Dual-Band Antenna with Minimalization of Radiation Towards Head

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ABSTRACT

Intensive development of cellular personal communications system has been observed lately. Thus, protection of a man, and especially protection of his head against non-ionizing electromagnetic radiation generated by cellular telephones is becoming one of the most important problems. The results of elaborated microstrip antennas which have minimized radiation towards the user’s head are presented in this paper.

1. INTRODUCTION

Wireless communication has been the fastest growing sector of telecommunication in recent years. Substantial contributions to this growth has been made in Europe, where many such systems have been developed: GSM (Global System for Mobile Communication), operating in the 900 MHz band, DCS-1800 (Digital Personal Communication System), using the 1800 MHz band DECT (Digital European (Enhanced) Cordless Telecommunications, using the 1900 MHz band and UMTS (Universal Mobile Telecommunications System) working in band circle about 2 GHz. Some experts predict that by the end of new century there will be more cordless than conventional telephones in use. In order to achieve an easy access to information, more and more modern cellular phones, which are able to work in two or three bandwidths, are being invented. This is why it is important to determine possible health effects of using such devices. New trends require antennas to be cheap to produce and to meet tough operational requirements. The following requirements should be met by the antenna:

- a radiation pattern ensuring reliable communication regardless of the antenna’s orientation;
- a wide operational frequency band, so that the spectrum of transmitted information should not be distorted;
- a minimum impact on the biological tissue of the user, to avoid health risks;
- little sensibility of the antenna parameters to the user’s proximity;
- small size to facilitate mounting the antenna and using the telephone.

It is clear that some of these requirements are mutually exclusive, so a compromise has to be worked out in the designing process.

II. REQUIREMENTS CONCERNING THE ANTENNA RADIATION PATTERN

Presently, there are no formal requirements in force or informal requirements accepted by specialists concerning the recommended radiation pattern. The problem is further compounded by the fact that the user’s head is in the near zone of the antenna (Table 1).

<table>
<thead>
<tr>
<th>Class mobile station</th>
<th>Distance from mobile station</th>
<th>Limited power density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 m</td>
<td>1 m</td>
</tr>
<tr>
<td>GSM 900 (0.8 W) Class 5</td>
<td>0.386 W/m²</td>
<td>0.09 W/m²</td>
</tr>
<tr>
<td>GSM 900 (2 W) Class 4</td>
<td>1.06 W/m²</td>
<td>0.26 W/m²</td>
</tr>
</tbody>
</table>

There is concern about possible health effects of the field generated by the cellular phone, placed so close to the user’s head. These are not groundless fears. Research conducted so far on the effects of the PEM energy on living organisms suggests that electromagnetic energy, regardless of its amount, affects the human body. Its impact is harmless as long as it remains within the adaptation,
compensation and regeneration capabilities of man, but may be harmful when it exceeds the limits of tolerance. The point is to make sure that signals emitted by a base station are correctly received from all directions and that the user’s head (especially bones, the brain and skin, which have a high level of thermal conductivity - 14.6, 8.05, 4.42 mW/cm²K respectively) is exposed to as little radiation power as possible.

A considerable part (45%) of energy, emitted by cellular phones now in use, is absorbed by the user’s head, which is a health risk [L-3]. An important task is to protect users against radiation from cellular phones, which can be achieved in two ways:

- by reducing the power of electromagnetic field emissions towards the head to the necessary minimum,
- by limiting the time of exposure to such fields.

The latter condition is connected with the duration of the call, which depends largely on the user. The former condition, i.e. cutting down the amount of radiation power absorbed by the user’s head, can be met - among other things - by modifying the omnidirectional radiation pattern of the antennas used in cellular phones so far. A compromise has to be reached between the requirements regarding the availability of signals received by the antenna from all directions and the protection of user’s head against radiation. It is assumed that the radiation pattern is as shown in fig.1.

![Figure 1. Requirements for antenna radiation pattern](image)

One of the ways of achieving this result is to replace stub antennas with an omnidirectional radiation pattern, popularly used in cellular phones, by antennas with a radiation pattern shaped in such way as to reduce radiation towards the user’s head. Such antennas should be relatively small to be fit for use with cellular telephones. Microstrip antennas on a multilayer dielectric meet all these requirements.

### III. MODELLING OF MICROSTRIP ANTENNAS

The throughout analysis of microstrip antennas which takes into account the structure of the layer and which is true for each frequency, is based on Green function and moment method. This method is based on solving the integral equation concerning the electric field generated by the currents flowing in the antennas element and its feeding systems. We simulate the flow of inducted current by means of distribution for base and test currents, then we test their mutual reaction by means of the functions. According to [L- 5] the reaction has the form of:

$$z_{mn} = - \langle J_m, J_n \rangle = - \int \int (E_m \cdot \nabla J_n) \, dx \, dy = - \int \int (E_{mx} J_{nx} + E_{my} J_{ny}) \, dx \, dy$$

(1)

The unlimited sequence of these functions is necessary for exact solution. We assume the limited number of these functions and, thus we obtain on approximate solution. The mutual reaction of the whole-analysed system can be expressed in the form of a matrix equation:

$$\begin{bmatrix}
I_1 \\
I_{M+1} \\
. \\
0.
\end{bmatrix}
\begin{bmatrix}
Y_{1,1} & \ldots & Y_{1,2M+2,2N+2} \\
. & \ddots & . \\
. \\
Y_{1,2M+2,2N+2} & \ldots & Y_{2M+2N+2,2M+2N+2}
\end{bmatrix}
\begin{bmatrix}
0 \\
V_{M+1} \\
. \\
0.
\end{bmatrix}$$

(2)
By solving this equation, we define the distribution of the currents flowing along the analysed structure on condition that the elements of general matrix impedance are now in our case they have the form of:

\[
 z_{nm} = -(2\pi)^2 \cos \vartheta \cdot F^{-1} \left[ F\left( G_{xx} \right) F\left( J_0 \right) F'\left( J_0 \right) \right] \left( x_m - x_n, y_m - y_n \right) + \n
+ (2\pi)^2 \sin \vartheta \cdot F^{-1} \left[ F\left( G_{yy} \right) F\left( J_0 \right) F'\left( J_0 \right) \right] \left( x_m - x_n, y_m - y_n \right) = \frac{1}{Y_{nm}}
\]

where:
- \( F\left[ G_{xx,yy} \right] \) - Fourier transform of Green function
- \( F\left[ J_0 \right] \) - Fourier transform of base current
- \( \sin \vartheta, x_n, y_n, x_m, y_m \) - respectively, the co-ordinates of the situated means of base and testing functions.

With the defined current distribution we can express the radiation pattern in the dipole plane by the following equation:

\[
 \vec{E}(\varphi) = \sum_{n=1}^{N} I_n \left[ \vec{E}(J_n) \right]
\]

where:
- \( I_n \) - coefficient of current distribution

The microstrip antennas patterns (presented in fig. 2.) have been calculated on the basis of these relationships.

IV. CONSTRUCTION OF MICROSTRIP DIPOLE ANTENNAS ON A MULTILAYER DIELECTRIC

The dipole antenna is designed to operate in the 900 MHz band, but the same technology can also be used to design the antennas for other bands, e.g. 1900 MHz. It was constructed in the multilayer technology mainly to ensure an adequately wide operating band (ca 10%). Due to small size requirements (mobile communication systems) two versions of dipole antennas were constructed and tested:

- open circuit half-wave dipole
- short circuit quarter-wave dipole.

These antennas are shown in fig.2.

![Figure 2. Dual band microstrip antenna.](image)

It is expected that the radiation pattern of the quarter-wave antenna in the E plane will be wide enough to achieve optimum antenna parameters. Results of measurements and calculation of antenna with feeding from an unsymmetrical strip line are shown in fig.3. Fig 3a,b presents the results of measurements of impedances and fig 3c the results of measurement of standing wave ratio. In fig 3d
characteristics of measured and theoretical radiation pattern for frequency band 900MHz are presented, and in fig 3e for frequency 1900 MHz

![Graphs of frequency, resistance, reactance, and standing wave ratio](image)

- a) Resistance
- b) Reactance
- c) Standing wave ratio
- d) f = 851 MHz
- e) f = 1965 MHz

Radiation pattern in free space
1- Theoretical characteristic
2- Measurement characteristic

Figure 3. Measurement results of dipole antenna with a microstrip feedline

The measurements were made in free space and in the presence of a user, in order to simulate a real life situation. The user stood on a rotating platform, holding the phone at 45° to the ground level.

V. CONCLUSIONS

The investigation confirmed that the antennas described here may be used in cellular phones operating in the 900 MHz band and in the 1900 MHz Radiation in the direction of the user’s head is reduced in all the examined antennas, which was the main goal of the research work. It was assumed that a currently used antenna will be replaced by a new one, without any changes in construction of mobile phone. A new design of mobile phone will be made in close future.

REFERENCES