September | 28

BCI Telemeter

Preliminary Design Report

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BME 401 Senior Design
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BCI TELEMETER

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A. BACKGROUND

The purpose of this section is to provide information regarding the technology of brain-computer interfaces and the current methods that exist for recording brain signals.

A.1 BRAIN-COMPUTER INTERFACE

Brain-computer interfaces (BCI) allow subjects to control devices using their own brain signals. Brain signals are recorded by one of several methods available: electroencephalography (EEG), single unit recordings (SU) and electrocorticography (ECoG). The signals are sent through a series of filters and amplifiers to a digital signal processor where they are converted into an output communicating the user's intent. BCI is very useful for patients with severe motor disabilities because it gives them a way to communicate and interact with their environment through non-muscular means. BCI is also an extremely useful neuroscientific tool to investigate new hypotheses on cortical population representations [1]. Work with BCI in the laboratory setting will lend researchers insight into the function of neural networks during specific tasks as well as during free behavior [4]. BCI technology was patented at Washington University in St. Louis by Dr. Eric Leuthardt, Dr. Gerwin Schalk, Dr. Daniel Moran, Dr. Jonathan Wolpaw, and Dr. Jeffrey Ojemann in 2006 [2]. Methods of BCI have evolved over time from using EEG to primarily SU recordings and most recently to the introduction of ECoG as a method of recording brain signals. The most significant limitation of current BCI methods is the necessity of cords plugged into the electrode array to carry signals from the brain to a digital signal processor.

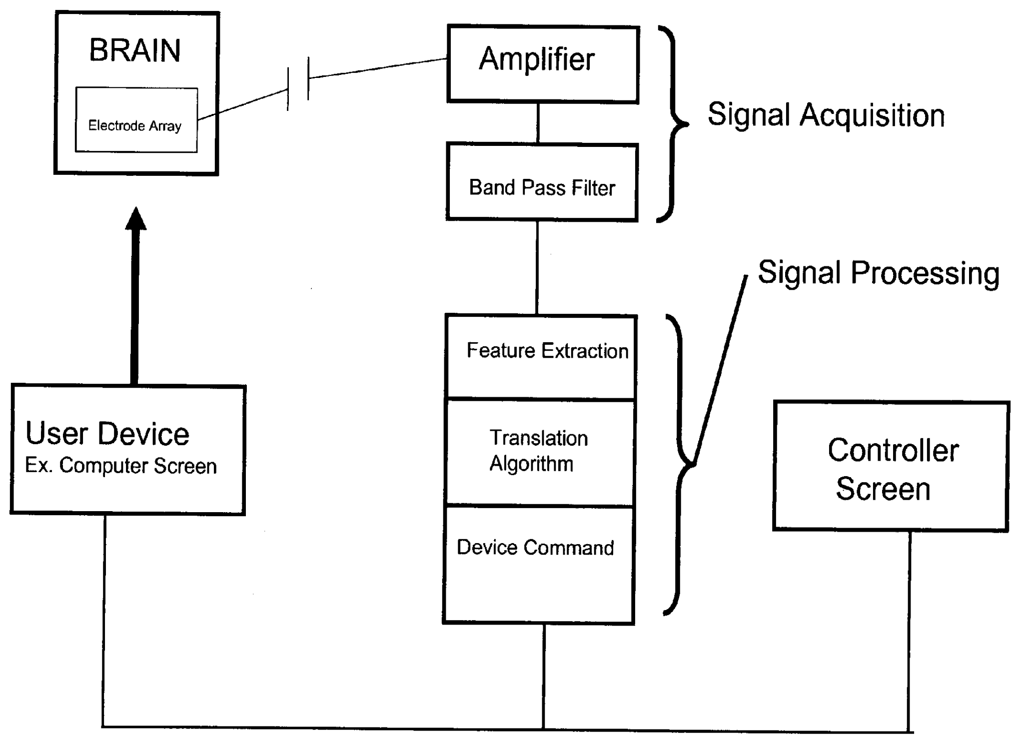


Figure 1: Block diagram of generic BCI system [2]

A.2 METHODS OF RECORDING BRAIN SIGNALS

This section will discuss three different methods that can be used to record brain signals for BCI systems.

A.2.1 ELECTROENCEPHALOGRAPHY

Electroencephalography takes recordings of electrical activity in the brain from electrodes placed on the scalp. It is non-invasive, very safe for the patient, and a convenient and inexpensive method of acquiring brain signals. Its use in BCI however is limited because recordings from EEG have low spatial resolution and are extremely susceptible to artifacts such as electromyographic (EMG) signals. Extensive user training is also required for the effective use of EEG [3].

A.2.2 SINGLE-UNIT RECORDING

Single-unit recordings aim to measure and record the activity of a single neuron. In order for these recordings to be taken an electrode must be placed into the brain, penetrating the parenchyma and entering the brain tissue. The electrode can be placed in close proximity to the neuron of interest, which allows SU recordings to have incredibly high spatial resolution. These high fidelity signals can be very useful for BCI because they contain very few artifacts and provide a clear signal for processing. There are consequences however that arise from placing a foreign object in a subject's brain. The electrodes in the brain tissue cause local neural and vascular damage and pose a risk of central nervous system (CNS) infection which could lead to encephalitis, or acute inflammation of the brain. This is incredibly dangerous for the subject undergoing the procedure and thus rules SU recording out as a clinically applicable method of BCI. A second disadvantage of SU is that it is difficult to achieve and maintain stable recordings. The irritation caused by the presence of a microelectrode in the brain causes a cascade of cell responses leading to the creation of a high impedance gliotic sheath surrounding the electrode. This sheath isolates the electrode from the surrounding neural tissue and the currents from the firing neuron of interest find other pathways around the electrode rather than flowing through the high impedance sheath [1]. SU recordings are therefore unreliable as well as dangerous, and are not a reliable source of recording brain signals for BCI.

A.2.3 ELECTROCORTICOGRAPHY

Electrocorticography is an alternative method of recording brain signals that provides higher quality signals than EEG and is less invasive than SU recording. The electrodes used in ECoG sit on the surface of the brain, but do not penetrate the parenchyma thus they do not provide a path for CNS infection. ECoG BCI offers many advantages over both EEG and SU BCI. ECoG has much higher spatial resolution than EEG, (tenths of millimeters versus centimeters) as well as a superior frequency range (0-200 Hz versus 0-49 Hz) that can be attributed to two factors [3]. The cell membranes of tissues overlying the brain have intrinsic electrical resistance that acts as a low-pass RC filter and eliminates higher frequencies from the EEG. In addition, higher frequencies tend to be produced by smaller cortical assemblies so they are more prominent at electrodes closer to the cortex [3]. ECoG can therefore achiever higher spatial resolution than EEG because the ECoG electrode array is place on the surface of the cortex whereas the EEG electrodes are placed on the surface of the head and signals from the brain must travel a farther distance through the skull. ECoG BCI also records higher amplitude signals than EEG (50-100 μV versus 10-20 μV), is much less susceptible to EMG artifacts, and has a much higher signal-to-noise ratio (SNR) [3]. Advantages of ECoG BCI over single-unit recordings lie in the fact that ECoG is recorded by epidural electrode arrays and thus does not require electrodes that penetrate into the cortex. This allows for greater long-term stability in recordings and is much safer for the patient. ECoG has evolved as the most effective method of recording brain activity for BCI; it combines the high fidelity signals of single-unit recording and the safety of EEG.

B. CURRENT STATUS OF TECHNOLOGY AND AREAS OF NEED

The purpose of this section is to introduce the mentor for this project, display his current work, the problem/need area of focus, and the potential benefits of addressing the need. The mentor for this design project will be Dr. Dan Moran. Dr. Moran runs a Neurobiology lab at Washington University School of Medicine. His research areas include motor cortical neurophysiology and musculoskeletal movement biomechanics. The engineering aspects of his work include single unit and ECoG BCI as well as functional neuromuscular stimulation.

B.1 CURRENT WORK BEING DONE BY MENTOR

Dr. Moran is currently researching the link between motor cortex activity and muscular movement. Using ECoG and local field potentials, his lab has created a paradigm that enables rhesus monkeys to control a cursor in several dimensions using solely their brain waves. His work focuses on how the brain encodes motor control and how the knowledge can be used to synthesize motion. One type of experiment he performs analyzes projectile kinematics and the induced brain activity. The aim is to observe what the brain is doing to prepare for and perform motions. For instance, a monkey moves a joystick in one-dimension and is then exposed to a force perturbation altering the direction of the movement. Brain signals are recorded before, during, and after the perturbation and the data is used to correlate the electrical signals to the monkey's reaction and motion. The majority of experiments in the lab however, incorporate brain control as a means for completing a task. Water-deprived monkeys have been trained to move animated cursors on a computer monitor in a variety of patterns. While performing the task, the monkey is rewarded with water to reinforce and develop brain control. This research proves that the monkey can learn to control an external cursor, which suggests potential human applications, specifically for paralyzed patients who have lost neural connections to peripheral muscles in their body. The data also shows that the high gamma band activity of local field potentials represent the surrounding single unit cortical activity, and can therefore be used as an ideal source of brain activity for BCI control of artificial devices.

B.2 NEED DEFINED BY MENTOR

Dr. Moran has expressed a specific need to improve his research techniques and greatly increase the amount of information that can be acquired from the experimental monkeys. Currently, the ECoG signals are recorded through percutaneous leads that are hooked up to an external computing source. This poses a few significant problems that the BCI Telemeter addresses. The most significant drawback of the current method is that data can only be recorded while the monkey is hooked up to the external device. Dr. Moran would ideally like to record from the monkeys continuously while they are behaving naturally in the “monkey room.” This requires low power consumption and a rechargeable battery than can meet our power specifications. In addition, percutaneous leads pose a serious risk of infection and the cables hooking the electrodes up to the external computing source introduce noise into the system. These problems are discussed in detail below in conjunction with how the BCI Telemeter is an overarching solution.

B.2.1 MOBILITY

The electrodes recording the ECoG signals are connected to an external recording device using fiber optic cables. These cables are inherently restricting. While this is not a concern in Dr. Moran's lab since the monkey's heads are fixed during brain control tasks, future applications in human subjects must be considered. Dr. Moran has asked for a device that allows him to record from the monkeys continuously 24 hours a day for at least one week. This invokes the need for a means by which to record from the monkeys while they are not in the lab, but in their cages in the "monkey room," away from the digital signal processors and external headstages. The BCI telemeter design replaces the existing external processors with a new *wireless* headstage. The replacement headstage is comprised of two internal circuits, that function cooperatively to record, transduce, amplify and transmit the signals to an external recording device. This freedom permits a diverse realm of situations and movements that the monkey performs throughout the day to be recorded rather than only collecting data within a controlled 1-4 hour time period. With this additional data, the brain waves that correlate to the unconstrained movements can be analyzed to further understand the brain activity during normal movements and help identify the key links between motor cortex communication and muscle control.

B.2.2 BATTERY OPERATIONS

In order to accommodate the wireless aspects of the device, the internal battery and power structure must be able to record data continuously. The battery included in the device and the associated circuitry account for this need, allowing researchers to observe brain signals not only while the monkeys are performing brain control tasks, but also while they are performing natural behaviors in their cages. Power consumption is an important factor in the design. A power save mode is incorporated into the battery which reduces the power usage while a monkey is inactive or sleeping, this allows signals to be recorded 24 hours a day for a least one week. The telemetry module operates in a low power state that can be powered up or down according to the brain activity of the monkey. Certain ranges of brain waves and particular frequency bands can switch the device on or off depending on identified patterns of behavior. The beta waves that correspond to sleep cycles are a good example of a potential indicator for operation. As the monkey moves from a set pattern of brain activity to another, the module activates or deactivates the power state. In addition, the radio frequency (RF) transceiver that will be used in the telemeter design is bidirectional, allowing the researcher to cue power save mode from an external location.

B.2.3 NOISE

The cables and external analog processors that typically connect to the device introduce noise into the system. Internalizing the analog processing using a series of instrumental amplifiers and differential amplifiers eliminates this source of noise, increasing the fidelity of the measurements.

B.2.3 INFECTIONS

With percutaneous leads, internal tissue is exposed to the external environment and is therefore extremely vulnerable to infection. Infections are a critical area of interest because they affect the life span of the monkey, incur extra costs to treat, and require extensive cleaning protocols to maintain sterilization of the exposed area. The BCI Telemeter removes the requirement of cables being connected directly into the monkey, which removes the source of infection between the external and internal environments. In Dr. Moran's current research the boundary between the skull caps and brain tissue will not be eliminated, however future applications of this device rely on it being implanted subcutaneously.

C. PROJECT SCOPE

To address both the problem of percutaneous leads and limited recording time, a modular system is designed to both process signals and wirelessly transmit them to an external receiver. The headstage will have a multi-channel system containing an Analog Signal Processing (ASP) module that amplifies and filters ECoG signals, producing a power spectrum. The telemetry module transmits these processed signals to a receiving agent. When the transmitted power spectrum is transmitted to the computer or intermediate device, an algorithm compares this signal to baseline recordings and the modulations are used to establish brain control. The goal of the headstage module is to consolidate multiple analog integrated circuits along with the required digital signal processing (DSP) functions into a custom ASIC (Application Specific Integrated Circuit). This multi-channel ASIC will be paired with a commercially available RF (Radio Frequency) telemetry chip.

As stated in Moran and Morley's SBIR Application [8], the proposed design will support the following features:

- Able to record signal with amplitude 1-10 μV with ability to distinguish modulation down to 300 nV
- Telemetry to PC for 8 ECoG channels in either raw (2000 Hz) or processed (20 Hz) modes.
- Each of the 8 channels chosen from one of eight groups of 4 electrodes with reference chosen from one of four electrodes

- Bidirectional RF(radio frequency) link for system configuration, control, and data telemetry
- Low-noise electronics offering large SNR (Signal-to-Noise Ratio) and CMRR (Common Mode Rejection Ratio)
- Low-power, rechargeable battery-operated
- Variable RF data rates (and power consumption) of up to 500 kHz
- One week of typical use between recharging
- Circuit dimensions of 1.5 inch diameter or less
- Transmit signals at least 50 feet

Figure 2 presents a diagram of the Analog Signal Processing (ASP) block. The differential signal from a pair of electrodes is first amplified by a chopper-stabilized (CHS) pre-amplifier. The continuous-time low-pass filter anti-alias filter (AAF) that follows provides additional gain and is used for anti-aliasing. The output of the low-pass filter is then applied to a 16-bit ADC (a second-order S-D converter). The output of the analog S-D modulator is a 1-bit 512 kHz data stream.

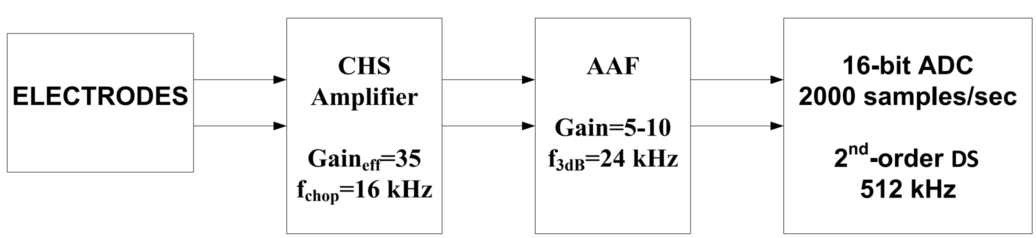


Figure 2: *Analog Signal Processing (ASP) Module [8]*

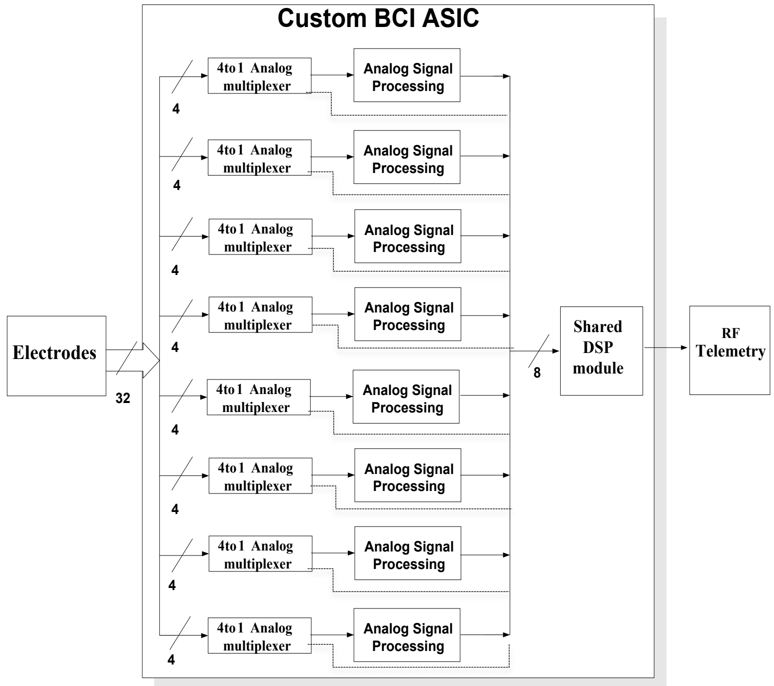


***Figure 3**: Block diagram of proposed multi-channel system. The ASIC receives input from a 32 channel µECoG grid array implanted epidurally in the subject. One electrode from each bank of four can be selected for processing and telemetering, leading to a total of 8 processed channels [8].*

The high-speed 1-bit data output from each channel is then processed by a digital signal processing (DSP) block to yield a 16-bit, 2000 samples/sec output stream. This signal is transmitted wirelessly by the TI C1101 Low-Power Sub-1 GHz RF Transceiver to the receiving computer. If the receiver "asks" the transmitter for a raw signal in the time domain, after the analog differential signal is selected by the 4 to 1 analog multiplexor, the signal is directly transferred to the shared DSP module at 2000 Hz before being transmitted by the telemetry module. The telemetry module transmits the processed ECoG signal from the device to the receiver. An Radio Frequency (RF) transmitter, such as the TI C1101 Low-Power Sub-1 GHz RF Transceiver, generates radio frequency waves in its circuit. This signal is called the carrier signal. The transmitter then adds information to this waveform by modulating the signal using frequency modulation or amplitude modulation. This composite signal is an analog waveform, and thus can propagate from an antenna. The antenna induces a corresponding signal into the atmosphere by altering the electric and magnetic fields at the same frequency.

The TI C1101 Low-Power Sub-1 GHz RF Transceiver acts as a transmitter and a receiver. An RF receiver receives the modulated signal from the atmosphere surrounding its own antenna. The receiver circuits then demodulate the signal, separating the information part from the carrier using a peak detector. The information portion is then amplified to a useful level for its intended purpose. Once the ECoG signal is received, the control algorithm uses the power modulation in each feature to move a cursor on the screen.

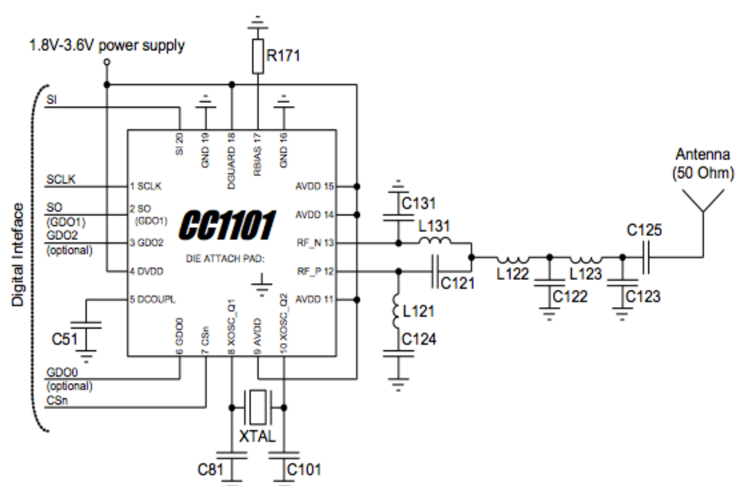


Figure 4: *Telemetry Module:Example application of TI C1101 Low-Power Sub-1 GHz RF Transceiver chip [9]*

The complete device operates using battery power and allows signals to be transmitted and recorded continuously all day. This will allow researchers to observe brain signals not only while the monkeys are preforming brain control tasks, but also while they are performing natural activities as a part of their daily routine. A power save mode will be incorporated that reduces the power usage of the internal processors while the monkey is inactive. The device will be completely internal, removing the need for percutaneous leads and the risk of infection. For testing purposes, to circuit boards will be designed to be placed inside one of the "hellboy" electrode interfaces already implanted in a monkey's skull. This is where the external headstages and preamplifiers are currently connected. The eventual goal is that the entire device could be implanted subcutaneously. This means that the battery must be rechargeable through the skin.

The modular nature of the design will allow Dr. Moran to use the headstage circuit board with monkeys that are not equipped with the hardware required for telemetry. The headstage circuit board will be designed to be compatible with both the telemeter and with an Omnetics 16-channel output, allowing monkeys that are not hooked up to the telemeter to have a contained headstage instead of the external processors. Recording high frequency μECoG activity requires extremely low-noise, high fidelity amplifiers. Standard amplifier designs for EEG or single-unit BCI are not capable of accurately recording such small signals. Thus, recording μECoG activity accurately requires a custom, low noise ASIC.

D. EXISTING TECHNOLOGIES AND SOLUTIONS

D.1 CURRENT METHODS OF BCI

The computerized algorithm identifies the intention of the user and correlates it with the activated areas of the brain. The user sees the movement of the cursor and fine-tunes the movement of the cursor to move it in a desired direction. Using established correlations and a bi-directional feedback system, the user learns how to acutely control the cursor.

For many functions controlled by the brain the population of neurons is more relevant than the tuning of an individual neuron. Georgopoulos et al. used SU BCI to record the activity of single neurons during microelectrode penetrations into the motor cortex contralateral to the arm at which rhesus monkeys performed motion tasks [5]. The relationship between activity in the arm-related cells and the direction of arm movement in 3-D space was examined using the frequency of discharge (neural impulses per second) as a measure of neuronal activity. It was found that specific neurons demonstrated greater activity when movements were made in specific directions, as demonstrated in figure 5. They used the following model to relate cell activity to movement direction, and found there is a particular movement vector C for which the cell's activity will be highest.

$$d(M) = b + b_x m_x + b_y m_y + b_z m_z$$

Equation 1*: Model relating cell activity to movement direction in Rhesus Macaques. d(M) represents the frequency of discharge of a particular neuron during movement in direction (m_x, m_y, m_z), and b, b_x, b_y, b_z are coefficients that vary between neurons. [5]*

The direction of this vector is the cell's preferred direction, and can be determined by estimating the direction cosines c_x, c_y, and c_z as follows:

$$c_x = \frac{b_x}{\sqrt{b_x^2 + b_y^2 + b_z^2}}$$
$$c_y = \frac{b_y}{\sqrt{b_x^2 + b_y^2 + b_z^2}}$$
$$c_z = \frac{b_z}{\sqrt{b_x^2 + b_y^2 + b_z^2}}$$

The directional tuning of single neurons suggests that individual cells do not code the direction of movement, but instead are coded by a unique neuronal ensemble. Each cell makes a vectorial contribution along its preferred direction, where the magnitude of the contribution (or length of the vector) is proportional to that cells activity [1]. The vector sum of these cell vectors is called the population vector, and is demonstrated in figure 6.

Electrocorticographic signals are composed of synchronized postsynaptic potentials (LFPs) that are recorded directly from the exposed surface of the cortex. Several groups have confirmed that high frequency (high gamma band activity) LFPs are well correlated to single unit activity [1]. Recent studies that investigated the columnar organization of the encoded movement parameters (preferred directions) suggest that primary motor cortex has a loosely columnar organization, meaning that location is correlated with neuronal firing rates. In ECoG, rather than having activity in individual neurons, specific electrodes on an electrode array detect increased activity at distinct locations in the brain. Each electrode, or channel, is split into several frequency bands, called features, and a population vector is determined based on the preferred direction of each of these features.

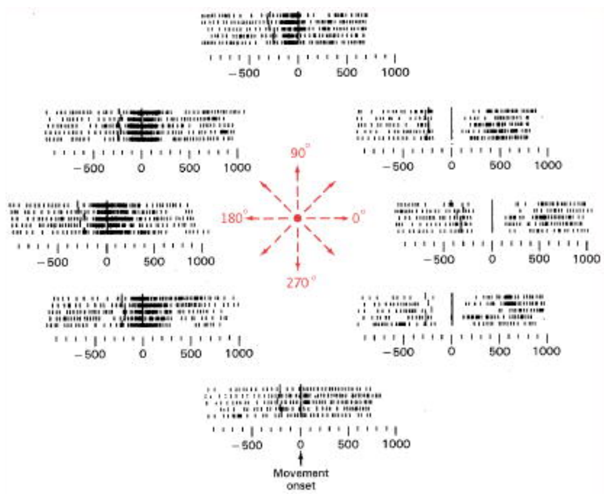


Figure 5: *As a Rhesus Macaque made reaching motions towards eight different targets, neuronal activity was recorded using single unit microelectrodes. It was noted that neuronal activity in specific neurons was correlated with directions of motion. [6]*

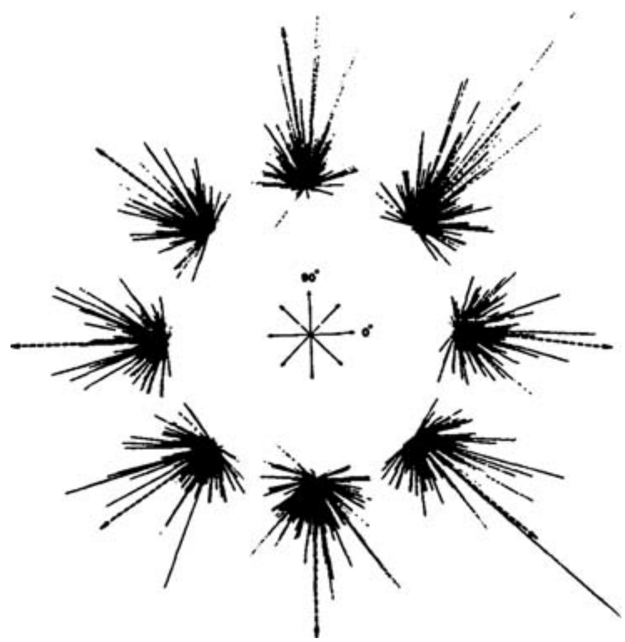
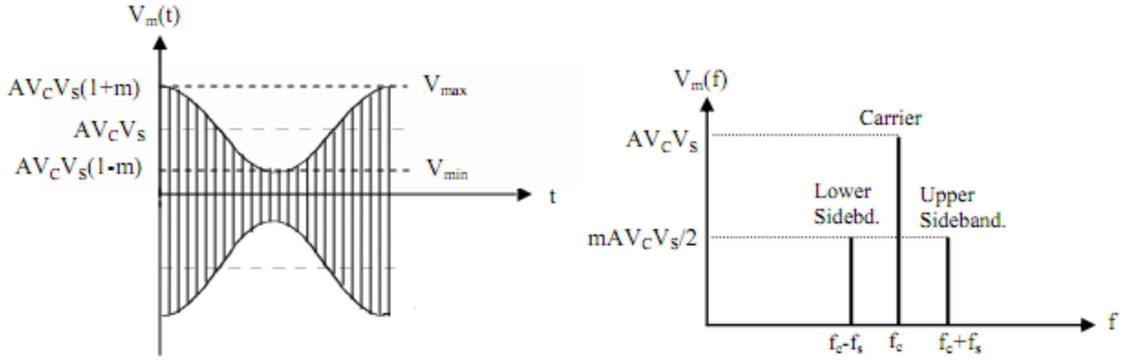


Figure 6: *Representation of movement direction by a neuronal population code. The directional vectors for neurons in M1 of a monkey are illustrated for each of eight directions of reaching movements. The population vector calculated from the individual cell vectors is closely aligned to its corresponding movement direction. [7]*

D.2 RADIO FREQUENCY TRANSMISSION

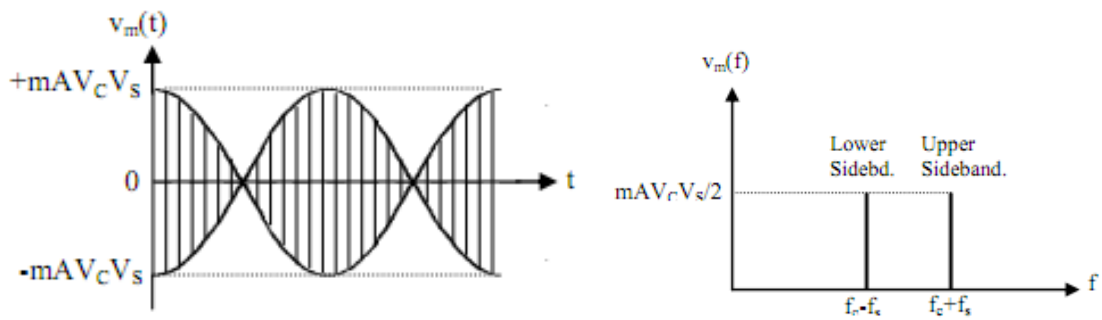
The use of an antenna is required to transmit signals. At any given point in time, there are thousands of radio signals propagating through the air. A radio tuner is necessary to tune in to a particular frequency in order to receive a specific packet of data. Signals are modulated using either pure tones or square waves, and then transmitted at a specific frequency to be picked up by the receiver. The receiver then demodulates the signal, preserving the encoded data. The RF receiver used in this telemeter was patented by Samsung Electronics Co., Ltd., in 2005 [10].

Amplitude modulation allows the transmission of the processed signals at a specific frequency while keeping frequency response of the ECoG data intact. There are two types of amplitude modulation, double sideband amplitude modulation (envelope modulation) and double sideband suppressed carrier modulation. Envelope modulation adds a DC bias in the time domain, enabling easy demodulation with the use of a peak detector. By detecting each peak in the carrier wave, the modulation envelope can be reconstructed, allowing the signal's frequency information to be extracted. However, due to the DC offset, power is used to send a carrier component that holds no information. Using double sideband suppressed carrier modulation saves power, but is much more difficult to demodulate in the time domain due to the lack of envelope and over lapping modulating signal. The cost and benefit of each method will be evaluated before finalizing a circuit design.



A) B)

Figure 7: *A) This figure demonstrates envelope modulation in the time domain. The envelope is the modulating signal surrounding the carrier signal and contains the encoded information. In this example, the modulating signal is a pure tone with peak-to-peak amplitude* V_{max}*-*V_{min}*. B) This is the frequency response of the modulated double sideband signal. The information has been shifted by the carrier frequency and is in a usable range for transmission. The carrier spike holds no information but expends power when it is transmitted.*



A) B)

Figure 8: *A) This figure demonstrates double sideband suppressed carrier modulation in the time domain. The modulating signal surrounding the carrier signal lies both above and below the axis, complicating the decoding algorithm. In this example, the modulating signal is a pure tone with peak-to-peak amplitude as shown. B) This is the frequency response of the modulated double sideband suppressed carrier signal. The information has been shifted by the carrier frequency and is in a usable range for transmission. There is no spike for the carrier signal, saving power.*

D.3 EXISTING SOLUTIONS

Existing methods of transmitting signals from the brain to a signal processor consist of plugging in an external headstage and preamplifier through means of percutaneous leads. The purpose of this design project is to improve this method of signal transmission by providing wireless transmission through an implantable headstage and telemeter. The need being addressed by this project is the desire for greater mobility and continuous recording of the experimental monkeys to observe brain activity during natural behavior. The only current methods of recording brain signals involve the use of cables being hooked up to the electrode array on the brain. This design project is attempting to improve the current BCI technology and there are no existing solutions that accomplish the goal of creating a wireless BCI system.

E. SCHEDULE

The tasks outlined in this section will need to be completed throughout the semester to yield a cohesive final design. The schedule presented will be followed to ensure that all necessary components of the design are accounted for. Each group member will maintain a design notebook in which he/she will detail his/her thought process, a complete account of the teams activities, conclusions, and design decisions. This notebook will convey logical and chronological evidence of the progress of the design project. In addition, a weekly report will be submitted each week outlining the progress that has made during the previous week and goals for the following week.

E.1 LIST OF TASKS TO BE COMPLETED

1. *Project Scope - Due September 14*

The project scope identifies the problem to be addressed and discusses the basic requirements of the design. It presents an overview of the project and lists foreseen challenges that will need to be addressed during the design process.

2. *Preliminary Report and Presentation - Due September 28*

The preliminary report focuses on defining the scope of the project. It includes background information about previous technologies and an in-depth analysis of the need for the design. The preliminary report includes detailed project specifications, taking into account both the consumer perspective and the eventual marketing potential.

3. *Headstage Circuit Design*

The headstage circuit board must retain the ability to amplify and filter ECoG signals and have a low noise floor in order to accommodate extremely small brain signals. The design for this circuit board will be completed using the specifications given by Dr. Moran. While most of the data processing algorithm is already finished and can be easily programmed onto a chip, the hardware that will make this compatible with multiple channels of ECoG recording needs to be designed.

4. *Telemeter Circuit Board*

The telemeter circuit board must transmit both raw and processed signals to an external receiver to be used for brain control tasks. Brain control is established in ECoG by using power modulation in the frequency domain, so transmitting the processed signal with the frequency response intact is essential.

5. *Web Page*

The project web page provides a clear representation of our project for public access. It includes an overview of the project, all weekly reports, presentations, design safe outputs, and other relevant information. This website will be used primarily to track progress of the project and will be kept active for a significant length of time to be used on resumes.

6. *Progress Report and Presentation - Due October 26*

The progress report outlines several possible solutions to the problem presented by our mentor. Each of these solutions will be examined and one will be presented as the best choice based on benefits and trade offs of each option. For this report, preliminary circuit designs will be completed and simulations in PSpice will be prepared for presentation. The information in this report will also be presented to the class in the form of a 12-minute oral presentation.

7. *Risk Assessment*

The risk assessment evaluates the potential dangers associated with our design and discusses ways to mitigate these risks. During the risk evaluation, the ways in which the design might malfunction as well as possible user errors that could contribute to product failure will be examined. The likelihood of these errors occurring and the significance of each risk will be evaluated. To mitigate these shortcomings of the design, ways to eliminate the cause, lower the probability, or protect against the effect of each risk will be determined. A safety assessment will be completed using DesignSafe software. The output of this evaluation will be posted on the project website.

8. *Final Report and Presentation - Due December 7*

The final report presents the complete solution and an evaluation of the design process. Circuit simulations for both the headstage circuit board and the telemeter circuit board will be completed and the results, matching the specifications of our mentor, will be presented. The information in this report will also be presented to the class in the form of a 12-minute oral presentation.

9. *Senior Design Poster*

The senior design poster presents the final design project in a succinct manner to be displayed to other students and faculty at the Undergraduate Research Symposium.

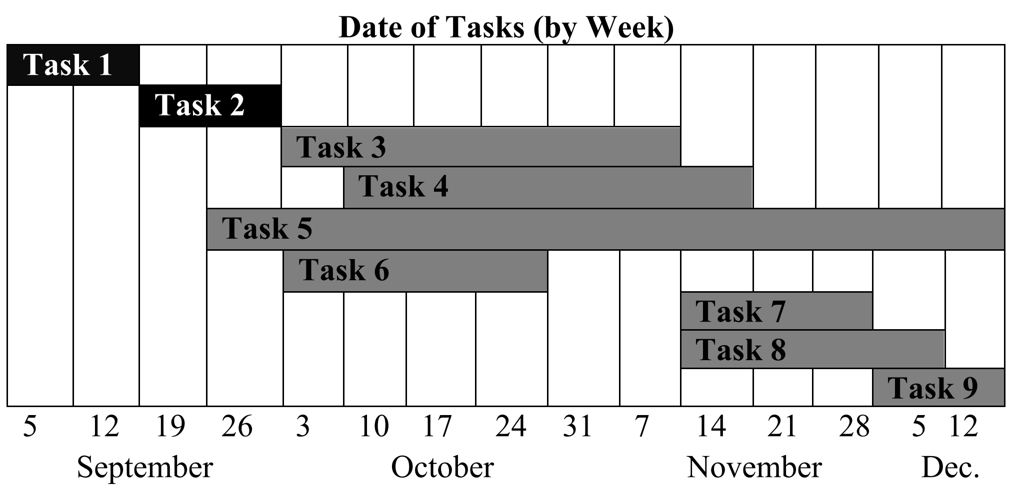
E.2 PRELIMINARY SCHEDULE

In order to complete this project in the allotted 16 weeks, a preliminary schedule was developed and will attempt to be followed. Tasks filled in with black have already been completed.

Table 1. Preliminary Design Schedule

Tasks

Task 1: Project Scope
Task 2: Preliminary Report
Task 3: Headstage Circuit
Task 4: Telemeter Circuit
Task 5: Web page
Task 6: Progress Report
Task 7: Risk Assessment
Task 8: Final Report
Task 9: Design Poster



F. ORGANIZATION OF TASKS AND TEAM MEMBERS

Tasks will be assigned to team members based on particular strengths. The table below outlines the specific work that needs to be done to complete each task.

Table 2. Organization of Tasks

	Report	Presentation	PSpice	CAD	Solid Works	Web Design	DesignSafe
Task 1: Project Scope	x						
Task 2: Preliminary Report	x	x					
Task 3: Headstage			x	x	x		
Task 4: Telemeter			x	x	x		
Task 5: Web page						x	
Task 6: Progress Report	x	x					
Task 7: Risk Assessment							x
Task 8: Final Report	x	x					
Task 9: Design Poster		x					

Table 3. Distribution of Tasks

Lindsey	Suyi	Jessi	Group Tasks
Preliminary Presentation	Progress Presentation	Final Presentation	Project scope
CAD drawings	Solid Works drawings	Pspice designs	All written design reports
Web page design	Design Safe assessment	Primary contact with mentor	

The team members have a diverse set of skills that will be utilize to complete the various set of tasks. In order to have a successful project, full communication and constant updates are fully encouraged.. Organization and task assignments are detailed in the table, but as the project progresses the team will adapt and take on any new challenges presented. Each team member is responsible for completing their assigned task, but full cooperation between members is expected to fulfill all the obligations of the project.

G. REFERENCES

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