Telemetry

Telemetry is a technology that allows measurements to be made at a distance, via radio wave or IP network transmission and reception of the information. The word is derived from Greek roots: *tele* = remote and *metron* = measure. Systems that need external instructions and data to operate require the counterpart of telemetry, telecommand.

Although the term commonly refers to wireless data transfer mechanisms (e.g. using radio, hypersonic or infrared systems), it also encompasses data transferred over other media such as a telephone or computer network, optical link or other wired communications like phase line carriers. Many modern telemetry systems take advantage of the low cost and ubiquity of GSM networks by using SMS to receive and transmit telemetry data.

History

Telemetering information over wire had its origins in the 19th century. One of the first data-transmission circuits was developed in 1845 between the Russian Tsar's Winter Palace and army headquarters. In 1874, French engineers built a system of weather and snow-depth sensors on Mont Blanc that transmitted real-time information to Paris.

In 1901 the American inventor C. Michalke patented the selsyn, a circuit for sending synchronized rotation information over a distance. In 1906, a set of seismic stations were built with telemetering to the Pulkovo Observatory in Russia. In 1912, Commonwealth Edison developed a system of telemetry to monitor electrical loads on its power grid. The Panama Canal (completed 1913–1914) used extensive telemetry systems to monitor locks and water levels.[2]

Wireless telemetry made early appearances in the radiosonde, developed concurrently in 1930 by Robert Bureau in France and Pavel Molchanov in Russia. Mochanov's system modulated temperature and pressure measurements by converting them to wireless Morse code.

The German V-2 rocket used a system of primitive multiplexed radio signals called "Messina" to report four rocket parameters, but it was so unreliable that Wernher von Braun once claimed it was more useful to watch the rocket through binoculars. In the US and the USSR, the Messina system was quickly replaced with better systems (in both cases, based on pulse-position modulation).

Early Soviet missile and space telemetry systems which were developed in the late 1940s used either pulse-position modulation (e.g., the Tral telemetry system developed by OKB-MEI) or pulse-duration modulation (e.g., the RTS-5 system developed by NII-885). In the US early work employed similar systems, but were later replaced by pulse-code modulation (PCM) (for example, in the Mars probe Mariner 4).

Later Soviet interplanetary probes used redundant radio systems, transmitting telemetry by PCM on a decimeter band and PPM on a centimeter band.

Applications

Meteorology

Telemetry has been used by weather balloons for transmitting meteorological data since 1920.

Space science

Telemetry is used by manned or unmanned spacecraft for data transmission. Distances of more than 10 billion kilometres have been covered, e.g. by Voyager 1.

Motor racing

Telemetry is a key factor in modern motor racing, allowing race engineers to interpret data collected during a test or race and use it to properly tune the car for optimum performance. Systems used in series such as Formula One have become advanced to the point where the potential lap time of the car can be calculated, and this time is what the driver is expected to meet.

Examples of measurements on a race car include accelerations (G forces) in 3 axes, temperature readings, wheel speed and suspension displacement. In Formula One, driver input is also recorded so the team can assess driver performance and (in case of an accident) the FIA can determine or rule out driver error as a possible cause.

Later developments include two-way telemetry which allows engineers to update calibrations on the car in real time (even while it is out on the track). In Formula One, two-way telemetry surfaced in the early 1990s and consisted of a message display on the dashboard which the team could update.

Its development continued until May 2001, when it was first allowed on the cars. By 2002, teams were able to change engine mapping and deactivate engine sensors from the pit while the car was on the track. For the 2003 season, the FIA banned two-way telemetry from Formula One; however, the technology may be used in other types of racing or on road cars.

Agriculture

Most activities related to healthy crops and good yields depend on timely availability of weather and soil data. Therefore, wireless weather stations play a major role in disease prevention and precision irrigation.

These stations transmit parameters necessary for decision-making to a base station: air temperature and relative humidity, precipitation and leaf wetness (for disease prediction models), solar radiation and wind speed (to calculate evapotranspiration), water deficit stress (WDS) leaf sensors and soil moisture (crucial to irrigation decisions).

Because local micro-climates can vary significantly, such data needs to come from within the crop. Monitoring stations usually transmit data back by terrestrial radio, although occasionally satellite systems are used. Solar power is often employed to make the station independent of the power grid.

Water management

Telemetry is important in water management, including water quality and stream gauging functions. Major applications include AMR (automatic meter reading), groundwater monitoring, leak detection in distribution pipelines and equipment surveillance. Having data available in almost real time allows quick reactions to events in the field.

Defense, space and resource exploration

Telemetry is used in complex systems such as missiles, RPVs, spacecraft, oil rigs and chemical plants since it allows the automatic monitoring, alerting, and record-keeping necessary for efficient and safe operation.

Space agencies such as NASA, the European Space Agency (ESA) and other agencies use telemetry and/or telecommand systems to collect data from spacecraft and satellites.

Telemetry is vital in the development of missiles, satellites and aircraft because the system might be destroyed during or after the test. Engineers need critical system parameters to analyze (and improve) the performance of the system. In the absence of telemetry, this data would often be unavailable.

Rocketry

In rocketry, telemetry equipment forms an integral part of the rocket range assets used to monitor the position and health of a launch vehicle to determine range safety flight termination criteria (Range purpose is for public safety). Problems include the extreme environment (temperature, acceleration and vibration), the energy supply, antenna alignment and (at long distances, e.g. in spaceflight) signal travel time.

Flight testing

Flight test programs typically monitor data collected from on-board flight test instrumentation over a PCM/RF link. This data is analyzed in real time for safety reasons and to provide feedback to the test pilot. Challenges to telemetering this data include fading, multipath propagation and the Doppler Effect.

The bandwidth of the telemetry link is often insufficient to transfer all data acquired; therefore, a limited set is sent to earth for real-time processing while an on-board recorder ensures the full data set is available for post-flight analysis.

Military intelligence

Telemetry was an important source of intelligence for the US and UK when Soviet missiles were tested; for this purpose, the US operated a listening post in Iran. Eventually, the Russians discovered the US intelligence-gathering network and encrypted their missile-test telemetry signals. Telemetry was also a source for the Soviets, who operated listening ships in Cardigan Bay to eavesdrop on UK missile tests performed in the area.

Energy monitoring

In factories, buildings and houses, energy consumption of systems such as HVAC are monitored at multiple locations; related parameters (e.g. temperature) are sent via wireless telemetry to a central location. The information is collected and processed, enabling the most efficient use of energy. Such systems also facilitate predictive maintenance.

Resource distribution

Many resources need to be distributed over wide areas. Telemetry is useful in these cases, since it allows the system to channel resources where they are needed; examples of this are tank farms in gasoline refineries and chemical plants.

Medicine

Telemetry also is used for patients (biotelemetry) who are at risk of abnormal heart activity, generally in a coronary care unit. Such patients are outfitted with measuring, recording and transmitting devices. A data log can be useful in diagnosis of the patient's condition by doctors. An alerting function can alert nurses if the patient is suffering from an acute (or dangerous) condition.

Systems are available in medical-surgical nursing for monitoring to rule out a heart condition, or to monitor a response to antiarrhythmic medications such as digoxin.

Fishery and wildlife research and management

Telemetry is used to study wildlife, and has been useful for monitoring threatened species at the individual level. Animals under study can be outfitted with instrumentation tags, which include sensors that measure temperature, diving depth and duration (for marine animals), speed and location (using GPS or Argos packages).

Telemetry tags can give researchers information about animal behavior, functions, and their environment. This information is then either stored (with archival tags) or the tags can send (or transmit) their information to a satellite or handheld receiving device.

Telemetry is used in hydro-acoustic assessments for fish (which had previously employed mobile surveys from boats to evaluate fish biomass and spatial distributions). Fixed-location techniques use stationary transducers to monitor passing fish.

While the first serious attempts to quantify fish biomass were conducted in the 1960s, major advances in equipment and techniques took place at hydropower dams during the 1980s. Some evaluations monitored fish passage 24 hours a day for over a year, producing estimates of fish entrainment rates, fish sizes, and spatial and temporal distributions.

During the 1970s the dual-beam technique was invented, permitting direct estimation of fish size *in situ* via its target strength. The first portable split-beam, hydro-acoustic system was developed by HTI in 1991; it provided more-accurate, less-variable estimates of fish strength than the dual-beam method. It also permitted tracking of fish in 3D, giving each fish's swimming path and absolute direction of movement.

This feature proved important in evaluations of entrained fish in water diversions and for studies of migratory fish in rivers. During the last 35 years, tens of thousands of mobile and fixed-location hydro-acoustic evaluations have been conducted worldwide.

Retail

At a 2005 workshop in Las Vegas, a seminar noted the introduction of telemetry equipment which would allow vending machines to communicate sales and inventory data to a route truck or to a headquarters. This data could be used for a variety of purposes, such as eliminating the need for drivers to make a first trip to see which items needed to be restocked before delivering the inventory.

Retailers also use RFID tags to track inventory and prevent shoplifting. Most of these tags passively respond to RFID readers (e.g. at the cashier), but active RFID tags are available which periodically transmit location information to a base station.

Law enforcement

Telemetry hardware is useful for tracking persons and property in law enforcement. An ankle collar worn by convicts on probation can warn authorities if a person violates the terms of his or her parole, such as by straying from authorized boundaries or visiting an unauthorized location. Telemetry has also enabled bait cars, where law enforcement can rig a car with cameras and tracking equipment and leave it somewhere they expect it to be stolen. When stolen the telemetry equipment reports the location of the vehicle, enabling law enforcement to deactivate the engine and lock the doors when it is stopped by responding officers.

Energy providers

In some countries, telemetry is used to measure the amount of electrical energy consumed. The electricity meter communicates with a concentrator and the latter sends the information through GPRS or GSM to the energy provider's server. Telemetry is also used for the remote monitoring of substations and their equipment. For data transmission, phase line carrier systems operating on frequencies between 30 and 400 kHz are sometimes used.

Falconry

In falconry, "telemetry" means a small radio transmitter carried by a falcon to allow the bird's owner to track it when it is out of sight.

Testing

Telemetry is used in testing where close observation is needed, but human presence in the vicinity of the test would be dangerous. Examples include munitions-storage facilities, radioactive sites and volcanoes. It is necessary to measure in places a human cannot access (for example, in space or deep in the ocean).

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