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DUAL-FREQUENCY LOOP SLOT ANTENNA WITH PARASITIC ELEMENTS

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1. Introduction

This paper presents a dual band, omni-directional antenna arrayed vertically. As antenna element, a loop slot antenna with parasitic conducting cylinder proposed in [1][2] is changed to the element with two conducting plates placed top and bottom of dielectric substrate to simplify its structure. For the dual band operation at 1.5GHz and 2GHz, each antenna element designed independently is connected by microstrip line to keep open impedance condition at the other resonant frequency, respectively [3][4]. We verify the performance of dual-frequency antenna by experiments.

2. Loop Slot Antenna

We analyzed the 2GHz loop slot antenna with parasitic elements as shown in Fig.1 using FDTD (Finite Difference Time Domain) method. The relative permittivity of dielectric substrate is 2.6 and its thickness is 0.8 mm. A loop slot etched on the ground plane, and loop length is about one wavelength. The FDTD parameters are as follows: The sell size is $\Delta x = \Delta y = 0.55$ mm and $\Delta z = 0.4$ mm; and number of time steps is 25,000.The absorbing boundary condition is the PML (perfectly matched layer) of 8 layers, and the space between the antenna edge and the PML is 18 cells.

The input return loss characteristics are changed by the parasitic element’s height **h** as shown in Fig.2. The optimum height is 10.4mm for the impedance matching. The element radiation pattern is shown in Fig.3, which shows omni-directional radiation pattern is obtained in zx-plane and a figure of eight pattern is in yz-plane. The parasitic elements are effective for the omni-directional antenna. In a similar way, the 1.5GHz loop slot antenna can be designed, but this loop antenna size is lager than the 2GHz loop antenna size.

3. Dual-Frequency Antenna

This section presents the loop slot antenna for 2GHz and 1.5GHz use as shown in Fig.4. Each antenna designed at different frequency independently is connected to feed port through T-junction by adjusting feed line length appropriately [3][4]. In this method, the length of microstrip feed line is adjusted so that it may become an open end at another resonance frequency at the connecting point of microstrip feed line. The antenna element parameters are calculated using FDTD method, and microstrip feed line length is determined by circuit design simulator (Micro Wave Office).

Fig.5 (a) shows the feed line circuit determined by circuit simulator for the 2GHz antenna, where the feed line length adjustments make the connecting point as an open end at 1.5GHz. The Smith chart of the antenna for 2GHz is shown in Fig.5 (b). The impedance of the antenna at the connecting point is infinite at 1.5GHz. In a similar way, the feed line circuit is determined for 1.5GHz antenna in Fig.6 (a). The Smith chart of 1.5GHz antenna is shown Fig.6 (b). The impedance of the antenna at the connecting point is also infinite at 2GHz.

Each antenna fed by the adjusted microstrip line is connected by T-junction, and the input port characteristics of dual-frequency antenna are calculated by the circuit analysis and FDTD method as shown in Fig.7. Unnecessary resonances appear in the frequency range between 1.5GHz and 2GHz.

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However, the FDTD analysis including whole structure, resonance frequency has shifted to lower side due to the mutual coupling of parasitic elements, not take into consideration in the circuit analysis.

As discussed above, it is effective to use circuit analysis for the determination of the maicrostrip feed line circuit for the configuration of the dual-frequency antenna. However it is necessary to use electromagnetic analysis such as FDTD method in order to actually optimize the antenna including mutual coupling of parasitic elements.

Next, experiment and analysis are examined for the prototype antenna to optimize parameters including mutual coupling between parasitic elements. The microstrip feed line of 1.5GHz antenna is extended by half wavelength to reduce the mutual coupling between two antennas. Then we experimentally optimize the parameters by cut-and-try method. By changing height and size of parasitic elements, the impedance matching and resonance frequency are optimized. In the analysis, the FDTD parameters are as follows: The sell size is $\Delta x = \Delta y = 0.55$ mm and $\Delta z = 0.2$mm; and number of time steps is 30,000. The return loss characteristics of the measurement and calculation are shown in Fig.8. The measurement agrees well with the calculation with a small error of each resonance frequency. The structure of the feeding connector is not modeled correctly in the analysis, because the sell size is not small enough due to the limited calculation resources. Another error factor in the measurement is that height of parasitic elements can not be correctly fixed in this experiment. The radiation pattern in measurement and calculation are shown in Fig.9 and 10. The measurements agree well with the calculation result, and good omni-directional radiation pattern is obtained in zx-plane. The pattern distortion in yz-plane pattern is caused by the effect of finite size of the ground plane.

4. Conclusion

This paper presented the omni-directional and dual-frequency antenna arrayed vertically for 1.5GHz and 2GHz use. The return loss characteristics of measurement agree with the calculation and omni-directional patterns are obtained at each resonance frequency. In addition, the design method for the multi-frequency antenna is demonstrated including mutual coupling between parasitic elements.

References

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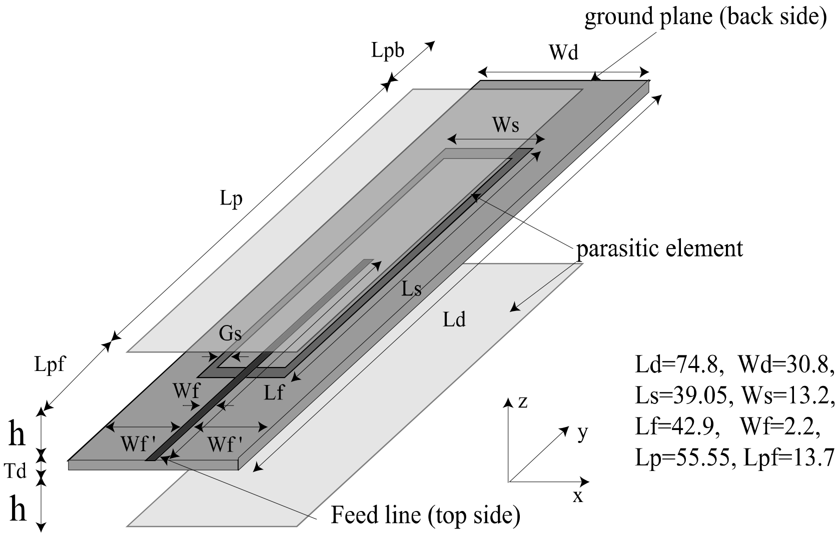


Ld=74.8, Wd=30.8, Td=0.8,
Ls=39.05, Ws=13.2, Gs=1.1,
Lf=42.9, Wf=2.2, Wf'=14.3,
Lp=55.55, Lpf=13.75, Lpb=5.5 unit [mm]

Fig. 1 Loop slot antenna for 2GHz

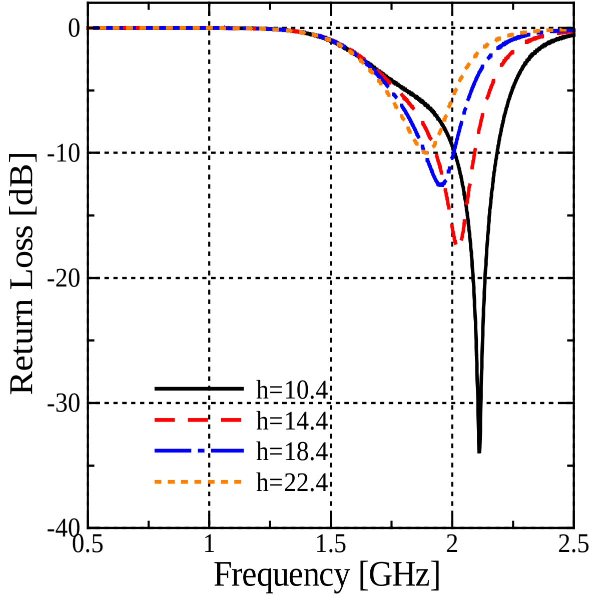
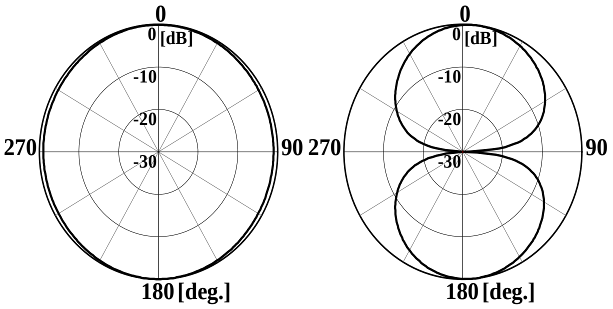


Fig. 2 Return loss characteristics



(a) zx-Plane **(b) yz-Plane**

Fig. 3 Radiation pattern (h = 10.4 mm)

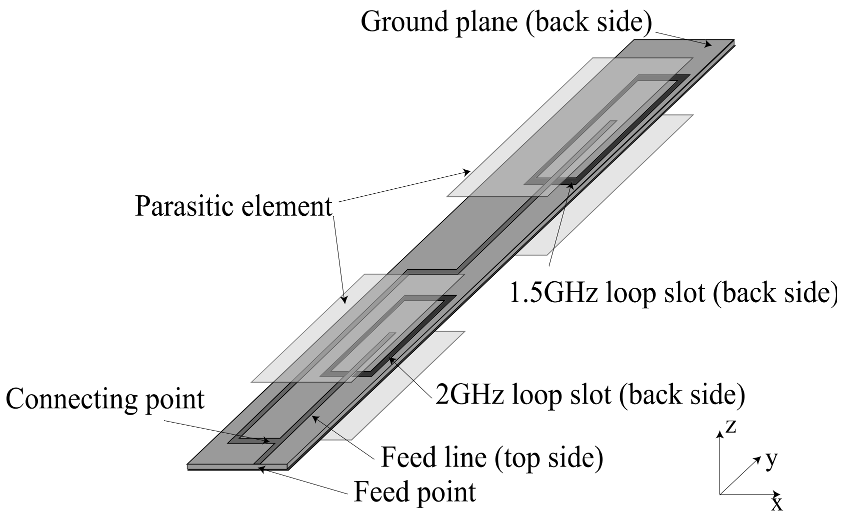
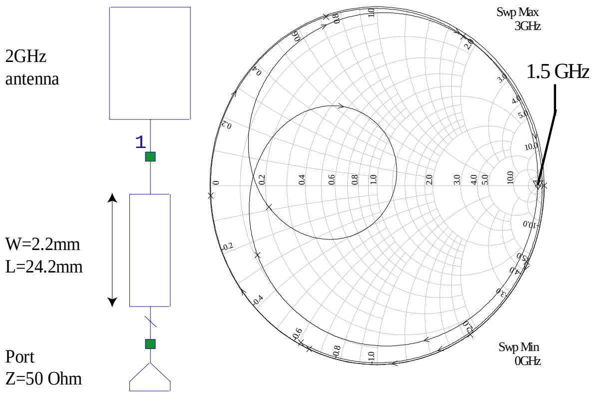
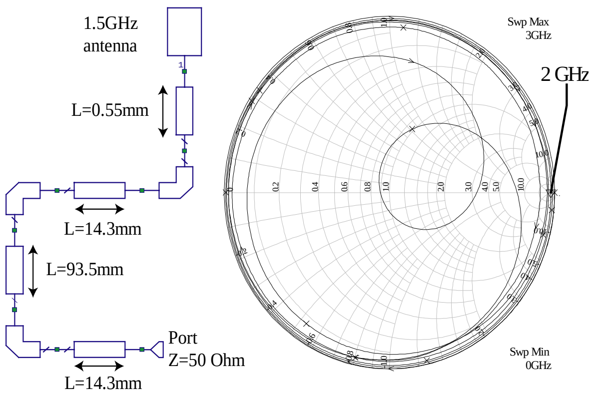


Fig. 4 Dual-frequency antenna configuration



(a) Analysis by MWOffice (b) Smith chart for 2GHz antenna

Fig. 5 Circuit analysis of 2GHz antenna



(a)Analysis by MWOffice (b) Smith chart for 1.5GHz antenna

Fig. 6 Circuit analysis of 1.5GHz antenna

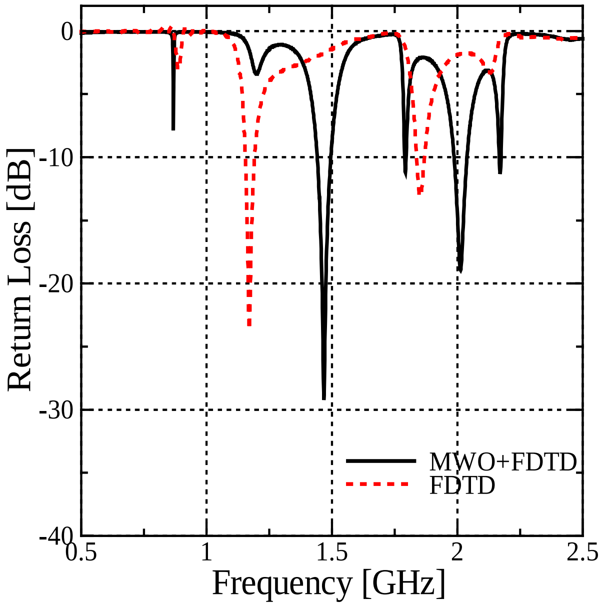


Fig. 7 Return loss characteristics by circuit analysis

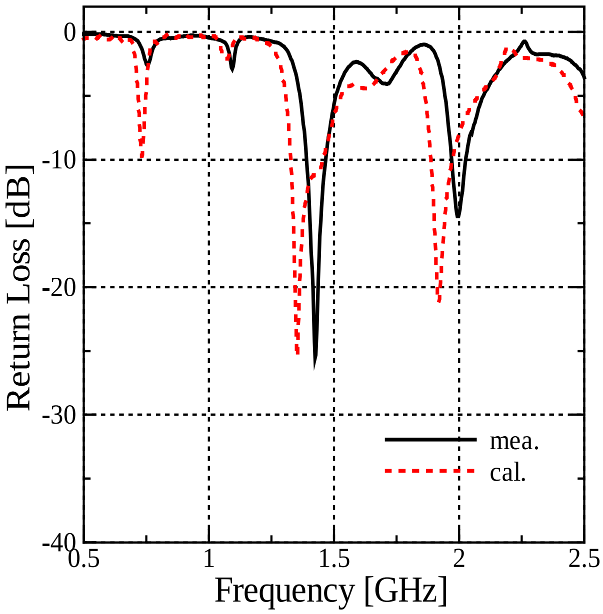
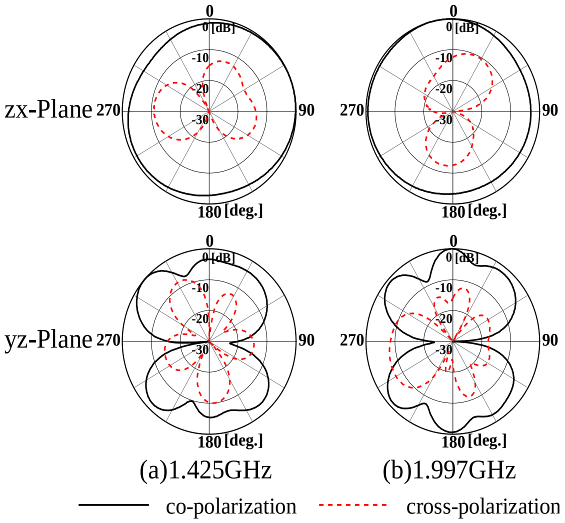
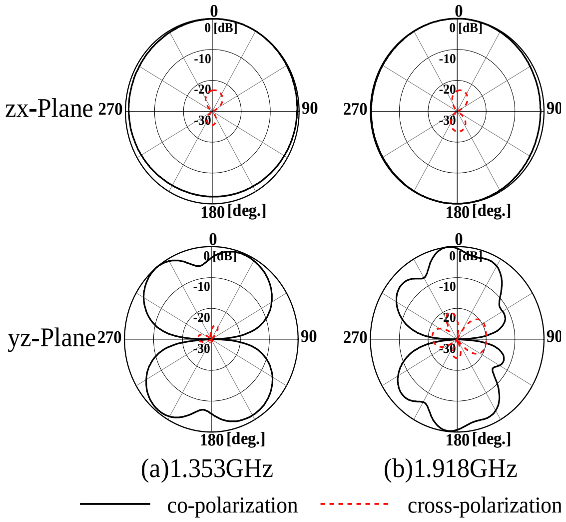


Fig. 8 Return loss characteristics by FDTD method



(a)1.425GHz (b)1.997GHz

Fig. 9 Radiation pattern (measurement)



(a)1.353GHz (b)1.918GHz

Fig. 10 Radiation pattern (calculation)