Proceedings of ISAP'04, Sendai, JAPAN

Microstrip Patch Antenna with Variable Bandwidth

Kazuhiro Kitatani and Yasuyuki Okamura
Graduate School of Engineering Science, Osaka University
1-3 Machikaneyama-cho, Toyonaka, Osaka 560-8531, Japan
E-mail address: kitatani@ec.ee.es.osaka-u.ac.jp

1. Introduction

A microstrip antenna with compactness and lightness is used in various radio communication systems such as satellite broadcasting and LAN and is compatible with mobile communications like an airplane, a car and a cellular phone, etc. A service of radio communications systems will become increasingly prominent in a microwave and millimeter wave band region. A variety of these usages require sophisticated antennas which operate at different frequencies and any polarization, and scan a beam. Recently, antennas based on a MEMS (Microelectromechanical-Systems) technology have been focused attention because they are excellent in loss, cost and power consumption compared with those made of semiconductor. So far a filter, a switch, and a phase shifter using the MEMS technology are reported in both microwave and millimeter wave regions[1]. Beam scanning dipole and patch antennas have been demonstrated by use of a piezoelectric actuator[2] and a magnet circuit[3], respectively. Moreover, a multi-band antenna[4] combined with a MEMS switch, and many other antennas using the MEMS technology are reported.

We have been developing a variable frequency antenna so far using a mechatronics technology. So far two types of such antennas have been reported. One is a patch antenna in a gap of which a dielectric material is inserted and demonstrates variability of frequency[5]. The other is a patch antenna whose feeder is directly connected by a coaxial line through the substrate, which enables to change a gap separation between a patch portion and a ground plane[6], [7]. In these types of antennas two parameters can be varied: a frequency and a polarization. Moreover, a bandwidth is also variable. We propose here a new functional antenna whose operating frequency and bandwidth are controllable by use of two mechanical mechanisms previous mentioned. This paper describes an antenna with a variable bandwidth while keeping an operating frequency constant. We have demonstrated its operation at the X band. The bandwidth of the tested antenna changed from 2% to 10%. The experimental results on the impedance characteristics and the radiation pattern characteristics are also shown.

2. Operation and structure of an antenna

Figure 1 shows a schematic configuration of the proposed antenna. This antenna consists of a movable rectangular patch portion formed on the one side of the copper tension printed circuit board, a ground plane and a coaxial connector, in which a signal is fed by a coaxial connector through a substrate and an air gap. This structure enables to rotate the patch portion as well. The rectangular patch antenna with length L and width W is printed on a dielectric substrate ($\varepsilon_r = 2.2$). Thickness t of the dielectric substrate is 0.4mm. A coaxial connecter (1.25mm in diameter) in the center of which a hole (0.8mm in diameter and 5mm in depth) is drilled is attached to the ground plane. The copper wire fixed to the feeding point of the rectangle patch antenna, the diameter of which is slightly smaller (0.78mm in diameter) than that of the hole in the center conductor, is inserted into the hole. Thus, the dielectric substrate with the patch is movable; that is, an antenna height between the patch and ground planes h is variable. In order to change the antenna height, an air layer region is set up between the patch antenna plane and the ground plane. The dielectric material which is movable in the air layer is loaded. Used dielectric materials are SV430 ($\varepsilon_r = 43$,Q>4400 at 10GHz: made by KYOCERA.) with a width of 10mm, and heights of 0.5mm (a length of 3mm) and 0.75mm (a length of 3mm). We changed the antenna height in incremental steps by loading a different thick dielectric spacer in order to confirm its basic operation. The insertion of the dielectric material was carried out manually.

ISBN: 4-88552-207-2 C3055

Here we briefly explain the operation of the proposed antenna. First, when the antenna height h is increased according to the air gap between the dielectric substrate and the ground plane, its resonance frequency increases and the bandwidth of the antenna becomes broader. On the other hand, the resonance frequency of the antenna decreases by loading dielectric material in the air gap. By combing these two mechanisms, we can bring the variable bandwidth while keeping the operating frequency constant to pass. Moreover, the reversed operation is attainable: changing the variable operating frequency while keeping the bandwidth constant.

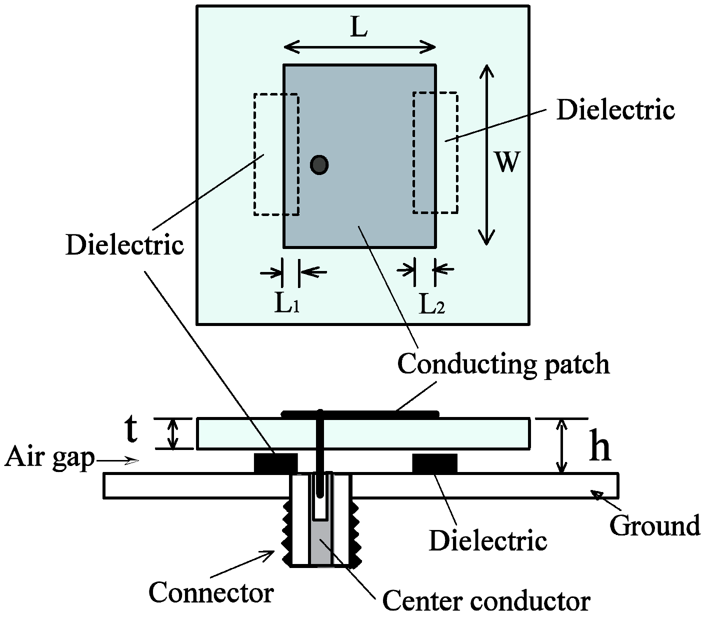

Fig.1. Structure of the proposed antenna.

3. Experiment results

A return loss of the tested antenna was measured by using a conventional network-analyzer (HP8510C). A measured frequency range was 8-12GHz. The measured results for the antenna heights ranging from 0.4 to 1.6mm are plotted in Fig.2. In this case, a dielectric material was not loaded in the tested antenna. A resonant frequency was increased from 9.94GHz to 11.18GHz when an antenna height was increased from 0.4 mm to 1.0 mm. However, when the antenna height was over 1.0 mm, the resonant frequency was decreased from 11.18GHz to 11.01GHz in connection with the increase of the return loss. Here, the bandwidth became wider as increasing the antenna height.

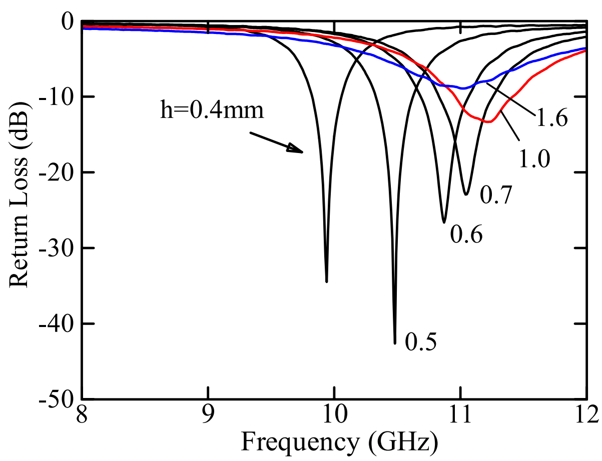

Fig.2. Return loss of the microstrip patch antenna for different antenna heights

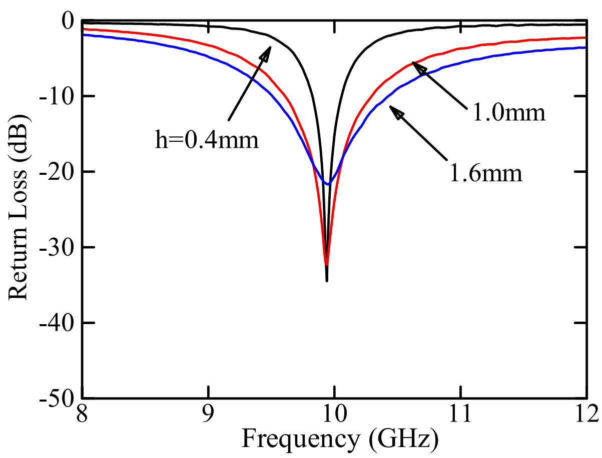

Fig.3. Return loss of the tested antenna at 9.94GHz

Next, a dielectric material was inserted in an air gap region. The antenna height was moved from 1.0mm to 1.6mm and the dielectric was loaded in the location where the antenna adjusted to operate at the fixed frequency each by changing the height h. The measured result is plotted in Fig.3. The operating frequency was 9.94GHz identical with when the height was 0.4mm. The result shows that the operating frequency of the tested antenna was adjusted well. The dielectric material was inserted from each open ends of the patch antenna. The thickness of the dielectric material mainly used was 0.5mm. L1 was constantly 1.4mm. L2 were -0.1mm, 1.6mm and 1.7mm for h = 1.0mm, h = 1.2mm and h = 1.4mm, respectively. In the case of h= 1.6mm, L2 was 1.5mm and the dielectric material used was the thickness of 0.75mm. The return loss was as good as -20dB or less. Relation between the bandwidth of VSWR=2 and the normalized antenna height is shown in Fig. 4. When increasing the antenna height, the bandwidth raised from 2% to 10%. The result shows that the bandwidth of the antenna is controllable.

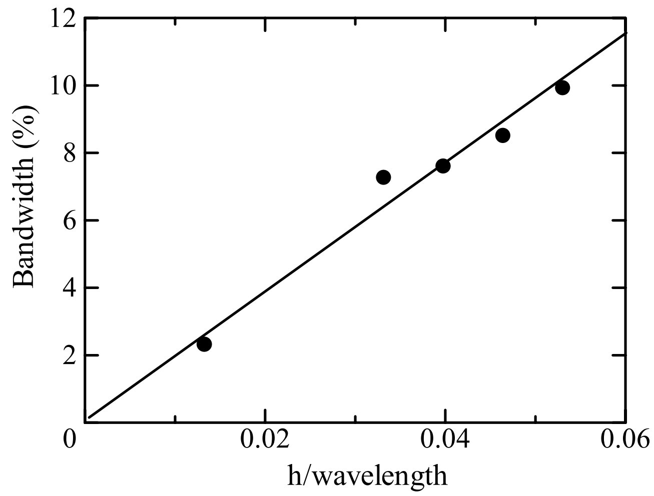

Fig.4. Bandwidth vs. antenna height.

The radiation pattern of the tested antenna is shown in Fig. 5. The left-hand side of the figure is shown the pattern of the cross polarization of the E-plane and the E-plane for the antenna heights of 1mm and 1.6mm. As the comparison the result for the antenna without loading the dielectric material is also shown, which indicates symmetrical characteristic. The antenna pattern is asymmetrical for the dielectric loaded antenna. Those antenna patterns show wavy variation for the influence of the end of the ground plane. The cross polarization ingredient of the E-plane was -23dB or less. The right-hand side of Fig.5 is the pattern for the cross polarization of the H-plane and the H-plane.

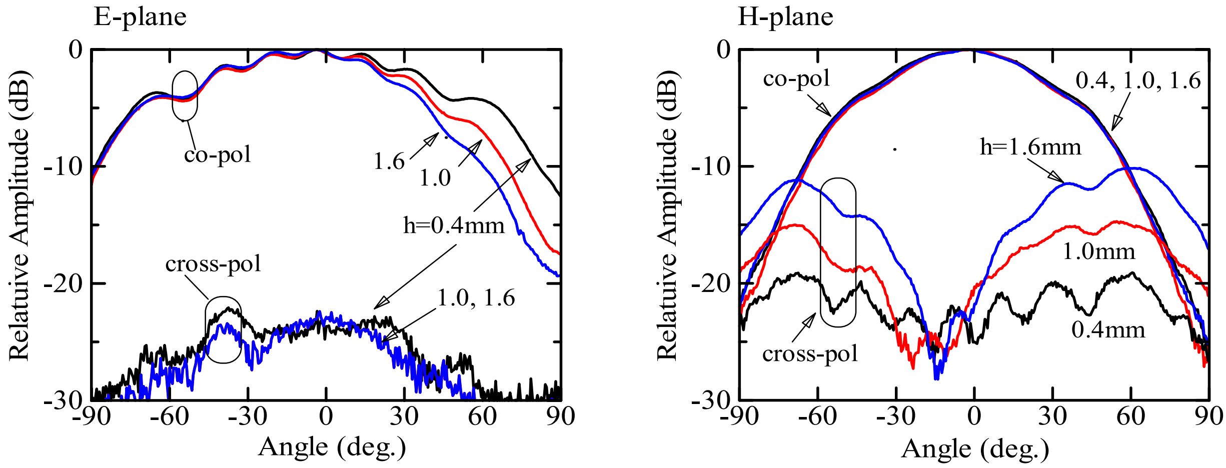

Fig.5. Radiation pattern of the tested antenna.

The antenna pattern of the H-plane is symmetrical for all antenna heights. On the other hand, the crossing polarization ingredient of the E-plane shows a large change by varying the antenna height. Separation between the crossed polarizations at the direction of the front is as good as -20dB. However, the magnitude of the radiation for the crossing polarization ingredients at the directions of near ±60 degrees were increasing as raising the height: –19.1dB, –14.7dB and –10.2dB for the heights of 0.4mm, 1.0mm and 1.6mm, respectively. The measured absolute gains at the front direction were 7.6dBi, 7.5dBi and 7.8dBi for the heights of 0.4mm, 1.0mm and 1.6mm, respectively.

4. Conclusion

We have demonstrated the microstrip patch antenna whose bandwidth is controllable while keeping its operating frequency constant. The antenna has been fabricated using a mechatronics technology and is designed by use of the contrary mechanisms when changing the antenna height and inserting the dielectric material in the air gap region under the substrate supporting the patch portion. The tested antenna showed the proposed operation: the bandwidth was changed from 2% to 10% while maintaining the operating frequency. We are planning to develop more sophisticated antennas using the mechatronics technology.

Acknowledgements

We would like to thank Emeritus Prof. S.Yamamoto, Drs. H.Murata, H.Shiomi, Y.Sakaguchi, and S.Nishimura for their constant encouragement. Furthermore, we are thankful to the Osaka University central workshop.

References

[1] Vijay K Varadan. K. J. Vinoy and K. A. Jose "RF MEMS and Their Applications," John Wiley & Sons, Inc. 2003.

[2]J.C.Chiao, Y.Fu, I.M.Chio, M.Delisio,and L-Y.Lin, "MEMS Reconfigurable Vee Antenna", IEEE MTT-S International Microwave Symposium, pp. 1515-1518, June 1999.

[3]C.W.Back, S.Song, J-H. Park, S.Lee, J.M. Kim, W.Choi, C.Cheon, Y.K. Kim, and Y.Kwon, "A V-Band Micromachined 2-D Beam-Steering Antenna Driven by Magnetic Force with Polymer-Based Hinges", IEEE Trans. on Microwave Theory Tech., vol51, no1, pp. 325-331, January 2003.

[4]W.H.Weedon, W.J.Payne, and G.M.Rebeiz, "MEMS-Switched Reconfigurable Antennas", IEEE Antenna and propagation International Symposium, (Boston,MA), July 8-13,2001.

[5]K.Kitatani, H.Kani, S.Yamamoto, "Tunable Microstrip Patch Antenna using Partially Loaded dielectric,"2002 Asia Pacific Microwave Conference., vol.2, TH2D-1,pp817-820, Kyoto, Japan, November 2002

[6]K.Kitatani, S.Yamamoto, "Coaxial Feed Type Microstrip Patch Antenna with Variable Antenn Height", J. IEICE Vol. J86-B, No.4, pp.671-676, April 2003. (in Japanese)

[7]K.Kitatani, Y.Sakaguchi, Y.Okamura, S.Yamamoto, "Microstrip Patch Antenna with Variable Height Adjustment,"2003 Asia Pacific Microwave Conference., vol.2, TEP-10, pp1172-1174, Seoul, Korea, November 2003.