Band Rejection Characteristics of Dipole Antenna with Parasitic Element Composed of Composite Right/Left-Handed Transmission Line

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1. Introduction

A dipole antenna composed of composite right/left-handed transmission line (CRLH TL) has been proposed [1]. The antenna is composed of lumped or distributed LC elements and interconnecting wires. The CRLH dipole antenna can be miniaturized in the fundamental resonant mode of n = −1. However, the bandwidth narrows and gain decreases by using CRLH TL as antenna element.

In this paper, the right-handed (RH) dipole antenna with the CRLH parasitic element is presented. The proximity effect of the CRLH parasitic element has the feature of the band rejection at the resonant frequency of the original RH dipole antenna. The return loss characteristics are simulated and measured to confirm the band rejection characteristics. The radiation patterns at the resonant and rejection frequencies are also shown.

2. CRLH Dipole Antenna

The equivalent circuit of the CRLH TL is represented as shown in Fig. 1 [2]. The ideal left-handed (LH) medium is infinite periodical structure consists of series capacitance C_L and shunt inductance L_L. The pure LH medium does not exist physically because of the existence of parasitic series RH inductance L_R and shunt capacitance C_R.

The configuration of the CRLH dipole antenna is shown in Fig.2 (a). The CRLH TL consists of four unit cells as shown in Fig.2 (b). The antenna is implemented on dielectric substrate with thickness of 0.8 mm, relative permittivity of 2.6, and loss tangent of 0.0018. The parallel line consists of two lines with 100 mm length and 1.75 mm width. The inherent inductance and capacitance in a parallel line corresponds to the L_R and C_R. The length and width of fingers and their gaps are 9.2 mm, 0.4 mm, and 0.05 mm for interdigital capacitor. The width of meander lines and their gaps are 0.4 mm and 0.1 mm for inductor. Conductivity of 5.8×10^7 S/m for copper with thickness of 35 μm is used.

Fig.3 shows the dispersion diagram of the unit cell of the CRLH TL. The dispersion diagram can be derived from the infinite periodic structure using finite element method simulation. From Fig.3, the LH range from 380 MHz to 980 MHz is appeared because phase velocity of ω/β and group velocity of $(d\beta/d\omega)^{-1}$ have opposite sign. The stop band is observed from 1.0 GHz to 1.1 GHz, and the RH branch is appeared above 1.1 GHz. Fig.4 shows the simulated and measured results of the return loss characteristics of the CRLH dipole antenna as shown in Fig.2. The resonant frequencies of n = −1 and n = −3 are 590 MHz and 390 MHz, respectively. Because of CRLH TL consists of four unit cells, the frequency of $\beta p/\pi$ = 0.25 from Fig.3 is the resonant frequency of n = −1 from Fig.4. The discrepancy between simulated and measured results at n = −3 is due to the simulation accuracy. The appropriate mesh size at each frequency should be chosen.

3. Band Rejection Characteristics Using CRLH Parasitic Element

3.1 Return Loss Characteristics

Fig.5 shows the configuration of the RH dipole antenna with the CRLH TL. The CRLH TL is used as a parasitic element. The length and diameter of the RH dipole antenna are 250 mm and 0.9 mm, respectively. The resonant frequency of the RH dipole antenna is 560 MHz. Fig. 6 shows simulated results of the return loss characteristics when the distance *h* between the RH dipole antenna and the CRLH parasitic element is varied. The proximity effect of CRLH parasitic element is the band rejection of the RH dipole antenna. When h = 5 mm, the band rejection frequency of 552 MHz is almost equal to the resonant frequency of the RH dipole antenna and the resonant frequency shifts lower frequency around 525 MHz. Furthermore, the band rejection frequency approaches to he resonant frequency of n = −1 mode of the CRLH dipole antenna, when *h* becomes larger.

The experimental results of return loss characteristics are shown in Fig.7 when the distance *h* is varied. The bazooka balun for 560 MHz is used in experiment. The band rejection frequency with *h* = 5 mm is observed at 562 MHz and the resonant frequency is appeared at 533 MHz. The band rejection frequency is almost equal to the resonant frequency of the RH dipole antenna. Therefore, the validity of the simulated results is confirmed. In experiment, the band rejection frequency is also approached to the resonant frequency of CRLH dipole antenna in experiment.

3.2 Radiation Patterns

Figs.8 and 9 show the simulated radiation patterns with h = 5 mm at the resonant and the rejection frequencies of 525 MHz and 552 MHz, respectively. At the resonant frequency, the peak gain is 1.3 dBi. At the rejection frequency, the radiation level becomes lower due to the mismatch loss. Especially, the radiation level of 90 degrees direction is −8.0 dBi, because the CRLH parasitic element operated as the reflector. On the other hand, the radiation level of the 270 degree direction is −1.7 dBi. Therefore, the proximity effect of the CRLH parasitic element is the suppression of the radiation to the undesired direction.

4. Conclusion

The band rejection characteristics of the RH dipole antenna with the CRLH parasitic element have been investigated. The dispersion diagram was simulated for the unit cell of the distributed LC element of CRLH TL. And the return loss characteristics of the CRLH dipole antenna were simulated and measured. The RH dipole antennas with the CRLH parasitic element were simulated and measured. The band rejection frequency can be shifted with varying the distance between the RH dipole antenna and the CRLH parasitic element. It is cleared that the proximity effect of the CRLH parasitic element is the band rejection and the suppression of the radiation to the undesired direction.

References

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[2] C. Caloz, T. Itoh, Electromagnetic Metamaterials, Willey Interscience, 2006.

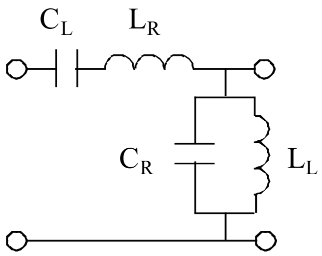


Fig.1: Equivalent circuit of unit cell

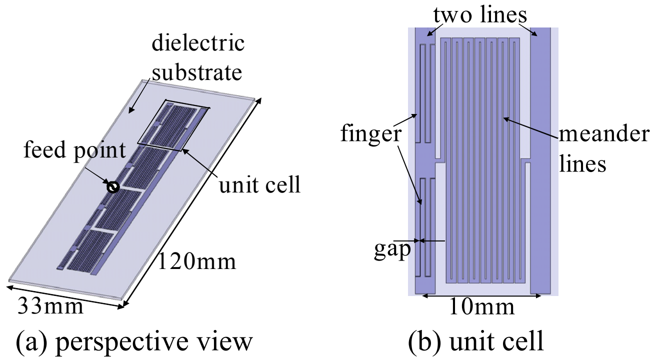


Fig.2: Configuration of CRLH dipole antenna

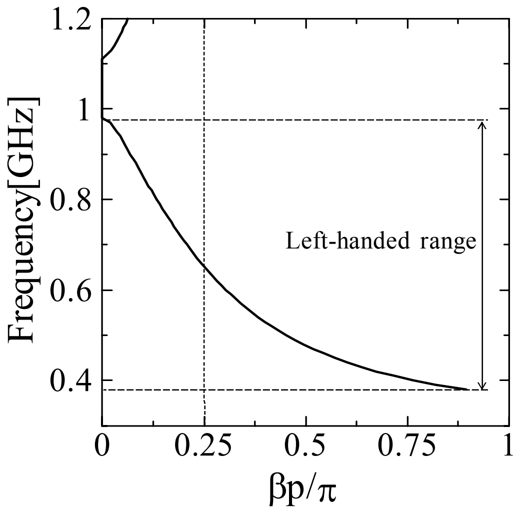


Fig.3: Dispersion diagram

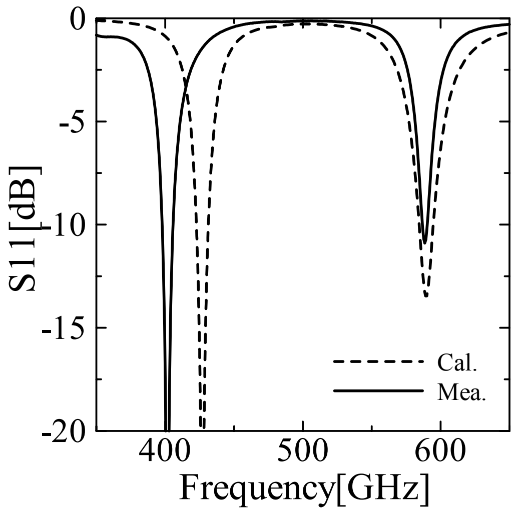


Fig.4: Return loss characteristics of CRLH dipole antenna

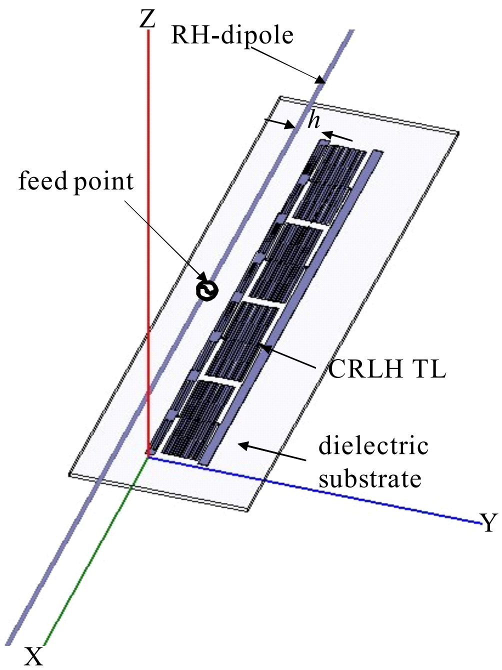


Fig.5: Configuration of RH dipole antenna with CRLH parasitic element

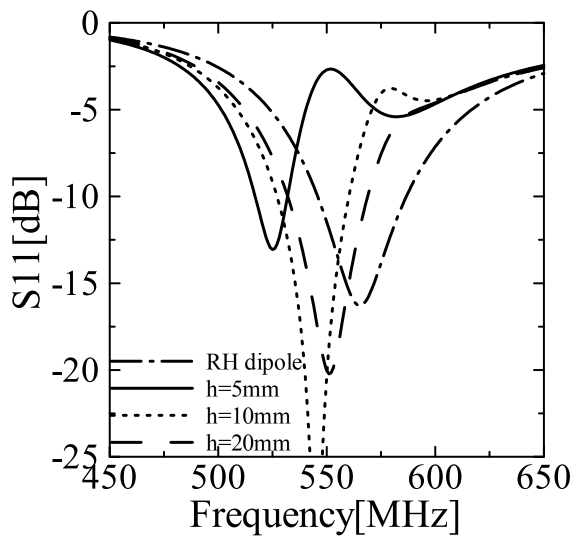


Fig.6: Return loss characteristics (Simulation)

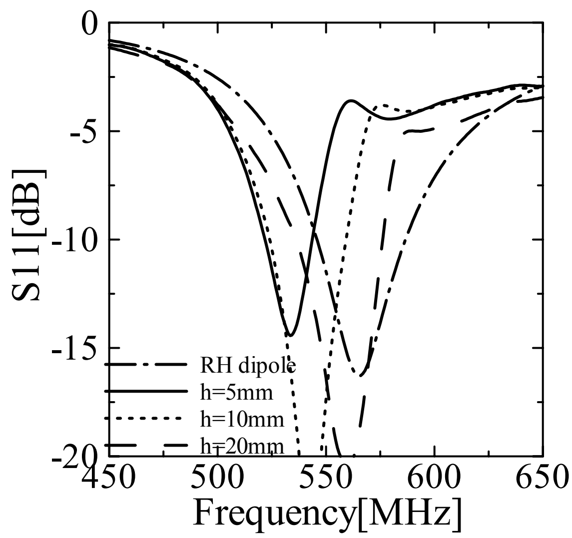
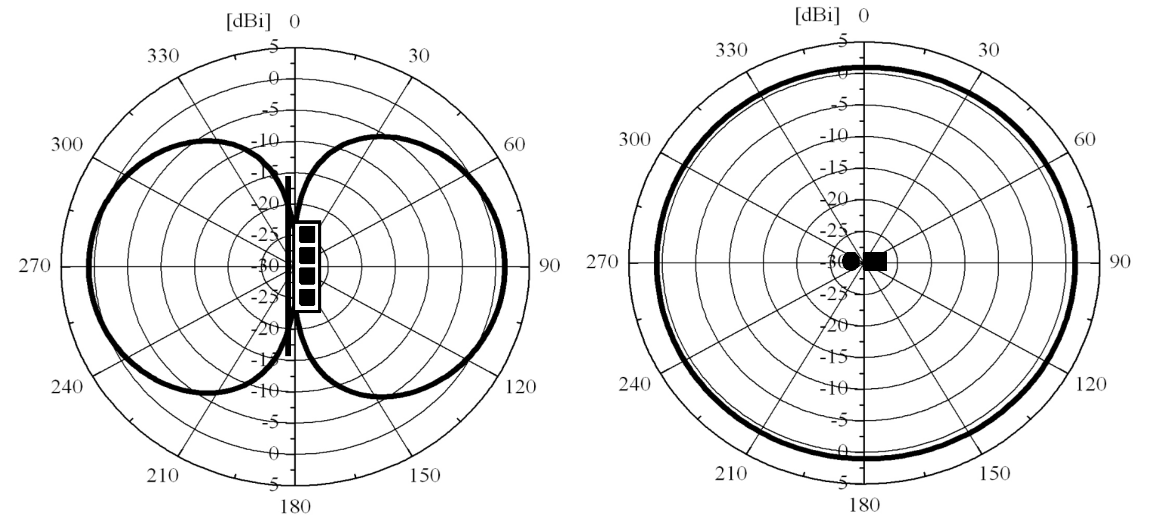
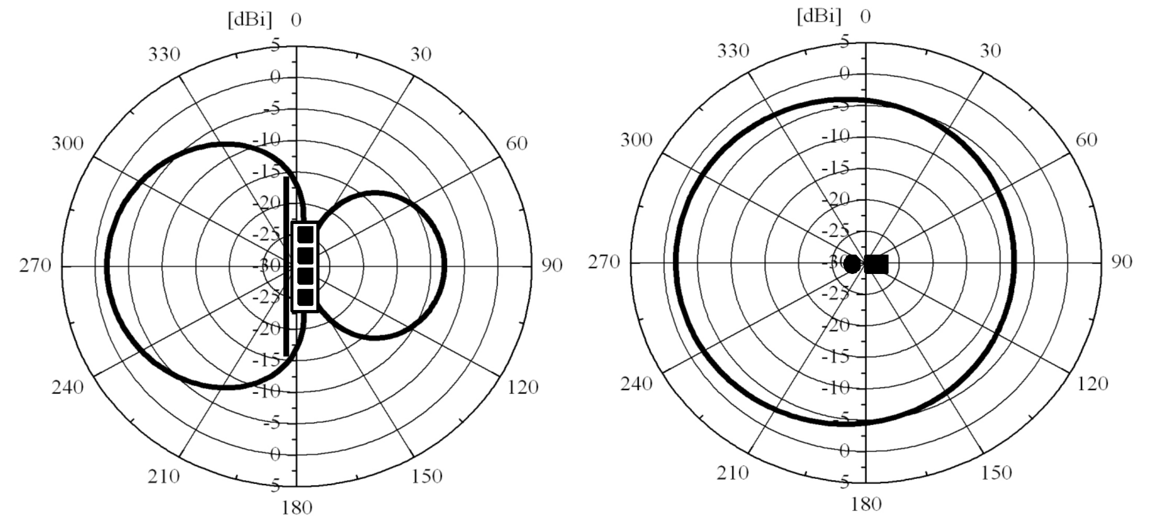


Fig.7: Return loss characteristics (Measurement)



(a) X-Y plane (b) Y-Z plane

Fig.8: Radiation patterns with *h* = 5 mm at resonant frequency of 525 MHz



(a) X-Y plane (b) Y-Z plane

Fig.9: Radiation patterns with *h* = 5mm at rejection frequency of 552MHz