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Methods of measurement for equipment used in digital microwave radio transmission systems - Part 2: Measurements on terrestrial radio-relay systems - Section 8: Adaptive equalizer (IEC 60835-2-8:1993)

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Meßverfahren für Geräte in digitalen Mikrowellen-Funkübertragungssystemen -- Teil 2: Messungen an terrestrischen Richtfunksystemen -- Hauptabschnitt 8: Adaptative Entzerrer

Méthodes de mesure applicables au matériel utilisé pour les systèmes de transmission numérique en hyperfréquence -- Partie 2: Mesures applicables aux faisceaux hertziens terrestres -- Section 8: Egaliseur auto-adaptatif

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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FOREWORD

The text of document 12E(CO)146, as prepared by subcommittee 12E: Radio relay and fixed satellite communication systems, of IEC technical committee 12: Radiocommunications, was submitted to the IEC-CENELEC parallel vote in November 1991.

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The text of the International Standard IEC 835-2-8:1993 was approved by CENELEC as a European Standard without any modification.

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METHODS OF MEASUREMENT FOR EQUIPMENT USED IN DIGITAL MICROWAVE RADIO TRANSMISSIONS SYSTEMS

Part 2: Measurements on terrestrial radio-relay systems

Section 8: Adaptive equalizer

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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This section of the International Standard IEC 835-2 has been prepared by sub-committee 12E: Radio relay and fixed satellite communication systems, of IEC technical committee 12: Radiocommunications.

The text of this standard is based on the following documents:

DIS	Report on Voting
12E(CO)146	12E(CO)157

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

METHODS OF MEASUREMENT FOR EQUIPMENT USED IN DIGITAL MICROWAVE RADIO TRANSMISSIONS SYSTEMS

Part 2: Measurements on terrestrial radio-relay systems

Section 8: Adaptive equalizer

1 Scope

This section of IEC 835-2 deals with measurements pertaining to the adaptive equalizers used in digital microwave radio-relay systems. These measurements are intended to characterize the system equalizer in the presence of selective fading and may also be performed on systems without adaptive equalizers.

To take account of those properties of the system which are especially influenced by the use of frequency and/or time domain equalizers, the results of measurements performed on the system are presented by so-called signatures. Additional measurements provide further means to characterize the performance of the system.

2 General

The performance of a digital radio-relay link may be influenced by multipath propagation [1]*. This is especially true in the case of high capacity multi-state QAM systems. In addition to reducing the received signal level, i.e. "flat fading", multipath propagation results in linear distortion, i.e. "dispersive fading", producing amplitude and phase distortion. Multistate modulation systems are especially vulnerable to this form of fading (see 835-2-4: Part 2: Measurements on terrestrial radio-relay systems – Section 4: Transmitter/receiver (in preparation)).

For a system operating under multipath propagation conditions the vulnerability of the time-variant channel to linear distortion is of utmost importance. In the majority of high-capacity line-of-sight digital radio-relay systems, adaptive equalizers are used to counteract "dispersive fading" in order to decrease outages.

The following types of equalizers are generally in use:

- frequency-domain equalizers, which are mainly, but not necessarily, implemented at i.f, and
- time-domain equalizers, which are mainly, but not necessarily, implemented at baseband.

* The figures in square brackets refer to annex A.

2.1 *Frequency domain equalizer*

It is the purpose of a frequency domain equalizer to correct the power density spectrum of the received signal, which, for example, can be analyzed with the aid of a bank of band-pass filters. Since there is usually no major redundant information in the transmitted signal, it is not possible to gain any information about the phase or group delay distortion of the channel; only the attenuation distortion can be recognized properly.

In some cases, the equalization network is of the minimum-phase type where the phase and magnitude responses are linked to each other via the Hilbert transform. If the channel distortion is also of the minimum-phase type, then by equalizing the magnitude response the phase response is equalized as well.

If the channel distortion is of the non-minimum phase type, for example in the case of two-path propagation where the weaker signal arrives before the stronger signal at the receiver site, the phase distortion may be increased and in some cases even doubled when the attenuation is equalized. This is the basic shortcoming of such a frequency domain equalizer.

Its main advantage, however, is that it will operate correctly, with certain limitations, without any need for a recovered carrier signal (for synchronous demodulation), or for a recovered timing signal (for making correct timing decisions). Therefore, in contrast to time domain equalization systems, lock-in/lock-out properties need not be investigated.

2.2 *Time domain equalizer*

It is the purpose of a time domain equalizer to achieve an intersymbol-interference-free (ISI-free) pulse shape at the input of the decision circuitry, although the channel itself may cause a considerable amount of ISI due to multipath propagation.

Basically, time domain equalizers optimize the eye-opening either in the worst-case sense, i.e. by using the zero-forcing algorithm, or in the minimum-mean-square-error (MMSE) sense, i.e. using the MMSE algorithm [2]. For proper operation, they require at least a correctly recovered timing signal. On the other hand, it is possible for the carrier- and timing-recovery circuits to take advantage of the operation of the equalizer by using the already equalized signal for the control of these loops.

By looking at the pulse response of the channel, time domain equalizers are usually capable of counteracting both minimum and non-minimum phase channel distortion.

In general, multipath propagation causes not only distortion in the I-I path and in the Q-Q path but also cross-talk contamination between the quadrature signals in a QAM system, (see figure 1). Therefore the time domain equalizer, if realized at baseband, shall have equalizing circuits not only in the I-I and Q-Q path, but also in the I-Q and Q-I path (see figure 2).

If this equalizer is realized at i.f., only two equalization networks may be used and it may be possible to have only two independent controls.

2.3 *Evaluation of system parameters influenced by the equalizers*

To evaluate the properties of a radio-relay system with respect to selective fading the important concept of the so-called signature is widely used. It is based on a two-path (two-ray) propagation model [3]. Due to peculiarities which occur in connection with equalizers, several variants of signature measurements are usually performed in addition to the basic signature measurement given in IEC 835-2-4.

In IEC 835-2-4, the signature is defined as the locus in the relative echo-amplitude versus notch offset-frequency plane or in the notch depth versus notch offset-frequency plane along which the system shows a given state. For example this state is characterized either by a specified bit-error ratio, BER, e.g. 10^{-3} or 10^{-6}, or by "lock-in" or "lock-out" conditions.

The relative echo-amplitude *b* is defined as the ratio of echo ray amplitude to direct ray amplitude. The notch depth *B* is defined as follows:

$$B = -20 \log (1-b) \qquad \text{for } b < 1$$
$$B = -20 \log (1-1/b) \qquad \text{for } b > 1$$

Note that the two-path delay difference has a fixed value for the signature measurement.

The calculation of the outage of a radio-relay system covers two main parts:

- channel statistics, and
- system properties.

The aim of the signature measurement is to characterize the system properties under specific propagation conditions. The fixed 6.3 ns delay difference, used in the signature measurement in accordance with [3], is not the average of a physical delay time, but only a useful fitting parameter to match measured data and a numerical model. It is important to note that a consistent use of this fixed value of delay difference is also the basis for using the signature for system comparison.

The outage signature defined below is an important special case of the general signature definition.

All subsequent measurements are taken on systems equipped with or without equalizers, not on isolated equalizers.

To quantitatively evaluate system performance under selective fading, a two-path simulator is inserted into the signal path. With the aid of this simulator and additional measuring equipment the behaviour of the system under the following situations is evaluated by the measurements described below:

- A slow increase of two-path distortion until outage occurs:
  - measurement of the "outage" signature. (The term signature without further specification, in common use until now, is defined hereinafter as outage signature.)