Evaluation of Bandwidth for Tunable Antennas with Physical Limitations on Small Antennas

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Abstract **- A tunable antenna is one of the solutions to enable a built-in antenna to operate over wideband wireless systems. In this report, the bandwidth of a tunable antenna is compared with that of physical limitations on antennas of arbitrary shape. The operating bandwidth of tunable antennas can be over 3 times wider than that of passive antennas.**

Index Terms **— tunable antenna, physical limitations, genetic algorithms**

1. Introduction

Since the number of available frequency bands increases and the size of antennas is limited, the requirements for antennas in mobile equipment become more difficult. One of the solutions for antennas which is used for the wideband wireless system is a tunable antenna. An automatic tunable antenna system has also been proposed [1, 2]. The wideband operation and the automatic optimization were demonstrated. Here, the shape of the antenna was designed by using the genetic algorithm (GA). However, the automatically tunable system has not been compared with passive antennas in terms of the operation bandwidth. On the other hand, Gustafsson et al have proposed the physical limitations on small antennas of arbitrary shape by using the convex optimization [3-5]. The limitations for the performance of passive antennas can be obtained and predicted with this method.

In this report, performance of our proposed tunable antenna is evaluated in terms of the operating bandwidth. Compared with the physical limitations on passive antennas, the operation bandwidth of the proposed tunable antenna can be confirmed to be wider than that of a passive antenna. In addition, to validate the optimization by GA, the comparison of an antenna optimized by using GA and physical limitations is shown.

2. Tunable Antennas

The proposed automatic tunable antenna system is shown in Fig. 1. Variable capacitors in a matching circuit are controlled based on the detected power at the probe near the tip of an antenna. When the detected power is decreased by changes in a matching condition, variable capacitors are controlled to increase the detected power. Moreover, the advantages of the system are the frequency independent operation, the lower insertion loss and not requirements for isolation [2].

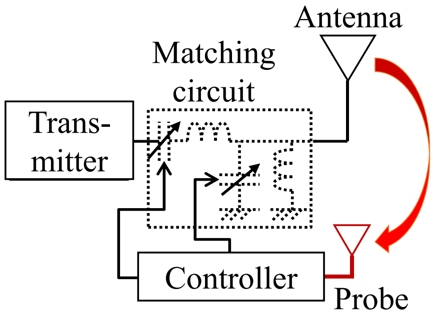

Fig. 1. Our proposed automatic tunable antenna system. Variable capacitors in a matching circuit are controlled based on the detected power at a probe.

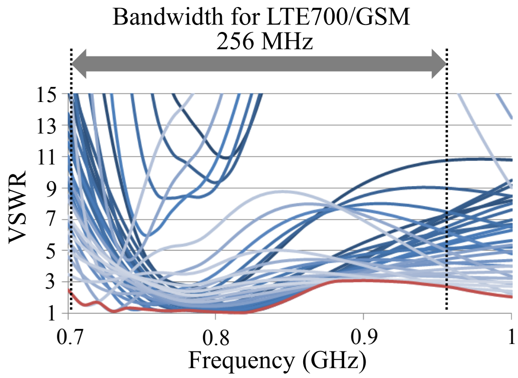

Fig. 2. VSWR for all variations of variable caparitors. The operation bandwidth where VSWR is less than 3 of the proposed tunable antenna is over 256 MHz.

In this case, the wireless communication system is assumed the lower operating bandwidth (256 MHz) for which is the LTE 700 and GSM. Fig. 2 shows the computed VSWR of the proposed antenna for all variations of variable capacities. In this case, the lowest VSWR for all variations is lower than 3 for assumed bandwidth.

3. Computational Results

To evaluate the proposed antenna system, we calculate the physical limitations for passive antennas. The computational model is a planer antenna as shown in Fig. 3 and consists of perfect electric conductor.

Here, the antenna is designed in a limited area 60 mm x H_a. The other region is a ground plane. The solid line in Fig. 4 indicates the physical limitations of the bandwidth where the VSWR is less than 3. The value increases as the antenna design area become wider.

The bandwidth is 83.1 MHz at H_a = 10 mm. When our proposed tunable antenna is designed in the same sized area, the operation bandwidth is over 256 MHz. Thus, the bandwidth of the proposed tunable antenna is over 3 times wider than that of passive antennas.

Next, for the validation of a designed antenna with GA, the bandwidth for a passive antenna is evaluated. The physical limitations for the G/Q are shown in Fig. 5 with a solid line. $G(\hat{z},\hat{\phi})$ is the gain in the direction $\hat{z}$ and the polarization $\hat{\phi}$, Q is the Q factor, k is the wavenumber, a is the radius of the circumscribing sphere and λ is the wavelength. The G/Q has the maximum value at $l_y/\lambda = 0.35$. The G/Q of the optimized antenna with GA as shown in a dashed line is obtained by the following steps;

(1) The limit bandwidth for the center frequency where the VSWR is less than 1.5 is calculated.
(2) The shape of an antenna is optimized with GA to maximize the bandwidth for the center frequency.
(3) After the optimization, the Q factor is calculated with the bandwidth where VSWR is less than 1.5.
(4) The gain of the optimized antenna is calculated.
(5) Finally, the G/Q of the optimized antenna is obtained.

G/Q of the optimized antenna is lower than that of the physical limitations. Especially, at $l_y/\lambda = 0.35$, the difference between both results is less than 5%.

4. Conclusions

In this report, the operation bandwidth of the proposed tunable antenna is evaluated. Compared with the bandwidth of the physical limitations of a passive antenna, the bandwidth of the proposed tunable antenna is over 3 times wider than that of the passive antenna.

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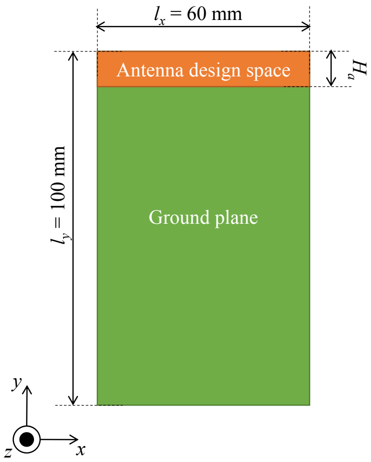

Fig. 3. Computational models. A planer antenna is assumed. Antennas is designed in space of 60 mm x H_a = 10 mm.

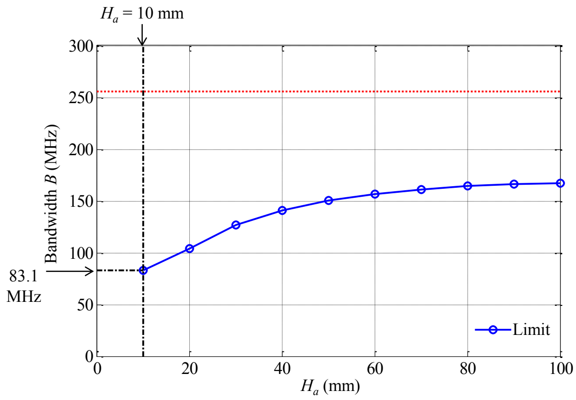

Fig. 4. The bandwidth for varying the antenna design space by H_a.

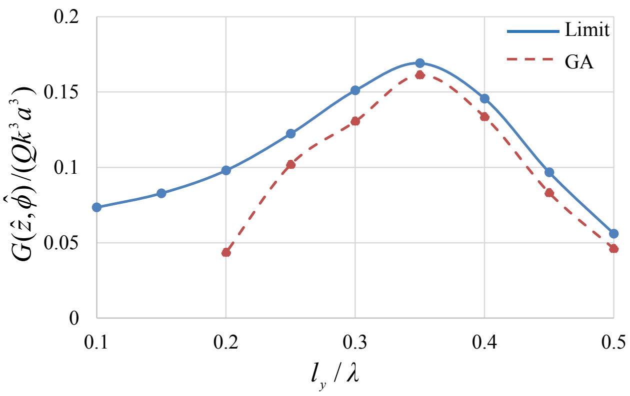

Fig. 5. G/Q for a planer antenna. The solid and broken lines represent G/Q obtained by the physical limitations and the optimized antenna by using GA.