Experimental Study on Compact, High-Gain, Low SAR Single- and Dual-Band Patch Antenna For Cellular Telephones

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Abstract

The presence of the human head and hand significantly alter the performance of cellular telephones. A considerable fraction of the power (30-70 percent) is generally absorbed by the human body, causing SAR concerns and drastic reduction in antenna efficiency. The use of high-gain, broad-band, microstrip patch antenna would alleviate the problem, leading to low SARs without decrease in radiating performance of the cellular telephone. In this paper we present experimental and numerical results on one single-band and one dual-band microstrip patch antennas designed in our laboratory. Results show that these antennas, mounted on a box simulating the handset, are characterized by radiating performance comparable to, or better than, typical cellular telephones. Moreover, the patch antenna handsets induce very low SARs in the human head compared to those of similar handsets equipped with typical whip antennas. Because of the reduced absorption in the head and resulting lower SARs, the patch antennas will require less power leading to longer battery life.

Introduction

The expanding use of cellular telephones has caused public concern about safety of EM power deposition in the head. The U.S. Federal Communication Commission (FCC) has recently established new SAR regulation that all new cellular telephones must comply [1]. Specifically, the SAR as averaged over any 1 g of tissue in the head must be lower than 1.6 W/kg. While many cellular telephones induce SARs below this value, it is in anycase desirable to minimize the power deposition in the head. This would not only eliminate the problem of safety concern of the user, but would also improve the performance of the handset that will then require lower power than that used to date.

A possible solution toward this direction is represented by microstrip patch antennas. When mounted on the handset on the side away from the human head, they intrinsically radiate much less power in the direction of the human head than the whip antenna typical of present day cellular telephones. This is not a limitation, since the power radiated in the direction of the head would mostly be absorbed causing decrease in antenna efficiency and higher SARs.

The microstrip antennas designed in our laboratory cover the desired wireless bands, i.e. 825-895 and 1850-1930 MHz, maintaining a low VSWR and high gain.

Dimensions and Fabrication of the Antennas

Both of the designed antennas are stacked microstrip patches, and both of them are characterized by an overall thickness of 4.8 mm. The dimensions of the lower patch of the dual-band antenna (835 - 1900 MHz) are 3.3 x 2.5 cm, while those of the single-band (1900 MHz) antenna are 2 x 1.6 cm. Both antennas use Duroid as dielectric and are fed with SMA connectors passing from bottom to the top patch. Three shorting pins are used on top and bottom patches in order to reduce the size of these antennas.

Experimental Set-Up

The radiation pattern measurements are carried out inside an anechoic chamber. A stepper motor driven computer-controlled system has been installed in it and is capable of completing the measurements in less than eight minutes. The box on which the antennas are mounted is made of plastic of dimensions 3.8 x 5.1 x 15.2 cm, and the antenna is mounted on the side away from the head. The box is coated with silver paint on the inside for all of the surfaces. Both vertically and horizontally polarized components have been measured with and without the head model with the handset held vertically and at a slanted angle of 30^{o}.

The peak 1-g SAR is measured by using an automated SAR measuring system that has been validated against FDTD-calculated SAR distributions for canonical geometries such as a phantom-filled rectangular box and a sphere.

Lastly, SWR measurements are carried using an HP8510 Network Analyzer.

Results

The measured VSWR of the dual-band patch antenna is given in Fig.1. It is possible to observe that both bands (825-895 MHz, 1850-1930 MHz) are characterized by a VSWR mostly lower than 2. The gains (in dBi) of the same antenna are given in Table 1, with and without the human head model, for vertical and horizontal polarization. It is possible to observe that the patch antenna is characterized by higher gain for all the considered cases compared to that of a typical monopole-whip antenna. It is very interesting to notice that the gain of the horizontally-polarized component is considerably higher, especially at 835 MHz, than that of the typical whip-type antenna. This is a considerable advantage, since in many real-life situation the handset could be in a position such as to be insensitive to the vertically polarized component of the base station. The radiation pattern performances with the head model of the two considered antennas at the 830 MHz frequency are also compared in Fig.2 (vertical polarization) and 3 (horizontal polarization). It is possible to note that the vertical polarization patterns for patch and for monopole-whip antenna are very similar, with the gain of microstrip antenna even higher than that of the monopole-whip antenna for all the side away from the human head model. Moreover (Fig. 3), the far-field pattern of the horizontally polarized component of the patch antenna is superior in all the direction compared to that of the typical whip-type antenna.

The measured and FDTD-computed 1g SARs for the dual-band patch antenna are, respectively, 0.03 and 0.06 W/kg at the PCS frequency of 1900 MHz, while a 1g SAR of 0.5 W/kg has been calculated for the 835 MHz band.

Conclusions

We have presented some results on the performance of patch antennas for mobile telephones designed in our laboratory. These antennas give drastically reduced SARs in the human head while maintaining comparable and somewhat superior radiation characteristics.

References

[1]. Federal Communication Commission, "Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation," FCC 96-326, Aug.1, 1996.

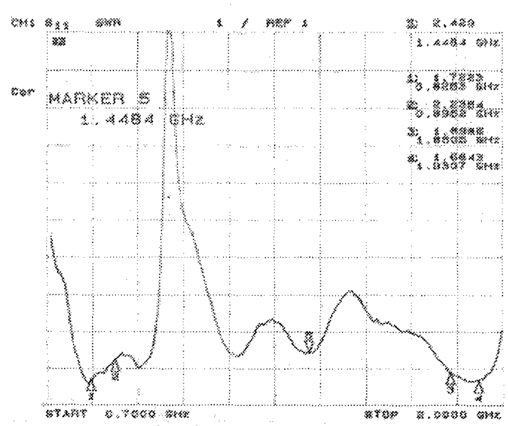

Fig.1: Measured VSWR of the dual-band patch antenna

Table 1: Measured gains in (dBi) of the dual-patch antenna and a commercial monopole-whip antenna with and without the head model

Frequency			Patch Antenna	Monopole-Whip Antenna
830 MHz	Vert. Pol.	With Head	3.04	0.10
		Without Head	2.12	1.98
	Horiz. Pol.	With Head	-3.21	-10.63
		Without Head	-4.88	-14.04
1900 MHz	Vert. Pol.	With Head	3.48	-0.30
		Without Head	2.79	1.23
	Horiz. Pol.	With Head	-7.15	-8.74
		Without Head	-8.06	-15.5

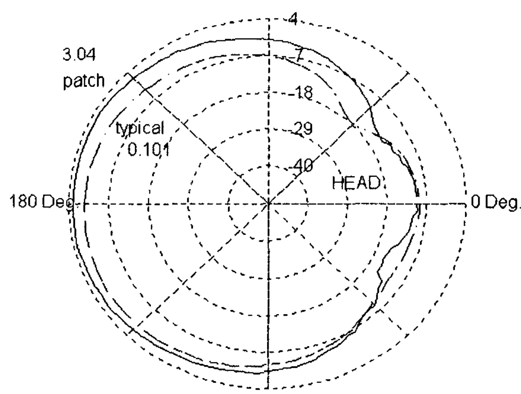

Fig.2: Comparison of the radiation pattern for the vertically polarized component at 830 MHz with the head model. Note the higher gain 3.04 dBi for the patch antenna as against 0.101 dBi for the typical whip antenna used for a commercial telephone

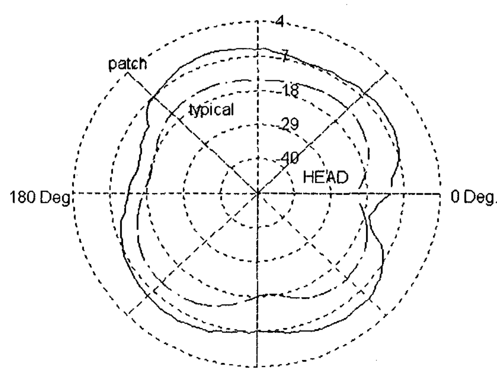

Fig.3: Comparison of the radiation pattern for the horizontally polarized component at 830 MHz with the head model