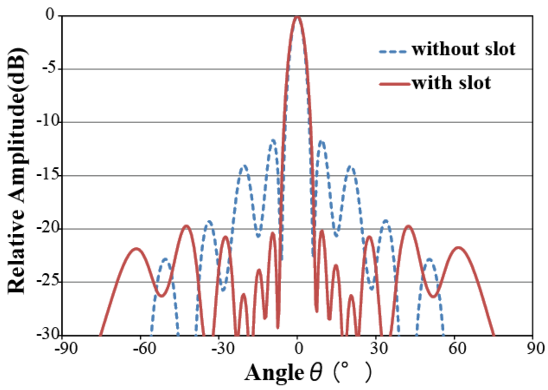


Figure6: Radiation patterns (2-line 6-element antennas)