SOLVING THE WIRELESS DATA COMMUNICATION PROBLEM BETWEEN BRAIN IMPLANTS AND COMPUTER

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There have been a number of previous or ongoing research studies on brain-computer interface. This research mainly target the access/delivery of meaningful signals from/to the human cortex so that the information in the bioelectric form can be converted to/from the information in the digital form. As a result, sophisticated electrodes and implantable chips performing such a conversion have been investigated and several prototypes of these devices have been demonstrated. However, one extremely important, but difficult, problem has not yet been addressed: Suppose that we have successfully converted the information, how do we pass this information between the implanted brain chip and the computer? In the current experimental settings, wires are utilized. This type of connection is clearly unacceptable in the outside world where reduction in mobility and high risk of infection rule out its feasibility. Wireless radio frequency (RF) connection provides an alternative. However, its feasibility is in serious question due to the following limitations: 1) RF antenna and certain circuit elements (e.g., induction coils) increase the size and the mass of the implantable device; 2) the conversion between signal and RF waves requires a considerable amount of energy which is drained from the internal battery within the implantable device, and this battery is difficult to recharge or replace; and 3) the ionic fluid of biological tissues, such as the cerebrospinal fluid (CSF), is highly conductive. As a result, transmitting an RF signal within the head is similar to transmitting a radio wave through an electrically shielded room. Such transmission is possible only when the RF signal is strong and its frequency is relatively low, which requires more energy consumption and larger capacitors and inductors, compounding the first two problems, and promoting adverse biological consequences due to the strong internal emission which generates heat and other effects. Currently, the RF data link has been limited to applications where the device size is large and the implantation time is short.

There exists a natural passageway of information which has been overlooked. The ionic fluid in the biological body conducts electrical current which, when intentionally manipulated, is capable of passing information. This conduction is called volume conduction. Electrostatic laws of physics state that a current source within a volume conductor results in an electrical potential distribution within and on the surface of the conductor. This potential can be easily measured by affixing a pair of stick-on electrodes on the scalp. We have been investigating this volume conduction based data communication method for several years. Our experiments on theoretical models, physically constructed models, and animal experiments have received encouraging results. We found that the volume conduction based system has the following advantages: 1) The strong shielding effect of ionic fluid in the body is no longer a problem. Instead, it is now employed as the information carrier. 2) The volume conduction link is simpler than the RF link, allowing an aggressive reduction in size and weight. 3) It does not require signal conversions to/from RF, thus this approach is highly energy-efficient, potentially enabling a battery that lasts for a life time.

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