A Genetic-Algorithm Designed Compact Planar Antenna for Dual-Band WLAN Applications

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Abstract

A planar antenna for the dual-band wireless local area network (WLAN) applications is proposed. The antenna is automatically designed by the genetic algorithm (GA) in which the antenna is first divided into small patches and the patches are selected. As the result, both the radiation element and ground plane of the antenna are optimized and a compact antenna is obtained. A prototype antenna shows good performance on the 2.4/5 GHz WLAN bands.
Keywords : Optimization theory Genetic algorithm Dual-band antenna

1. Introduction

In recent years, antennas for small mobile devices such as laptop PCs and cellular phones are strongly demanded to have multiple band operation and high efficiency in spite of their narrow installation space. Planar or film antennas are good candidates for the purpose thanks for their small volume, light-weight and flexibility. However, it is not easy to design such antennas due to their compactness and it will be very helpful to automate their designing process.

To this end, several optimization theories have been proposed for the designing of antennas [1]-[5]. An ultra-wideband printed monopole antenna is designed by using a genetic algorithm (GA) where the radiation element is divided into some trapezoids and a part of the ground plane is treated as chromosomes in [1]. An ultra-wideband monopole antenna is also designed by the GA where the radiation element is divided into small patches which are treated as the chromosomes in [2]. The geometry of a planar inverted-F antenna is optimized by the GA and the positions of feed point, short-pin and the length of the antenna are treated as the chromosomes in [3]. A probe fed microstrip patch antenna is designed by the GA by which broadband operation is realized in a single frequency band in a few iterations [4]. The radiation element of a patch antenna is divided to many small patches which are assigned to chromosomes with a new procedure for rapid convergence and triple band operation is obtained even for a small radiation element [5]. However, the ground plane is not fully taken into consideration in these papers in spite that they are very important in the design of compact antennas.

In this paper, we designed a planar antenna for dual-band wireless local area network (WLAN) operation by using the GA. Not only the radiation element but also the ground plane are divided into small patches and are regarded as chromosomes in the optimization. In this way, desired characteristics of the antenna can be obtained by keeping the size of the antenna as small as possible because the ground plane also acts as a radiator and contributes to the impedance matching. Furthermore, rapid convergence can also be expected. A multiband antenna is designed and fabricated. The calculation is compared with the measurement of a fabricated antenna and good agreement is obtained between them. Radiation efficiency is measured to investigate if the part of the ground plane influences the radiation efficiency or not.

2. Design Scheme

The design scheme of the planar antenna is described as follows. First, we start the design by regarding the antenna as a large rectangular shape which is divided into small patches. Value 0 or 1 is assigned to every piece of the patches where 0 means the remove of the patch and 1 means the remain. The characteristics of the antenna are calculated by the commercial available software Wipl-D™ and a simple GA is applied to control the software from outside.

Generally, a GA has recursive calculation composed of evaluation, selection, crossover and mutation. We perform the algorithm by using the following procedures:

Step 1: Initialize the planar antenna by removing randomly several small patches. Some individuals are prepared by this procedure. This manipulation is executed by arranging the file of the geometry of the antenna by a Fortran program.

Step 2: Evaluate all the individuals and select some of them by using elite and random selections (evaluation and selection). This procedure is done to avoid the convergence to local optimized solution. If the criterion is matched, the calculation is finished.

Step 3: Permute the chromosomes of two individuals selected randomly and generate two offsprings (crossover). One point crossover is adopted in this investigation.

Step 4: Give small disorder to the chromosomes of several individuals in generations (mutation). The number of the mutations is set to relatively small value for avoiding random searching.

Step 5: Repeat procedures from Step 2 to 4 until the criteria is matched. These steps are controlled by a programmed macro.

3. Antenna Structure

An antenna for dual WLAN bands of 2.4-2.48 GHz and 5.15-5.85 GHz is designed by the GA. The initial geometry of the antenna has a dimension of 40×20 mm^2 which is divided into 2mm-square patches. This means that 20×10 patches are used in the optimization. Parameters used in the optimization are set as follows: Optimization object is the voltage standing wave ratio (VSWR), the number of individuals is 20 and the probability of crossover is 0.8. The probability of the mutation for individuals per generation is about 0.14 and the probability of the mutation of chromosomes is 0.015. The fitness function for the evaluation is defined by

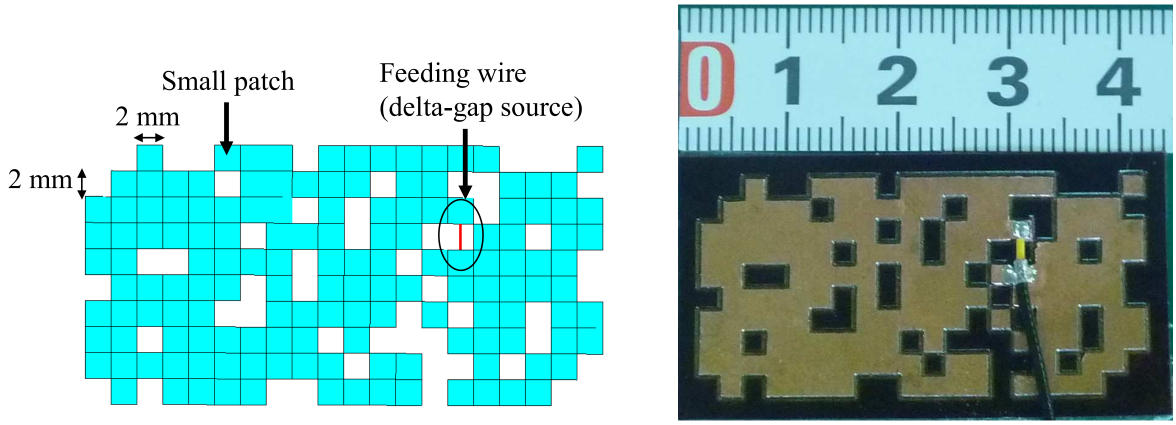
$$F(x_1, x_2) = w_1 x_1 + w_2 x_2 \quad (1)$$

$$x_1 = \max\{\text{VSWR at the lower band}\} \quad (2)$$

$$x_2 = \max\{\text{VSWR at the higher band}\} \quad (3)$$

where w_1 and w_2 are weighted coefficients. In this investigation, w_1 is 0.6 and w_2 is 0.4 because there is a difficulty in matching the impedance of the antenna at the lower band.

The geometry of the optimized antenna is shown in Fig. 1 where the probability of the initial subtraction of patches is 0.3 and the generation of this individual is 20. A feeding wire is connected between two patches and acts as a delta-gap source. The antenna is fabricated on a polyimide (PI) film with a thickness of 125 μm and a dielectric constant of about 3. A coaxial cable with a length of 100 mm is connected to the feeding point.



(a) Optimized model (b) Fabricated antenna

Figure 1: Geometry of optimized dual-band WLAN antenna.

For investigation of convergence, the worst value of the VSWR with the lowest fitness function in generation is shown in Fig. 2 for different probabilities of the initial subtraction. Rapid convergence is observed for probabilities of 0.2 and 0.3. Reason of the fast convergence is owing to the consideration of the ground plane in the optimization.

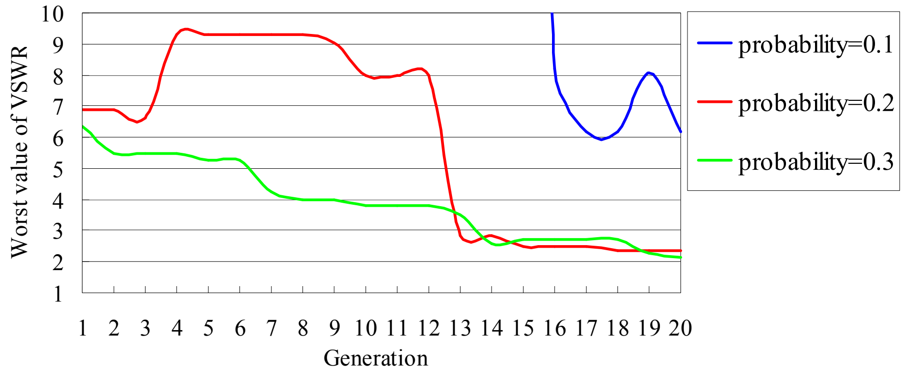


Figure 2: Worst value of VSWR in generations.

Comparison of frequency characteristics of the VSWR between the calculation and measurement is shown in Fig. 3 where reasonable agreement is obtained. The difference between them is due to the influence of the PI film and the feeding coaxial cable. As being seen, multiband characteristics have been actually realized by this method.

Measured radiation efficiency of the optimized antenna is shown in Fig. 4. The efficiency is higher than 75% in all the operation range. Figure 5 shows the radiation patterns at 2.45 GHz. Omni-directional radiation appears so that this antenna is applicable for mobile devices.

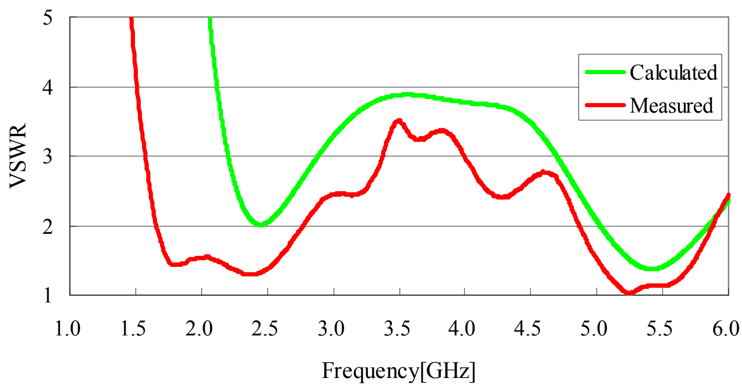


Figure 3: Frequency characteristics of VSWR for the optimized antenna.

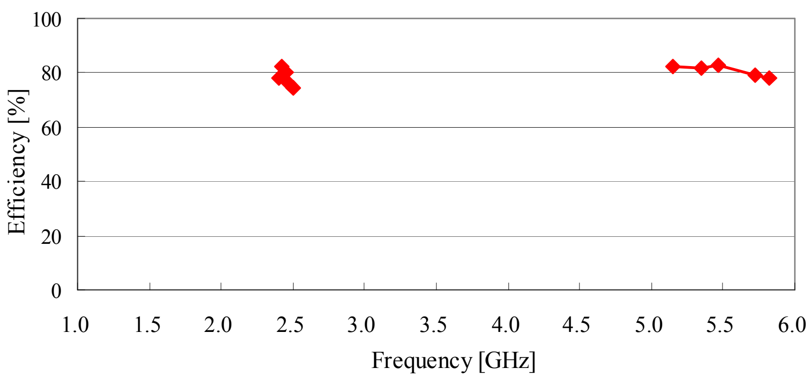


Figure 4: Measured radiation efficiency for the optimized antenna.

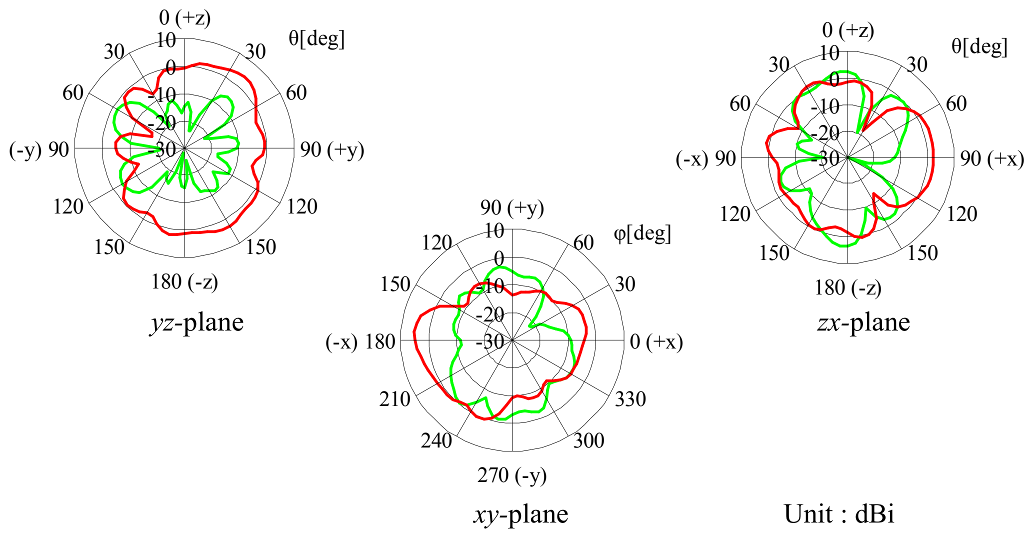


Figure 5: Measured radiation patterns at 2.45 GHz.

4. Conclusion

A planar antenna for dual-band WLAN applications is automatically designed by using the genetic algorithm. The radiation element and ground plane are taken into account in the optimization process. As the result, fast convergence is obtained. The optimized antenna has a compact dimension of 40 × 20 mm^2 and operates in the dual WLAN bands with a radiation efficiency higher than 75% and omni-directional radiation patterns.

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