

HIGH EFFICIENCY DIELECTRIC LOADED PILED TYPE SMALL MEANDER LINE ANTENNA

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1. Introduction

For very small RFID-tags, small meander line antennas with high efficiency were proposed [1][2]. It was shown that antenna efficiencies were enhanced by piled meander line structures and employing high ϵ_r materials [3]. By high ϵ_r material loading, a meander line structure becomes sparse. And the ohmic resistance can be reduced effectively. In this paper, increase of antenna efficiencies and decrease of antenna sizes by loading a $\epsilon_r = 1$ to 60 material are studied in the 0.02 and 0.05 wavelength piled type structure. Antenna electrical characteristics such as antenna impedances, radiation efficiencies, and current distributions are shown.

2. Effects of dielectric material loading

Figure 1 shows configurations of original type meander line antennas. In an original type, L and W express the antenna length and width, respectively. The antenna is composed of a bended thin conducting film whose width is expressed by d . Number of turns is expressed by N . In the case of Figure 1, N is 10. Meander line antennas shown in Figure 1 are packed both sides by dielectric substrates of thickness h . In calculation, dielectric substrate has infinite width. Figure 2 shows decrease of N by increasing ϵ_r . In the case of $L=0.05\lambda$, N becomes 6 at $\epsilon_r=20$ ($W=0.04\lambda$). In the case of $L=0.02\lambda$, N becomes 58 at $\epsilon_r=10$ ($W=0.016\lambda$). It is practical very interesting that N decrease dramatically by increasing ϵ_r . Figures 3 and 4 show the dielectric loaded piled type meander line antenna. The antenna is piled by the interval g and is covered by the thickness k . By selecting the suitable value of g , the occurrence of self-resonance is determined.

Figure 5 shows radiation resistances in $\epsilon_r = 1$ to 60 at 700 MHz band. Conductor thickness is $t=0.035$ mm and dielectric substrate thickness is $h=1.0$ mm, $g=2.0$ mm, and $k=1.0$ mm. Calculation is conducted through an electromagnetic simulator that uses the Moment Method (IE3D). Relations of these resistances are expressed by

$$R_{in} = R_r + R_l \quad (1)$$

R_r is determined by L/λ , and is not depend on ϵ_r . The step up ratio of R_r is 8 by effect of piled

structure. Theoretical value of step up ratio of R_r is 4 in the case of a folded structure. Increase of step up ratio from 4 to 8 in R_r is supposed to be produced by mutual coupling between two meander line sheets. Figure 6 shows ohmic resistances in $\epsilon_r = 1$ to 60 at 700 MHz band. R_l is given by

$$R_l = \frac{L_t}{2(d+t)} \sqrt{\frac{\omega\mu}{2\sigma}} \quad (2)$$

where L_t is total length of conductor, $\omega=2\pi f$ (f denote frequency), σ is conductivity, and μ is permittivity. In the case of $L=0.02\lambda$, ϵ_r can be varied from 10 to 60. This corresponds with decreasing N from 58 to 10. Calculated reduction rate of R_l is $1.4/19.1=1/13.6$ because the conductor width (d) can be increased from 0.07 mm to 0.35 mm. The step up ratio of R_l is 2 by effect of piled structure. Figure 7 shows radiation efficiencies (η) of various meander line antennas. Radiation efficiency (η) is given by

$$\eta = R_r/R_{in} \quad (3)$$

Calculation is not included the surface loss of dielectric substrate. Efficiencies (η) of -1.1 dB and -2.4 dB are achieved by employing $\epsilon_r=20$ material for $L=0.05\lambda$ and $\epsilon_r=60$ material for $L=0.02\lambda$, respectively. Usefulness of a high ϵ_r material is confirmed and high efficiency is achieved for 0.02 and 0.05 wavelength meander line antenna.

3. Other Electrical Characteristics of 0.02 Wavelength Piled Type Antenna

Figure 8 shows input impedances of the piled type ($N=10$, $\epsilon_r=60$). Near the resonant frequencies, 1.6% bandwidth of $VSWR < 2$ is expected. Figures 9 and 10 show current distributions of the piled type of $\epsilon_r=60$ at 696.3 MHz and 716.4 MHz, respectively. Currents amplitudes become large in the center areas and vanish at both edges at 696.3 MHz. And, the different resonant mode can be confirmed at 716.4 MHz. However, currents on neighboring conductors flow in the opposite directions at both frequencies. So, these currents cancel out each other. Currents on the piled antenna conductors flow in the same directions. These current flows express features of a folded structure. So, this antenna works as a short dipole antenna. A maximum value of antenna gain shifts to higher frequency in comparison with the self-resonant frequency because reflection loss at the antenna input port is the lowest around the higher mode.

4. Conclusion

The electrical performances of 0.02 and 0.05 wavelength original and piled type meander line antennas are investigated in $\epsilon_r = 1$ to 60. By loading a dielectric substrate of $\epsilon_r=60$, antenna efficiency of -2.4 dB is achieved in the case of 0.02 wavelength antenna.

Acknowledgement

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References

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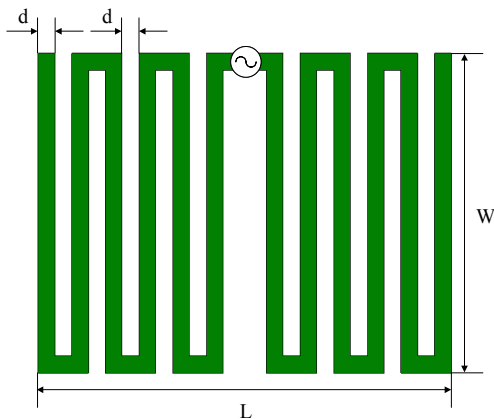


Figure 1 Original type meander line antenna
(N = 10 turn)

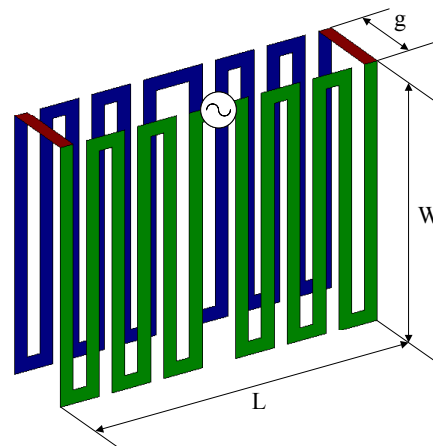


Figure 3 Piled type meander line antenna

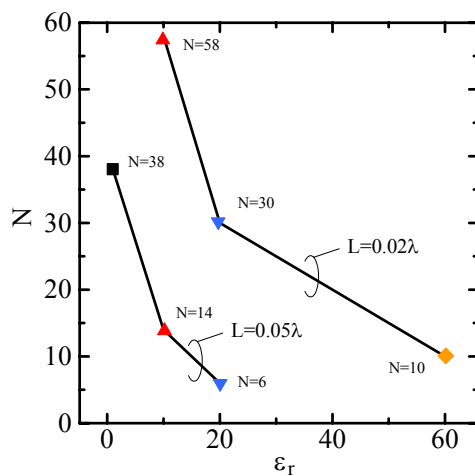


Figure 2 Structural condition of dielectric loaded meander line antenna

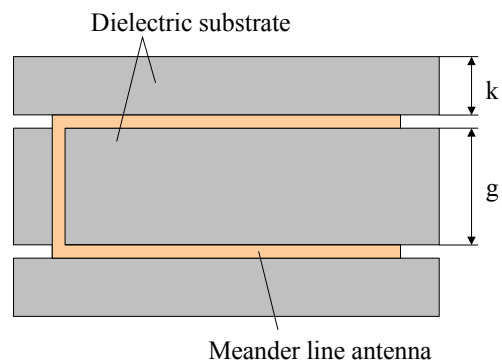


Figure 4 Dielectric loaded piled type antenna

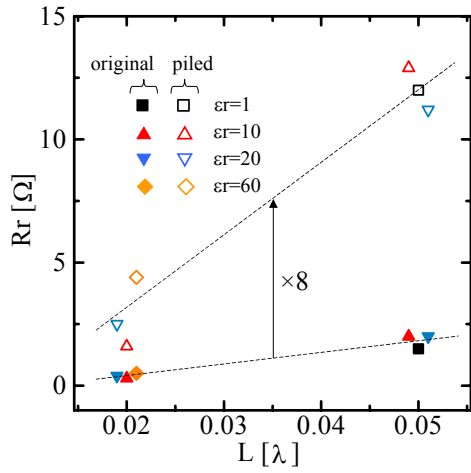


Figure 5 Radiation resistances of original and piled type antennas

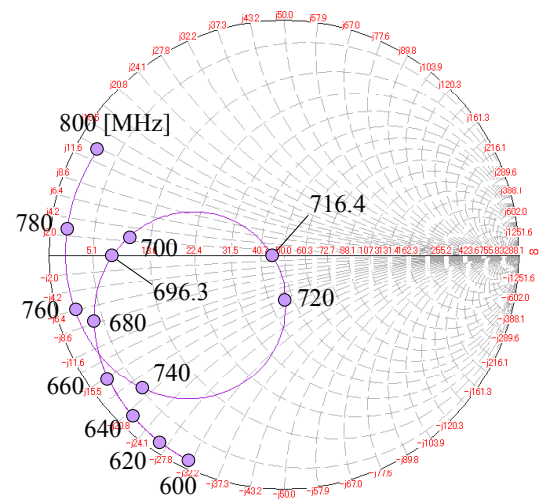


Figure 8 Input impedance (R_{in}) of 0.02 wavelength piled type antenna

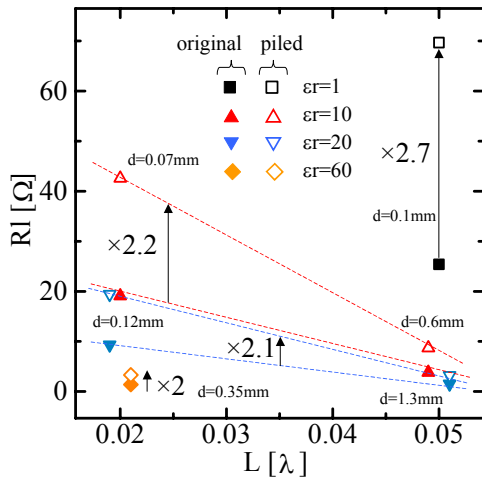


Figure 6 Ohmic resistances of original and piled type antennas

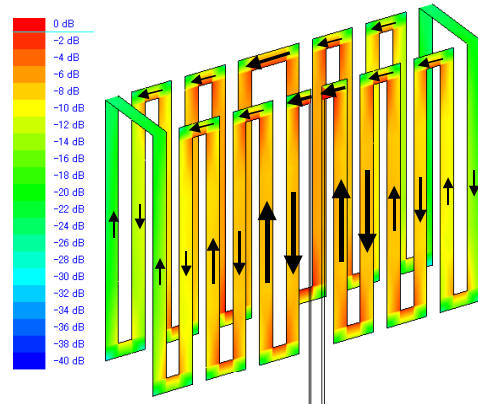


Figure 9 Current distribution of 0.02 wavelength piled type antenna (696.3 MHz)

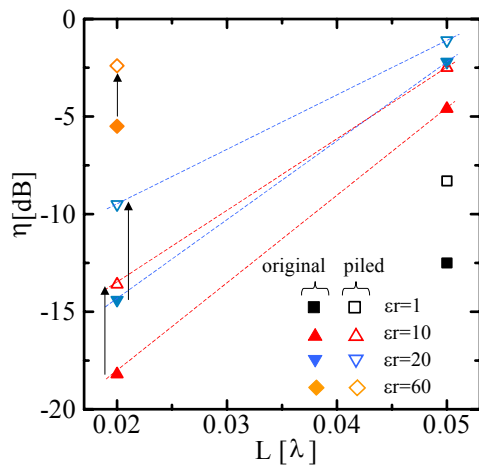


Figure 7 Radiation efficiencies of original and piled type antennas

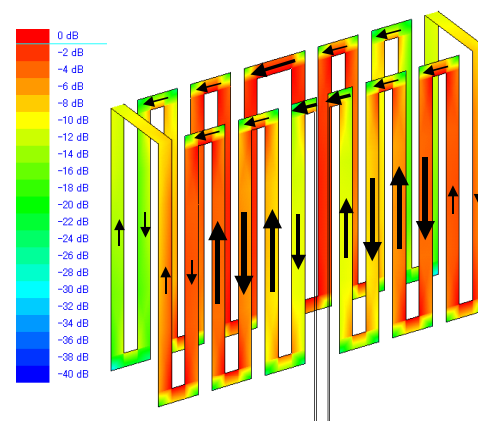


Figure 10 Current distribution of 0.02 wavelength piled type antenna (716.4MHz)