A Design of a Meander Antenna using Magneto-dielectric Material for 433.92 MHz band

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433.92 MHz대 Magneto-dielectric 매질을 이용한 미앤더 안테나의 설계

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Abstract

The paper describes a meander antenna using magneto-dielectric composite for 433.92 MHz band. The antenna with magneto-dielectric material in this paper is suggested for miniaturization of antenna size. The return loss of meander antenna is achieved by optimizing the permittivity, ϵ_r=1.71-j0.004 and permeability, μ_r=2.39+j2.58. Over all dimension of the antenna is 51 × 11 × 1.6 mm. The return loss and gain are -41 dB, -5dBi, respectively at 433.92 MHz.

Key words : magneto-dielectric, miniature, meander antenna

I. Introduction

Recently, small antenna research is most widely progress. Some kinds of small antenna are planer inverted-F antenna(PIFA), chip antenna, and meander line antenna, etc. These antennas are generally used for internal antenna of mobile terminals. The PIFA and chip antenna generally used for high frequency, for example, mobile communication(cellular and PCS), wireless LAN (2.4 and/or 5.8 GHz). The meander line antenna also could use for previous applications. However, PIFA and chip antenna is not suitable for low frequency such as 433.92 MHz. This frequency could use for harbor logistics field[1].

The meander line antenna was proposed by Rashed and Tai for antenna size reduction such that the antennas were made from continuously folded wire intended to reduce the resonant length. The meander line antennas tend to resonate at frequencies much lower than an ordinary antenna of equal length[2].

As shown in Fig. 1, the meander line technique is formed by folding the line back and forth. By this way, the total electrical length of antenna is still long while the size is small. This is also called a slow wave structure.

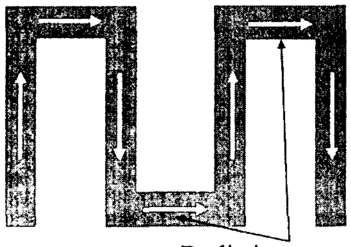

Fig. 1 Meander line technique

However, because of the strong coupling effects between adjacent meandered sections and between the corners of the right bends, the electrical length of the main strip meandered part is reduced. Consequently, the corresponding resonant length are relatively much larger than that(λ/4) of a simple straight strip one.

II. Antenna design and simulation

II-1. Magneto-dielectric material

The magneto-dielectric not only exhibits band-gap rejection values much higher than the ordinary dielectric, but also for the same physical dimensions, it shows a rejection band at a much lower frequency. The higher rejection is a result of higher effective impedance contrasts between consecutive layers of the magneto-dielectric structure. Some kind of the material of magneto-dielectric is Ni-Zn, Mn-Zn, and carbonyl Fe, etc. Properties of these materials are described in $\epsilon_r = \epsilon' + j\epsilon''$, and $\mu_r = \mu' + j\mu''$. Generally only the permittivity of dielectric is considered in antenna design, but in this paper the permeability component μ_r is also considered.

Magneto-dielectrics composite also provide certain advantages when used as substrate for planar antennas. These substrates are used to miniaturize antennas while maintaining a relatively high bandwidth and efficiency. An artificial anisotropic meta-substrate having $\mu_r > \epsilon_r$ made up of layered magneto-dielectric and dielectric materials is designed to maximize the bandwidth of a miniaturized patch antenna[3].

Although miniaturization can be achieved by using high dielectric materials, but the field remains highly concentrated around the high permittivity region(field confinement) causes low efficiency and narrow band characteristics to the antenna. In addition, the characteristic impedance in a high permittivity material is rather low which creates difficulties in impedance matching of the antenna. The magneto-dielectric materials can also miniaturize the antenna by the same factor however using moderate values of permittivity and permeability. Thus, the field confinement is minimized and the medium is far less capacitive. Furthermore, since the characteristic impedance of magneto-dielectric medium $\eta = \eta_0 \sqrt{\mu_r \epsilon_r}$ is close to that of the surrounding medium η_0, it allows for ease of impedance matching over a much wider bandwidth.

II-2. Antenna design

The structure of suggested antenna is shown in Fig. 2. Both meander technique and magneto-dielectric material are used to miniature the antenna size. The upper metal plate contains a meander line structure with 16 turns. The line width is 1 mm and the gap between two adjacent meandered sections is 0.5 mm. In the bottom metal plate, the ground size is reduced to 35 × 4 mm to achieve omni-directional characteristic like dipole antenna. The antenna is probe fed and the feed point position is optimized for good characteristics such as return loss, radiation patterns, etc. The permittivity and permeability is chosen at 5.21-j0.012 and 2.39+j2.58.

As an example, one kind of meander line

antenna which has a small size is a commercial product from Matrix Electronica S.L(Spain) named MTX-Green Chip 434. It is a quarter wave meander line surface mount chip antenna operates at 434 MHz, which is ground plane dependent, peak gain of -1 dBi, and return loss of -7 dB. Although its original size is 37 × 20 × 2.2 mm, but it needs a ground plane outside to radiate effectively[4]. So, the total size should be larger. The suggested antenna in this paper is half wavelength meander line antenna. However, the magneto-dielectric material is used, so the size of antenna can be smaller than meander antenna just with ordinary dielectric material.

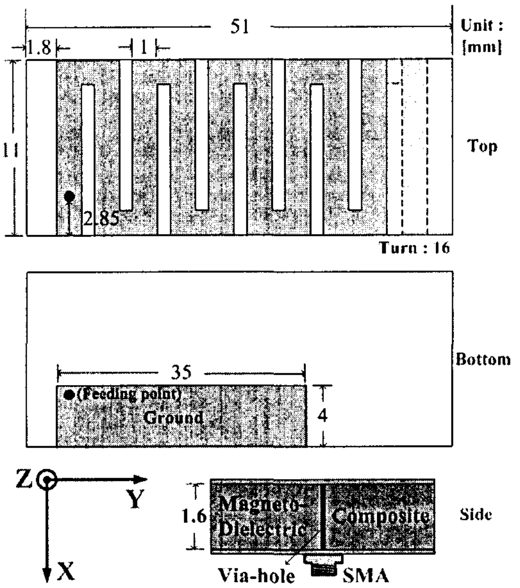

Fig. 2 Suggested meander line antenna

II-3. Optimize the parameters

The parameters of meander line antenna are length of section, line width, line gap, and section number. In the Fig. 2, the value of these parameters are optimized. These parameters are fixed and only change the material properties to optimize the performance at 433.92 MHz.

First, when the permeability, namely μ_r is 2.39+j2.58, dielectric constant ϵ' is changed. The value of μ_r is decided from the property data of magneto-dielectric. The results are shown in Fig. 3. When dielectric constant increases, the resonant frequency shifted to low frequency area. At ϵ'= 1.71, we get the good resonant characteristic. In the Fig. 3 and 4, diamond, rectangular, triangular, circular point lines are results of permittivity variation, respectively. At the case of triangular line, return loss of meander line antenna has a good performance(-30 dB at 433.92 MHz).

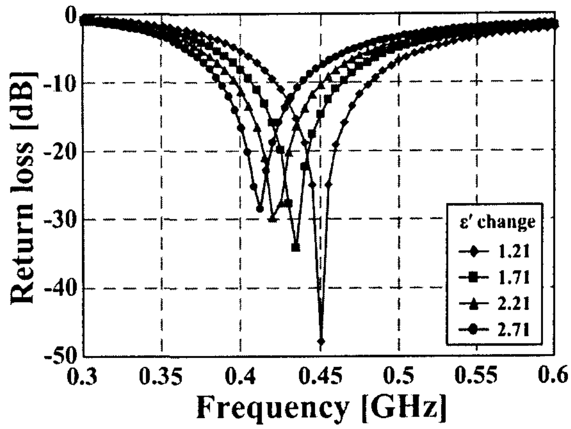

Fig. 3 Return loss according to ϵ' change

Second, in the permittivity component, only ϵ'' is changed. ϵ' value is fixed at 1.71 and permeability is not changed. The affect of ϵ'' changing applies only to return loss level as shown in Fig. 4. ϵ_r is express as $\epsilon' + j\epsilon''$. Also $\epsilon' + j\epsilon'' = \epsilon'(1 + j\epsilon''/\epsilon')$, where $(j\epsilon''/\epsilon')$ is defined as dielectric tangent loss.

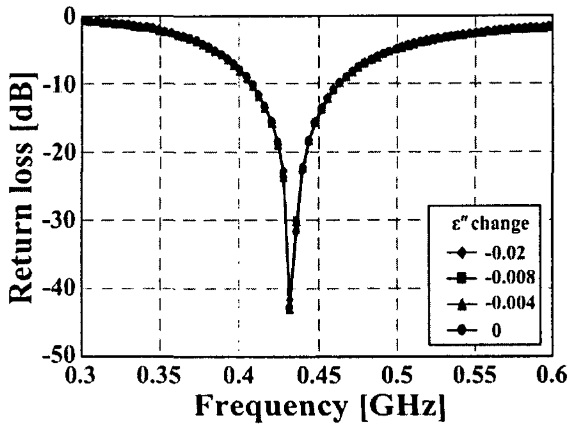

Fig. 4 Return loss according to ϵ'' change

Continuity, the variants of permeability parameters also lead to some affect to return loss level and resonance frequency of the antenna as shown in Fig. 5 and Fig. 6. In the Fig. 5 and 6, diamond, rectangular, triangular, circular point line are results of permeability variation, respectively. From Fig. 5 and 6, when the permeability increases, the resonance frequency is shifted to low frequency. The results of rectangular line show a good performance at 433.92 MHz. The μ_r is defined as $\mu' + j\mu''$ and it also can express as $\mu' + j\mu'' = \mu'(1 + j\mu''/\mu')$, where $(j\mu''/\mu')$ is defined as magnetic tangent loss.

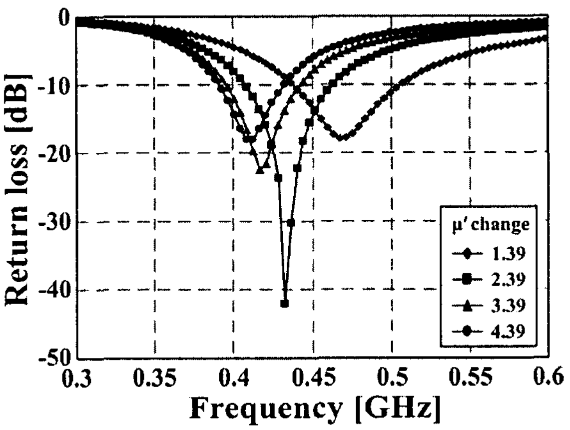

Fig. 5 Return loss according to μ'

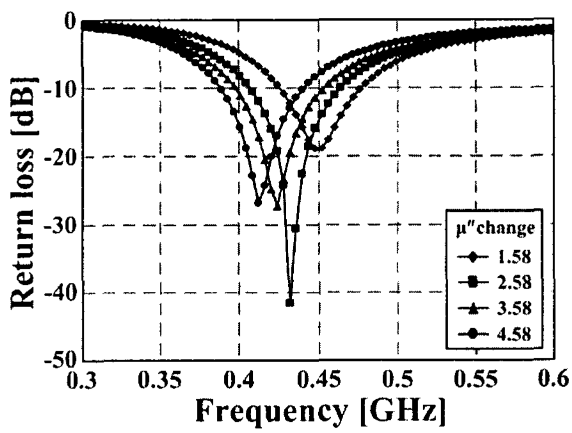

Fig. 6 Return loss according to μ''

The small antennas techniques are generally used dielectric with high permittivity. However, proposed meander antenna has low permittivity of dielectric of 1.71, but the results show the good performance and small size compare with previously mentioned antenna.

Fig. 7 show the return loss according to ground size variation of proposed meander antenna. The magneto-dielectric composite has permittivity, ϵ_r=1.71-j0.004 and permeability, μ_r= 2.39+j2.58. The ground size is change from 25 × 4 mm to 45 × 6 mm. It also shows the frequency shift and the frequency is shifted to high frequency area when the size is smaller.

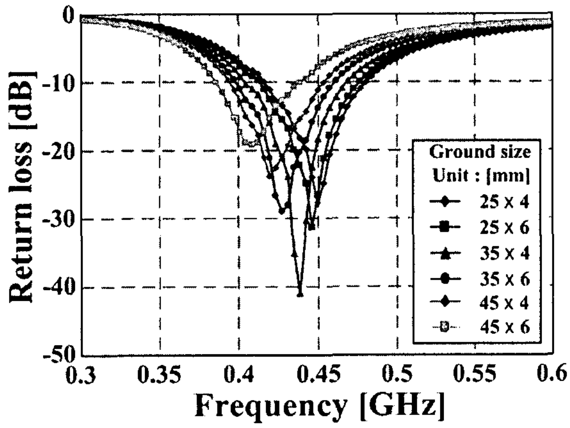

Fig. 7 Return loss according to ground size

Fig. 8 shows the current distribution of proposed meander antenna. In the introduction, the meander line characteristics are mentioned. The sections along y-direction are radiated parts, so the current is mainly distributed on those area of antenna surface. The other area, occupied by sections along x-direction, has less current existence because of cancelation between adjacent components.

Fig. 9 shows the gain radiation pattern of proposed antenna after optimization, that is ϵ_r= 1.71-j0.004, μ_r=2.39+j2.58. It is omni-directional in XY-plane(phi). In ZX-plane(theta), because of the existence of the ground, there is a null point. The maximun gain is -5 dBi. The gain is achieved low performance. Because of we use the magneto-dielectric material is used for miniature, the gain of antenna is low performance.

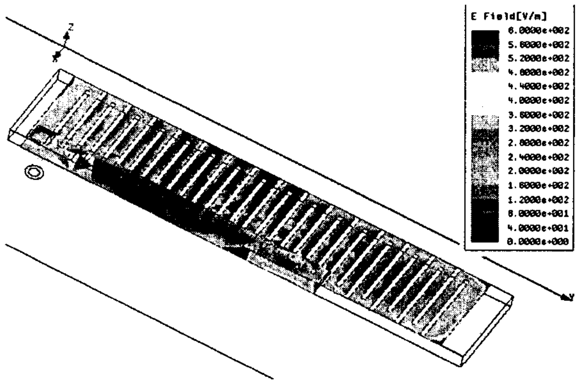

Fig. 8 Current distribution of meander antenna

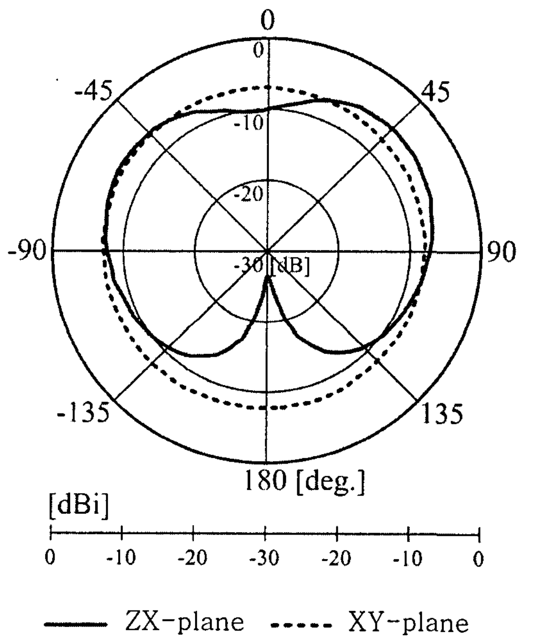

Fig. 9 Gain radiation pattern of proposed antenna

III. Conclusion

The paper describes a meander antenna using magneto-dielectric composite for 433.92 MHz band. The antenna with magneto-dielectric material in this paper is suggested for miniature of antenna size. The magneto-dielectrics composite provide certain advantages when used as substrates for planar type antennas. These substrates are used to miniaturize antennas while maintaining a relatively high bandwidth and efficiency.

The small antennas techniques are generally using dielectric which has high permittivity, increasing dielectric thickness, etc. However, proposed meander antenna has low permittivity of dielectric at 1.71, but the results show the good performance and small size compare with another meander antenna with dielectric only.

The return loss of meander antenna is achieved by optimizing the permittivity, ϵ_r=1.71-j0.004 and permeability, μ_r=2.39+j2.58. Over all dimension of the antenna is 51 × 11 × 1.6 mm. The return loss and gain are -41 dB, -5dBi, respectively at 433.92 MHz

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