A New Effective Antenna for Mobile Headsets

M. Bank, M. Haridim, S. Tapuchi. J. Gavan
HIT-Holon Institute of Technology, Sami Shamoon College of Engineering
bankmichael1@gmail.com

Abstract.
The main problems concerned with the design of mobile headsets antennas treated in this paper are low efficiency and the difficulty of installing two antennas or more for Multiple Input-Multiple Output (MIMO) applications. This paper proposes a radical solution to the mentioned problems by avoiding the use of special antennas as radiating elements. The proposed efficient radiating element is the mobile headset printed circuit board. The proposed solution is compared with other classical solutions.

***Keywords*—** MB antenna, dipole, monopole, PIFA, mobile headsets.

I. Dipole and monopole in small ungrounded devices.

The effective antenna for small handsets is a dipole as shown in Figure 1a. Less effective but more handy is a monopole as shown in Figure 1b[1].

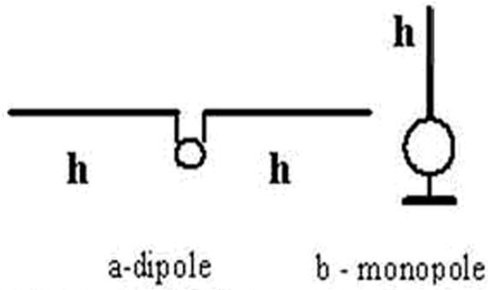


Figure 1. Dipole (a) and monopole (b)

They have the following basic parameters [1]:
Dipole h = l/4:
Rrad = Ra =73.2W, G = 2.15 dB, he = l/p.
Dipole h << l/4:
Rrad @ 20(mh)2W, G = 1.76 dB, he = h.

Monopole h = $\lambda/4$ in open space:
Rrad ≅ 52Ω, he = $\lambda/2\pi$.
Monopole h << $\lambda/4$ in open space:
Rrad ≈14(mh)2Ω, he = h/2.
Monopole h = $\lambda/4$ above ground in transmitter:
Rrad ≅ 36Ω, G = 5.15 dB, he = $\lambda/2\pi$.
Monopole h << $\lambda/4$ above ground in transmitter:
Rrad ≅ 10(mh)2Ω, G = 4.76 dB, he = h/2.

Where h - length of antenna, λ - wave length, h_e – antenna effective height, R_{rad} – radiation resistance, G – antenna gain,

$$m(or \quad \beta, \quad or \quad k) = \frac{2\pi}{\lambda}$$

2. The alternative Planar Inverted F antenna (PIFA)

Attempts to use the antennas of figure 1 in a small headset did not lead to unsatisfactory results. However the trend is to avoid them because it is difficult to obtain satisfactory performance of the monopole, dipole or a magnetic antenna, if they are located close to the Printed Circuit Board (PCB). The main reason is the reluctance of consumers to use these bulky headsets from which the antenna is sticking out. As a possible solution to these problems was the development of PIFA [3].The bandwidth of PIFA is around 10%and its efficiency (P_{rad}/P_{feed})is low less than 0.65 [4]. A typical PIFA is depicted in figure 2 and equation (1) provide the relations between the antenna dimensions.

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

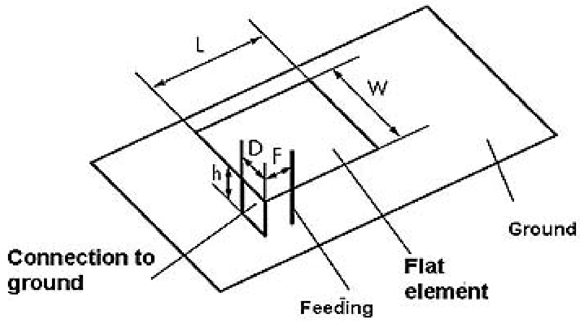


Figure 2 Principal construction of PIFA

$$D = 0 \qquad L + W + h = \frac{\lambda}{4}$$

$$D = W \qquad L + h = \frac{\lambda}{4}$$

$$\begin{matrix} 0 < D/W < 1 \\ W/L \le 1 \end{matrix} \qquad \frac{D}{W}\frac{1}{(L+h)} \cdot \left[1-\frac{D}{W}\right]\frac{1}{(L+h+W-D)} = \frac{4}{\lambda} \qquad (1)$$

$$\begin{matrix} 0 < D/W < 1 \\ W/L > 1 \end{matrix} \qquad \left(\frac{D}{W}\right)^{W/L} \cdot \frac{1}{(L+h)} - \left[1-\left(\frac{D}{W}\right)^{W/L}\right]\frac{1}{(L+h+W-D)} = \frac{4}{\lambda}$$

The advantage of the PIFA is the possibility of placing it on the PCB. However, the PIFA performances are inferior to the dipole and also to a quarter wave monopole. In addition ,the PIFA requires a relatively large space as shown in Figure3 .

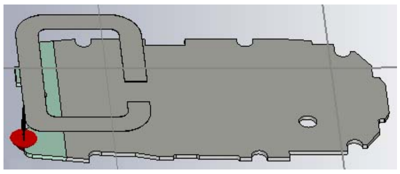


Figure3 The schematic of a PIFA, obtained by using a CST simulation.

3. MB antenna

The bases of MB antenna [5] are derived from two ideas: using PCB or its part like a radiating element and implementing dipole for small handsets, but not monopole. Let us consider MB antenna peculiarities in chronologic order.
The first thoughts were using PCB simultaneously like dipole ray as shown in Figure 4.

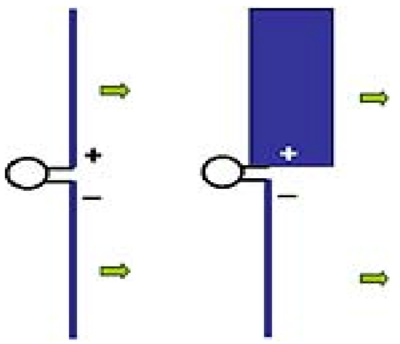


Figure 4.First stage of the MB antenna design.

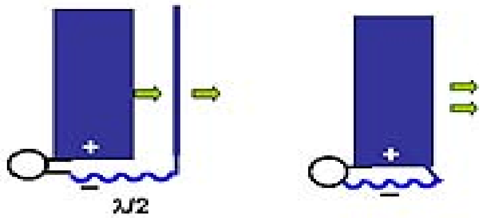
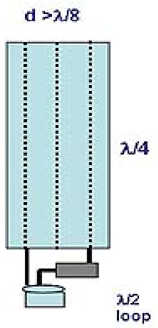
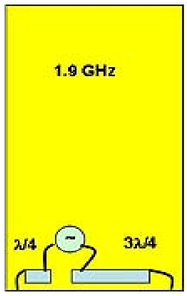


Figure 5.Second stage of the MB antenna design.

On one side of the second beam dipole should not stick out from the device, on the other hand it should not compensate for the radiation emission of the PCB. To resolve this problem, the signal at the second beam is fed through a delay line at the $\pi/2$.The Currents in the PCB and in second ray will be equi-potential, therefore we can combine the PCB and the second dipole ray as shown in Figure 5.
The delay line can be implemented by Surface Acoustic Waves (SAW) devices, for example CDM-Type LTCC Chip Delay Line of the ELMEC Technology firm which has bee able to accommodate a very compact overall area of only 5mm x 2.5mm.
For feeding a MB antenna is needed a symmetrical signal which can be implemented using a differential amplifier stage or a BALUN. The wide of the radiated part PCB has to be around $\lambda/8$. For current uniform distribution along the PCB the feed points must be far from the PCB edges and separated by a distance of 1/8 λ as shown in Figure 6.
In case of MB antenna
For cellular phone headsets operating near the 1GHz frequency the height of the PCB is approximately 75 mm, that is $\approx \lambda/4$. The second group of frequencies for cellular systems is near 2GHz where the PCB height is approximately

equals to λ/2. Here it is profitable to use the Co phase antennas principle [6]. MB antenna in this case operate actually as a λ/2 dipole as shown in Figure 7.





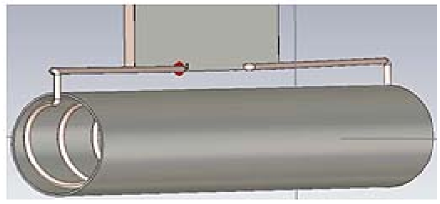


Figure 6. MB antenna feeding points. Figure 7. λ/2 MB antenna Figure 8 Coil delay line.

It is interesting to note that in the case of MB antennas for the 2 GHz frequency band the field density in the far field, does not decrease as it follows from the Friss equation (2), but increases. This is due to the transition from the λ/4 to the λ/2 MB

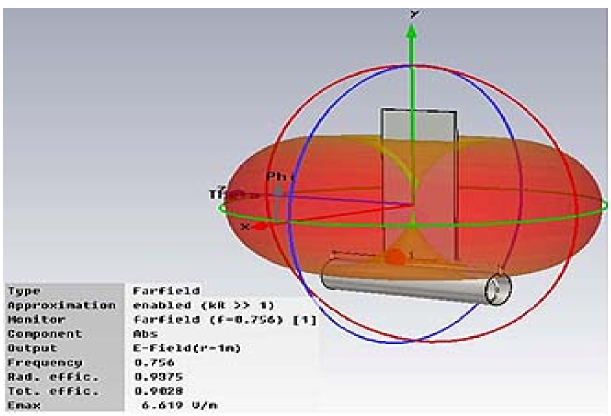
$$\frac{P_R}{P_T} = \frac{\lambda^2 G_T G_R}{(4\pi d)^2} \qquad (2)$$

where
P_R - Receiver input power,
P_T - Transmitter output power,
G_R and G_T - antennas gain,
d – The distance between T_x and R_x.

This is due to increasing antenna gain because of the transition from λ/4 MB to λ/2 MB.

4. Simulations

The concept of the MB antenna was repeatedly tested at first by using a CST simulation program. At this stage, the authors have not been able to verify the main findings of the MB mode using LTCC Chip Delay Line, required by the SMT technology. For the simulations and preliminary experiments have been used shielded delay line in the form of printed coils in spiral or in snake forms. The spiral form delay lines like a coil is show in Figure 8.
It should be noted that it is primarily found an absolute absence of radiation from the delay line itself.
Below one can see simulations results examples. Simulations in far field shows high efficiency of more than 0.9 and almost ideal radiation patterns as shown in Figure 9.



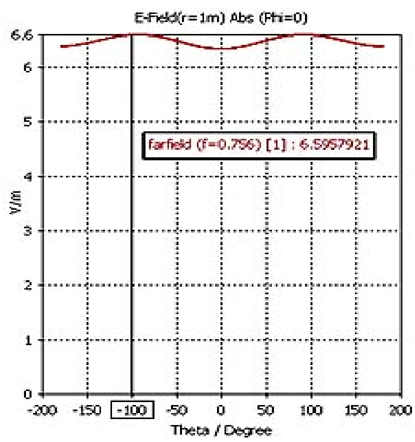


Figure 9. MB antenna radiation patterns in far field Figure 10. Radiation in the horizontal plane

Particularly important characteristic of radiation in the horizontal plane as the flat antenna design may cause some doubt. As seen from Figure 10 the unevenness? of the radiation in the horizontal plane is less than 1.5%
The simulation results show a bandwidth around 50 MHz for the MB antenna which is not sufficient for future cellular systems. However, a significant improvement is possible by allowing arbitrarily expansion of the bandwidth by applying modifications of the delay line. Figures 11 and 12 shows the design of the delay line and the simulation results of the parameter S11 for the case of doubling the bandwidth..

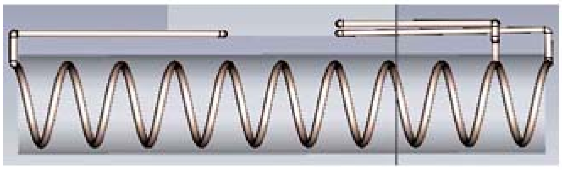


Figure 11. Delay line with additional pipe

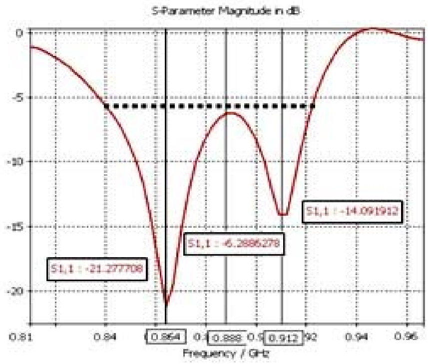


Figure 12. S11 of MB with a doubled bandwidth.

As indicated above, a twofold increase in the frequency of the MB antenna can be achieved using the idea of the Co phase antenna [6]. In this case, the delay line consists of two parts as shown in Figure 13.

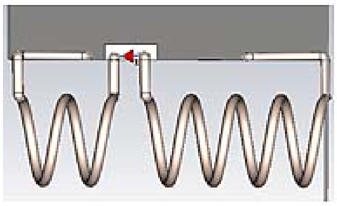


Figure 13. Delay line construction for the 2GHz band.

Antenna	$E_{V/m}$ on distance 1m	Total eff, dB	Gain, dB
PIFA F ≈ 0.9 GHz (From CST)	4.63	- 3.4	1.64
MB with one DL, F ≈ 0.9 GHz	6.95	- 0.01	2.06
MB with 2 DL, F ≈ 1.8 GHz	8.3	- 0.04	3.66

Table 1

The results of simulations on the two frequency bands for the MB antenna and the simulation results of a PIFA are shown in Table 1.

5. Conclusions

- ***A new kind of antenna MB for compact mobile headsets is proposed.***
- ***Parameters of the MB antenna are equivalent to a quarter wave or half wave dipole parameters.***
- ***Electrical and constructional parameters of MB excels the PIFA parameters.***

References:

1. S. Kalichman, Y. Levin. Fundamentals of theory and calculation of the broadcast receivers based on semiconductors instruments” Communication, Moscow, 1965
2. M. Bank, On some misunderstandings using a Dipole or Monopole antennas, IEEE Antennas & Propagation Magazine, 45(1), 2003 (143-147).
3. **http://mobiblues.ru/post_1234816635.html**
4. M.C.T.Huynh. A numerical and experimental Investigation of PIFA for Wireless Communication Application. – Virginia State University .-Blacksburg, Virginia. –Oct. 19.2000
5. M. Bank, M. Haridim "A printed monopole antenna for cellular handset" INTERNATIONAL JOURNAL OF COMMUNICATIONS, Issue 2, Volume 3, 2009.
6. Nadenenko, “Antennas.” Radio and Communications, Moscow, 1959.