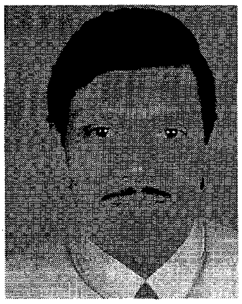
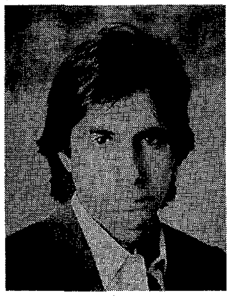
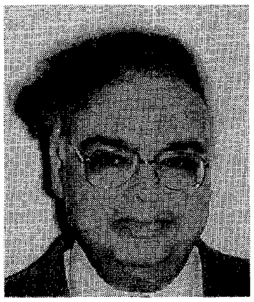
Tom Milligan
Miligan & Associates
8204 West Polk Place
Littleton, CO 80123
(303) 977-7268
(303) 977-8853 (Fax)
Tmilligan@compuserve.com (e-mail)



Shyam S. Pattnaik



Gianluca Lazzi



Om P. Gandhi

Editor's introduction

The power radiated into the head of a mobile-telephone user from the antenna is a prime consideration for design. The group at the University of Utah has measured the level of the power radiated into the head. They found that the microstrip-patch antenna they have built reduces this loss, compared to a monopole, and increases the margin of safety. Although the fields inside the head have been calculated using FDTD, our thanks to Shyam S. Pattnaik, Gianluca Lazzi, and Om P. Gandhi for providing us with measured results that point to a solution.

On the Use of Wide-Band, High-Gain, Microstrip Antennas for Mobile Telephones

Shyam S. Pattnaik, Gianluca Lazzi, and Om P. Gandhi
Department of Electrical Engineering
University of Utah
50 S. Central Campus Dr., Rm. 3280
Salt Lake City, UT 84112-9206 USA
Tel: (801) 581-6941
Fax: (801) 581-5281
E-mail: pattnaik@ee.utah.edu

1. Introduction

The ever-increasing use of cellular telephones has spawned considerable research effort on the design of compact, high-efficiency antennas for mobile telephones, exhibiting low EM coupling to the human head. Microstrip antennas seem now to render possible the achievement of all these characteristics. We present in this note some recent results on a stacked microstrip antenna designed in our laboratory, comparing its performance with that of a typical handset equipped with the conventional monopole antenna. The authors' main thrust is to highlight the problems associated with today's typical mobile-telephone antennas, and to show how microstrip-antenna technology could solve most of these problems.

Results show that the microstrip antenna is capable of maintaining high gain in the presence of the human head. They also show that the directionality of the radiation pattern would help in reducing the power absorbed in the human head (typically by 30-50 %), contributing to reduced SAR (specific absorption rate) and extended battery life.

2. Experimental measurements

The experimental measurements were carried out by using a computer-controlled automated system, capable of giving a fully annotated radiation pattern in less than eight minutes. The system is capable of considering realistic user conditions of exposure (a tilted handset and/or the presence of the human hand).

For the analysis presented in this contribution, we have considered a commonly available cellular telephone (with the antenna pushed in and pulled out), and a stacked-patch antenna, mounted on the side of a box fabricated for the purpose. The microstrip antenna was mounted on the shielded side of the box, i.e., the side opposite to that of the human-head model, in a position close to the top of the handset. Shorting pins were used to reduce the dimensions of the antenna, which measured even less than $\lambda_0/10$ at 835 MHz (3.4 cm × 2.5 cm).

The measurement system had been previously validated against measurements provided by cellular-telephone manufacturers and Finite-Difference Time-Domain (FDTD) computations [1].

3. Results and observations

Figure 1 shows the measured VSWR of the microstrip antenna. As seen there, the antenna was characterized by a large bandwidth, rendering possible its use for USA (825-895 MHz) as well European (890-960 MHz) frequencies. The antenna was also well-matched in the 1900 MHz band (1850-1970 MHz), giving the possibility of using it as a dual-mode antenna.

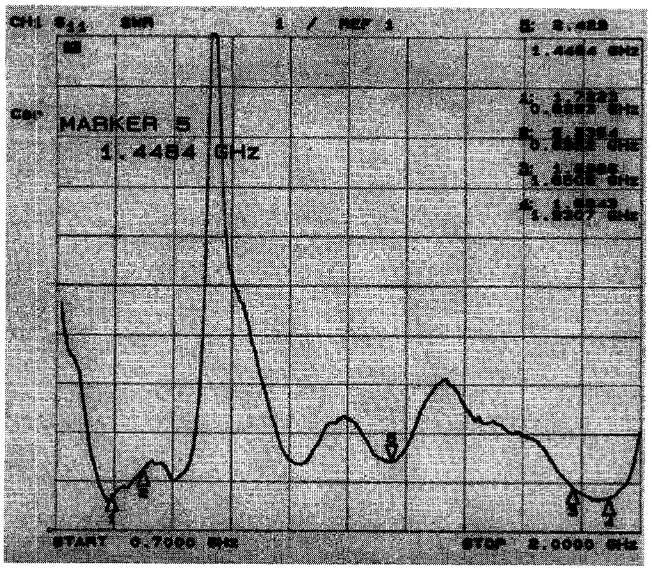


Figure 1. The measured VSWR of the microstrip antenna designed in our laboratories.

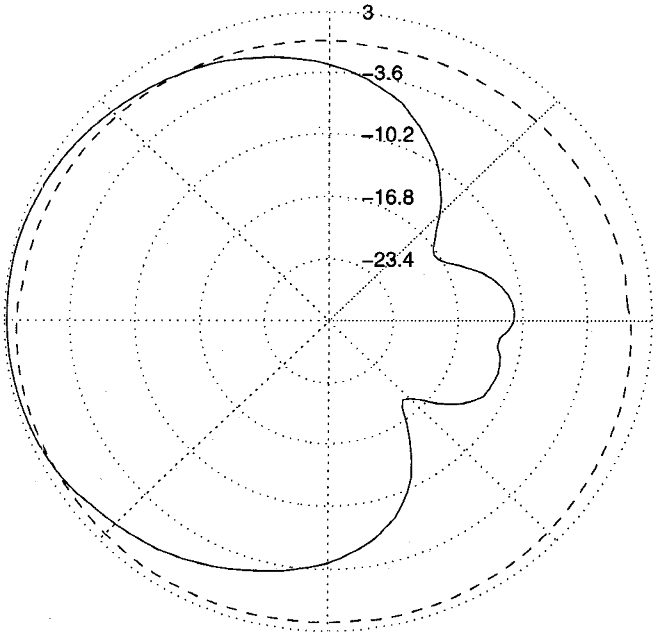


Figure 2. The measured radiation pattern, in air, of the microstrip antenna, mounted on a cell-phone box (solid line), compared to that of a typical mobile telephone with a monopole antenna, pulled out (dashed line).

Figure 2 shows the radiation pattern, in air, of the microstrip antenna, mounted on a cell-phone box, compared to that of a commercial mobile telephone with a monopole antenna, pulled out. It can be observed that the radiation pattern of the handset with the patch antenna had a higher gain on the side opposite to that of the human head, while exhibiting a lower gain on the side of the earphone. This characteristic is highly desirable, since in real conditions of use, the radiated fields through the human-head model are already greatly diminished by the presence of the human head. The gain in the first and second quadrants in such a condition decreases considerably for typical cellular telephones, because of significant absorption in the human head. It has also been observed that the gain of the typical telephone antenna decreases by 0.4 to 0.8 dBi, when tilted 30° with respect to the vertical position, in air, and 1 to 2.5 dBi in the presence of the human head. Instead, the microstrip-antenna handset showed low radiation in the first and second quadrants, and low coupling to the human head in real conditions of use. These observations are demonstrated in Figure 3, where the radiation patterns of the same two handsets are given in the presence of the human-head model. While the efficiency of the typical handset decreased considerably, the radiation pattern of the patch-antenna handset remained virtually unaltered. This also showed a slight benefit from the presence of the head model, probably due to reflections from the head.

Table 1 summarizes these observations, giving a comparison of the maximum gains obtained with the patch antenna and typical antenna handsets, in various operating conditions. The case of the antenna being pushed-in, for the case of a typical handset, was also considered, this situation being fairly common in a typical situation

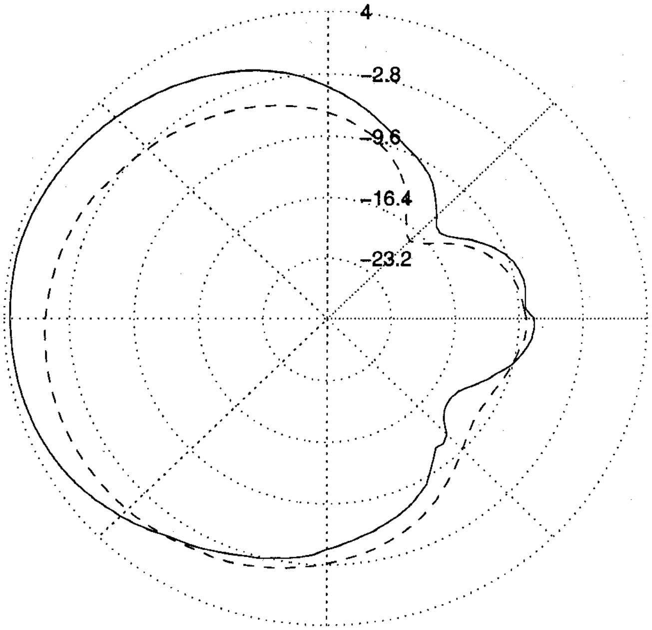


Figure 3. The measured radiation pattern, in the presence of the human head, of the microstrip antenna, mounted on a cell-phone box (solid line), compared to that of a typical mobile telephone with a monopole antenna, pulled out (dashed line).

Table 1. The measured maximum gain for the microstrip-antenna telephone and a typical cellular telephone, with and without the human-head model, for various conditions of use. Except where noted, all of the numbers are for the vertical configuration of the telephone, relative to the head.

Case	Co-Polar Gain (dBi)	Cross-Polar Gain (dBi)
Microstrip - Air	2.79	-8.06
Microstrip - Head	3.48	-7.15
Microstrip - Head (30° tilt of the phone)	2.70	-2.80
Typical - Air	2.10	-14.04
Typical - Head	0.10	-10.63
Typical - Air (antenna pushed in)	0.59	-13.51
Typical - Head (antenna pushed in)	-0.94	-9.99

of use. We can observe that the microstrip antenna handset was characterized by a higher gain for all the cases considered. Since the gain achieved with the microstrip antenna was higher, battery life could be longer, because of reduced radiated power. It is interesting to note that the cross-polar gain was significantly higher for the microstrip antenna, and particularly for a realistically tilted configuration of the antenna relative to the head, which would lead to better transmission capabilities in a multi-path environment.

Finally, initial FDTD simulations showed that the power absorbed in the head with such an antenna was lower than 15%, with a good margin for improvement, against 30 - 55% for today's typical cellular telephones. More investigation will be done in the near future to prove the better possibilities of the microstrip antenna for considerably reducing the SAR induced in the human head.

4. Conclusions

Realistic conditions of use render the design of high-gain, well-matched antennas in the presence of the human head imperative. Concern for the user's safety also plays a crucial role in the design of low-SAR mobile-telephone antennas, and slightly directional radiation characteristics could help in reducing the SAR deposition in the human head. Microstrip antennas seem to have suitable characteristics to achieve better antenna performance from all these points of view, leading also to the possibility of realizing devices working in a multi-frequency mode.

5. Acknowledgement

The help of Mr. J. Johnson during the experimental measurements is thankfully acknowledged.

6. Reference

1. G. Lazzi, S. S. Pattnaik, C. M. Furse, and O. P. Gandhi, "Comparison of FDTD-Computed and Measured Radiation Patterns of Commercial Mobile Telephones in Presence of the Human Head," submitted to *IEEE Transactions on Antennas and Propagation*.

Ideas for Antenna Designer's Notebook

Ideas are needed for future issues of the *Magazine*. Please send your suggestions to Tom Milligan and they will be considered for publication as quickly as possible. Topics can include antenna design tips, equations, nomographs, or shortcuts as well as ideas to improve or facilitate measurements.

Special Offer to Contributors

How would you like a complete set of the Antenna Designer's Notebook articles published since this column began, in the August, 1983, issue? Send an idea which is used for a future issue of our Notebook to Tom Milligan, and you will be rewarded with a notebook containing copies of all items, **including yours**, when it is published. This column is a **great opportunity** for many of our AP-S members who are too busy to publish a lengthy paper, but who would like to share some **practical information** which can help to increase the productivity of the antenna and propagation engineers.

Updated Table of Contents

An updated Table of Contents for the Antenna Designer's Notebook was published in the August, 1983, issue of the *Magazine*.

Richard Dowden Awarded Sidey Medal

Richard L. Dowden was awarded the 1997 T. K. Sidey Medal of the Royal Society of New Zealand at a ceremony held in Dunedin, New Zealand, March 16, 1998. The citation stated that he received the award "for his pioneering work in the use of electromagnetic waves as probes of the Earth's atmosphere, upper atmosphere, and magnetosphere." John Lekner was also awarded the medal at the same time for his work in optical phenomena.

The Sidey medal is awarded at irregular intervals for outstanding scientific research concerning electromagnetic radiation. Such research may include interaction with matter, its impact on living organisms, its use in communications, or its application in any other manner beneficial to human welfare. While the original terms of the award pertained to solar electromagnetic radiation in particular, the Royal Society of New Zealand takes the broad view that the work may be related to electromagnetic radiation of any wavelength, and, from time to time, it may award the medal for research involving radiation of any kind. Previous recipients of the medal (and the year awarded) are as follows: Ernest Rutherford (1933), George Vernon Hudson (1933, special award), Leonard Hill (1936), David Forbes Martyn (1947), Victor Albert Baley (1951), Henry Arthur Whale (1955), John Hobart Piddington (1959), Walter Sidney Metcalf (1966), Norman Jack Rumsey (1973), Roy Fergus Benseman (1977), Ian James Warrington (1984).

Richard Dowden was born September, 21, 1932, in Boorowa, Australia. He received his BSc (Hons) at Sydney University and his MSc, PhD, and DSc at the University of Tasmania. He was appointed Professor of Physics, University of Otago, New Zealand, in August, 1965. He took this post in January, 1966, and held it until retirement in January, 1998. He remains "advisory" supervisor of his PhD students. His research has been in radio science for over 40 years. He was founder and Editor-in-Chief of *The Radioscientist*, and Vice President of URSI, 1990-1996. Just before retirement from the University of Otago, he set up his company, "Low Frequency Electromagnetic Research," to service his current research contract and enable bidding for new ones.