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Design of a Wideband Microstrip Antenna for Mobile Handset Applications

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An optimum design for a broadband small microstrip patch antenna is presented, showing the agreement between predicted results and measured data

This article summarizes the design, construction and experimental results for a new wideband miniaturized antenna operating in the 1.9 GHz band. This antenna is intended for handset applications, and may also be used as an element in a larger array. Using shorting pins at the zero-potential plane, a compact antenna with a 21 percent bandwidth was designed and tested, with quite good agreement between measured data and the performance predicted by simulation.

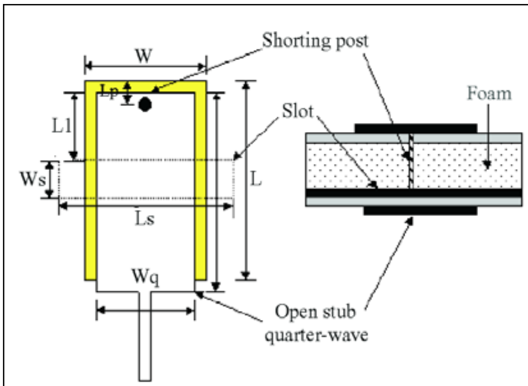

Figure 1 · Geometry of the miniaturized wideband microstrip patch antenna.

Introduction

Future personal communications systems (PCS) will use mobile handsets with antenna arrays for spatial processing. This type of applications places more constraints on compactness and pattern control of each antenna element. To meet these demands, printed microstrip antennas have recently been proposed for applications in the 1.9 GHz band [1], but their size is not yet small enough to be implemented in a mobile handset application. For this reason, recent studies have proposed using special substrates with a high dielectric constant for reducing microstrip antenna size [2]. However, using high dielectric constant substrates increases the surface wave effect, which yields poor performance in terms of radiation efficiency.

One effective way to reduce antenna size is to use a shorted quarter wavelength patch [3]. This approach takes advantage of the fact that the electric field component beneath the patch—between the patch and the ground plane—is approximately a cosinusoidal function of the length. It has a maximum value at the edge, goes to zero at the middle plane, and returns to a maximum at the other edge. Because the electric field is null at the middle plane, a short circuit can be placed at this position without affecting the antenna's basic operations. This short circuit at the zero-potential plane reduces the size of the microstrip antenna to half of its original length. It is not necessary to short the whole zero-potential plane; only a few points of this plane need to be shorted. This can be done by simply using shorting pins between the patch and the ground plane [3]. For this configuration, a coaxial probe is often used to feed the patch antenna, with good impedance matching achieved when the shorting pin is close to the probe. However, the use of coaxial probes increases the difficulty of manufacturing this antenna. In addition, the typical design of this antenna does not offer enough bandwidth to

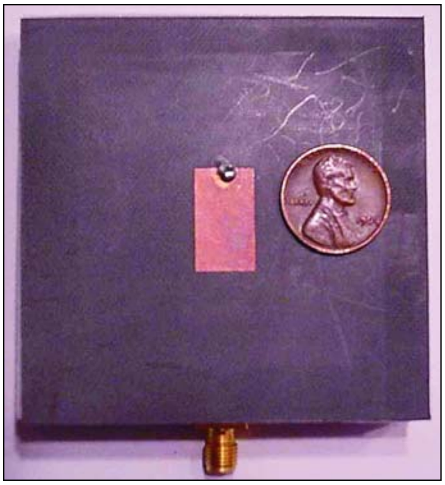

Figure 2 · Photograph of the prototype of the miniaturized patch antenna.

satisfy the needs of high data rate modern communications systems such as 2.5G and 3G PCS.

Design Approach

The approach described here uses a multilayer structure combined with an aperture feeding technique for improving bandwidth. The coaxial probe used as the feedpoint in previous versions has been replaced by an aperture coupling slot [2], which does not require the probe to penetrate through the substrate layer. Under these conditions, it has been noted that the shorting pins of the antenna appear as an inductive reactance rather than a pure short circuit, as is the case for the shorted plane. To compensate for the effects of this inductance, the patch dimensions must be adjusted.

Thus, a new small wideband patch antenna fed via a wide coupling slot located on the ground plane was developed for this experiment. To achieve a wide bandwidth, a low dielectric constant substrate and low permittivity foam were used to build the prototype antenna. With this approach, we achieved a bandwidth of 21 percent around the center frequency. In single-element form, this type of antenna could be used to replace conventional wire antennas. The patch antenna could be located in the phone handset by integrating it into the printed circuit board (PCB) or incorporating it into the plastic case of the phone. For future handsets that require more gain and space diversity, this antenna design could be used for the individual elements in miniature antenna arrays.

Antenna Implementation and Performance

Figure 1 (on the previous page) shows the geometric configuration of the proposed antenna. To achieve a large bandwidth, a foam layer was used between two substrate layers as shown in the illustration. The rectangular patch has been etched in the top layer. This first layer, which is followed by hard foam, supports the microstrip feed line on one side and the ground plane with coupling aperture on the other side, as illustrated in the figure.

Two methods were considered for implmenting the short at the middle plane of the antenna. In the first design, only one shorting post was used, as shown in Figure 1. In the second case, three pins were employed in the antenna structure, resulting in a 60 percent increase in VSWR bandwidth.

To examine the performance of this new antenna, a prototype was built composed of three layers. The first layer uses 0.787 mm RT/Duroid 5880 ($\varepsilon_r = 2.42$). This layer is followed by a hard foam of 12.7 mm thickness with a dielectric constant $\varepsilon_r = 1.07$. The last layer uses 1.27 mm Rogers R06006 ($\varepsilon_r = 6.15$). This high-dielectric constant material allows us to reduce the radiation from the feedline. The dimensions of the patch, feedline, and coupling aperture are as follows:

Patch: W = 10.2 mm, L = 17.35 mm.
Aperture slot: $L_s = 19.2$ mm, $W_s = 3$ mm, $L_1 = 6.175$ mm
Feed line parameters: $W_q = 9.2$ mm, $L_q = 17.38$ mm
Pin parameters: $L_p = 0.95$, r = 1.63, N = 1.

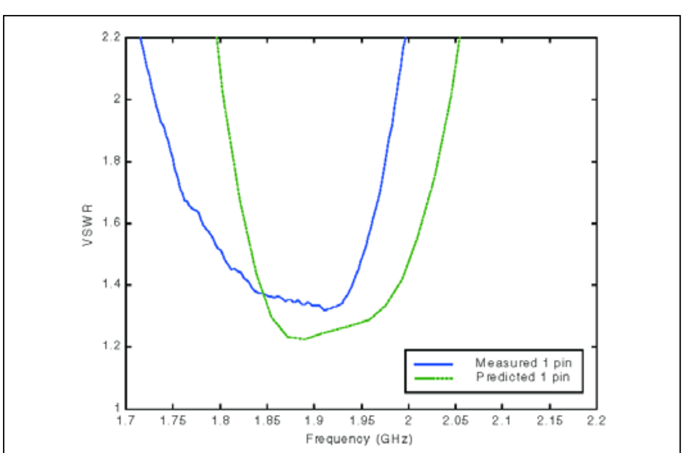

Figure 3 · Predicted and measured VSWR of a miniaturized microstrip antenna with one shorting post.

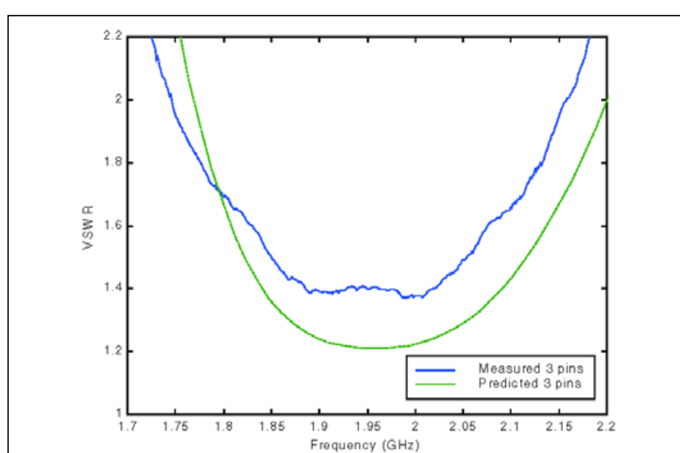

Figure 4 · Predicted and measured VSWR of the second antenna prototype with three shorting posts.

A photograph of the antenna prototype is shown in Figure 2.

The predicted and measured VSWR for the first antenna prototype (with one shorting pin) is shown in Figure 3. The 2:1 VSWR measurements exhibit approximately 13 percent relative bandwidth around the center frequency; F_0 = 1.9 GHz. Computed results predicted a bandwidth from 1.81 GHz to 2.04 GHz, yielding a relative bandwidth of 12 percent. From these curves, it can be concluded that there is a good agreement between measured data and predicted results. However, there was a slight shift between experimental and predicted results, mainly due to the influence of the position of the shorting pin. To correct this situation, some tuning or greater precision in fabrication will be necessary in final production. The antenna's length (L) is 17.35 mm, which represents a 69 percent reduction over the conventional $\lambda/2$ microstrip antenna at the same operating frequency. With this configuration (one shorting pin), a bandwidth of 13 percent (VSWR 2:1) can be achieved, which is sufficient for PCS applications.

For other wireless applications where more bandwidth is needed, a second antenna prototype with three pins was built using the same substrates as the first one. The computed and measured VSWR for this second prototype is shown in Figure 4. A computed bandwidth (VSWR <2:1) from 1.772 GHz to 2.2 GHz (21.5 percent) agreed quite well with a measured bandwidth from 1.75 to 2.172 GHz (21.5 percent). From these results, it can be concluded that the first prototype is recommended for PCS cellular phones, but for applications where more bandwidth is required, multiple shorting pins can be used to give 21 percent bandwidth. However, the use of multiple shorting pins creates many more difficulties for actual production.

References

1. Denidni, T. A., and Hotton, M., "Experimental Investigations of Broadband Microstrip Antenna for PCS Applications," *IEEE Vehicular Technology Conference*, 1999, Huston, USA, Vol. 3, pp. 1764-1767.

2. Lo, T. K., Ho, C. O., Hwang, Y., Lam, E. K. W., and Lee, B., "Miniature aperture-coupled microstrip antenna of very high permittivity," *Electron. Lett.*, 1997, vol. 33, pp 9-10.

3. Waterhouse, R. B., Targonski, S. D., and Kokotoff, D. M., "Design and Performance of Small Printed Antennas," *IEEE Trans. Antennas and Propagation*, 1998, Vol. 46, pp. 1629-1633.

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