Chapter 1

TELEMETRY BASICS

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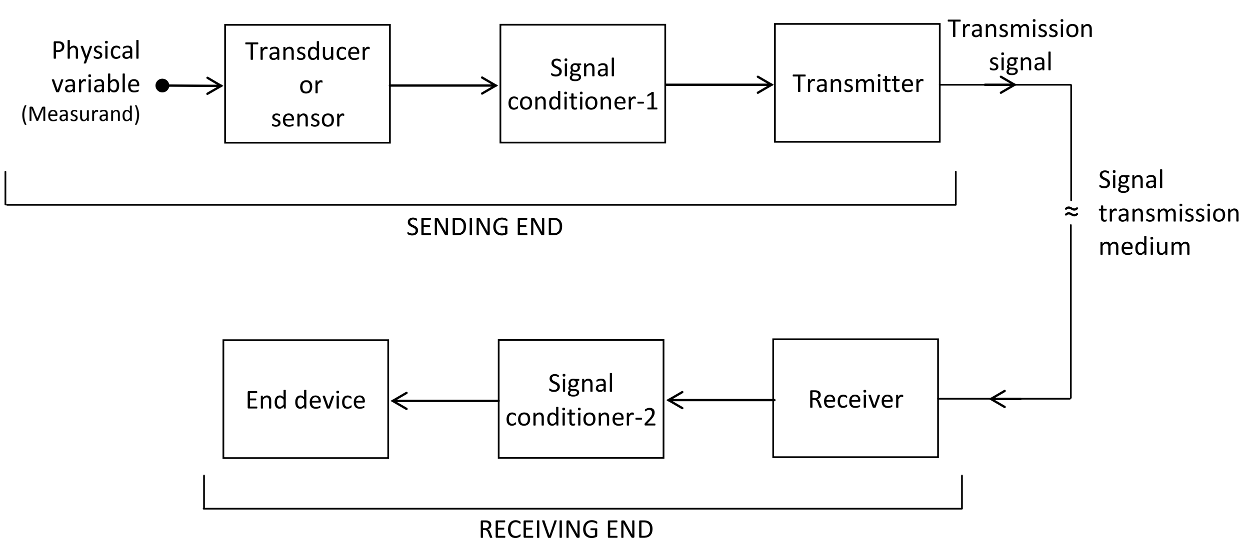
1. What is Telemetry?

The term telemetry is derived from the two Greek terms: *"tele"* and *"metron"*, which mean *"remote"* or *"far off"* and *"measure"*, respectively. Accordingly, telemetry is the measurement of remote (or far-off) physical variables or quantities. A physical variable or quantity under measurement is called *measurand.*

2. Elements of Telemetry System

Block schematic of a basic telemetry system is given below. Location of the physical variable or measurand (from where the information, that is, the value of the measurand is sent) is called the *Sending End* of the telemetry system while the location of the user or the end device (where the information is received and used) becomes the *Receiving End* of the telemetry system.



Block schematic of basic telemetry system

Purpose and function(s) of each of building-block or element of the telemetry system shown in the figure are briefly described below:

(a) Transducer or Sensor: Converts the physical variable to be telemetered (that is, the measurand) into an electrical quantity. This quantity in most cases is either an electrical parameter (variable resistance, inductance or capacitance) or an electrical signal (voltage or current).

(b) Signal Conditioner-1: Converts the *electrical output* (which may or may not be a signal, as explained above) of the transducer (or sensor) into an *electrical signal* compatible with the next element, i.e. the transmitter. The incompatibility could be either in the form (such as parameter versus signal, voltage versus current, analog versus digital, etc) or in the magnitude of the signal (that is, it is too weak to be used by the next element).

(c) Transmitter: Its purpose is to transmit the information signal (a signal containing information, i.e. a signal which is a function of the value of the measurand) coming from the signal conditioner-1 using a suitable carrier signal to the receiving end. It may perform one or more of the following functions:

(i) *Modulation:* Modulation of a carrier signal by the information signal.

(ii) *Amplification:* As and if required for the purpose of transmission.

(iii) *Signal Conversion:* As and if required for the purpose of transmission. For example, voltage to current conversion, or analog to digital conversion, or electrical signal to radio wave conversion, or electrical signal to optical beam conversion, depending on the nature of the carrier signal and the signal transmission medium.

(iv) *Multiplexing:* If more than one physical variables need to be telemetered simultaneously from the same location, then one of the following multiplexing techniques is used: (1) time-division multiplexing (TDM), (2) frequency-division multiplexing (FDM), and (3) wavelength-division multiplexing (WDM).

(d) Signal Transmission Medium: It is the medium or link that connects the sending or transmitting end to the receiving end, over which the transmitter can transmit its output signal to the receiver. Broadly, there are three signal transmission media in use: (i) copper wires, (ii) radio link, and (iii) optical fibre.

(e) 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:

(i) *Amplification:* Amplification of the received signal as and if required for the purpose of further processing.

(ii) *Demodulation:* Demodulation of the received signal to recover information signal. The demodulation process has to be complementary of the modulation performed by the transmitter.

(iii) *Reverse Signal Conversion:* This conversion is generally the reverse of the conversion performed by the transmitter. Thus the receiver is required to perform current to voltage conversion, or digital to analog conversion, or radio wave to electrical signal conversion, or optical beam to electrical signal conversion, depending on the nature of the carrier signal and the signal transmission medium.

(iv) *De-multiplexing:* It refers to the process of segregating or separating various information signals so that they can be delivered to their respective end devices. The process in the receiver has to be essentially the reverse of the multiplexing carried out by the transmitter.

(f) Signal Conditioner-2: Processes the receiver output as necessary to make it suitable to drive the given end device.

(g) End Device: The element is so called because it appears at the end of the system. Depending on the purpose of the telemetry in the given application, the end device may be performing one of the following functions:

(i) *Analog Indication:* Analog indication of the value of the measurand through the deflection of a pointer on a scale. The device used is very often a permanent magnet moving coil (PMMC) meter.

(ii) *Digital Display:* Digital display of the value of the measurand on LEDs, LCD, monitor screen etc.

(iii) *Digital Storage:* Storage of the digital value of the measurand in electronic or optical storage device for a later use.

(iv) *Data Processing:* The digital values of the mesurand may be given to a data processor, such as a microprocessor, digital signal processor or computer, for analysis etc.

3. Subsystems of Telemetry System

The schematic of basic telemetry system shown and discussed above indicates that it is comprised basically of two subsystems:

(a) Measurement Subsystem: It comprises the transducer (or sensor), signal conditioners and the end device, like any conventional measurement system.

(b) Communication Subsystem: It comprises the transmitter and receiver along with the signal transmission medium (STM) linking the two, like any communication system.

4. Where and Why is Telemetry Required?

Use of telemetry techniques becomes essential in two situations, or in other words for two cases, explained below, where the conventional measurement or local measurement techniques may not work satisfactorily:

(a) *Distant location of the measurand:* Telemetry uses electrical communication for transmitting electrical signal representing the value of the measurand from the location of the measurand to the location of the user.

(b) *Inaccessibility of the measurand:* In some situations, the electrical output of the transducer (or sensor) sensing the measurand, or that of the associated signal conditioner, *cannot be accessed by the conventional method* of connecting copper wires. Let us consider two examples:

Example-1: We want to measure the temperature of rotor winding of an electrical machine by embedding a temperature sensor in the winding. It will not be possible to take the sensor output by using copper wires. As a convenient solution, we can use telemetry. The electrical output of the *continuously rotating* temperature sensor may be converted into a radio wave, which is then transmitted by a radio transmitter to a *stationary* radio receiver and display device placed nearby on the ground. As the telemetry is employed here for covering a short distance using radio wave transmission, it is called *Short Range Radio Telemetry* (For a detailed description, please see Chapter-2: Telemetry Systems).

Example-2: We want to measure the vibrations of a conductor of an extra-high-voltage (EHV) line by attaching a vibration sensor to the conductor. If the electrical signal from the sensor is taken as such to the display device using copper wires, the low current signal would be severely affected by the strong electro-magnetic field near the conductor and the electrical insulation required will also be very expensive. A technically superior and much cheaper solution will be to convert the electrical output of the sensor (at high potential) into an optical beam and transmit it through an optical fibre to a light detector and display device placed nearby on the ground (at ground potential). Since the telemetry employed here uses optical-fibre as the STM, it is called *Optical-Fibre Telemetry* (For a detailed description, please see Chapter-2: Telemetry Systems).

5. Types of Signal Transmission Media Used in Telemetry

The signal transmission medium for telemetry can be one of the following types:

5.1 Copper Wires

A pair of copper wires (or conductors) provides a closed-circuit path for the flow of an electrical signal from the transmitter to the receiver of the telemetry system.

5.2 Radio Link

The space between transmitting and receiving antennas of the transmitter and receiver, respectively, provides a radio link or path between the two ends of the telemetry system by allowing the propagation of radio waves (high frequency electromagnetic waves) generated by the transmitting antenna through it.

5.3 Optical-Fibre Link

An optical fibre, acting as a waveguide for the propagation of an optical beam (in infra-red wavelength band) generated by the transmitter, delivers the same to the receiver. It acts as an optical-signal transmission link or path between the transmitter and receiver of the telemetry system.

6. Telemetry Classification Based on Signal Transmission Medium

Telemetry methods and systems are sometimes classified on the basis of the signal transmission medium used. Accordingly, the following nomenclature is used:

6.1 Wire-Link Telemetry or Wire Telemetry

It uses a pair of copper wires (or conductors) as the signal transmission medium or link between the sending and receiving ends.

6.2 Radio Telemetry or Wireless Telemetry

It uses a radio link between the transmitting and receiving ends. Very often, references are made to the following two special types of radio telemetry:

(i) *Short-Range Radio Telemetry:* When *radio link* is used for the reason that the sensor output cannot be taken through wires whereas the distance involved is so *short* that even conventional methods of measurement could have been used, then this type of radio telemetry is called short range radio telemetry.

(ii) *Satellite-Radio Telemetry:* When satellite radio communication is used for linking widely spaced transmitter and receiver of a radio telemetry system, it is referred to as satellite-radio telemetry.

6.3 Optical-Fibre Telemetry or Fibre-Optic Telemetry

It uses optical fibre as the signal transmission medium or link between the transmitting and receiving ends.

7. Necessity of Modulation in Telemetry

The information signal (that contains the value of the measurand) is very often not suitable for transmission from the transmitter to the receiver and is, therefore, used to modulate a carrier signal compatible with the given transmission medium. The modulated carrier, which now contains the information, is transmitted by the transmitter to the receiver.

In all, following are the reasons for using modulation in telemetry:

(a) To achieve compatibility with the given transmission medium:
A carrier signal compatible with the given transmission medium is selected for modulation. Following are some examples:
(i) An audio-frequency carrier signal is used with AC copper wire links.
(ii) A radio-frequency carrier is used with radio links.
(iii) An optical-beam is used as the carrier for optical fibre links.

(b) To improve signal-to-noise ratio:
A proper choice of the type of modulation and the type and frequency of the carrier signal can improve SNR considerably thus improve the fidelity of the communication sub-system of the telemetry system.

(c) To enable multiplexing of STM:
Modulation allows transmission of several information signals on a single STM or link. If a pair of copper wires or a radio link is used as the STM, different carrier frequencies will be used for modulation by different information signals, resulting in *frequency division multiplexing (FDM)*. Similarly, if an optical fibre is the STM, optical beams of different wavelengths, modulated by different information signals, will be made to propagate through the single optical fibre. This is *wavelength division multiplexing (WDM).*

In most telemetry systems, a single-stage modulation is employed to take care of the above requirements. But *there are two exceptions* as under:

(i) In very simple situations of wire telemetry of a single measurand (means no multiplexing required) over a short distance (means that SNR is not an issue), the information signal itself can be transmitted and *no modulation* would, therefore, be necessary.

(ii) In some complex situations, *two or even three stages* of modulation are employed for better performance of the communication subsystem of the telemetry system.

8. Modulation Methods and Telemetry Classification Based on Modulation Method

In regard to the modulation, there are three possibilities and accordingly there are three categories of telemetry systems as follows:

8.1 DC Telemetry Systems

These telemetry systems use no modulation. The information signal which varies very slowly and is considered as a DC signal is transmitted as such.

There are two telemetry systems in this category:

1. Direct voltage telemetry system
2. Direct current telemetry system

8.2 AC Telemetry Systems

These telemetry systems use an AC carrier, which is modulated using one of the AC modulation techniques.

There are two telemetry systems in this category:

1. Amplitude modulation (AM) telemetry system
2. Frequency modulation (FM) telemetry system

8.3 Pulse Telemetry System

These telemetry systems use a pulse carrier, which is modulated using one of the pulse modulation techniques.

There are five telemetry systems in this category:

1. Pulse amplitude modulation (PAM) telemetry system
2. Pulse width modulation (PWM) telemetry system
3. Pulse phase modulation (PPM) telemetry system
4. Pulse frequency modulation (PFM) telemetry system
5. Pulse code modulation (PCM) telemetry system

9. Telemetry Classification Based on Type of Information Signal

Telemetry methods and systems are very often also classified on the basis of the type of the information signal, which can be either analog or digital. Accordingly the telemetry system is called analog or digital telemetry system. It may be noted that in all the telemetry systems listed in the last section, the input to the transmitter is an analog signal, with only one exception, viz. PCM telemetry system. Accordingly, the above telemetry systems can be re-classified under two categories as follows:

9.1 Analog Telemetry Systems

1. Direct voltage telemetry system
2. Direct current telemetry system

3. Amplitude modulation (AM) telemetry system
4. Frequency modulation (FM) telemetry system
5. Pulse amplitude modulation (PAM) telemetry system
6. Pulse width modulation (PWM) telemetry system
7. Pulse phase modulation (PPM) telemetry system
8. Pulse frequency modulation (PFM) telemetry system

9.2 **Digital Telemetry System**

Or

Pulse code modulation (PCM) telemetry system

10. **Telemetry Classification Based on Number of Channels**

Depending on the number of physical variables (measurands) telemetered by a telemetry system, it may be either a single-channel or a multi-channel telemetry system. One of the following methods of multiplexing is used in a telemetry system of multi-channel type in order to send signals of all the channels on a single STM:

(a) Time Division Multiplexing (TDM): It can be used with all types of signal transmission links.

(b) *Frequency Division Multiplexing (FDM):* It can be used with copper wire links and radio links only.

(c) *Wavelength Division Multiplexing (WDM):* It can be used with optical fibre link only.

11. **Telemetry Error**

11.1 Definition

Telemetry error is the difference between the telemetered value of the measurand and its true value. Generally this error is specified or calculated as percent of the true value of the measurand. Thus it can be defined by the following mathematical equation:

$$\text{Percent telemetry error} = \frac{\text{Telemetered value} - \text{True value}}{\text{True value}} \times 100$$

11.2 Components of Telemetry Error

The total telemetry error has two components:

(a) *Measurement Error:* This component of the total telemetry error is introduced by the measurement subsystem, that is, by the sensor, signal conditioners and the end device all together.

(b) *Transmission or Communication Error:* This component of the total telemetry error is introduced by the communication subsystem, that is, by the transmitter, receiver and the signal transmission medium all together.

11.3 Sources and Control of Telemetry Error

If we can identify the sources of the above two error components, it would be possible to control (i.e. minimize) them.

(a) The main sources or causes of the measurement error are:

1. Improper choice of the measurement components (sensor, signal conditioners and end device)
2. Improper design of the measurement components
3. Drifts in the measurement components.

(b) The measurement error resulting from the above causes can be controlled (minimized) by resorting to the following measures:

1. Proper selection of the measurement components
2. Proper design of the measurement components
3. Periodic calibration of the telemetry system on the whole or that of the critical components in the system.

(c) The main sources or causes of the transmission or communication error are:

1. Attenuation of the transmission signal, if information is contained in its amplitude or magnitude
2. Distortion of the transmission signal, if information is contained in its wave-shape
3. Noise in communication, both internally generated and externally induced.

(d) The transmission or communication error resulting from the above causes can be controlled (minimized) by resorting to the following measures:

1. Proper choice of the transmission signal
2. Proper choice of the modulation method
3. Proper choice of the signal transmission medium

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