Novel Antenna Feeder with Cylindrical Magneto-Material for Antenna Miniaturization

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1. Introduction

With the advance of wireless communication systems and the appearance of various wireless applications in recent years, the broadband antenna with small size is strongly demanded [1]. The service channels of handy terminal are going to extend toward low frequency band such as the FM radio band (88 MHz ~ 108 MHz) and the terrestrial digital multimedia broadcasting band (174.512 MHz ~ 215.504 MHz). Since it has long wavelength to compare handy terminal size, it is physically difficult to miniaturize the antenna size. In order to solve the above problems, the researches of the miniaturized antenna operated at low frequency have been widely studied. There are some representative examples for antenna miniaturization by special materials such as meta-material substrate [2][3] and Magneto-Dielectric Material (MDM) [4]-[6]. According to the work of R. C. Hansen and M. Burke, it has been proposed the basic concept of antenna operated at low frequency band by application of the magneto-dielectric material as substrate of plate antenna[4][5]. For antenna miniaturization, the research on artificial magneto-dielectric loading for improving the impedance bandwidth properties of microstrip antennas has been proposed by Sergei A. Tretyakov team [6]. However, it was appeared the decrease of bandwidth, gain and efficiency at above research even though it had been used for the ideal MDM without tangential loss. It is natural phenomena that the MDM antenna has narrow bandwidth and low gain because of high permeability and high permittivity even the antenna size can reduce physically. In order to solve the problem of narrow bandwidth and low gain of the MDM antenna, this paper presents novel antenna feeder with a cylindrical magneto-material (CMM) for antenna miniaturization. Antenna feeder is closed by the CMM assumed the ideal material with tangential lossless. A role of the CMM is to generate a strong current induced by the electro-magnetic field around the feeding metal pin. The generated current is transmitted to antenna radiator.

2. Single CMM design

Fig. 1 shows a reference antenna structure to compare with design for feeder closed by the CMM. Block part in Fig. 1 is basically filled by air [7]. The antenna size, the resonant frequency, the maximum directivity gain and the bandwidth of the reference antenna as shown in Fig. 1 are 205 × 90 × 26.6 mm, 0.92 GHz, about -6.69 dB and 0.32 GHz (0.72 ~ 1.04 GHz) at - 10 dB below, respectively.

Fig. 2 shows return loss with respect to the various values of relative permeability and permittivity when block part is filled with dielectric material and magnetic material substrate. Tangential loss equals to zero in theoretical design. When values of ε_r and μ_r increase, the resonance frequency is moved toward low frequency because the effective permittivity and permeability are in inverse proportion to frequency. This phenomenon of Fig. 2 appears the similar result in the references [4]-[6]. Other reason is due to reflection at boundary surface that the antenna radiator is directly located on loss materials substrate.

Fig. 3 shows gain variations as functions of both relative permittivity and relative permeability of block part in Fig. 1. Gain sensitivity of relative permittivity is higher than that of relative permeability calculated at the same frequency. It means that the electric current is more sensitive at antenna on dielectric substrate than that on magnetic substrate. In other words, the dielectric material has high frequency dependence in comparison with the magnetic material. Moreover, when either relative permittivity or relative permeability is increasing to values at same frequency, antenna gain is decreased due to extension of the guided wavelength in material.

Fig. 4 (a) shows feeding line structure sealed by the CMM and the block part in Fig. 1 is filled with air ($\varepsilon_r = \mu_r = 1$). The parameters of t_1 and r_1 are thickness of magnetic material and distance between the surface of feeding line and inner surface of the CMM, respectively. Fig. 4 (b) shows the calculated return loss as functions of t_1 and r_1, when μ_r equals to 10 and tangential loss is assumed zero. The calculated return loss of antenna with the CMM feeding line structure shows the results shifted to low frequency in comparison with one of antenna without the CMM. Even the values of t1 and r1 change; the resonant frequency shifted to low frequency is not almost changed. Therefore, the resonant frequency depends on the relative permeability of magnetic material. In comparison with the calculated return loss result between Fig. 2 (b) and Fig. 4 (b), when μ_r equals to 10, the resonant frequency of antenna with a single CMM feeding structure of Fig. 4 (a) is shifted to low frequency. This means that the CMM feeding structure is more suitable than antenna with magnetic material structure used as substrate of block part as mentioned in Fig. 1 (a) for antenna miniaturization.

3. Dual CMM design

Fig. 5 shows the structure of dual CMM feeding line for improving of bandwidth as shown in Fig. 4(a). The dual CMM feeder structure can realize broad bandwidth rather than single CMM feeder structure, because the spin effects of magnetic material increase. The parameters of t_2 and r_2 are thickness of the second CMM and distance between the surface of feeding pin and inner surface of the second CMM, respectively.

Fig. 6 shows the calculated return loss and gain directivity pattern of antenna with dual CMM feeding structure. The parameter values of t_1, r_1 and t_2 are given. Dual resonant frequencies are appeared by the dual CMM structure. Broad bandwidth and high gain are realized as shown in Fig. 6. Especially, the resonant frequency is shifted to low frequency and the bandwidth is 0.04 GHz ~ 0.75 GHz at -10 dB below. It is considered that the electric current excited by feeding pin generates the magnetic field by Ampere's law. This magnetic field reacts to the first CMM and the strong magnetic spin effects occur. In turn, the magnetic current generated at the first CMM by Faraday's law produces the electric field rotation in the sealed second CMM. Therefore, the strong current of feeder will be transmitted and the antenna gain will increase progressively.

Fig. 7 shows the calculated gain variation of the proposed antenna feeder structure with and without the CMM. Antenna gain is increased by insertion of the CMM. Antenna gain with dual CMM is higher than that with single CMM. It is considered that stronger current on feeding line is induced by the dual sealed CMM even it depends on the parameter of r_2 sensitively.

4. Summary

This paper presents novel patch antenna feeder structure with dual cylindrical Magneto-Material for Antenna Miniaturization and broad bandwidth. Dual CMM feeding structure has dual resonant frequency and frequency is moved to low frequency direction. It means that antenna can be minimized by control of relative permeability as well as the parameters between feeding line and magnetic material. This is mainly because of the high concentration of electric and/or magnetic fields within a small volume of antenna feeding structure due to small size, in addition to a loss material as only magnetic material. This result gives very attractive information that antenna size and bandwidth can be controlled by only magnetic material use. It is expected that the proposed method of this paper can be applied for any other antenna feeding structures.

Acknowledgments

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References

[1] Jingjing Huang, Fuqi Shan, Jingzhao She and Zhenghe Feng, “A novel small Fractal Patch antenna”, Asia-Pacific Conference Proceeding, , Vol. 4, pp. 4-7, 2005

[2] Mishra D, Arun Kumar G, Poddar D. R and Mishra R. K, “ Simulated resonant characteristics of embedded metamaterial patch antenna”, Applied Electromagnetics Conference, pp. 1-3, Dec. 2007.

[3] Kyung Duk Jang, Jae Hee Kim, Dong Hyun Lee, Gi Ho Kim, Won Mo Seong and Wee Sang Park, ”A small CRLH-TL metamaterial antenna with a Magneto-dielectric material”, Antenna and propagation society international symposium, Vol. 5, pp. 1-4, July 2008.

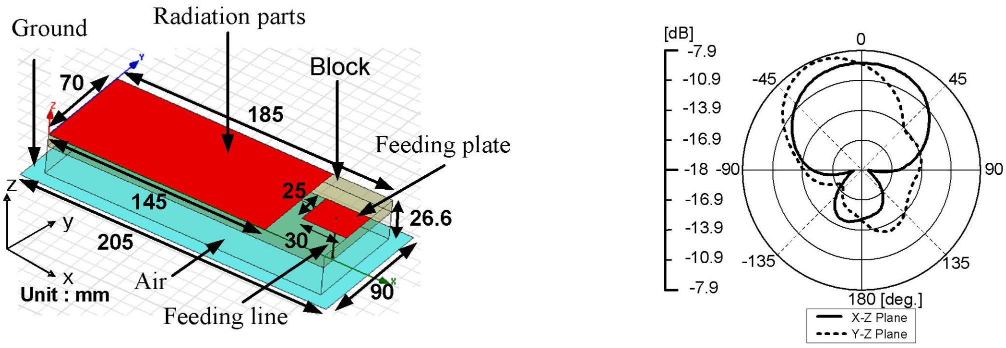
[4] R. Hansen and M. Burke, “Antennas with magneto-dielectric materials in electro-magnetos: Concept and applications”, IEEE Transactions on antenna and propagation, Vol. 52, pp. 1558-1576, Jun. 2004.

[5] R. C. Hansen and M. Burke. “Antenna with magneto-dielectrics,” Microwave Opt. Technol. Lett., Vol. 26. no.2, pp. 75-78, 2000.

[6] Pekka M. T. Ikonen, Stanislav I. Maslovski, Constantin R. Simovski and Sergei A. Tretyakov, “On artificial magnetodielectric loading for improving the impedance bandwidth properties of microstrip antennas”, IEEE transactions on antennas and propagation, Vol. 54, pp. 1654-1662, June. 2006.

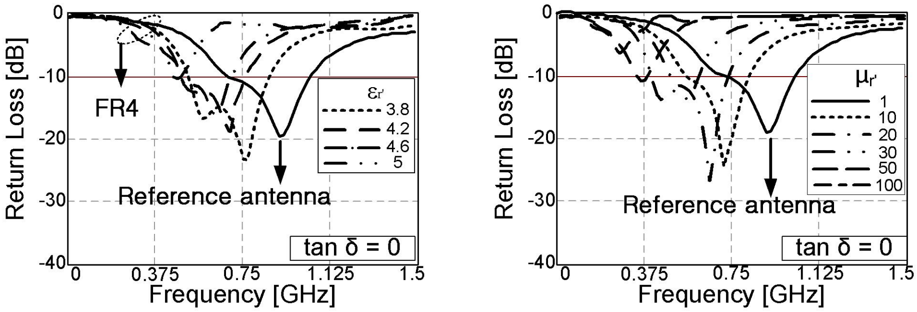
[7] Kyeong-Sik Min and Dong-Jin Kim, “4-channel patch array antennas for home network system”, The Korea Electromagnetic Engineering society, Vol. 5, pp. 122-125, Sep. 2005.

Figures



(a) Reference antenna structure (b) Gain directivity pattern at 920 MHz

Fig. 1 Structure and gain directivity pattern of a reference antenna.



(a) Dielectric material (b) Magnetic material

Fig. 2 Return loss of εr and μr.

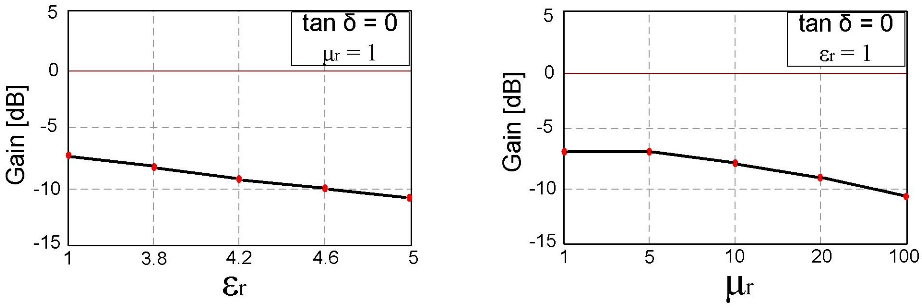
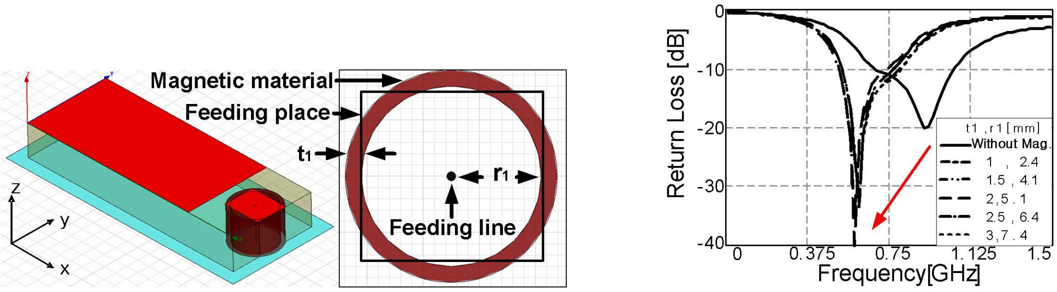


Fig. 3 Gain variations of εr and μr at 920 MHz.



(a) Feeder structure sealed by the CMM (b) The calculated return loss

Fig. 4 Structure of a cylindrical magnetic material and return loss.

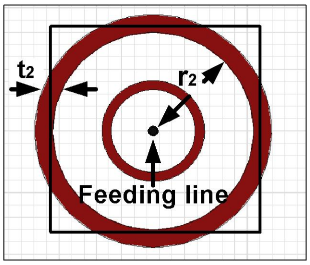
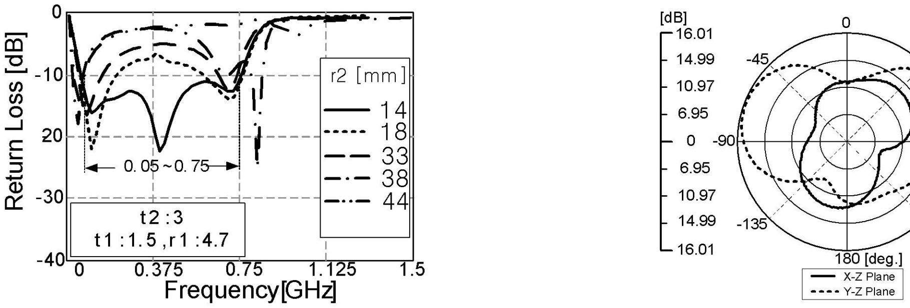


Fig. 5 Structure of dual CMM feeding line.



(a) Calculated return loss (b) Gain directivity pattern at 400 MHz

Fig. 6 Return loss and gain directivity pattern of antenna with dual CMM feeding structure.

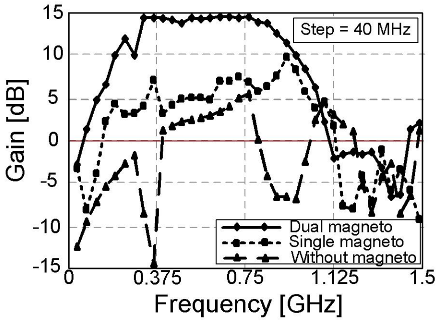


Fig. 7 The calculated gain variation.