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Design of Microstrip Patch Antenna using Endwall Coupling

Se-Hwan Choi, Jae-Young Lee, Jong-Kyu Kim and Jin-Sup Kim
Wireless Components and Telecommunication Research Center, Korea Electronics Technology Institute
68 Yatap-dong, Bundang-gu, Seongnam-Si, Gyeonggi-do, 463-816, Korea, shchoi@keti.re.kr

1. Intruduction

Millimeter-wave antennas are important for sensor system and low-cost communication. In recent years, planar antennas are widely used in the millimeter-wave range due to low cost and profile, simple and lightweight construction, ease of fabrication and reproducibility. While it is often desirable to select planar antennas and circuits, there are still many applications that need the waveguide circuitry because the waveguide bulkiness becomes less a factor and its losses are smaller than those of a microstrip line in millimeter-wave the range. So waveguide-to-microstrip transitions are needed to connect the waveguide and a microstrip line or antenna. Traditionally, waveguide-to-microstrip transitions use types of microstrip probes or fin-line transitions. Although these types have a wideband characteristic, they suffer from several disadvantages such as manufacturing complexity and large bulk. This paper presents a 2 by 2 array microstrip antenna using an aperture coupled waveguide. As a waveguide-to-microstrip transition, the waveguide endwall coupler is used [1] [2]. This technique is suited for low cost and mass production for commercial millimeter-wave applications. Moreover, this antenna configuration is applicable to other planar antennas.

2. Antenna Design

The basic structure of the antenna consists of a substrate and a waveguide. At the first time, we did design the 2 by 1 array antenna. Subsequently, we design the 2 by 2 array antenna. Fig. 1 shows the 2 by 1 array antenna structure and design parameter. Feeding waveguide uses the WR-42 (10.7mm * 4.3mm) standard waveguide. To resonate within useful frequency range of the waveguide, a resonant iris with the dumbbell shape is inserted. Patterns are fabricated on the *Taconic TLX-9* (ϵ_r = 2.5 and t = 31mil) substrate. Microstrip pattern is coupled with waveguide through a slot on the ground plane. The size of a metallic plate and a slot decides a degree of coupling. The next high impedance line has the length of $\lambda/2$ and this line plays an impedance transformer between a metallic plate and a patch [3].The length of $\lambda/2$ can keep in-phase of two patches.

A metallic plate is coupled simultaneously as the phase of a rectangular waveguides dominant mode (TE_{10}) changes. Seeing at the center of a metallic plate, both sides of a plate have a phase difference of 180 degree. This field excites two patches that are located symmetrically, finally it makes a 2 by 1 array antenna. Spurious radiation from the slot is not an issue because it should be co-polarized and combined with the radiation of the patch.

On the basis of the 2 by 1 array antenna, we design the 2 by 2 array antenna. The 2 by 2 array antenna has the same structure basically. It consists of two separate 2 by 1 array antenna. To feed two 2 by 1 array antenna, the size of the slot on the ground is increased. In the center of the slot, two metal lines are added to increase the efficiency of coupling. Fig. 2 shows the structure of 2 by 2 array antenna.

3. Simulation and Measurement

The antenna is simulated by a 3-dimensional full-wave electromagnetic simulator *Ansoft HFSS V9.1*. Fig. 3 shows the simulated return loss and radiation patterns. It has the bandwidth of 1.3 GHz and the gain of 13.4 dBi. Fig. 4 shows the electric field on the patches. In this figure, we can see that the phase of both patches is opposite and a 2 by 1 array antenna is composed. Fig. 5 is a picture of the manufactured patch and waveguide feeder. The antenna is completed by assembling of them.

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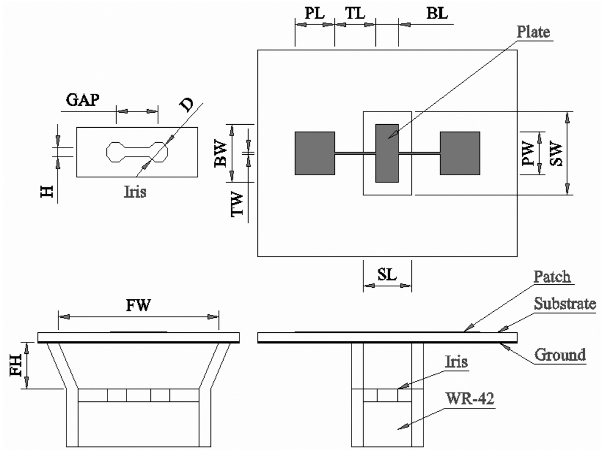

Figure 1: Antenna Structure and Design Parameter

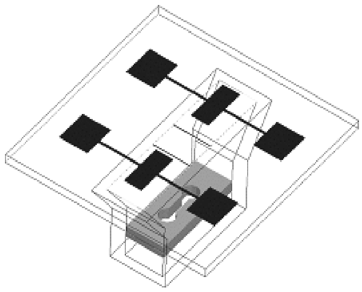

Figure 2: 2 by 2 Array Antenna

This antenna is analyzed by a network analyzer HP8510c and a measurement system. To measure the return loss of antenna, a coaxial-to-waveguide transition is used. Fig. 6 is the measured return loss and Fig. 7 is the measured radiation patterns. The antenna has the bandwidth of 1.3 GHz and the gain of 10 dBi. And Half-power beamwidth is 35° on the E-plane and 31° on the H-plane. Because center frequency is moved and radiation efficiency is decreased, the difference of the gain between simulation and measurement is occurred.

4. Conclusion

This paper describes the 2 by 2 array microstrip patch antenna using an aperture-coupled waveguide at 24.125 GHz. The antenna consists of a waveguide feed and four patches that are excited by the endwall coupler. The endwall coupler has narrower bandwidth than microstrip probes or fin-line transitions. But it shows excellent performance as a microstrip patch antenna feeder. Because this technique has simple structure and high tolerance, it is suited for low cost and mass production for commercial millimeter-wave applications. Besides, the n-by-n array antenna can be designed if needed.

References

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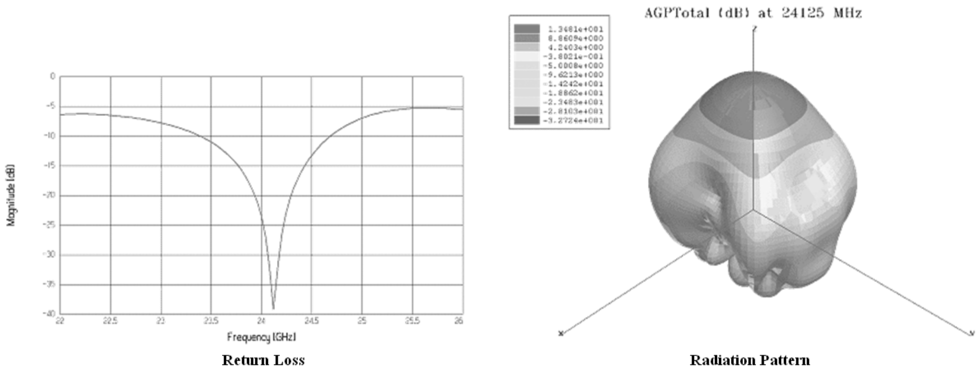

Figure 3: Simulation Results

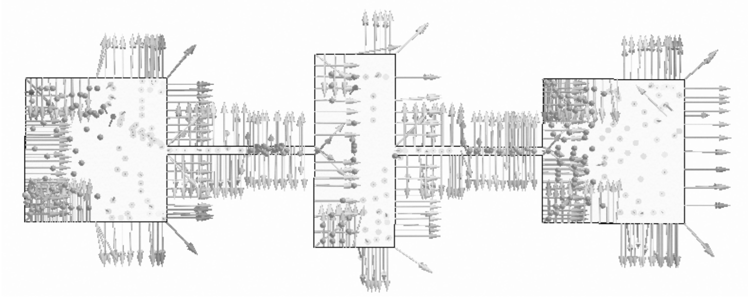

Figure 4: Electric Field on a Patch

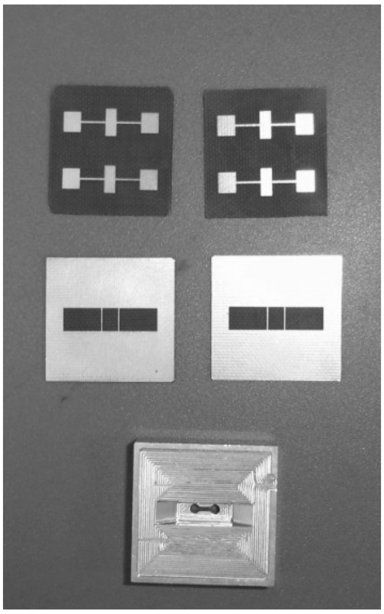

Figure 5: Manufactured Patch and Waveguide Feeder

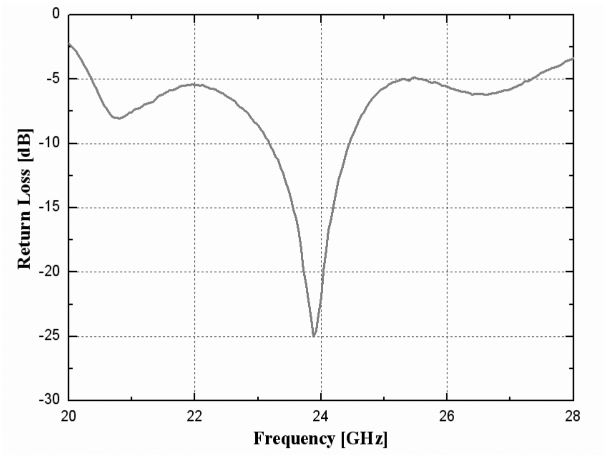

Figure 6: Measured Return Loss

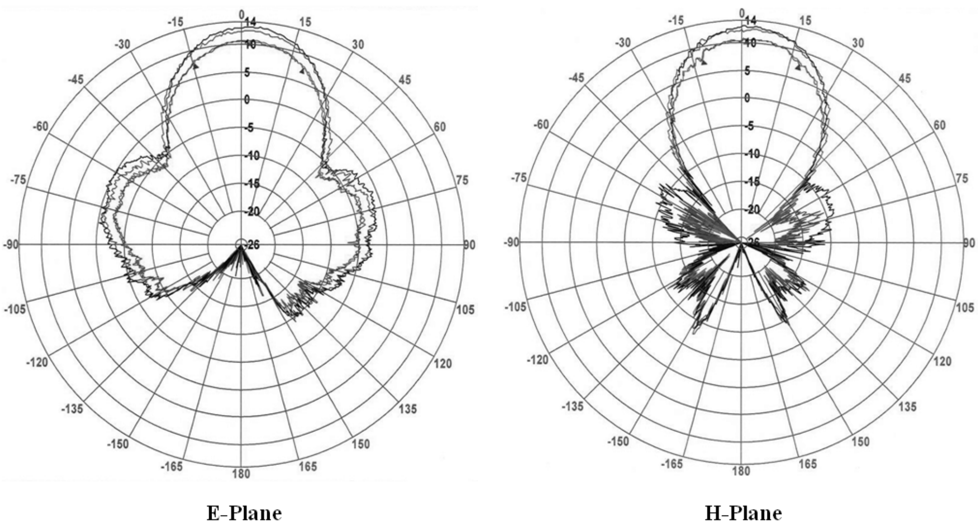

Figure 7: Radiation Patterns on the E-plane