



INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

O.81

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

SERIES O: SPECIFICATIONS OF MEASURING
EQUIPMENT

Equipment for the measurement of analogue parameters

**Group-delay measuring equipment for
telephone-type circuits**

ITU-T Recommendation O.81

Extract of **Blue Book Fascicle IV.4 (1988)**

NOTES

- 1 ITU-T Recommendation O.81 was published in Fascicle IV.4 of the *Blue Book*. This file is an extract from the *BlueBook*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).
- 2 In this Recommendation, the expression “Administration” is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation O.81

GROUP-DELAY MEASURING EQUIPMENT FOR TELEPHONE-TYPE CIRCUITS

(Geneva, 1972)

The characteristics for a group-delay measuring set for telephone-type circuits which are described below must be adhered to in order to ensure compatibility between equipments standardized by the CCITT and produced by different manufacturers.

1 Measuring principle

In the case of group-delay distortion measurements over a line (straightaway measurements), a signal for phase demodulation is required on the receiving side whose frequency corresponds exactly to the modulation (split) frequency on the transmitting side and whose phase does not change during the measurement. With the proposed measuring principle, this frequency is generated in a split-frequency oscillator in the receiver whose frequency is controlled with the aid of a reference carrier having a fixed frequency of 1.8 kHz. The reference carrier is amplitude modulated with the same modulation frequency as the measuring carrier and is transmitted over the path to be measured in periodical alternation with the measuring carrier. During the changeover from measuring carrier to reference carrier no phase or amplitude surge must occur in the sending signal. For the sake of identification the reference carrier is furthermore amplitude modulated with an identifying signal.

If the path to be measured has different group delay and/or attenuation for the measuring carrier and the reference carrier, a phase and/or amplitude surge appears at the output of the path to be measured at the carrier changeover point within the receiver. This phase or amplitude surge is evaluated by the receiver of the measuring set. Thus, the receiver is provided with a phase measuring device for the purpose of group-delay measurements. This measuring device includes the above-mentioned frequency controlled split-frequency oscillator whose phase is automatically adjusted to the mean value derived from the phases of the split-frequencies transmitted with the measuring and the reference carriers. The split frequency voltage fed to the phase meter is taken from the output of an amplitude demodulator which can simultaneously be used for measuring amplitude variations. In order to recognize the actual measuring frequency on the receiving side – particularly during sweep measurements – a frequency discriminator may be provided.

If the frequency of the measuring carrier differs from the frequency of the reference carrier during the measurement and if the path to be measured has different group-delay and attenuation values for the two frequencies, a square-wave signal appears at the outputs of the phase meter, the amplitude demodulator and the frequency discriminator in the receiver, whose amplitudes are proportional to the respective measuring results – referred to the frequency of the reference carrier – and whose frequency corresponds to the carrier changeover frequency on the transmitting side. These three square-wave signals are subsequently evaluated with the aid of controlled rectifiers and allow indications, together with the correct signs, of differences in group-delay distortion, attenuation and measuring frequency between measuring and reference carrier frequencies.

2 Technical details

2.1 Transmitter

The modulation split frequency shall be 41.66 Hz (= 1000 Hz/24). With the aid of this signal the reference and measuring carriers are amplitude modulated to a modulation depth of 40%. Both sidebands are transmitted. The modulation distortion factor shall be smaller than 1%. The changeover from measuring carrier to reference carrier is carried out within a switching time of ≤ 100 microseconds. The changeover frequency is rigidly tied to the modulation frequency by binary frequency division and is 4.166 Hz (41.66 Hz/10). The carrier changeover occurs at the minimum of the modulation envelope. Deviations of $\leq \pm 0.2$ milliseconds are admissible. The carrier frequency which is not transmitted in each case has to be suppressed by at least 60 dB referred to the sending signal.

The identifying signal which is required for identifying the reference carrier is also rigidly tied to the modulation (split) frequency. The assigned frequency 166.6 Hz is derived by multiplying the modulation (split) frequency by four or by dividing 1 kHz by six. The rectangular-shaped identifying signal derived from 1 kHz through frequency division can be used for direct modulation after having passed through an RC lowpass filter with a time constant of $T = 0.43$ milliseconds since a pure sinusoidal form is not required in this case. The modulation depth is 20%. The identifying signal is only transmitted during the last 24 milliseconds of the reference carrier sending time. The shape of the different signals on the transmitting side shown as a function of time and their respective forms can be seen from Figure 1/O.81.

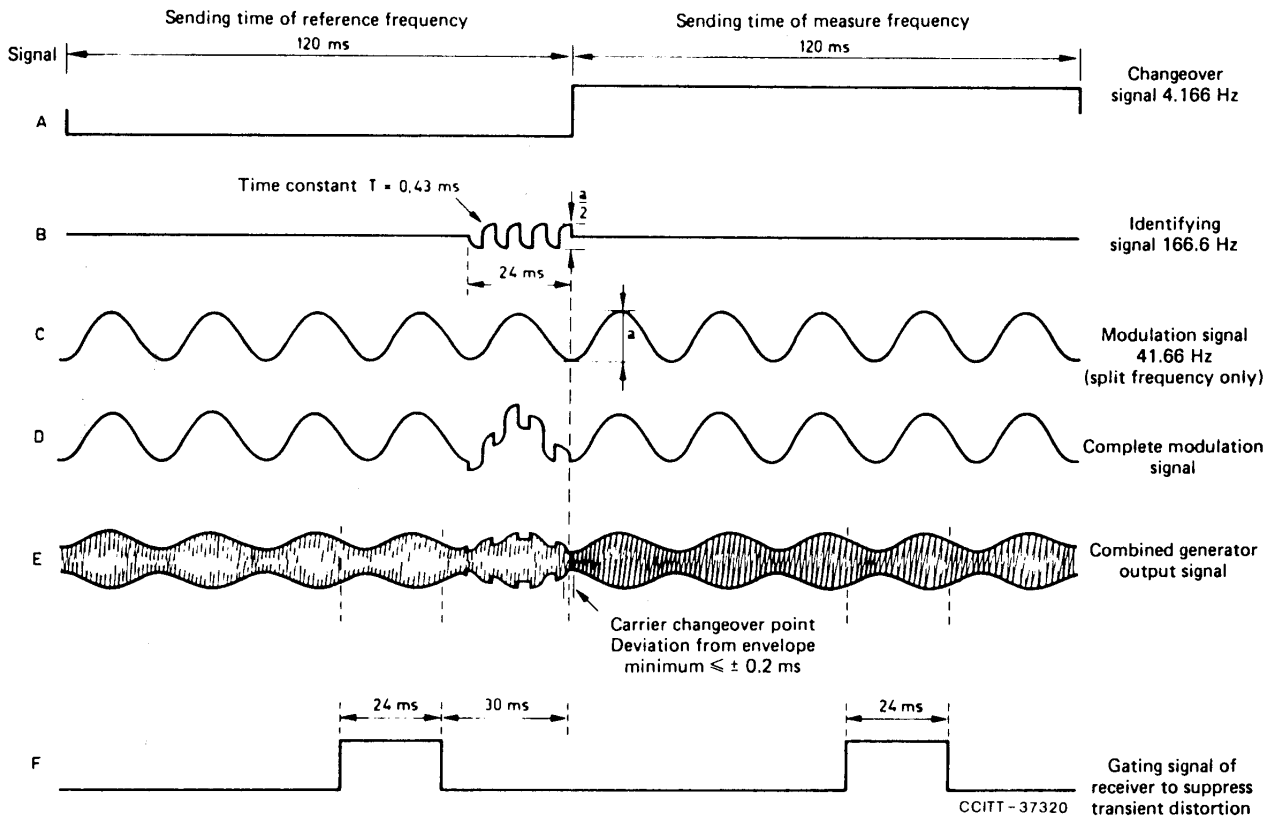


FIGURE 1/O.81

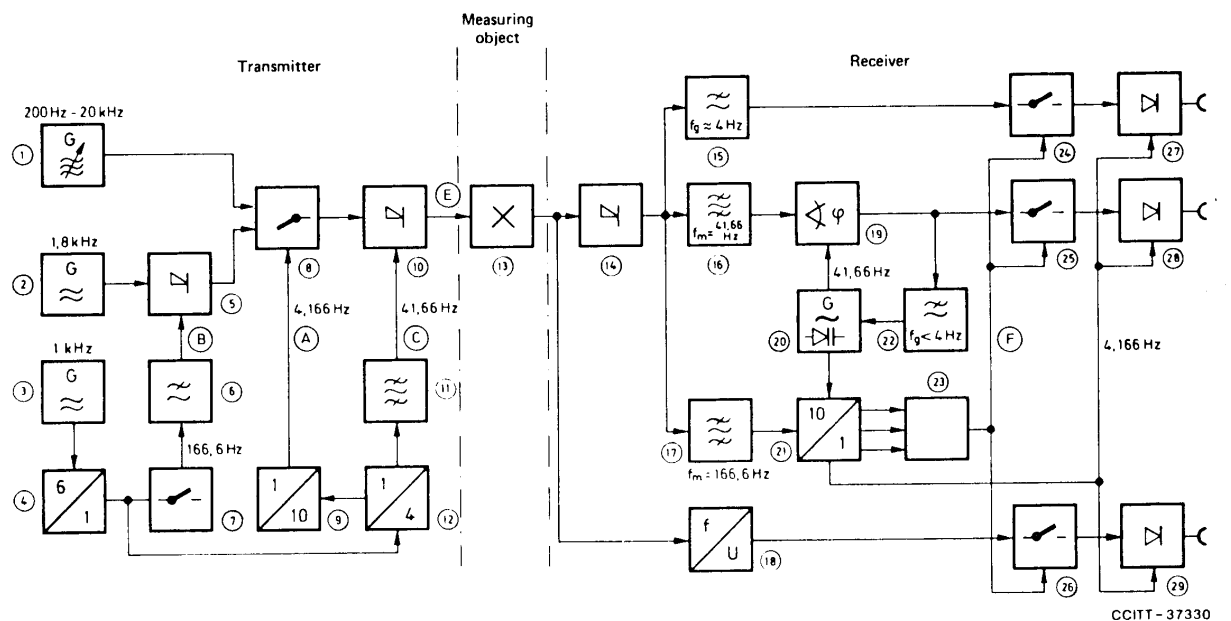
Timing of various signals of group-delay measuring set

2.2 Receiver

2.2.1 Group-delay measurements (see Figure 2/O.81)

The signal coming from the path to be measured is demodulated and the modulation frequency of 41.66 Hz so obtained is filtered out by a bandpass filter. This modulation voltage is rectangularly phase modulated, the frequency of the phase modulation being equivalent to the changeover frequency, 4.166 Hz. The phase deviation is proportional to the group-delay difference between the measuring carrier and the reference carrier. The phase demodulation is carried out in a phase meter whose second input is fed, for example, by a 1 kHz oscillator via a frequency divider 24/1. This oscillator forms a closed-phase control loop involving the phase meter and a lowpass filter which suppresses the changeover frequency. Thus, the modulation frequency generated in the receiver corresponds exactly to the modulation frequency coming from the transmitter.

At the output of the phase meter a 4.166-Hz square-wave voltage is obtained, whose amplitude is proportional to the measuring result. In order to enable a correct evaluation of this signal, a controlled rectification is required. The control voltage is derived from the modulation (split) frequency which is generated in the receiver by frequency division (10/1). The correct phase position with regard to the transmitting signal is enforced with the aid of the identifying signal 166.6 Hz. The controlled rectifier is connected both to an indicating instrument and to the direct current output.



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|--------------|---------------------------------------|----------------|--|
| 1 | oscillator, measure frequency | 14 | amplitude demodulator |
| 2 | oscillator, reference frequency | 17 | bandpass filter, identifying frequency |
| 3 | oscillator, 1 kHz | 18 | frequency discriminator |
| 4, 9, 12, 21 | frequency dividers | 19 | phase meter |
| 5, 10 | amplitude modulators | 20 | controlled oscillator |
| 6, 15, 22 | low pass filter | 23 | And circuit |
| 7 | gate, identifying signal | 24, 25, 26 | gates |
| 8 | carrier changeover switch | 27, 28, 29 | controlled rectifiers |
| 11, 16 | bandpass filter, modulation frequency | A to F signals | see Figure 1/O.81 |
| 13 | measuring object | | |

FIGURE 2/O.81

Principle of group-delay measuring set

2.2.2 Amplitude measurements

If the amplitude measurement is to be referred also to the reference carrier, the signal at the output of the amplitude demodulator (4.166-Hz square-wave proportional to Δa) can be subsequently evaluated as already described in the case of the group-delay measurements. Furthermore, it is possible to indicate the respective absolute carrier amplitude.

2.2.3 Frequency measurements

For sweep measurements it is necessary to generate in the receiver a voltage which is proportional to the measuring frequency. This can be achieved with the aid of a frequency discriminator which, in turn, supplies its output voltage to a controlled rectifier. The indicated measuring result is the frequency difference between the measuring carrier and the reference carrier. Optionally, only the measuring carrier frequency may be indicated.

2.2.4 Blanking of transient distortion

Due to the carrier changeover it may happen that transient distortions occur in the path to be measured as well as in the receiver. These interfering signals can effectively be blanked out by means of gate circuits. The gates will release the ensuing measuring devices only during those periods which are indicated in Figure 1/O.81.

3 General

The transmitter output and the receiver input must be earth free and balanced. It must be possible to apply a maximum direct current of approximately 100 mA to the connected measuring instruments for the purpose of loop holding.

4 Specifications for a group-delay measuring set for telephone-type circuits

4.1 General

4.1.1 Accuracy of group-delay measurements (see also § 4.2.1 below):

– 200 Hz to 400 Hz	$\leq \pm 100$ microseconds	} $\pm 3\%$ of measuring range ¹⁾
– 400 Hz to 600 Hz	$\leq \pm 30$ microseconds	
– 600 Hz to 1 kHz.....	$\leq \pm 10$ microseconds	
– 1 kHz to 20 kHz	$\leq \pm 5$ microseconds	

Outside a temperature range of +15 °C to +35 °C the stated accuracy may be affected by variations of the modulation frequency, causing a measuring error of 4% instead of 3% (see § 4.1.4 below).

The additional error due to amplitude variations shall not exceed:

– variations up to 10 dB	± 5 microseconds
– variations up to 20 dB	± 10 microseconds
– variations up to 30 dB	± 20 microseconds

4.1.2 Measuring frequency 200 Hz to 20 kHz

4.1.2.1 Measuring frequency accuracy:

– in temperature range +15 °C to +35 °C	$\leq \pm 1\%$ of actual frequency reading ± 10 Hz
– in temperature range +5 °C to +50 °C	$\leq \pm 2\%$ of actual frequency reading ± 10 Hz

4.1.3 Reference frequency 1.8 kHz

(plus a vernier adjustment to avoid coincident interfering tones).

There should be an option to include two additional reference frequencies to increase accuracy at the edges of the band.

4.1.3.1 Reference frequency accuracy:

– in temperature range +15 °C to +35 °C	$\leq \pm 1\%$
– in temperature range +5 °C to +50 °C	$\leq \pm 3\%$

4.1.4 Modulation frequency (1 kHz : 24): ²⁾

– in temperature range +15 °C to +35 °C	41.66 Hz $\pm 0.5\%$
– in temperature range +5 °C to +50 °C	41.66 Hz $\pm 1\%$

4.1.4.1 Modulation depth ²⁾ $m = 0.4 \pm 0.05$

4.1.4.2 Modulation distortion factor ^{2), 3)} $\leq 1\%$

4.1.5 Identifying frequency (1 kHz : 6) derived from modulation frequency ²⁾ 166.6 Hz

4.1.5.1 Modulation depth ²⁾ $m = 0.2 \pm 0.05$

4.1.5.2 Sending time of identifying signal ²⁾ 24 milliseconds terminating with the end of the sending time of the reference frequency

4.1.5.3 The commencement of the identifying signal shall cause a decrease in the amplitude of the carrier (as shown in Figure 1/O.81).

1) The measurement range is taken to be the indicated value at full-scale deflection on the range in use.

2) Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.

3) The modulation distortion factor is taken to be:

$$\frac{\text{r.m.s. value of unwanted sidebands}}{\text{r.m.s. value of wanted sidebands}} \times 100\%$$

4.1.6	Changeover frequency (1 kHz : 240) derived from modulation frequency ⁴⁾	4.166 Hz
4.1.6.1	Carrier changeover time ⁴⁾	Less than 100 microseconds
4.1.6.2	Deviation between carrier changeover point and envelope minimum ⁴⁾	≤ ± 0.2 milliseconds
4.1.7	<i>Range of environmental conditions⁵⁾</i>	
4.1.7.1	Power supply voltage variation	+10 to -15%
4.1.7.2	Temperature range	+5 °C to +50 °C
4.1.7.3	Relative humidity range	45% to 75%
4.1.8	<i>Additional requirements</i>	
4.1.8.1	Speaker arrangements	Optional
4.1.8.2	Internal check. Internal checking circuits shall be provided to verify the proper operation of the group-delay/frequency and attenuation/frequency distortion measurement functions, using appropriate outputs from the sender.	
4.2	<i>Sender</i>	
4.2.1	Error introduced by the sender in the overall accuracy of the group-delay measurement (as indicated in § 4.1.1 above) shall not exceed ⁴⁾ :	
	– 200 Hz to 400 Hz	± 10 microseconds
	– 400 Hz to 600 Hz	± 3 microseconds
	– 600 Hz to 20 kHz	± 1 microsecond
4.2.2	Range of send levels (average carrier power) (the maximum send level may be restricted as an option)	-40 dBm to +10 dBm
4.2.2.1	Send level accuracy	≤ ± 0.5 dB
	at the reference frequency	≤ ± 0.3 dB
4.2.3	Output impedance (frequency range 200 Hz to 20 kHz):	
	– balanced, earth free	600 ohms
4.2.3.1	Return loss	≥ 40 dB
4.2.3.2	Signal balance ratio	≥ 46 dB
4.2.4	Harmonic distortion of send signal	≤ 1% (40 dB)
4.2.5	Spurious distortion of send signal	≤ 0.1% (60 dB)
4.2.6	Frequency sweep rate	Adjustable from 10 Hz/sec to 100 Hz/sec. At least four sweep rates shall be provided
4.2.7	Preventing possible response of dial tone receivers	Optional
4.2.8	Provision for loop holding	Yes
4.2.9	Arrangements shall be included in the sender so that when required, prior to measurement, the test and reference carrier frequencies can be measured to a resolution of 1 Hz. This may be achieved by providing suitable outputs at the sender for use with an external frequency counter.	

⁴⁾ Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.

⁵⁾ These values are provisional and require further study.

4.3	<i>Receiver</i>	
4.3.1	Input level range	-40 dBm to +10 dBm
4.3.1.1	Dynamic range of receiver	30 dB
4.3.2	Input impedance (frequency range 200 Hz to 20 kHz):	
	– balanced, earth free	600 ohms
4.3.2.1	Return loss	≥ 40 dB
4.3.2.2	Signal balance ratio	≥ 46 dB
4.3.3	Range for measuring group-delay frequency distortion	$\left\{ \begin{array}{l} 0 \text{ to } \pm 100, \pm 200, \pm 500 \text{ microseconds} \\ 0 \text{ to } \pm 1, \pm 2, \pm 5, \pm 10 \text{ milliseconds} \end{array} \right.$
4.3.3.1	Accuracy of group-delay measurements in accordance with §§ 4.1.1 and 4.2.1 above.	
4.3.4	Measuring range for attenuation/frequency distortion measurements	$0 \pm 2, \pm 5, \pm 10, \pm 20, \pm 50 \text{ dB}^{(6)}$
4.3.4.1	Accuracy (+5 °C to +50 °C)	$\pm 0.1 \text{ dB} \pm 3\% \text{ of measuring range}$
4.3.5	Measuring range for input level measurements at the reference frequency	+10 dBm to -20 dBm
4.3.5.1	Accuracy (+15 °C to +35 °C)	$\pm 0.25 \text{ dB}$
	(+5 °C to +50 °C)	$\pm 1 \text{ dB}$
4.3.6	D.c. outputs shall be provided to drive an X-Y recorder.	
4.3.7	Measuring ranges for frequency measurements	$\left\{ \begin{array}{l} 200 \text{ Hz to } 4 \text{ kHz} \\ 200 \text{ Hz to } 20 \text{ kHz} \end{array} \right.$
4.3.7.1	Accuracy of frequency indications	$\pm 2\% \pm 10 \text{ Hz}$
4.3.8	Provision for loop holding	Yes
4.3.9	<i>Noise immunity</i>	
4.3.9.1	There shall be an option to include a lowpass filter to reduce the effect of interfering frequencies above 4000 Hz, for example, metering pulses.	

The group-delay/frequency distortion of the filter shall not exceed 5 microseconds at 2600 Hz and 30 microseconds at 2800 Hz relative to the group delay at 1000 Hz. The attenuation/frequency distortion shall not exceed 0.1 dB at 2600 Hz and 0.2 dB at 2800 Hz relative to the attenuation at 1000 Hz.

4.3.9.2 The r.m.s. value of the error in indication due to a white noise level at 26 dB per 4-kHz band below the mean carrier level of the received test signal shall not exceed 20 microseconds when the sweep rate does not exceed 25 Hz per second.

When testing an apparatus for its ability to meet this requirement, the group-delay/frequency distortion of the test object shall not vary at a rate exceeding 1.5 ms per 100 Hz.

4.3.9.3 The error in indication due to discrete tones $\pm 150 \text{ Hz}$ around either test or reference signals shall not exceed $\pm 20 \text{ microseconds}$ and for $\pm 200 \text{ Hz}$ shall not exceed $\pm 2 \text{ microseconds}$ when the level of such interfering frequency is 26 dB below the mean carrier level of the received test signal.

Bibliography

COENNING (F.): Progress in the Technique of Group Delay Measurements, *NTZ Communications Journal*, Vol. 5, pp. 256-264, 1966.

⁶⁾ On the $\pm 50 \text{ dB}$ range stated accuracy applies over the $\pm 30 \text{ dB}$ range only (see § 4.3.1.1).