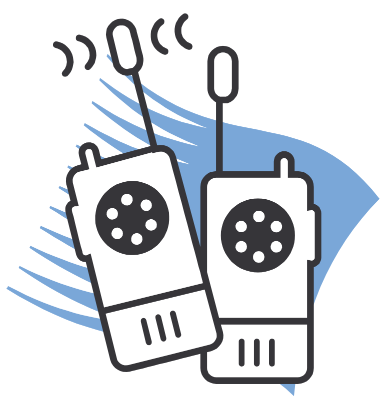
# Wireless Medical Telemetry Laboratory




**CleveLabs Laboratory Course System Version 6.0**

# Introduction

The development of wireless medical telemetry has become an increasingly popular application in recent years. As the elderly population continues to increase, healthcare costs also continue to rise. Systems that are developed for monitoring diseases at home provide several benefits. First, by monitoring a person at home the disease progression or fluctuation can be monitored continuously instead of only obtaining a snapshot in the doctor's office. Secondly, healthcare costs can decrease since the monitoring may be done outside of the clinic. Finally, the quality of life for the patient may increase since they can be monitored in the comfort of their own homes.

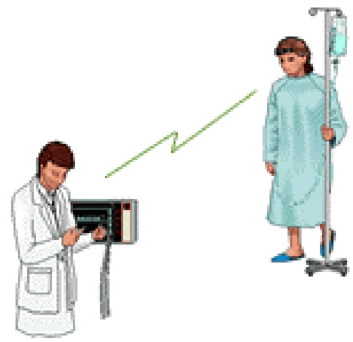


**Figure 1.** Wireless medical telemetry transmits physiological data from a patient to a computer.

Current bedside monitoring systems in the clinic involve tethering a patient to large cart mounted boxes at the bedside. Types of signals that may be monitored include electrical activity of the heart (electrocardiography), electrical brain activity (electroencephalography), pulse oximetry, and many others. Electrodes worn by the person are connected to leads that plug into the cart mounted bedside monitors. In the home setting, someone cannot be continuously monitored while connected to large boxes and still perform activities of daily living.

A wireless system worn by the patient provides them freedom to move around the house or clinic. Electrodes and transducers connect to a small radio transmitter worn by the patient. Their physiological data is transmitted from the user worn unit to a computer over a radio link. Telemetry systems not only make the patient more comfortable but may reduce costs for hospitals by allowing them to monitor any patient in any room, minimizing the costs of transferring data to a single location, and minimize the amount of equipment that must be kept in the patient room.

**Equipment Required:**

- CleveLabs Kit
- CleveLabs Course Software
- BioRadio Capture Lite Software installed on a separate computer
- At least one extra BioRadio system
- If possible, a cordless phone operating in the 900MHz range

# Background

Wireless medical telemetry was first used in hospitals for fetal heart rate monitoring more than 30 years ago. Originally developed by NASA engineers to monitor the physiological parameters of astronauts, wireless medical telemetry has since been utilized to monitor everything from oxygen saturation to orthopedic device loading. Wireless medical telemetry offers the advantage of obtaining accurate physiological signals from freely moving, untethered patients. Given the hectic hospital environment, wireless medical telemetry has become and will continue to be an important technological innovation.

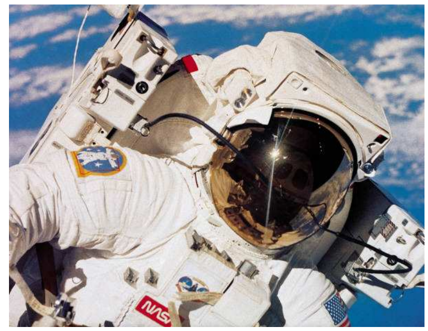
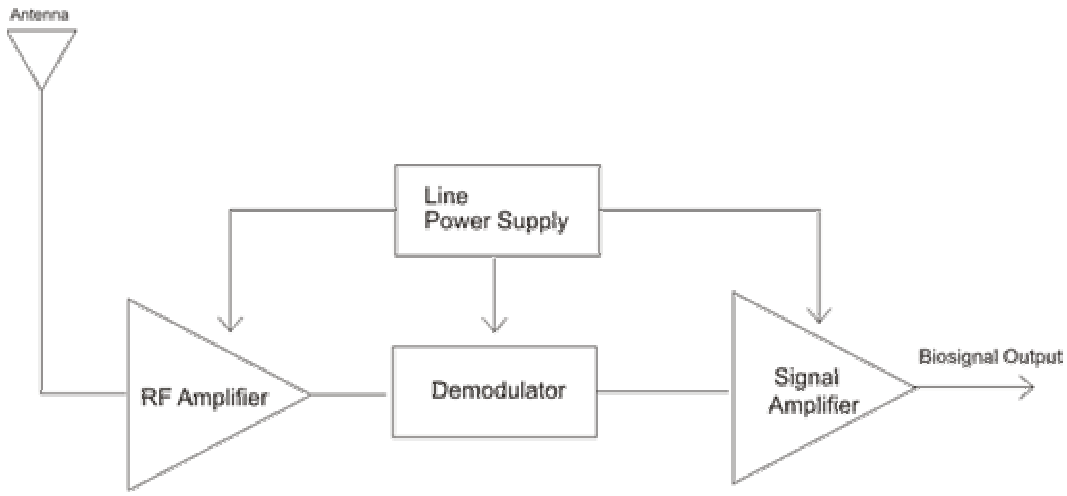


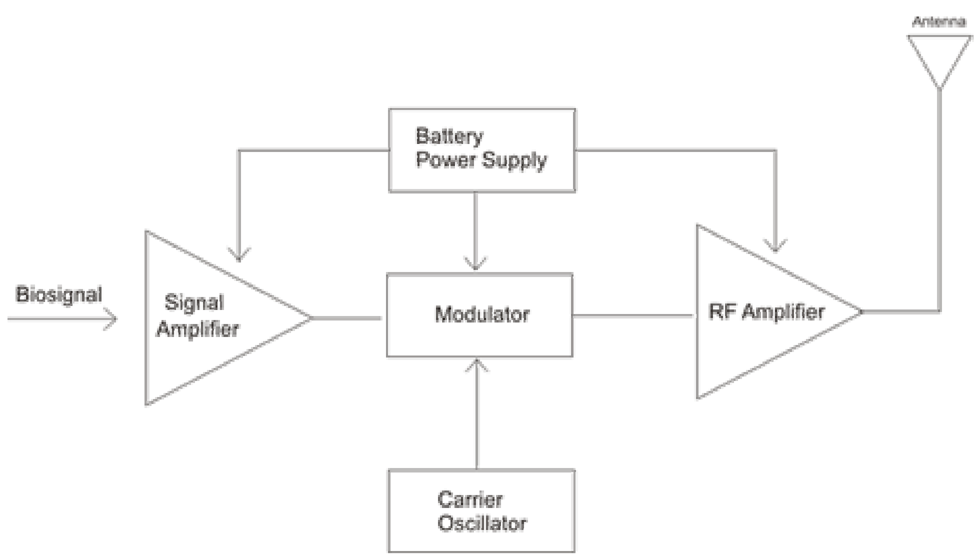
**Figure 2.** NASA first employed telemetry to monitor astronauts.

In order to understand how a wireless medical telemetry device works, one must be familiar with the electromagnetic spectrum. Electromagnetic energy is composed of alternating electric and magnetic fields traveling through space. The energy carried in these fields can manifest when it interacts with a certain type of matter. What differentiates different types of electromagnetic energy is the wavelength of the fields. Wavelengths can vary dramatically, as can their effects. For example, x-ray and gamma-ray energy have wavelengths ($10^{-10}$ – $10^{-14}$m) so small that they can fit between individual atoms. Radio waves, on the other hand, have much longer wavelengths (1 - $10^4$m) and are most commonly used for communication purposes. A wireless medical telemetry device, as defined by the Federal Communications Commission (FCC), is a device that transmits physiological signals via radio frequency (RF) from a transmitter worn by the patient to a remote receiver.

A typical wireless medical telemetry system is composed of a small, battery-operated radio transmitter that is connected to electrodes placed on the patient. The signal is transmitted to a remotely located receiver that recovers the signal for further processing. Block diagrams for a single channel medical telemetry system transmitter and receiver are presented in Figure 3.




(a) Transmitter




(b) Receiver

**Figure 3.** Block diagram of simple one-channel telemetry system showing transmitter (a) and receiver (b) function.

The first step in the wireless medical telemetry process is to amplify the bio-signal. Once amplified, the signal can modulate the RF carrier generated by an oscillator. The modulated RF signal can then be directly applied to the radiating antenna. The transmitter is usually powered by a small battery pack operating at a low voltage, minimizing the electrical hazards and risks to the patient.

At the receiver, an antenna receives the modulated RF signal and amplifies it through a RF amplifier. Next, the signal is demodulated in order to recover the original information from the transmitter. Receiver units are most commonly powered by a wall outlet because of their permanent location in an isolated location from the patient.

One problem hospitals are facing while trying to integrate telemetry technology into their operations is signal interference from other wireless devices. For example, as you may have seen in many hospitals, there is often a sign not to use cell phones. Signal interference can have major implications on patient safety. To ease this integration, the FCC has developed the Wireless Medical Telemetry Service (WMTS), a set of RF bands used solely for wireless medical telemetry applications. These frequencies are 608-614 MHz, 1395-1400 MHz, and 1427-1432 MHz. Devices transmitting in these frequencies can operate protected from interference caused by other RF sources such as wireless phones and wireless local area networks (WLAN).

The WMTS bands offer the advantage of being the first bands dedicated solely for the use of medical telemetry equipment. This, in turn, allows for faster and more reliable two–way communication. However, the WMTS bands are very narrow, making video and voice transmission virtually impossible.

The BioRadio 150 operates within a set of RF bands known as the ISM bands. These bands were originally set aside for Industrial, Scientific, and Medical applications and have since been used for technologies such as WLAN and Bluetooth. The ISM bands are 902-928 MHz, 2400-2500 MHz, and 5725-5875 MHz. The BioRadio 150 operates in the 902-928 MHz band.

The ISM bands offer users the advantage of increased bandwidth, making voice and video transmissions possible. However, this increased bandwidth is more susceptible to interference from devices such as wireless telephones and microwave ovens because they are not exclusive to medical telemetry equipment. All RF bands have positive and negative attributes to consider when developing a wireless device for medical purposes. Regardless of the band chosen, constant management is crucial to reduce the probability of interference from other wireless devices.

One method to combat signal interference and maintain constant contact with a patient is spread spectrum modulation. Spread spectrum modulation involves transmitting a signal over a wide range of frequencies and then collecting these signals onto their original frequency at the receiver. There are two methods by which spread spectrum modulation can occur: frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS). The latter occurs by a continually changing the center frequency of the signal by "hopping" between available frequencies according to a specific algorithm. A "packet" of data is sent to the receiver by the transmitter that then tunes to a different frequency and transmits again. The receiver works in tune with the transmitter, collecting the "packets" of data and reorganizing them onto their original frequency. DSSS occurs by multiplying the signal by a spreading function, keeping the center frequency of the data constant. The receiver then multiplies the incoming data by the spreading function again to decode the signal and collect it onto its original frequency.

**BioSpectrum Application**

The BioSpectrum Application allows a user to analyze the wireless environment around them. The application puts the BioRadio computer unit into an RF sweep mode. This means that the unit sweeps the environment for any devices which are transmitting in the 900MHz range. More specifically, the unit scans the environment and calculates the current power at discrete intervals in the range of 900 to 928 MHz. The discrete intervals that are analyzed actually refer to the available channels that the BioRadio can be programmed to using BioRadio Capture Lite.

To begin sweeping the environment, click on the Start Sweep button. The application completes one sweep approximately once a second. The x axis can be toggled between BioRadio channels or the actual RF frequency. The bottom plot displays the current power for each channel in the sweep. The top plot is known as a waterfall display which shows a history of previous sweeps. Using this plot, you can see how the RF environment has been changing over time. Each horizontal slice represents a past sweep. Areas shown in red have the greatest power where areas in blue have the lowest power.

This type of plot is useful because it can show a user what is the best channel to program the BioRadio to where the least amount of interference will occur. A user should avoid programming it to a channel where there is already high power. A channel should be selected that currently has low power since it means nothing in the environment is currently operating in that band and it will minimize potential interference.

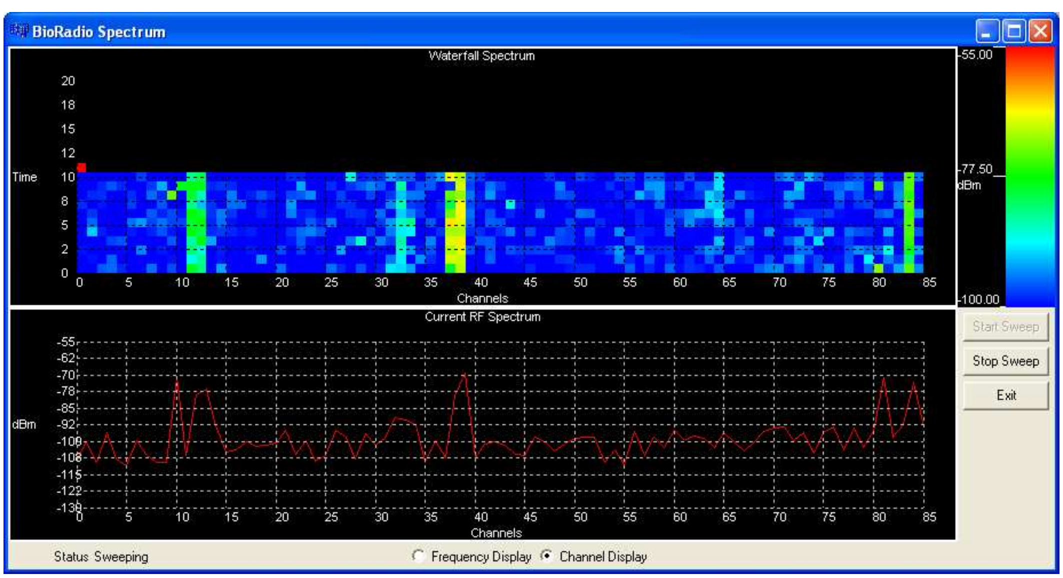



**Figure 4.** BioSpectrum radio frequency sweep application.

## Experimental Methods

*Experimental Setup*

During this laboratory session you will use one BioRadio computer unit with the BioSpectrum application to complete an RF sweep of the environment. You will then use another BioRadio unit operating with Capture Lite on a separate computer to create changes in the RF environment that will be displayed on the BioSpectrum application. Additionally, you may use a cordless phone that operates in the 900MHz range to create additional power in the 900MHz band that will appear on the display.

1. Connect the computer unit of one BioRadio to the computer with which you are running CleveLabs. You will not need the User unit for this system.

2. Run the CleveLabs Course software. Log in and select the "Wireless Medical Telemetry" laboratory session under the Engineering Basics subheading and click on the "Begin Lab" button.

3. Click on the "Run BioSpectrum" button to launch the BioSpectrum application.

4. Click on the "Start Sweep" button to begin sweeping the environment.

*Procedure and Data Collection*

1. Connect the computer unit of a separate BioRadio system to a computer running BioRadio Capture Lite. Turn the BioRadio User unit for that system on.

2. Launch the BioRadio Capture Lite application and click on "Start". It does not matter what configuration the BioRadio is programmed to.

3. However, you should note the number that appears in the "RF Channel" box of the Capture Lite software application.

4. Go back to the computer using BioSpectrum and set the x-axis to channels.

5. You should see a high power in the channel where the other BioRadio system is operation.

6. Using BioRadio Capture Lite, change the RF channel at which the system is operating and note any changes in the BioSpectrum display.

7. Using BioRadio Capture Lite, change the RF channel at which the system is operating to HOP or hopping mode and note any changes that occur in the BioSpectrum display.

8. If you have a cordless phone that operates in the 900MHz range, turn that on and note any changes in the BioSpectrum display.

## Discussion Questions

1. What are some advantages to using a wireless system over a tethered medical monitoring system?

2. Why is an RF sweep useful?

3. What bands are allocated for medical technology?

4. Why is it important that certain bands are allocated for specific applications?

5. What is the difference between fixed frequency and frequency hopping mode? What are the advantages and disadvantages of each?

6. Describe what the differences in the waterfall and spectrum plots during each procedure you completed in the lab session.

## References

Webster, J. G. Medical Instrumentation, Application and Design Third Edition. John Wiley and Sons Inc., New York, 1998.