POS1-56

Bandwidth Enhancement Technique for Stacked Patch Antennas Using Slot Couplings

#Takanori NORO [1, 2], Masaharu Takahashi [3], Koichi ITO [4]
[1] Graduate School of Science and Technology, Chiba University
1-33 Yayoicho Inage-ku Chiba-shi, 263-8522, Japan, noro.takanori@graduate.chiba-u.jp
[2] Communication Equipment Division, Japan radio Co., Ltd.
1-1 Shimorenjyaku 5 Chome Mitaka-shi, Tokyo, 181-8500, Japan
[3] Research Center for Frontier Medical Engineering, Chiba University
[4] Faculty of Engineering, Chiba University

1. Introduction

Microstrip patch antennas possess very attractive features such as simple structures, low profiles, light weights, low cost, and so on. A drawback of the conventional patch antenna is narrowband characteristics concerning impedance matching. To improve the narrowband characteristics, many works are available [1]-[4]. In reference [1], a dielectric substrate with low permittivity is used to reduce the Q factor. In reference [2],[3], an aperture coupling structure such as a non-resonant slot is employed to feed the patch antennas. In this configuration, a reflector behind the patch antenna is required to suppress the backward radiation. In reference [4], stacked patch antennas using parasitic elements are used to enhance the bandwidth. In this configuration, the bandwidth is controlled by the distance between a feeding patch and a parasitic patch. Therefore the height of the antenna increases as the bandwidth of the antenna increases.

In this paper, a bandwidth enhancement technique for the patch antenna is investigated that uses an equivalent network model. This equivalent network model is referred to that of a band-pass filter. Finally, a stacked patch antenna configuration with low profile and wideband characteristics is proposed based upon the investigated results of the equivalent network model.

2. Reference Stacked Patch Antenna

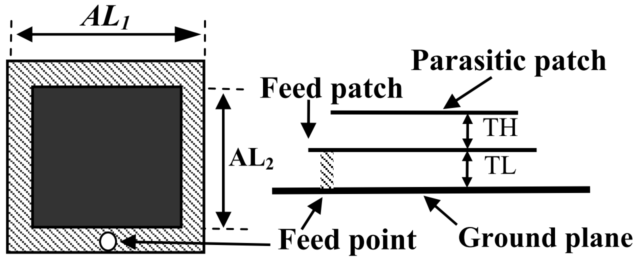
Figure 1 shows a conventional stacked patch antenna configuration that uses square shaped radiators. The stacked patch antennas are fed using metal probe. The probe is 4 mm in diameter. The method of moments is used to design the antennas. The operating frequency is 1.6 GHz. The distance TH between the excited patch and the parasitic patch is varied from 4 mm to 10 mm. The distance TL between the excited patch and ground plane is fixed at 8 mm. The length and width of the excited patch AL1 and those of the parasitic patch AL2 are also changed to adjust the operation frequency to approximately 1.6 GHz.

The simulated frequency responses of the return loss are shown in Fig. 2. The varied parameters are also depicted in the same figure. When the distance TH increases, the minimum return loss between two resonant frequencies decreases. The minimum return loss mainly determines the bandwidth of this kind of stacked patch antenna. Therefore, the bandwidth of the return loss is enhanced because the two resonant frequencies are close to each other.

3. Equivalent Network Model

The equivalent network model of these patch antennas is represented as shown in Fig. 3. In the equivalent network model, the configuration is slightly modified from the model described in reference [5]. The modified equivalent network model consists of one LC network, one transformer, two resonators, and one gyrator. The LC network and the transformer correspond to the feeding

ISBN: 978-4-88552-223-9 C3055©IEICE



(a) Top view (b) Side view

Figure 1: Conventional stacked patch antenna.
(TL=8mm, TH=6mm, AL_1=91mm, AL_2=81mm)

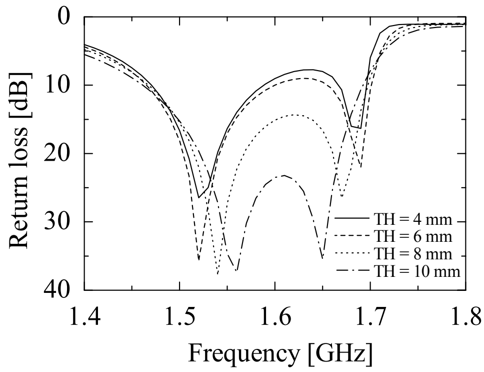


Figure 2: Return loss versus TH.

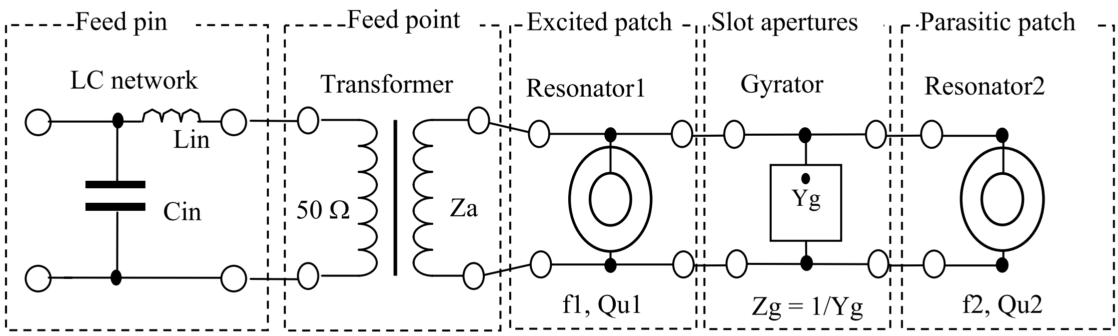


Figure 3: Equivalent network model of stacked patch antenna.
(Lin= 2.5nH, Cin=1.4pF, Za=7.5Ω, f1=1.585GHz, Qu1=14.7, f2=1.6GHz, Qu2=9, Zg=5.5Ω)

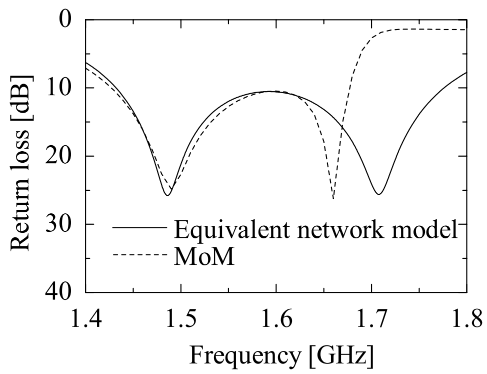


Figure 4: Comparison of return loss characteristics.

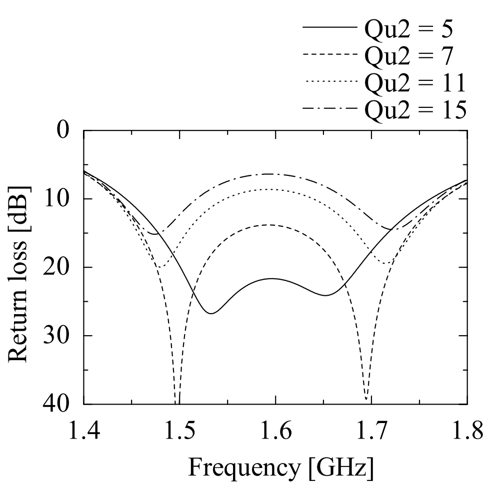


Figure 5: Return loss versus Qu2.

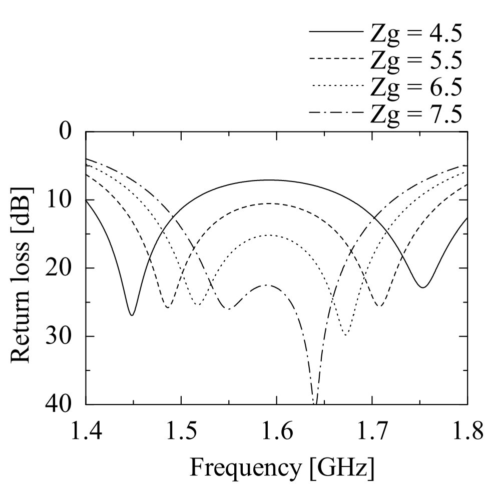


Figure 6: Return loss versus Zg.

structure of the patch antennas, the resonators correspond to the patch elements and the gyrator corresponds to the electromagnetic coupling between the feed patch and the parasitic patch. From the analogy of a band-pass filter, the following observations are made. Firstly, the transformer decides the impedance matching toward certain terminated impedance. Secondly, the resonator [6] has two parameters: resonant frequency f_o and unloaded Q. The resonant frequency f_o determines the operating frequency of the antenna. The unloaded Q determines the bandwidth of the antenna. In this model, the effect of the higher-order modes of the patch antenna is not considered. Lastly, the gyrator decides the bandwidth of the patch antenna because the inverse of the gyrator impedance is equivalent to the electromagnetic coupling coefficient.

To derive the parameters of equivalent network as shown in Fig.3, the calculated return loss of the equivalent network is compared with the simulated return loss by the method of moments. The initial value of the inductance Lin is calculated using the equation described in reference [7], the initial values of the resonant frequencies f1 and f2 are assumed to be the operating frequency, 1.6 GHz, and the initial value of the unloaded Q for the excited patch Qu1 and that for the parasitic patch Qu2 are calculated using the equation described in reference [8].

Figure 4 shows the calculated return loss characteristics of the equivalent network when the distance between the excited patch and the parasitic patch TH is assumed to be fixed at TH = 6 mm. The calculated return loss of the equivalent network agrees well with the simulated return loss by the method of moments although a different response between them is observed in the higher frequency region.

Figure 5 shows the calculated frequency response of the return loss when the unloaded Q of resonator 2 is varied from 5 to 15. When the Qu2 decreases, the return loss at the operating frequency, 1.6 GHz, increases. In general, the parameter Qu2 decreases when the distance between the patch element and the ground plane decreases. This trend agrees with the simulated results as shown in Fig.2.

Figure 6 shows the calculated frequency response of the return loss when the gyrator impedance Zg is varied from 4.5 to 7.5 Ω. When the Zg increases, the return loss at the operating frequency, 1.6GHz, also increases. This phenomenon corresponds to the fact that the coupling between the excited patch and the parasitic patch weakens and agrees with the simulated results as shown in Fig.2. Therefore, the parameter Zg is considered to be related to the electromagnetic coupling between the excited patch and the parasitic patche.

From these two figures, Fig.5 and Fig.6, it is found that to control the coupling between the patch antennas is effective to enhance the bandwidth of the patch antennas instead of increasing the height of the patch antennas.

4. Stacked Patch Antennas with Slot Apertures

The proposed antenna structure with low profile and wideband characteristics is illustrated in Figure 7. The proposed antennas are different from the conventional stacked patch antennas by the insertion of a slot plate between the excited and parasitic patch antennas. The slot plate has two slot apertures which are arranged along the x-axis. The slot apertures control the bandwidth of the stacked patch antenna to adjust the coupling between the excited and parasitic patch antennas.

The proposed antenna is designed at the operation frequency, 1.6 GHz using the method of moments. In our simulations, an infinite-sized ground plane is assumed. The feeding structure to the patch antennas is the same as that described in Sect.2.

Figure 8 shows the simulated frequency response of the return loss. In this case, the slot length Lsl and the slot width Wsl is adjusted so that the minimum return loss is greater than 14dB at the operation frequency. The bandwidth of the return loss greater than 14 dB is approximately 10 %. For comparison, the return loss characteristics of the conventional stacked patch antenna is shown. Total height of the conventional patch antenna is same as that of the proposed antenna.

Figure 9 shows the gain characteristics of the proposed antenna. A flat frequency response of the gain is obtained. The gain reduction in the higher frequency range is thought to be due to the effect of the parallel plate modes between the slot plate and the ground plane.

For example, the radiation pattern in the ZX plane is shown in Fig. 10. The radiation pattern is simulated at the operation frequency 1.6 GHz.

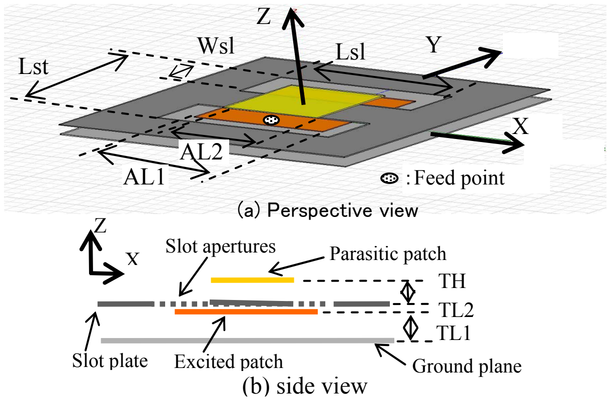


Figure 7: Geometry of proposed antenna.
(TL1=8mm, TL2=1mm, TH=5mm, Wsl=65mm)

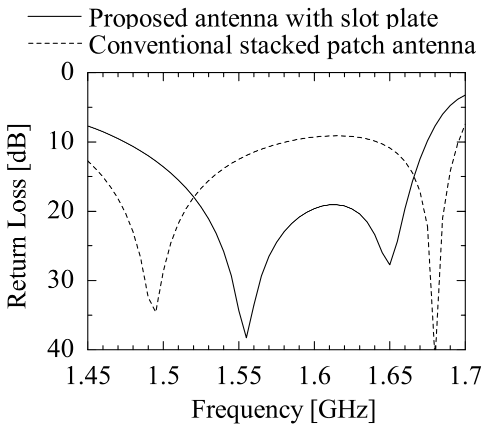


Figure 8: Return loss of proposed antenna.

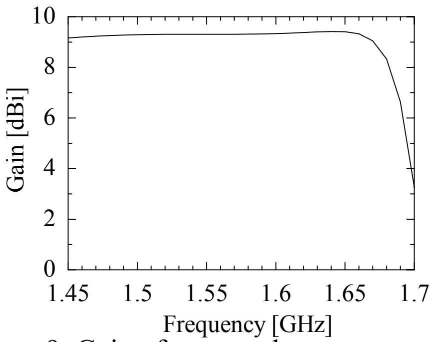


Figure 9: Gain of proposed antenna.

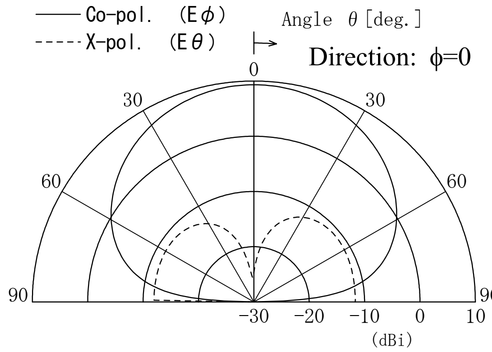


Figure 10: Example of Radiation pattern at operation frequency 1.6 GHz.

5. Conclusion

To realize the bandwidth enhancement, a stacked patch antenna inserted the slot plate between the excited patch and the parasitic patch is proposed. This antenna configuration is based upon the results of investigation using the equivalent network model of a stacked patch antenna. As a result, it is found that the proposed antenna configuration is effective for controlling the bandwidth of the stacked patch antenna.

References

[1] Y. Suzuki and T. Chiba, “Designing method of microstrip antenna considering the bandwidth,” IECE Trans. Japan, vol.E-67, pp.488-493, 1984.

[2] F. Croq and D.M. Pozar, “Millimeter-wave design of wideband aperture-couple stacked microstrip antennas,” IEEE Trans. Antennas and Propagat., vol.AP-39, No.12, pp.1770-1776, Dec. 1991.

[3] S. Mestdagh ,W.D. Raedt, and G.A.E Vandenbosch, “CPW-Fed Stacked Microstrip antennas,” IEEE Trans. Antennas and Propagat., vol.AP-52, No. 1, pp. 74-83, Jan. 2004.

[4] S.A. Long and M.D. Waltman, “A dual-frequency stacked circular disk antenna,” IEEE Trans. Antennas and Propagat., vol.AP-27, No. 2, pp. 270-273, Mar. 1979.

[5] G.L. Matthaei, L. Yound, and E.M. Jones, *BMicrowave Filters, Impedance Matching Networks and Coupling Structures*, Mc Graw Hill, NY, 1964.

[6] H.S. Pues and A.R. Van De Capelle, “An Impedance-Matching Technique for Increasing the Bandwidth of Microstrip Antennas,” IEEE Trans. Antennas and Propagat., vol.AP-37, No. 11, pp. 1345-1354, Mar. 1989.

[7] B.C. Wadell, *Transmission Line Design Handbook*, Artech house, Boston, pp.382-383, 1991.

[8] J.R. James, P.S. Hall and C. Wood, Microstrip Antenna *Theory and design*, Peter Peregrinus, Stevenage, UK, and NY, 1981.