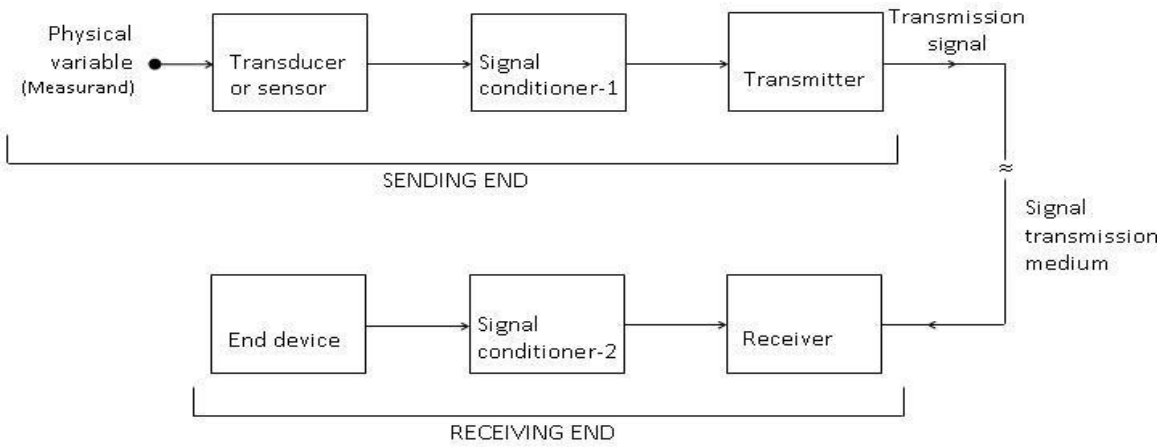
Biotelemetry systems

Biotelemetry is the use of telemetry methods in order to remotely observe, document, and measure certain physiological functions in human beings or other living organisms. The field consists of several subfields, including medical and human research telemetry, animal telemetry, and implantable biotelemetry. Medical telemetry is of particular importance because it can be used to remotely trackthe vital signs of ambulatory patients.

Measurements which have been done in biotelemetry can be determined in two categories:Bioelectrical variables, such as electrocardiogram (ECG), electromyogram (EMG) and electroencephalogram (EEG).

Physiological variables that require transducers, such as blood pressure, gastrointestinal pressure, blood flow and temperature. By using suitable transducers, telemetry can be employed for the measurement of a wide variety of physiological variables.

Elements of Telemetry



Block schematic of basic telemetry system

1. Transducer or Sensor:

• Converts the physical variable to be telemetered into an electrical quantity.

2. Signal Conditioner-1:

• Converts the electrical output of the transducer (or sensor) into an electrical signal compatiblewith the transmitter.

•

3. Transmitter:

Its purpose is to transmit the information signal coming from the signal conditioner-1 using asuitable carrier signal to the receiving end.

The transmitter may perform one or more of the following functions:

- **Modulation**: Modulation of a carrier signal by the information signal.
- **Amplification**: As and if required for the purpose of transmission.
- **Signal Conversion**: As and if required for the purpose of transmission.
- **Multiplexing**: If more than one physical variable needs to be telemetered simultaneously from the same location, then either frequency-division multiplexing (FDM) or time-division multiplexing (TDM) is used.
- **Receiver:** Its purpose is to receive the signal(s) coming from the transmitter(located at the sending end of the telemetry system) via the signal transmission medium and recover the information from the same.

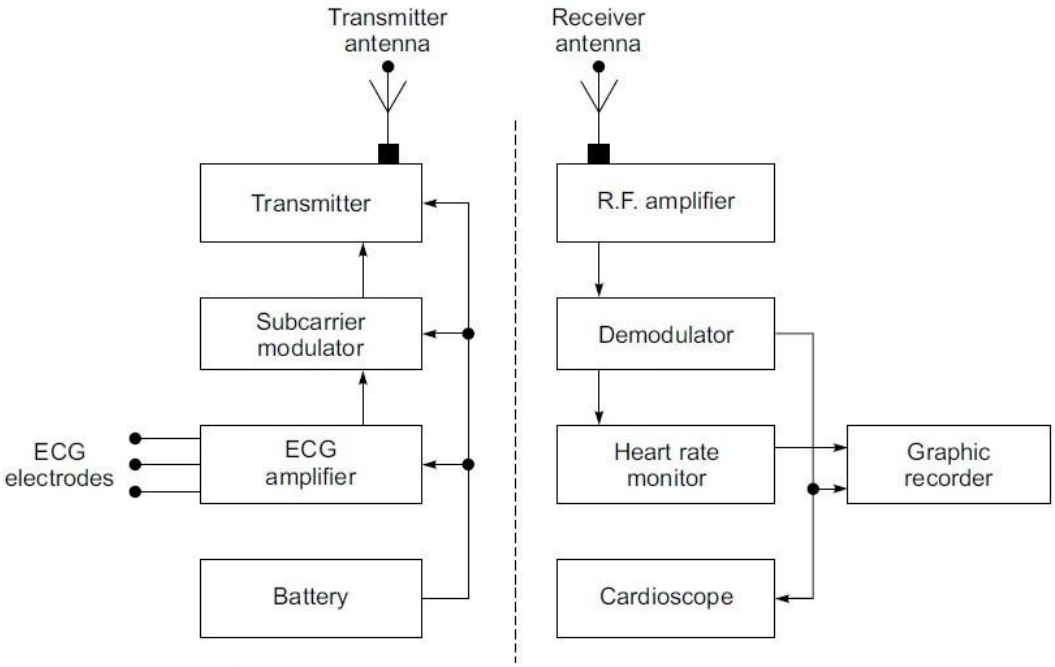
- It may perform one or more of the following functions:
  1. Amplification
  2. Demodulation:
  3. Reverse Signal Conversion
- De-multiplexing
- **Signal Conditioner-2**: Processes the receiver output as necessary to make it suitable to drive thegiven end device.
- **End Device**: The element is so called because it appears at the end of the system.
- End device may be performingone of the following functions:
  1. Analog Indication:
  2. Digital Display

Single Channel Telemetry Systems

In a majority of the situations requiring monitoring of the patients by wireless telemetry, the parameter which is most commonly studied is the electrocardiogram. It is known that the display of the ECG and cardiac rate gives sufficient information on the loading of the cardiovascular system of the active subjects.

ECG Telemetry System

- The Telemetry Transmitter which consists of an ECG amplifier, a sub-carrier oscillator anda UHF transmitter along with dry cell batteries.
- Telemetry Receiver consists of a high frequency unit and a demodulator, to which an electrocardiographcan be connected to record, a cardio scope to display and a memory deviceto store the ECG. A heart rate meter with an alarm facility can be provided to continuouslymonitorthe beat-to-beat heart rate of the subject.

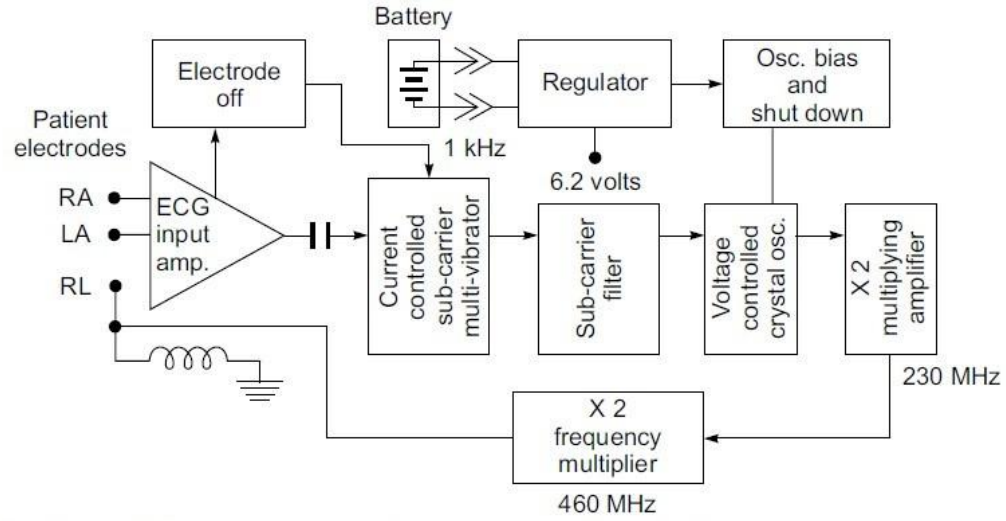


➤ Fig. 11.6 *Block diagram of a single channel telemetry system*

- While monitoring paced patients for ECG through telemetry, it is necessary to reduce pacemaker pulses. The amplitude of pacemaker pulses can be as large as 80 mV compared to 1–2 mV, which is typical of the ECG. The ECG amplifiers in the

transmitter are slew rate (rate of changeof output) limited so that the relatively narrow pacemaker pulses are reduced in amplitude substantially.

- Some ECG telemetry systems operate in the 450–470 MHz band, which is well-suited for transmission within a hospital and has the added advantage of having a large number of channels available.
- The ECG signal, picked up by three pre-gelled electrodes attached to the patient's chest, is amplified and used to frequency modulate a 1 kHz sub-carrier that in turn frequency-modulatesthe UHF carrier. The resulting signal is radiated by one of the electrode leads (RL), which servesas the antenna. The input circuitry is protected against large amplitude pulses that may result during defibrillation.



➤ Fig. 11.7 *Block diagram of ECG telemetry transmitter (Redrawn after Larsen et al permission of Hewlett Packard, U.S.A.)*

MULTI-CHANNEL WIRELESS TELEMETRY SYSTEMS

- Medical measuring problems often involve the simultaneous transmission of several parameters.For this type of application, a multi-channel telemetry system is employed. Multi- channeltelemetry is particularly useful in athletic training programs as it offers the possibility ofsimultaneously surveying several physiological parameters of the person being monitored.With appropriate electrodes/transducers and preamplifiers, the multi-channel systemspermit the transmission of the following parameters simultaneously depending upon thenumber of channels required: ECG and heart rate, respiration rate, temperature, intravascularand intra-cardiac blood pressure.
- In multi-channel telemetry, the number of sub-carriers used is same as the number of signalsto be transmitted. Each channel therefore has its own modulator. The RF unit—the same for allchannels—converts the mixed frequencies into the transmission band. Similarly, the receiverunit contains the RF unit and one demodulator for each channel.
- Pulse width modulation is better suited for multi-channel biotelemetry systems. Such systemsare insensitive to carrier frequency shifts and have high noise immunity. FM-FM systems forsimilaruse may have low power consumption and high baseline stability, but they are morecomplicated and turn out to be more expensive. They can be troubled by interference betweendifferent channels. Techniques for separation usually require expensive and complex filtersand even with these, cross-talk can still be a problem. Similarly, pulse-position amplitudemodulation easily gets into synchronization difficulties caused by noise and thus results in aloss of the information transmitted. On the other hand, advantages of pulse-width modulationinclude lower sensitivity to temperature and battery voltage changes and its adaptability tominiaturization due to availabilityof suitable integrated circuits.

- For multi-channel radiotelemetry, various channels of information are combined into a singlesignal. This technique is called multiplexing.

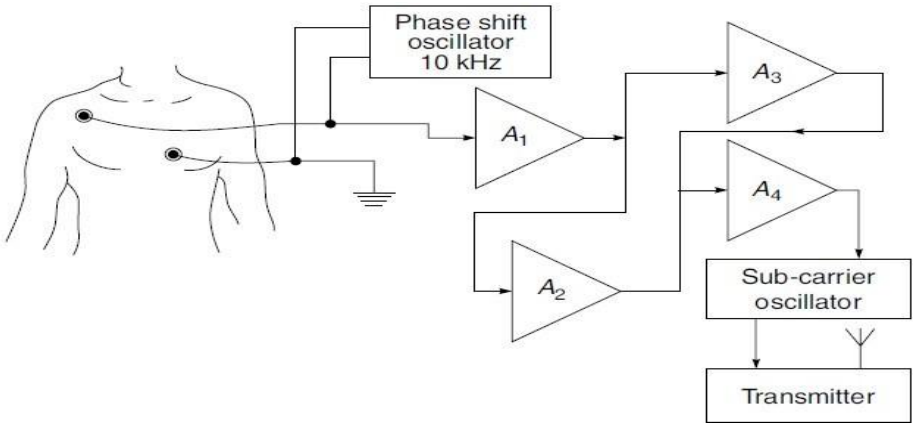
There are two basic methods of multiplexing these are:

- Frequency–division multiplexing: The method makes use of continuous-wave sub-carrierfrequencies. The signals frequency–modulate multiple subcarrier oscillators, each being at such a frequency that it's modulated signal does not overlap the frequency spectra of the other modulated signals. The frequency modulated signals from all channels are added together through a summing amplifier to give a composite signal in which none of the parts overlap in frequency. This signal then modulates the RF carrier of the transmitter and is broadcast.
- Time–division multiplexing: In this technique, multiple signals are applied to a commutatorcircuit. This circuit is an electronic switch that rapidly scans the signals from differentchannels. An oscillator drives the commutator circuit so that it samples each signal for

  aninstant of time, thereby giving a pulse train sequence corresponding to input signals. A frame reference signal is also provided as an additional channel to make it easy to recognize the sequence and value of the input channels.

Telemetry of ECG and Respiration

An FM-FM modulated radiotelemetry transmitter for detecting and transmitting ECG and respiration activity simultaneously on a single carrier frequency in the FM broadcast band. Respiration is detected by the impedance pneumographic principle by using the same pair of electrodes that are used for the ECG.



Obstetrical Telemetry System

There has been a great deal of interest to provide greater freedom of movement to patients during labour while the patient is continuously monitored through a wireless link. Thus, from a central location, it is possible to maintain a continuous surveillance of cardiotocogram records for several ambulatory patients. In the delivery room, telemetry reduces the encumbering instrumentation cablesat the bedside. Moreover, when an emergency occurs, there is no loss of monitoring in the vital minutes needed for patient transfer.

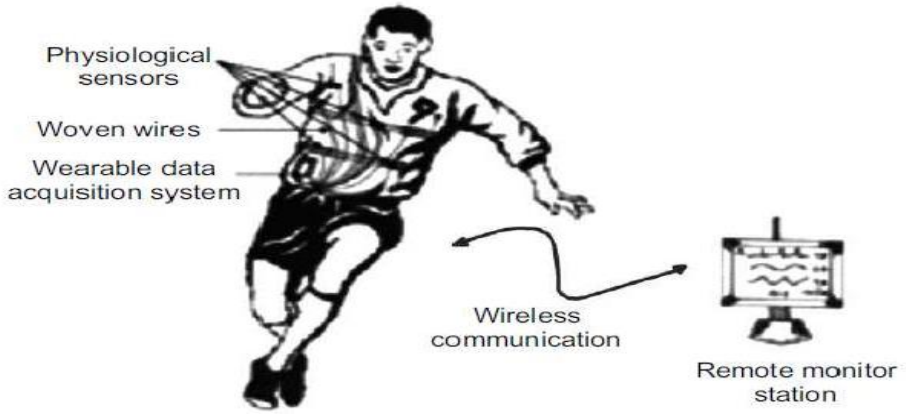
The patient carries a small pocket-sized transmitter which is designed to pick up signals for foetal heart rate and uterine activity. The foetal heart rate is derived from foetal ECG which is obtained via a scalp electrode attached to the foetus after the mother's membranes are ruptured. Uterine activity is measured via an intra-uterine pressure transducer. If only foetal ECG is measured, the patient herself can indicate uterine activity or foetal movement by using a

handheld push button.
The receiver located away from the patient, is connected to a conventional cardiotocograph. If the patient exceeds the effective transmission range or the electrode has a poor contact, it is appropriately transmitted for corrective action.

MULTI-PATIENT TELEMETRY

- The establishment of instrumented coronary care units has resulted in substantial reduction in the mortality rates of hospitalized patients. When a patient's condition has stabilized within a fewdays, it is necessary that he is monitored during the early stages of increased activity and exertion to determine if his heart has sufficiently recovered. This can be conveniently done bythe use of telemetry which provides a sort of intermediate stage of care that smoothens the

  patient's transition back to a normal life. It thus permits surveillance of suspected coronaries without the unnatural constraints of confining the patient to bed.
- The main advantage of a multi-patient single parameter telemetry system is that patients making satisfactory recovery can vacate the hard-wired instrument beds in the ICU/CCU units, which provides a positive psychological effect. The patients regain mobility after an extended period of confinement thereby improving their muscle tone and circulation. Transmitters as small in size and weighing less including battery are commercially available. Data from different patients is received at the nurse's central station. The station may have the facility of non-fade display of received waveforms, an ECG recorder which gets activated when the patient goes into alarm, loose lead/loss of signal alarm.



Implantable Telemetry Systems

Implantable telemetry systems allow the measurement of multiple physiological variables over long periods of time without any attachment of wires, restraint or anaesthesia to the monitored

subjects, no sensors need to be attached even to the body surface. Most of the work in implantable telemetry has been used exclusively in animal research. Single or multi-channel systems have been used successfullyto monitor ECG, EEG, blood pressure, blood flow, temperature, etc.