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O.81
Appendix I
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SERIES O: SPECIFICATIONS OF MEASURING EQUIPMENT

Equipment for the measurement of analogue parameters

Group-delay measuring equipment for telephone-type circuits

Appendix I: A measuring signal (multitone test signal) for fast measurement of amplitude and phase for telephone type circuits

ITU-T Recommendation O.81 – Appendix I

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION O.81

GROUP-DELAY MEASURING EQUIPMENT FOR TELEPHONE-TYPE CIRCUITS

APPENDIX I

A measuring signal (multitone test signal) for fast measurement of amplitude and phase for telephone type circuits

Summary

In the following Appendix I a brief description of a test signal is given, stating its particular advantages for measurement of amplitude and phase simultaneously.

It was formerly published as Supplement 3.7 in the Blue Book (1988), Fascicle IV.4, and then renumbered on 26 June 1998 as Appendix I to ITU-T O.81 without further modification.

Source

Appendix I to ITU-T Recommendation O.81, was prepared by ITU-T Study Group 4 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 26 June 1998.

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation the term *recognized operating agency (ROA)* includes any individual, company, corporation or governmental organization that operates a public correspondence service. The terms *Administration*, *ROA* and *public correspondence* are defined in the *Constitution of the ITU (Geneva, 1992)*.

INTELLECTUAL PROPERTY RIGHTS

The ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. The ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, the ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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APPENDIX I

A measuring signal (multitone test signal) for fast measurement of amplitude and phase for telephone type circuits

(Geneva, 1998)

I.1 The multitone test signal

I.1.1 General description

The multitone test signal (MTTS) consists of a spectrum of N discrete signals separated by frequency spacing of 100 Hz in the low frequency range.

The spectral lines are all of equal amplitude; their phase relationship to each other is chosen on the basis of mathematical considerations so that the energy of the test signal is distributed approximately evenly across the entire period of the test signal.

The transmission characteristics, i.e. the amplitude and phase distortion of a telephone line, produce changes in the test signal. On the receive side, these changes are measured and evaluated, e.g. by means of a Fourier analysis. The results may be displayed on a screen in the form of an amplitude and/or phase graph and also, for example, the group delay may be derived from this.

I.1.2 Measuring principle

The transmit signal consisting of N cosine waveforms is generated in digital circuits: a sufficient number of instantaneous values of the MTTS is read out of a ROM with a clock frequency. After passing through a D/A converter and a filter which suppresses the clock frequency, the composite signal is available:

$$u(t) = \sum^{N} A_n \cdot \cos(2\pi nft - \varphi_n)$$

where

A amplitude of a single waveform

f is 100 Hz (see Note 2)

φ phase of the single waveforms

n serial number of the single waveforms

t time

N total number of waveforms.

At f = 100 Hz, the duration of one period of the MTTS is 10 ms.

The MTTS is passed to the object to be tested which changes the properties of the MTTS, i.e. the amplitudes and phases of the single waveforms.

In the receiving section, the changed signal is passed to an evaluation circuit, where the signal is sampled with the clock frequency. The sampled analogue values are digitized and stored in a memory. The stored values of the time function are then transferred by means of the Discrete Fourier Transform into the frequency domain. All necessary calculations are performed in a microcomputer.

At measurements where the objects to be tested include carrier frequency systems, frequency shift of the measuring signal can appear. In such cases it is recommended to use window functions in the signal processing section of the receiver.

The characteristics of the object to be tested are derived from the deviation of the received values against the transmitted values.

I.1.3 Data of the multitone test signal

Transmitter

Transmit frequencies

- 35 signals (cosine) simultaneously;
- $n \times 100$ Hz; $n = 2$ to 36 in steps of 100 Hz from 200 to 3600 Hz, or see Notes 1 and 2;
- Accuracy: 1×10^{-4}.

Transmit level (multitone test signal) +10 to –40 dBm.

This level corresponds to the level of a single sinusoidal signal which has the same peak value as the test signal.

- Accuracy at 1000 Hz 0.2 dB
- Frequency response 0.1 dB
- Harmonic distortion 40 dB
- Spurious distortion at +10 dBm 50 dB
- Phase constellation

0	2π/7	4π/7	6π/7	8π/7	10π/7	12π/7
n: 2, 3, 4, 5, 6, 8, 15, 22, 29, 36	9, 12, 20, 24, 35	10, 16, 18, 26, 28, 34 37 (Note 1)	11, 13, 31, 33	21, 23, 27, 32 1 (Note 1)	14, 19, 25, 30	7, 17 38 (Note 1)

Note 1 – Serial numbers of 1, 37 and 38 are optional values.

Note 2 – The French Administration uses frequency steps of 101.56 Hz according to $[26 \times (n - 1)] \times f$, where $f = 8000/2048$. This is in accordance with the principle of frequency offset contained in Recommendation O.6 concerning PCM equipment.

Receiver

The receiver takes into account the level and the phase constellation of the transmitted signal.

I.2 Advantages of the multitone test signal

With the technical means available today the multitone test signal can be generated at low cost with excellent stability of frequency, amplitude and phase. The quantity of 35 discrete signals and thus test points in the frequency range 200 to 3600 Hz is quite adequate for the testing requirements occurring in practice. Optionally, the frequency band can be widened according to Note 1.

When the received signal is evaluated, e.g. with the aid of a Fourier analysis to determine amplitude/frequency response and/or phase or group delay, a test cycle time, allowing for processing time and screen display time, of only less than one second is needed. This short test cycle is of great advantage mainly when equalization work has to be done.

Because the MTTS is normally a continuous signal there are no settling time problems which occur using a sweep mode signal.

The MTTS is an ideal band-limited “noise signal” for determining the rms bandwidth of filters, for example for the filter (psophometric weighting) in Recommendation O.41 or for calibrating PCM instruments measuring quantizing distortion.

Considering the ripple at the frequency response curve one can recognize very clearly that there are frequency components caused by any non-linearity of an item under test.

Using the Fourier analysis to evaluate the received MTTS one can recognize both the amplitude and frequency of unwanted signals; that means, the procedure works like a swept selective receiver.

The period of this MTTS is 10 ms (which corresponds to one period of a 100-Hz fundamental). Since for Fourier analysis it is sufficient to sample just one period of the test signal, i.e. 10 ms, at the receiving side, and 10 ms plus at the sending side, measurements could be performed during correspondingly short gaps in the speech or data transmission signal. These gaps occur in any case in these signals, or they may be created by technical means.

The use of the MTTS in combination with the Fourier analysis makes it possible to provide measurements of parameters which normally require filters; e.g. weighted noise, quantizing distortion, selective crosstalk, etc. In these cases filtering is provided by appropriate calculations in the microcomputer carrier out for the frequency domain of the input signal.

For measurements including PCM sections it is not necessary to shift the frequencies in order to avoid submultiples of 8 kHz, in this case a MTTS without frequency shift leads into a frequency response with a ripple of up to ± 0.1 dB. With the help of an averaging procedure (e.g. 4 or 16 measuring cycles) the ripple can be reduced to a negligible value.

A further possibility to reduce the ripple is to use shifted frequencies of $n \times 101.56$ Hz, according to Note 2.

In this case the ripple is less than ± 0.05 dB after one measuring cycle; even this relatively small error can be reduced by an averaging procedure.

I.3 Practical experience

Since 1981, instruments using multitone test signals have been used by various Administrations all over the world.

Measurement results are obtained quickly and unambigously and are compatible with those obtained with conventional methods.

The USSR Telecommunication Administration is investigating theoretically and practically the MTTS in order to determine the best use for further applications.

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