Design of Antenna System for Radio Wave Type Laparoscope

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***Abstract*—In this paper, an antenna system for radio wave type laparoscope is proposed. The antenna system consists of one transmitting antenna and four receiving antennas. The simulated transmission coefficients of the one layer microstrip antenna (conventional microstrip antenna) and the stacked microstrip antenna are compared in the frequency domain and the time domain.**

Keywords—Laparoscope, blood vessel, microstrip antenna, transmission coefficient

I. INTRODUCTION

In current laparoscopic surgery, it is necessary to know the position of the blood vessel in fat. However, it is impossible to detect it using a camera type laparoscope which is used in current laparoscopic surgery. Authors have proposed an antenna system for radio wave type laparoscope [1][2]. The proposed system consists of one transmitting antenna and four receiving antennas. The position of the blood vessel is detected by signal-processing the received radio wave to image data by the method of processing synthetic aperture. In [1][2], the possibility of the proposed method was investigated by examining the differences between the transmission coefficients in the cases with and without the blood vessel in the frequency domain. In this paper, the possibility are investigated in the time domain.

II. ANTENNA DESGN AND ANALYTICAL MODEL

In this system, the diameter of the practical laparoscope is usually 10mm. In this study, however, a system with a 25mm-diameter (a 2.5-times scale model) is investigated in order to facilitate of the measurement.

Fig. 1 shows the antenna system of the proposed laparoscope. Stacked rectangular microstrip antennas (MSAs) are used as an antenna element in the laparoscope to increase the reception level. Generally, the stacked MSA is used to enhance the impedance bandwidth. However, in this system, a parasitic element is installed in 1/4 wavelength above the fed patch element to improve the antenna gain. A transmitting antenna (Antenna element #1) is located at the center and four receiving antennas (Antenna element #2- #5) are arranged in the vicinity of the transmitting antennas. In all of the antennas, the dimension of the rectangular patch is W_a x L_a. The relative dielectric constant, the thickness and the loss tangent of the dielectric substrate are ε_r =3.8, h_a =1.6mm and $\tan\delta$= 0.022, respectively.

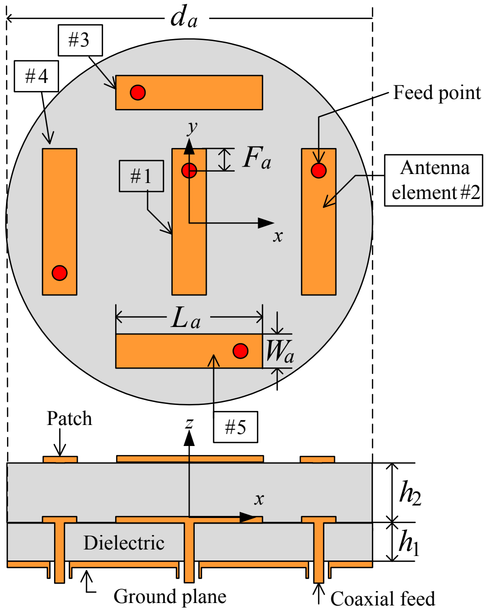

Fig. 1 Proposed antenna system.

Figure 2 shows the simulation model. The transmitting antenna and the receiving antennas which are located on top of the fat and face the both the fat and the blood vessel. The dimension of the fat is W_f x L_f x D_f = 200mm x 200mm x 50mm. The diameter of the blood vessel is d_b. The relative dielectric constant and the conductivity of the fat are 4.42 and 0.76S/m, respectively. Those of the blood vessel are 29.64 and 12.03S/m, respectively.

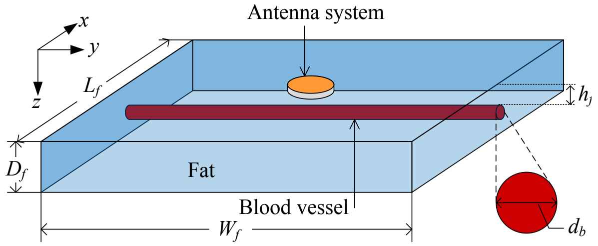

Fig. 2 Simulation model (Fat & Blood vessel).

III. ANALYTICAL RESULTS

For the simulation in this paper, the simulation software package XFDTD ver. 7.4 [3], which is based on the finite difference time domain method (FDTD), is used. In this simulation, the blood vessel is located at the center of the fat x=0 along the y axis. The dimensions of the designed rectangular patch are W_a=3.0mm, L_a=7.92mm, F_a=0.96mm, and S_a=1.5mm. The diameter of the blood vessel d_b=10mm and the distance h_f=10mm.

Figs. 3(a) and (b) show the transmission coefficient |S21| of the one layer MSA and the stacked MSA in the frequency domain, respectively. The difference between |S21| in the cases with and without the blood vessel is small in the one layer MSA. In the stacked MSA, however, the great difference is observed around 8GHz in between |S21| in the cases with and without the blood vessel. The effect of the parasitic element can be confirmed.

Figs. 4(a) and (b) show the transmission coefficient |S21| in the one layer MSA and the stacked MSA in the time domain, respectively. When |S21| in the frequency domain is transformed to |S21| in the time domain, the second-order differential gaussian function with the center frequency 8GHz is used as weight function. Similar to |S21| in the frequency domain, the magnitude of |S21| in the time domain of the stacked MSA is greater than that of the one layer MSA. The direct wave from the transmitting antenna (#1) can be observed around 0.07ns. Moreover, the reflected wave by the blood vessel can be observed around 0.16ns. In contrast with frequency domain, the difference between |S21| with and without the blood vessel in the one layer MSA is big compared with that in the stacked MSA. In the stacked MSA, the oscillation continues after 0.25ns in both with and without the blood vessel. It is predicted that the oscillation occurs due to the multireflection between the transmitting and receiving antennas.

IV. CONCLUSION

An antenna system for radio wave type laparoscope has been proposed. In this paper, the simulated transmission coefficients of the one layer MSA and the stacked MSA were compared in the frequency domain and the time domain. In the stacked MSA, the differences between the transmission coefficient of the cases with and without the blood vessel were observed in the frequency domain. In the time domain, however, the difference in the case of the on layer MSA is greater than that in the case of the stacked MSA

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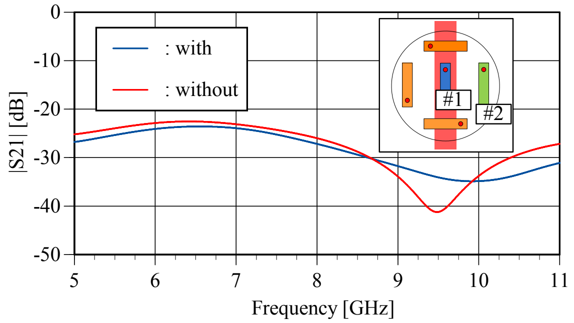
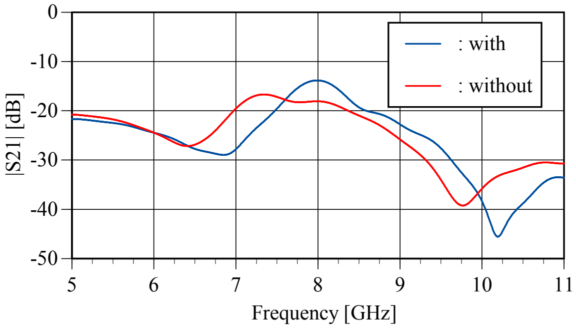
[3] http://network.kke.co.jp/products/xfdtd

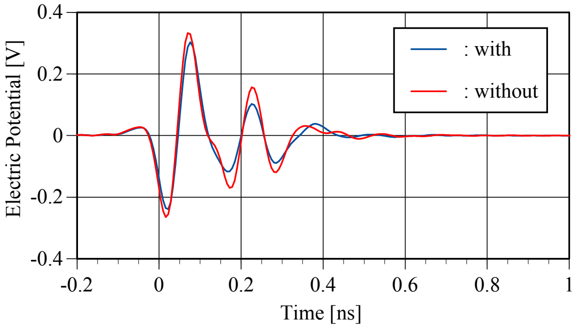


(a) One-layer MSA

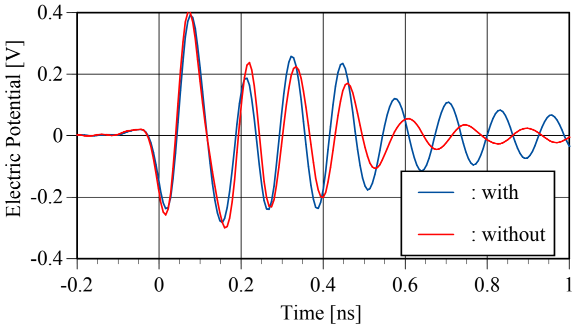


(b) Stacked MSA

Fig.3 Transmission coefficient in the frequency domain.



(a) One-layer MSA



(b) Stacked MSA

Fig.4 Transmission coefficient in the time domain.