Recent Patents on Non-Contact Electrodes for Measuring EEG and EKG

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Abstract: At present, electroencephalogram (EEG) and electrocardiogram (EKG) recording requires contact electrodes that are inconvenient and time-consuming to apply. Emerging technology based on non-contact electrodes may alter the way such data are gathered in clinical, field and research settings. A number of investigators have demonstrated that clinical-grade EKG and EEG tracings can be obtained using electrodes that make no direct contact with the body. Using non-contact electrodes, an EKG can be taken from outside a person's clothing. The data can be transmitted wirelessly and stored in a cell phone. This technology is the basis of a number of patents and patents pending. It may also lead to new devices such as a whole body electromagnetic scanner, with potential applications in medicine, anthropology, agriculture, geophysics and nutrition.

Keywords: Electromagnetic fields, electrocardiogram, electroencephalogram, non-contact electrodes.

INTRODUCTION

Contact electrodes are widely used in medicine for recording the electrocardiogram (EKG) and electroencephalogram (EEG). Currently, the electrodes must make direct physical contact with the body; in the case of EEG, this involves the use of a contact paste. For a 20-lead quantitative EEG (qEEG) the application of paste and establishing good contact can take 20 minutes, which requires a great deal of technician time per year in an EEG laboratory. For 24 or 48-hour ambulatory EEG monitoring, the contact paste is extremely difficult to remove from the hair.

In the case of EKG, standard electrodes do not require paste but the chest may need to be shaved to establish good contact. Outside the clinical setting, for instance in a combat or high-endurance sport situation, no form of contact electrode is practical. The electrodes can be uncomfortable or detract from peak performance, and good contact can be disrupted by perspiration, movement, dust, rain, or simply time. A sensitive non-contact electrode would be a useful advance for both EKG and EEG recording. This would be especially true in field situations but also in clinical settings. For instance, if an electrode could be mounted in the ceiling, on an IV pole, or on a retractable arm in a hospital room, ambulance, helicopter or other vehicle, an EKG could be taken without having to remove clothing or apply electrodes. In a military context, the electrode could be built into the combat uniform and could transmit data wirelessly to a central monitoring station or a field medical officer. Similar technology could be used in training by both military and civilian personnel, for instance, in monitoring competitive cyclists, mountain climbers, divers and skiers. The technology could be used with normal, healthy individuals, high-performance athletes, special forces troops, and individuals who have defined or suspected cardiac problems. One could also incorporate an EKG electrode into a cell phone, with an EKG transmitted to a physician by email or text message [1, 2].

I. THEORETICAL REASONS FOR DEVELOPING NON-CONTACT ELECTRODES

In addition to practical reasons for developing a durable, reasonably priced non-contact electrode, there is a theoretical rationale for such technology. Currently, the only widespread monitoring of the electrical field of the human body is the EKG and EEG; electromyograms are also standard clinical practice, but are not used as often. In these three applications, the electrical signals emitted by the body are analyzed for making diagnoses, planning treatment, monitoring response to treatment and estimating prognoses. However, every cell of the human body, and the body as a whole, emits an electrical field. According to the theory of human energy fields [3], the electromagnetic (EM) field of the entire body could be scanned in order to obtain clinically relevant information. A Whole Body EM Scanner could be used for many purposes: to detect disease at the EM level, before it trickled down to the biological level; to monitor responses to conventional and alternative treatments; to investigate alternative practices such as acupuncture, healing touch and other "energy" medicine techniques; to study EM signaling and control processes within the human body; to study EM signaling between one person and another, or one person and the environment; to study the effects of diet, exercise, yoga, meditation, aerobic exercise and other activities on the electrical field of the body; to develop applications in anthropology [4, 5] and agriculture; to study the electrical components of wound and fracture healing; and to study the effects of combat stress, non-lethal weapons, submarine duty, space flight, high altitude and other extreme environments. All such applications would require an array of non-contact electrodes. Clearly, one could not apply standard contact electrodes to the entire body surface.

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Various traditional beliefs could be investigated with such technology. For instance, the idea that a shaman or medicine man could conduct a fertility ritual that would affect the germination of crops, is dismissed as superstition by most academics and scholars. This belief can be restated as a testable scientific hypothesis: perhaps the body of the medicine man emits a focused EM signal that actually affects the germination of seeds in a field. This EM signal could be identified and quantified with a Whole Body EM Scanner. Then a device could be constructed that emitted a similar signal and it could be used in a controlled experiment in a hydroponic garden to determine if an EM signal can in fact affect germination. The EM signal emitted by the device could be adjusted by frequency and amplitude to obtain optimal effects for different crops. An array of such emitting devices could then be set in an agricultural field. This is a plausible hypothesis because we already know that plants capture photons to drive the synthesis of chlorophyll. Other examples of biological processes driven by the capture of photons by receptors include the synthesis of vitamin D and melanin in the skin, and visual perception.

In terms of food and nutrition, it is possible that nutrients exert their effects not just through their interaction with receptors, incorporation into proteins and other processes at the biological level. It is also possible that different nutrients (and medications) have EM signatures that are aspects of their mechanisms of action. It is possible, for instance, that some neurotransmitter-receptor interactions are specific not due to matches at the level of physical conformation, but due to matches at the EM level. Ultimately, this must be true because all biochemical reactions consist of couplings and un-couplings between the electron clouds of atoms. Since it is not feasible to insert contact electrodes into individual cells in living people, some kind of non-contact sensor technology must be developed to investigate such hypotheses.

A number of patents and a small peer-reviewed literature deal with non-contact electrodes and their potential applications. When a practical, economical non-contract electrode becomes available, this literature should expand exponentially. Non-contact measurement of human electrical signals, with data transmission wirelessly to central monitoring stations, will bring medicine into the wireless technology era.

II. NON-CONTACT ELECTROCARDIOGRAM SYSTEMS

Harland, Prance and colleagues [6-9] at the University of Sussex in England developed a system for detection of the EKG at a distance of one meter from the body, however the resulting EKG tracing was primitive and unsuitable for clinical use. After some further development, they have succeeded in producing a clinical-grade EKG tracing at 3 millimeters distance from the body surface [9]. This means that clinically useful EKGs can be taken without the person having to remove any clothing. Since the heart signal can also be detected at one meter, it seems that clinically useful EKGs taken from a distance of a meter or greater away will be possible once technical problems in signal acquisition, electrode sensitivity and noise reduction have been solved.

Lee and colleagues [10] at the Walter Reed Institute of Research in Maryland, USA have developed a non-contact EKG system that can record a tracing from outside a person's clothing. They are particularly interested in military and field applications of such technology, and in the possibility of including EKG and other non-contact biosensors in a combat uniform of the future. Their system involves a strap placed horizontally around a person's torso at about 4 inches below the nipple line, with the non-contact electrodes mounted on the external surface of the strap. The sensing electrodes are on the front of the person and the reference electrode on the back. Like Prance and colleagues, they have obtained a clinical grade EKG.

Chi and colleagues [11-13] at the University of California, San Diego have developed a similar system that yields a clinical-grade EKG from outside a person's clothing. They have added the additional feature of transmitting the data wirelessly to a receiver. Chi, however, notes that the EKG tracing degrades as the thickness of the person's clothing increases, with the p wave disappearing. Chi [13] also states that, "a practical device for patient use has yet to be realized." Likewise, Park and colleagues at the Seoul National University Industry Foundation in Korea [14, 15] have developed a non-contact EKG system that can be imbedded in a bed or chair, and which does not require the person to remove his clothing.

Wong [1,2], a high school student in Morristown, New Jersey, USA has developed a wireless system for transmitting EKG data or auditory heart data obtained by a stethoscope to a cell phone. She has not incorporated non-contact electrodes into her system, however. Three other patents [16-18] that, at first glance, might appear to be part of this collective body of work, are not because, although they involve non-contact electrodes, the systems either require an intracardiac catheter or an implanted device such as a cardiac pacemaker. They require invasive procedures and are not suitable for routine clinical use.

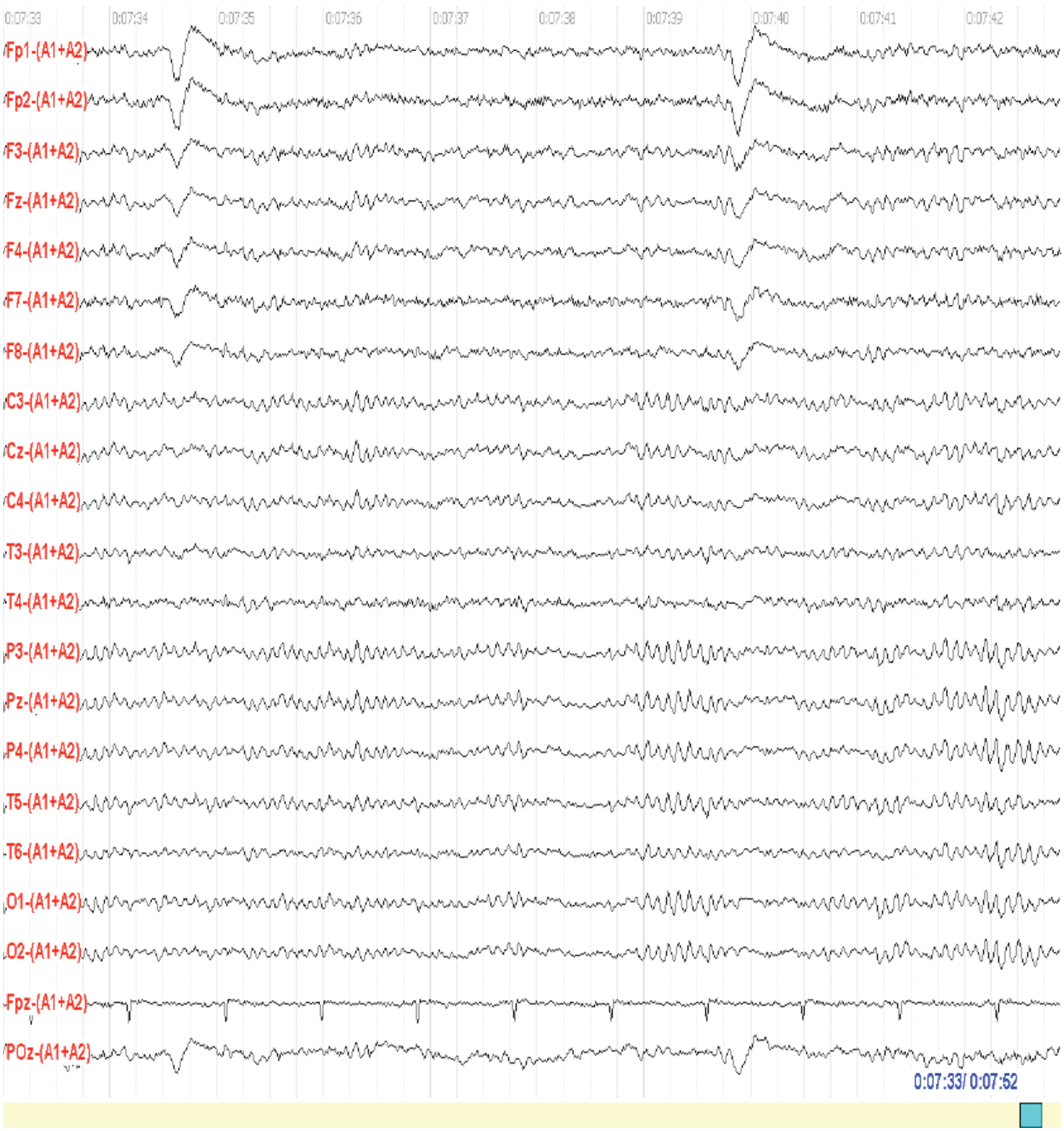
The work of the above investigators demonstrates that monitoring the EKG from outside a person's clothing is technically feasible. The problems to be solved in order to bring such a device into routine clinical practice include: noise reduction; realistic manufacturing costs and pricing; durability of the systems; physical lightness and user-friendliness of the systems; and data security and encryption for wireless transmission of data. Embodiments of such a system would include an electrode mounted in a light jacket for 24-hour monitoring, a 12-lead EKG system, and versions that can be mounted on an IV pole, retractable arm or ceiling.

III. NON-CONTACT ELECTROENCEPHALOGRAM SYSTEMS

The same non-contact electrode can be used to record an electroencephalogram (EEG). As for the EKG, the electrode is a high-impedance capacitive electrode that makes no contact with the body. For an EEG application it can be mounted in a cap or helmet, as described by Schilling and colleagues [19-21] at the Institute of Electrical Measurement and Fundamental Electrical Engineering in Germany. Their helmet system yields a quantified electroencephalogram (qEEG), which is a form of electrical activity brain map displayed in a color-coded format [19]

Ross [22-25] has developed a high-impedance non-contact electrode with which he has obtained a clinical grade EEG wave form [23]. Table **1** shows an EEG tracing taken with this system. The tracings from Fp1 to O2 are standard contact leads embedded in an EEG cap: Fp1 and Fp2 are leads attached to the scalp in standard positions. POz is a non-contact electrode housed inside goggles that are electrically insulated from the outside environment by layers of copper mesh and aluminum foil. The POz electrode makes no contact with the skin or eye lashes, and is about 2 cm in front of the eye. Fpz is a comparison electrode housed in space in front of the goggles that is not in contact with the goggles or the body. The Fpz wave form consists of low-amplitude 60 Hz background noise with a heart beat artifact registered by the reference electrodes attached to the ear.

Table 1. An EEG Obtained with a Standard Contact EEG System and a Simultaneous Non-Contact Electrode (POz)



The tracing in POz is very similar to the two contact electrodes on the forehead. Eye blink artifact can be seen at the same time in the form of two large deviations from the baseline tracing. The eye blink artifact becomes less and less noticeable as one moves down the print-out because these leads are positioned further and further away from the forehead and the origin of the eye blink muscle artifact. Table **1** demonstrates that a physiological, clinical-grade EEG signal can be obtained using a non-contact electrode that makes no physical contact with the body. Such an electrode can be placed either over the scalp, as it is in a helmet embodiment, or in front of the eye as it is in this application.

The reason for placing the electrode in front of the eye in this experiment was to determine whether a brainwave signal is emitted through the eye, as well as generally though the skull. The data demonstrate that this is the case. This technology is the foundation of a US Patent [24]. If this signal can be captured and analyzed at distances of meters, and if properties of the signal, such as amplitude, differentiate it from the general electrical field emerging through the skull, then one has an on-off switch activated by looking at it. This switch could be coupled to any electrical device to turn it on, off, up or down, much like a clapper light is turned on by clapping one's hands.

For routine clinical use, a cap with non-contact electrodes appears to be achievable. A similar system for use in combat, sports or other high stress environments would require extra durability, but otherwise would consist of the same technology. As for the EKG, data could be transmitted wirelessly to a receiver. In the field, a hand-held device could include both EKG and EEG modes, and could be used to verify whether a person was brain dead or still had salvageable brain function. This information could be useful for triaging decisions in a battle zone. For regular clinical use, the primary advantage of such a system is its ease of use and comfort for the patient.

IV. A NON-CONTACT WHOLE BODY ELECTROMAGNETIC SCANNER

A Whole Body Electromagnetic (EM) Scanner is the basis of a US Patent Pending [25]. This system consists of an array of non-contact electrodes that are the same as the EKG and EEG electrodes. Since it is not feasible to attach contact electrodes to the entire body surface, a Whole Body EM Scanner requires non-contact electrodes. The system can have a number of different embodiments. One resembles an MRI machine, in that the person being scanned lies down on a table under the array of electrodes. The electrode array and the person can both be stationary or the array can move over the person being scanned. Alternatively, the electrode array can be stationery and the table can move under it.

Two other embodiments include a version that scans only the head and torso with the person sitting, and a hand-held version that can be moved over the body. In all embodiments, the electrical field of the body can be displayed in digital format or color-coded by frequency and amplitude. The physician or technician will be able to scan by selected frequency bands or by the overall signal within the range of frequencies samples.

The EKG and EEG systems, as envisioned so far, will be used in exactly the same way as standard equipment, in terms of data display and clinical use of the data. For the Whole Body EM Scanner, however, a wide range of novel clinical applications is possible including: detection of disease; monitoring response to treatment; studying normal and high-performance physiology; and studying the electrical effects of environmental inputs including diet, nutritional supplements, medications, and artificial electrical fields generated by modern technology. This will require considerable work with different populations and comparison groups to establish norms and determine the utility of the technology in a variety of settings, for a variety of purposes.

V. CURRENT AND FUTURE DEVELOPMENTS

Current and near-term future work on non-contact electrodes is described above. In a more long term perspective, it is difficult to envision where this kind of technology could lead, especially if we consider the growth in computers, wireless communication and satellites over the last 50 years. It might be possible to survey the electrical health of the planet from outer space, for example, including the health of crops and oceans. It might be possible to capture an electrical signature of an individual just as we do currently for voice, retina, DNA and fingerprints. It appears that medicine will soon transition to wireless collection and transmission of clinical data.

CONFLICT OF INTEREST

The author holds US patent 7,806,527 [24] and US Patent Pending 2010/0152602 A1 [25] and is currently involved in developing this technology through his company, Ross Energy Systems.

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Declared none.

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