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Hydrometric data transmission systems — Part 1 : General

Systèmes de transmission de données hydrométriques — Partie 1 : Généralités

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Foreword

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Hydrometric data transmission systems — Part 1 : General

0 Introduction

A system of hydrometric stations, data transmission and data handling constitutes a hydrometric data acquisition system, the density of which should relate to the scale of both existing and potential objectives.

Collection of hydrometric data may be governed by legal, present and anticipated scientific and operational needs.

If the network is sufficiently dense, generating large quantities of data, or if the time-interval of the necessary reaction to measurement is relatively short, then recourse to modern techniques of fast, concentrated data handling is necessary.

The advances already made and the continuing development in the technology of measurement, data transmission and data handling result in a wide variety of design and operation of data systems. However, with the increasing size and complexity of such systems and the special requirements of hydrometric data systems, it has become evident that standarization of some aspects of hydrometric telemetry would improve the design, specification and operation of systems, as well as delaying equipment obsolescence.

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1 Scope and field of application

This part of ISO 6419 specifies the general functional requirements for hydrometric telemetry. It defines characteristics of the system required to transmit field data to a receiving station and the minimum processing for subsequent use.

2 References

ISO 646, *Information processing — ISO 7-bit coded character set for information interchange.*

ISO 772, *Liquid flow measurement in open channels — Vocabulary and symbols.*

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

3 Definitions

For the purposes of this part of ISO 6419, and in addition to those given in ISO 772, the following definitions shall apply.

3.1 bit : A binary digit; a digit (1 or 0) used to represent a number in binary notation.

3.2 baud : A unit for measuring data flow on a communication path, equivalent to one bit per second.

3.3 remote station; outstation : All facilities and equipment associated with the sensing and transmission of valid data from a hydrometric station.

4 Units of measurement

The units of measurement used in this part of ISO 6419 are SI units in accordance with ISO 1000.

5 System description

5.1 General

The end-product of hydrometry is data, relating to measurements of relevant parameters.

The common objective in hydrometry is to acquire continuous data in which the acquisition rate will make it possible to understand the phenomena in general and predict its development in time.

It is convenient to examine the data acquisition system by means of each of the distinct stages through which the data shall pass before its ultimate use. Figure 1 illustrates this in block form.

5.2 Data system stages

Six distinct stages may be identified in any data acquisition system, however simple the system may be :

a) primary measurement;

b) encoding;

c) transmission;

d) decoding;

e) validation;

f) use.

The extent of a telemetry system encompasses stages b) to e), as indicated in figure 1.

An interface exists between each of these stages and it is at these interfaces that the greatest opportunity for standardization exists, thus minimizing the adverse effect on the user of technological obsolescence.

5.2.1 Primary measurement

A primary measurement is made with the object of describing a physical process in a form which can be interpreted by human senses, or which enables this objective to be met.

In hydrometric instrumentation this is achieved by sensing energy changes, as reflected by changes in the natural parameter and converting such changes into a form suitable for subsequent processes. The device which performs this function is called a transducer.

The most common outputs are either mechanical or electrical.

5.2.2 Encoding

The measurements taken at the field site will be required at some other place and/or some other time.

This requirement can be met by coding a transducer output, thus making it more convenient for transmission and/or storage.

5.2.3 Transmission

The movement of the information from place of measurement to the place of use.

5.2.4 Decoding

The reversion of the coded information into physical units.

5.2.5 Validation

This is the process of confirming, using some specified means, that the data as received (immediately following the decoding process) are acceptable within the tolerance limits specified.

The validation of data shall be treated as an integral part of any acquisition system and validation is best carried out as soon as possible after reception.

5.2.6 Use

A large proportion of the use made of hydrometric data involves the analysis of time-series data.

The method chosen for storage of, and access to, the data shall recognize this and the fact that data archives tend to grow at an accelerating rate.

6 Principles of operation

6.1 General

In this clause it is necessary to keep in mind the sequential nature of the system, described in clause 5, and especially the concept of a definite interface between each stage.

6.2 Hydrometric telemetry

Hydrometric telemetry is the transmission of data from primary sensors to another location.

The mode of transmission influences many other system design considerations.

6.3 Means of transmission

6.3.1 General

The most readily available, and most widely used, energy form is electrical, and further considerations in this part of ISO 6419 are confined to this form.

Sufficient power shall be generated by the transmitter to guarantee the integrity of the received signal, allowing for energy losses along the transmission path.

In a terrestrial environment these losses can be considerable, whereas outside the Earth's atmosphere they become insignificant.

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6.3.2 Transmission by line

6.3.2.1 Lines may be "dedicated" or shared with general purpose communications. In some networks, lines are dedicated to data transmission but shared between users.

6.3.2.2 Advantages :

a) low probability of atmospheric interference;

b) high value of mean-time-between-failure (MTBF);

c) systematic energy loss is predictable;

d) system commissioning is simplified.

6.3.2.3 Disadvantages :

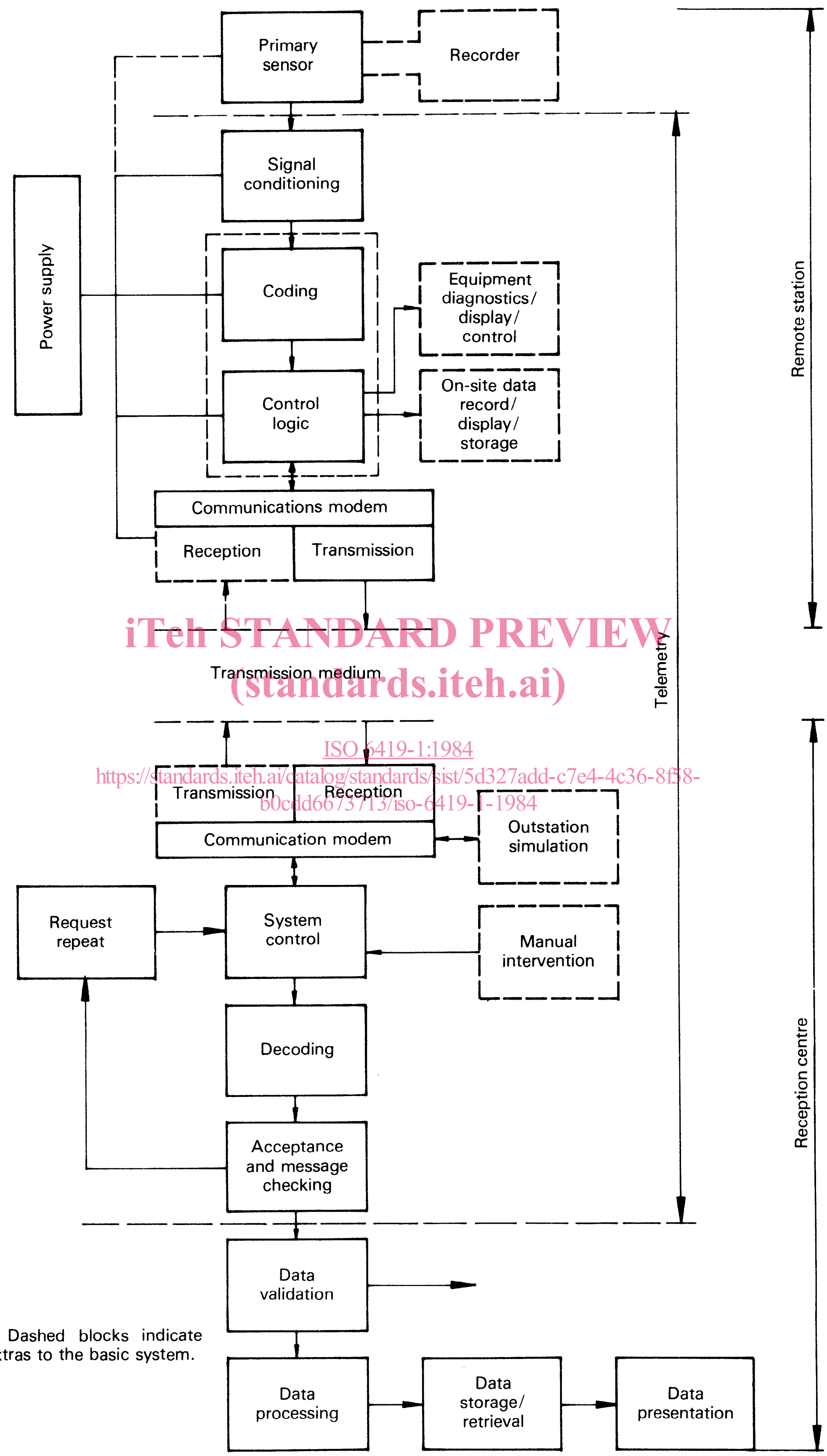
a) installation cost increases with distance;

b) overhead lines are susceptible to failure due to high winds and ice or snow;

c) underground lines can be damaged by numerous causes, including flooding, earth movement and construction activity;

d) failure may occur anywhere along the line;

e) probability of interference increases with line length;



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NOTE — Dashed blocks indicate optional extras to the basic system.

Figure 1 — Data acquisition system — Functional block diagram

f) natural temperature changes affect line impedance, particularly with overhead lines;

g) increase in line impedance with length limits the choice of signal type;

h) installation of temporary outstations is inhibited;

j) traffic becomes high during critical hydrological events.

6.3.2.4 A dedicated line would have a high level of system integrity, but the installation and maintenance costs would also be dedicated to the user and could certainly be higher than for a shared line.

6.3.2.5 The use of other than dedicated lines will, almost certainly, involve compatibility with signal standards imposed by others.

6.3.2.6 If a comprehensive public network exists some of the disadvantages may be mitigated by the provision of alternative transmission paths.

6.3.3 Transmission by radio

6.3.3.1 Radio waves are specified by frequency (in hertz) and occupy the portion of the electromagnetic spectrum having frequencies less than visible light. For convenience, these frequencies are identified by band widths which are set out in annex D.

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6.3.3.2 Allocation of radio frequency (RF) bands, for whatever purpose, is agreed internationally under the auspices of the International Telecommunication Union (ITU) and in some parts of the world some bands are heavily loaded, which can influence overall system design. Any use of radio transmitters shall be licensed by the appropriate national body.

6.3.3.3 Both terrestrial and satellite radio systems are in use. Their relative merits, and their comparison with line transmission, are mainly :

6.3.3.3.1 Terrestrial radio systems

6.3.3.3.1.1 Advantages :

a) installation cost is less dependent on distance than transmission by line;

b) equipment failure is limited to discrete sites, facilitating fault diagnosis;

c) once frequencies have been allocated there is a high degree of exclusiveness, equivalent to a dedicated line;

d) there is more flexibility in the use of temporary outstations.

6.3.3.3.1.2 Disadvantages :

a) susceptible to atmospheric interference, although this tends to be of short duration;

b) signal loss is less easily predicted;

c) in abnormal atmospheric conditions there can be mutual interference between systems on similar frequencies;

d) repeater stations may be required to overcome signal loss due to distance or topography.

6.3.3.3.2 Satellite radio systems

6.3.3.3.2.1 Advantages :

a) repeater stations, other than the satellite itself, are not required;

b) equipment failure is limited to discrete sites, facilitating fault diagnosis;

c) stations are easy to relocate;

d) one receiver site can provide continental coverage;

e) antennae are less obtrusive than for terrestrial radio;

f) site selection is less inhibited by topography.

6.3.3.3.2.2 Disadvantages :

Consequences of the failure of a satellite, or receiver site, are critical; alternative spacecraft and/or receiver equipment may not be readily available.

6.3.4 Conclusion

It can be seen that the advantages and disadvantages of line and radio tend to be complementary.

6.4 Signals

Signals in this context mean information represented in a form suitable for the operation of the system.

6.4.1 Signal representation (see annex A)

6.4.1.1 Analogue technique

The principal advantage of an analogue signal is, that by a relatively simple transformation, a continuous signal can be received which reflects the continuity of the original parameter.

The analogy may be obtained electrically by means of one of the following :

a) voltage modulation;

b) current modulation;

c) amplitude modulation (AM);

d) frequency modulation (FM);

e) phase modulation.

The term "modulation" is used here to mean the simple alteration of the signal to follow the variation of the measured parameter with time.

6.4.1.2 Digital techniques

Digital representation necessitates a fundamental departure from the basic continuity of the original measured parameter by the technique of sampling; parameter values between the discrete samples are available only by inference.

If the sampling rate is high, relative to the variation of the measured parameter, the continuity can be restored, if necessary, by integration to give an analogue output. The sampling rate should enable the hydrological process to be reproduced within a specified accuracy, but a compromise is usually necessary between time/space/cost.

Four examples of digital techniques which can be used in this way are :

a) pulse duration modulation;

b) pulse amplitude modulation;

c) pulse code modulation;

d) pulse position modulation.

6.4.1.3 Summary of signal representation

Two basic types of signal have been discussed :

a) analogue : which retains the continuity of the measured parameter, representing its variation by the modulation of some dimension(s) of the signal. But distortion of the signal, from whatever source, is difficult to compensate and this can result in undetected errors;

b) digital : which samples the measured parameter periodically, presenting the output in the form of pulses which can have a high level of distortion rejection and of error detection. This is the same technique as that used for communication to, and within, computers and other high technology electronic devices.

Between these techniques are the hybrids of pulse duration modulation and pulse amplitude modulation which, in some measure, depending on the overall system configuration, share the advantages and disadvantages of both techniques.

6.4.2 Data coding (see annex A)

Reference is made in 6.4.1.2 c) to pulse code modulation. In this technique, identical pulses, unmodulated in amplitude, duration or frequency, are grouped in a pattern according to a specified code.

Such codes fall into one of the following categories :

a) unique codes, in which a single group of pulses, or byte, represents a value uniquely;

b) character codes, in which a byte represents a single character, for example a numeral or a letter, and full representation of a value entails the assembly of several bytes.

6.4.3 Signal transmission

Any signal may be transmitted by line but, since radio transmission depends upon the emission of alternating polarity signals it follows that direct current techniques, such as voltage or current modulation, cannot be transmitted by radio.

6.4.3.1 Base band

Information is said to be in its base band when the transmitted signal frequency equals the original information frequency.

Except in short length line systems using voltage or current modulation it is unusual to transmit the base band alone.

6.4.3.2 Carrier signals

The concept of carrier signals can be seen from annex A (see figures 2 and 3) where the measurement signal is superimposed on, and so modulates, an independent carrier frequency.

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Carrier signals are required for one or more of the following purposes :

a) transmission is achieved with less distortion of the measurement signal;

b) to permit transmission of a measurement signal within a specified bandwidth;

c) greater utilization of a given band width is possible by multiplexing (see annex B).

6.4.3.3 Coding for transmission

The objective of a data acquisition system is to provide the users with data at the specified sampling rate, and within specified limits of uncertainty, with the minimum loss of data.

The principal constraints on the achievement of this objective are the availability of adequate technology and the allocation of sufficient resources, the latter usually being the more significant.

It is unusual in hydrometric networks, in other than the very simplest systems, for data to be transmitted from a sensor continuously; even with dedicated lines it is usual for sensor output to be sampled in some specified sequence.

In systems where transmission facilities are shared each user's data are usually received in batches.

Similar circumstances exist with satellite transmission systems. The batch reception principle shall apply to polar orbiting satellites which are only in "view" for limited periods, and in this case information may have to be stored between transmissions, introducing the need for sensor sampling time to be known.

With geostationary satellites, channels may have to be shared between users, but even if this is not the case the data sources can be expected to transmit in some sequence.

In all these circumstances it becomes necessary to ensure that transmission is in synchronism with reception and that the data themselves should be accompanied by source identification and other control information.

Techniques have been developed to increase system reliability, and user confidence, but these tend to be specified by the hardware designer and consequently vary from system to system.

While the specification may vary in detail, there are common elements identifying :

a) start of message;

b) station identification;

c) time of sensing, where necessary;

d) sensor reading;

e) system control information (see 6.6.1 and 6.7);

f) end of data block and/or message.

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6.4.3.4 Multiplexing

When two or more signals are transmitted on the same path, whether by line or radio, the signals are said to be multiplexed.

There are two multiplexing techniques available (see annex B) :

a) frequency domain;

b) time domain.

6.4.3.5 Influence of transmission on choice of signals

Line and radio should not be considered to be mutually exclusive in system design.

However it has been stated (see 6.4.3) that d.c. signals cannot be transmitted by radio : therefore, if a radio link is incorporated, such signals shall be restated before being presented to the radio path.

Although the base band of individual hydrometric signals is low, with commensurate sampling rate requirements, a comprehensive network, with due allowance for expansibility, can result in a concentration in data reception rate at the system information centre which requires special consideration. This may be the factor which ultimately governs the required transmission rate.

6.5 Polling (interrogation)

The act of polling outstations provides the required time-series data at rates suited to the known rate of change of the parameter concerned.

At the same time the act of polling allows the state of the system, as a whole, to be examined.

Thus polling frequencies are both data and system dependent and there are three approaches which satisfy these requirements :

a) Cyclic, or sub-cyclic, polling :

In this case, the whole system may be polled at the frequency of the most demanding criterion, or the system could be sub-divided into frequency demand groups and these polled at independent cyclic frequencies;

b) On-demand polling :

In this case, each parameter is polled at its own required frequency, whether data or system dependent.

This is a more complex approach, requiring the commitment of more resources to the management of the system than the "free running" cyclic case, but represents the minimum loading of the transmission system;

c) Batch reporting :

In this case, a group of data is stored at the outstation and transmitted in batches, either as a result of polling or by a self-timed reporting action at the outstation.

This mode of operation may be a design choice but is more likely to be imposed by a particular transmission system, for example a polar orbiting satellite.

In no case need data be recorded at more than the frequency which each parameter demands.

6.6 System capacity

In a perfect system the desired rate of transmission would equal the system's capacity for transmission.

This situation is not common but the statement identifies the two quantitative criteria.

6.6.1 Rate of transmission

In specifying or assessing the capacity of a network it is important to recognize the presence of two distinct sub-systems :

a) the hydrometric system, which generates data as the product of the number of outstations, the number of parameters per outstation and the polling frequency;

b) the acquisition system which adds overheads of data in the form of base and relay stations (equivalent to outstations), control and system state information (equivalent to extra parameters), and additional bits in the data word for synchronization, parity and other system purposes. The latter are often referred to as "housekeeping bits".

6.6.2 Potential system capacity (see annex C)

The capacity of a transmission system is a function of three variables :

a) the frequency band width available;

b) the time available, or required, for transmission;

c) the signal-to-noise ratio.

A useful technique, as a basis for estimation and comparison, is to idealize the number of states of information into the equivalent number of bits, even if the information is not coded in this way.

6.7 System control

Other than for installations the simplicity of which places them outside the scope of this part of ISO 6419, there is in any system the inherent need for some form of automatic control, at least for polling and probably for logging. Additional control may be included for system monitoring and diagnostics, and alarm signalling.

Even at a basic level this implies some time-based programmed logic, preferably having an "interrupt" facility.

Most modern systems incorporate some degree of programmable logic. In small systems this has sometimes been provided by a purpose-built unit, but developments in micro-electronics have increased the availability, and reduced the cost, of general purpose data processing units which have the advantage of executive software (system management programme) supplied and supported by the manufacturer.

The added flexibility which this provides is particularly suitable to hydrometric systems where changes in system size, speed and even function are to be expected.

6.8 Validation

Reference has been made previously to the significance of time-series data to hydrology and its increase in worth with record length.

Worth is also a function of accuracy and the validation of data is an essential stage of a data acquisition system.

The incorporation of an electronic central processing unit, for system control, makes possible an increasingly rigorous check on data as they are received.

7 System design and performance criteria

7.1 Accuracy considerations

7.1.1 General

The overall uncertainty with which information can be received will depend upon the existence of systematic and random errors, and is affected by the range, resolution and environment of the primary sensors and by the reliability of the system elements.

7.1.2 Systematic errors

These errors cannot be eliminated entirely but can be minimized by proper design and maintenance. Generally, the communication system will convey information with a precision exceeding that of the measurement and encoding elements. For that reason the most likely source of significant systematic error will be either the primary sensing or in the encoding, and appropriate initial checks should be made, taking into account their specified performances.

Operational experience will determine the frequency of subsequent checks.

7.1.3 Random errors

The theory relating to the probability of random errors is well documented and need not be repeated here.

The likely sources of such errors in a telemetry system are from atmospheric disturbances of the transmission path and from component malfunction, or failure, and the expression of this in terms of mean-time-between-failure (MTBF) is itself a random probability statement.

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7.1.4 Resolution

Resolution is the ability of a device to define the value of a parameter; it is qualified by the degree of discrimination possible. Resolution may be specified in either absolute or relative terms; for example, ± 1 cm, ± 0,5 % of full scale, 1 part in 1 000.

7.1.5 Range

The range (of a measuring device) is the interval between the lower and upper measurement limits. This has an influence on accuracy only when resolution is related to range.

7.1.6 Environment

Outstations on hydrometric networks are, by their very nature, at remote locations and their working environment can often be hostile to the proper continuous functioning of equipment.

Most equipment has a specified, or obvious, acceptable environmental range and component elements commonly have different working ranges.

The effects of environmental extremes can be progressive, as with the change of resistance with temperature, or abrupt, as occurs when low temperature reduces the output voltage of a battery below the operating threshold of the driven equipment.

Analogue systems and signals are more susceptible to progressive degradation in comparison with digital versions which, when their threshold is reached, cease to function.

7.1.7 Reliability

It has been stated that hydrometric data are required basically as time-series information. Reliability is specified as the proportion of time during which information is received, usually as a percentage.