RECOMMENDATION ITU-R F.753*

PREFERRED METHODS AND CHARACTERISTICS FOR THE SUPERVISION AND PROTECTION OF DIGITAL RADIO-RELAY SYSTEMS

(1992)

The ITU Radiocommunication Assembly,

considering

a) that supervision of digital radio-relay systems is necessary;

b) that stand-by switching arrangements to increase the availability of digital radio-relay systems and to facilitate maintenance, are under study;

c) that supervision and protection techniques may extend across international borders;

d) that the principles of supervision of digital radio-relay systems should take account of overall maintenance considerations for digital networks, as outlined in ITU-T Recommendations M.20 and M.30;

e) that overall performance and availability are affected by the methods used for supervision and protection;

f) that digital radio-relay systems forming part of a synchronous digital hierarchy (SDH) network should take into account ITU-T Recommendations G.784 and G.773 and Recommendations ITU-R F.750 and ITU-R F.751,

recommends

1. that the preferred methods and characteristics for the supervision and protection of digital radio-relay systems conform with Annex 1;

2. that wherever possible such methods and characteristics should reflect the design and maintenance philosophies recommended by the ITU-T for the digital network.

ANNEX 1

1. Preferred supervisory principles

The introduction of digital telecommunications equipment with enhanced maintenance operations functions, including the facility for remote reporting and control, provides new opportunities for centralized supervisory control. There are many benefits that can be gained, they include the ability to:

– improve the quality of service,

– increase the availability of transmission and switching systems,

– utilize more effectively data and data bases,

– improve maintenance effectiveness and decrease maintenance costs,

– permit full integration with fibre based transmission facilities.

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Note 1 – By the use of remote terminals, an administration can choose how it allocates its technical staff between local and centralized locations. Because of these benefits, it is recommended that centralized supervisory control be considered when specifying new telecommunications systems and equipments.

The general principles for planning, operating and maintaining a telecommunication management network (TMN) may be obtained from ITU-T Recommendation M.30.

2. Protection principles – Performance and availability

Under normal conditions in the network, radio relay system performance information should be gathered from maintenance entities on a continuous or periodic basis. This data can be used to detect acute fault conditions which generate alarm reports. Further analysis may also reveal subtle degradations which generate information reports.

After the occurrence of a failure in a radio-relay system, a number of phases are required to correct the fault and to protect, when possible, the traffic affected by the fault if it has been interrupted.

For further information on maintenance philosophies and definitions, see ITU-T Recommendation M.20, in particular Fig. 6 which lists the phases which are involved before and after a failure occurrence in a maintenance entity.

2.1 Performance measuring

The choice of a performance measurement mechanism depends on the requirements for the “quality of service” as seen by the customers, and on the technical network performance, and the nature of the equipment. For further information on availability and reliability, see also ITU-T Recommendation G.106.

If necessary, several mechanisms may be operated in the same item of equipment.

2.2 Failure dectection

Failures should be discovered by the operating authority independently of, and preferably before, the customer, i.e., the majority of failures are both detected and remedied without the customer having been aware of them.

Failures are classified depending on their nature, and may be categorized depending on their severity. Corresponding maintenance alarm information is then passed on to the appropriate supervisory control entities.

2.3 System protection

When failure has occurred or performance has degraded, a signal must be available which contains sufficient information for protection switching and maintenance functions.

A specific protection method is recommended for radio-relay transmission systems which use manual or automatic restoration on a maintenance entity basis:

a) If a failure occurs either in maintenance entities without automatic changeover capabilities, or with automatic changeover capabilities but no standby available, the following actions should be executed:

   – initiate maintenance alarm information identifying the maintenance entity containing the failed equipment;

   – transmit an alarm indication signal (AIS) in the downstream direction, and give an upstream failure indication (UFI), to upstream equipment;

   – initiate a service alarm indication at the appropriate entities.

b) If a failure occurs in a maintenance entity having automatic changeover capability with a standby available, the following actions should be automatically executed:

– changeover to the standby;

– initiate maintenance alarm information indicating the maintenance entity containing the failed equipment.

2.4 Failure/performance information transfer

Information on failure, unacceptable performance or degraded performance will normally be transmitted to the supervisory control centre, and other parts of the network when appropriate.

Information for the use of supervisory or maintenance personnel is available either in the entity, when the processing of defects or confirmed faults is internal, or via a unit which provides processing, when external to the entity.

2.4.1 Alarm information categories

The following alarm information may be associated with the information of failure or unacceptable or degraded performance (see ITU-T Recommendation M.20):

a) *Prompt maintenance alarm (PMA)*

A prompt maintenance alarm is generated in order to initiate maintenance activities (normally immediately) to remove from service a defective equipment, for the purpose of restoring good service and effecting repair of the failed equipment.

b) *Deferred maintenance alarm (DMA)*

A deferred maintenance alarm is generated when immediate action is not required, e.g., when performance falls below standard but the effect does not warrant removal from service, or generally if automatic changeover to standby equipment has been used to restore service.

c) *Maintenance event information (MEI)*

This information has to be generated as a consequence of events when no immediate actions are required because the total performance is not endangered. The maintenance actions can be performed on a scheduled basis, or after the accumulation of maintenance event information indications.

Figure 7 of ITU-T Recommendation M.20 shows the alarm information process for a maintenance entity. The actual PMA, DMA or MEI may or may not be generated in the maintenance entity. When generated outside the maintenance entity, the alarm information process may combine information from other sources (e.g., other maintenance entities, time of day, traffic load, etc.) with the output from the malfunction supervisory process to decide if a PMA, DMA or MEI should be generated. When an AIS or UFI is received, a maintenance entity may be required to generate a service alarm (SA).

Both the malfunction supervisory process and the alarm information process, including the use of PMAs, DMAs and MEIs, can also be applied to other non-telecommunications equipment (e.g. power, temperature control, etc.).

2.4.2 Other fault and service indications

In order to avoid unnecessary maintenance actions and to signal the unavailability of the service, the following fault indications are used as described in ITU-T Recommendation M.20:

– alarm indication signal (AIS),

– service alarm (SA),

– upstream failure indication (UFI).

2.4.3 Transmission and presentation of alarm information

The failure information at the alarm interface is used to determine the faulty maintenance entity or part of the maintenance entity. The information can be presented either locally, or remotely via an alarm collection system.

The alarm may be presented as:

– an indication at an alarm interface (e.g., contact function, DC signal),

– an alarm message on the man-machine interface.

2.4.4 Alarm information to the remote end

Equipment which is a source of digital multiple signals (i.e multiple equipment) may, in case of a fault condition, transmit alarm information within a specified bit or specified bits of the pulse frame. This information is intended for evaluation at the remote terminal (at the end of the digital link). For examples see ITU-T Recommendation G.704, § 2.3.2, and ITU-T Recommendations G.733, § 4.2.4 and G.784.

2.5 Fault localization

Where the initial failure information is insufficient for fault localization within a failing maintenance entity, it has to be augmented with information obtained by additional fault localization routines. The routines can employ maintenance entity internal or external test systems, initiated manually or automatically, at the local and/or remote end.

2.6 Logistic delay

The logistic delay is the period of time between the fault localization and arrival of the maintenance staff on site, which will depend on the type of failures and how they are reported, i.e., PMA, DMA and MEI.

2.7 Fault correction

Fault correction normally requires change or repair of a maintenance entity, maintenance supervisory entity or a part thereof. One or more fault corrections can be performed in the course of a maintenance visit. It is desirable that strategies be developed to accomplish fault correction satisfying overall system objectives with a minimum number of maintenance visits, using the concept of logistic delay.

Failed interchangeable items will be sent to a specialized repair centre, where appropriate test equipment is available (the system itself should not act as a test machine).

2.8 Verification

After the fault has been corrected, checks must be made to assure that the maintenance entity is working properly. The verification can be made locally or remotely.

2.9 System restoration

The corrected part of the maintenance entity or maintenance supervisory entity is restored to service. Blocked maintenance entities are de-blocked and the changeover to the spare equipment may be terminated.

3. Methods and characteristics of protection

3.1 General

Protection switching equipment is characterized mainly by:

– the service to be provided (improvement of availability or quality, switching time, etc.);

– the point at which switching is carried out;

– the switching criterion/criteria to be taken into account, for example: non-priority requests (BER $\geq 10^{-6}$), priority requests (BER $\geq 10^{-3}$), early switching requests (error correcting activity), etc.;

– the transmission mode of the switching instructions.

3.2 Need for protection

The main purpose of protection switching is to improve circuit availability by switching to available standby channels in the event of equipment malfunction or failure. The additional benefit of some degree of protection against outages caused by frequency selective fading, may result in systems employing multi-line protection switching. Space diversity protection may also be used to improve system performance during these poor propagation conditions.

Dual route diversity protection facilitates the use of greater hop lengths in frequency bands where attenuation due to precipitation becomes appreciable.

3.3 Types of protection arrangements

Single route systems may be protected in one of four ways:

– multi-line and single line switching with a dedicated protection channel;

– multi-line and single line switching with a non-dedicated protection channel;

– space diversity operation;

– polarization, angle and pattern diversity operation.

In theory, the switch may operate at RF, IF or baseband, but in practice, baseband switching is preferred since this may protect the complete channel from input port to output port with a minimum duplication of equipment outside the switched path.

Dual route protection involves the use of switching at the terminal receiver. It may be necessary to equalize the difference in transmission time between the path lengths of each route, in order that the signal on both routes may be aligned at the instant of changeover.

3.4 Factors influencing the choice of switching criteria

The switching criteria are influenced by the main role of the protection switching.

If switching is used to protect against equipment failure, relatively slow recognition of the switching criteria, transmission of the switching instructions and switch changeover can be tolerated. This will result in loss of synchronization downstream, and provision may be required to minimize the number of interruptions to service caused by these switching operations.

If switching is used to improve performance during poor propagation conditions, this would require the rapid recognition of switching criteria and it is desirable to switch to a stand-by channel without loss of synchronization. This also facilitates preventive maintenance operations. It should be noted that the addition or loss of a bit, due for instance to switching without prior arrangements to ensure coincidence or to a spurious impulse affecting the timing, may completely desynchronize the downstream transmission chain and cannot be considered an isolated error. This phenomenon affects system performance and should be studied further. To realize this, the following should be considered:

a) Synchronization of bit and frame pulses between either:

  – all channels, or

  – the stand-by and the working channel experiencing a BER exceeding the switch threshold, depending on the length of time required to establish frame synchronization and the length of time between the experiencing of the threshold BER and the misframe BER.

b) Static equalization of the difference in steady transmission time between the stand-by channel and the working channels.

c) Dynamic equalization of the fluctuations in transmission time between the stand-by channel and the working channel or working channels during multipath fading.

4. Service channel considerations

The proposals to provide service channels to carry the supervision and control signals (SC) are of three types:

– transmitting by inserting supervision and control signals into the main signal pulse sequence, e.g. radio frame complementary overhead;

– transmitting separately from the main signal pulse sequence. This includes using additional modulation of the main carrier;

– transmission means other than the main signal path.

For supervising and controlling intermediate repeater stations, insertion and detection of the supervision and control signal must be accomplished at each station.

The second method proposed above can be suitable in some cases for the transmission of small capacity supervision and control signals. In particular, additional FSK or FM modulation of the main carrier is suitable for supervision and control signal transmission, because these modulation methods typically exhibit longer transmission availability than the main signal, during fading conditions. However, the upper limitation of transmission capacity depends on the main signal modulation method and supervision and control signalling pulse shape (see Appendix 1).

Considering the implementation of radio systems in SDH networks, the following supervision and control signal transmission method should also be taken into account.

4.1 Transmission of supervision and control signals for regenerator stations

In digital radio-relay systems, the serial signals received from transmission terminals are generally divided into low-rate parallel sequences suitable for the modulation systems and the differential logic conversion process. Consequently, in order to use overhead bits at regenerator stations, the equipment has to perform speed conversion and differential logic processing.

Forward error correction (FEC) may be used to achieve high quality in multi-state modulation. In radio-relay systems installed with FEC, it is possible to synchronize supervision and control signals at regenerator stations without special frame signals and to transmit them. This is achieved by accessing the additional supervision and control bits that are added to the FEC.

4.2 Transmission of supervision and control signals between SDH radio-relay stations

In the synchronous digital hierarchy (SDH), overhead bytes are provided for the transmission of information for maintenance and operation as an alternative to the methods stated in § 4 above. Six bytes of the overhead have been allocated for media specific usage. These six bytes may be accessible at both terminal and regenerator stations and may be suitable for the transmission of maintenance and operation signals such as supervision and control, and protection switching (see Recommendation ITU-R F.751).

APPENDIX 1

OF ANNEX 1

Optimum pulse shape and maximum capacity for supervision and control signal transmission using FSK additional modulation

FSK additional modulation for SC transmission is evaluated by tracking phase error in the main signal coherent detector and by assessing the SC demodulated *S*/*N* ratio performance. The SC signalling pulse shape should not have any d.c. component. Among the pulse shapes considered, class 4 partial response signalling was found to be well suited to tracking phase error.

The upper limit for SC transmission is the bit rate which just causes the allowable tracking phase error. The relationship between the tracking phase error and PLL noise bandwidth (B_L) is shown in Fig. 1. This relationship is based on the condition that SC signals of various bit rates have an equal *S/N* ratio. The maximum SC capacity for 16-QAM and 64-QAM systems is limited to 96 kbit/s and 32 kbit/s, respectively.

FIGURE 1

Tracking phase error due to class 4 partial response signalling FSK