TR 102 082 V1.1.1 (1999-01)

Technical Report

Speech Processing, Transmission and Quality Aspect (STQ); Guidance on writing specifications and tests for non-linear and time variant telephony terminals

Reference

DTR/STQ-00002 (ja000ics.PDF)

Keywords

quality, signal processing, speech, telephony,
testing, transmission

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Speech Processing, Transmission and Quality Aspects (STQ).

Introduction

From being a relatively stable discipline for many years, telephonometry is presently facing a massive need for development and renewal.

A major reason for this need is the current rapid development of communications technology in general. This has been reflected in the establishment of several new telephone transmission networks and in an effective break up from the previously dominating handset/office user situation. Examples of important areas with unresolved measurement problems are terminals with hands-free mode of operation, conference systems, and the often difficult conditions associated with mobile telephony.

Equally important, however, is the evolution from a national protectionist environment via a more objective European regulatory environment to tomorrows fully open competition on quality as perceived by the individual user. In this environment, it is most important for the credibility of objective testing that results are much less dependent on specific test procedures than in the past. Testing should be based on well-defined test procedures. The results should be reproducible and comparable, by using the same procedures so that results are independent of test system implementations. The need for documented test system performance, necessitates a significant increase in the current specification level of standards and recommendations.

A methodology needs to be developed that is applicable to a much wider variety of telephony applications while ensuring the development of more subjectively related though objectively more well defined tests. It is essential for the future to eliminate the perceived difficulties that have previously been associated with telephonometry in the ordinary telephone engineers mind.

On the basis of presently accepted objective criteria for speech transmission quality, the present document deals with the various considerations that have to be made to avoid pitfalls in the selection and description of practical instrumentation and test procedures. There is, however, a clearly recognized need to derive a range of new or improved objective parameters describing various aspects of the subjectively perceived transmission quality. Definition of new objective parameters is outside the scope of the present document, where the intention is to form the general basis for the standards engineer in the work of describing test methods for existing objective parameters. However the considerations are expected also to be useful when defining new or improved objective parameters for terminals containing various types of signal processing. The considerations should also be useful when specifying test methods for end-to-end measurements ("mouth-to-ear" measurements including the telephony terminal and the acoustical environment).

1 Scope

The present document provides guidance on writing objective specifications and tests for non-linear and time variant telephony terminals but excluding the speech coding functions.

The present document provides general guidance on the formulation of test specifications including emphasizing the need for the requirement and test specification to be prepared together so that they are correctly matched to each other. This general guidance has wider application than the main scope of the present document.

The present document provides specific guidance on the treatment of non-linearity and time variance in order to enable existing requirement and test methodologies to be applied to these terminals. The method used is to treat the terminal as a system that can be subdivided into different parts so that the non-linearity or time variant element can be characterized separately. A checklist is given for the description of any specific non-linearity or time variant element so that the necessary decisions can be taken on the most appropriate way to formulate a test method including the selection of the test stimulus.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] CCITT Recommendation P.10 (1988) (Blue Book): "Vocabulary of terms on telephone transmission quality and telephone sets".

[2] ITU-T Recommendation P.501: "Test signals for use in telephonometry".

[3] ITU-T Recommendation Q.7: "Signalling systems to be used for international automatic and semi-automatic telephone working".

NOTE 1: Relevant to ITU-T Recommendation P.501 is ITU-T Q.7/ITU-T Q.12

NOTE 2: In general a large number of the ITU-T P series of recommendations will be relevant to use together with the present document when writing specific test specifications. Question 20/12 provides important information on activities in the ITU-T SG 12.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply.

non-linearity: a property whereby the magnitude of the instantaneous output signal is intended not to have a direct linear relationship to the applied stimulus. Examples of non linearity are µ-law / A-law companding and centre clipping.

time Variant: a property whereby the output signal of the device is intended to be dependent not only on the instantaneous value of the applied stimulus, but on earlier values of stimulus. Examples are echo cancellers which take time to optimize and automatic level systems which may have long (attack +) decay times.

NOTE: Devices may exhibit both non-linear and Time dependent characteristics. An example is VAD (Voice Activated Detection) used in DCME, which are inherently non-linear but the switching threshold may be time dependent.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AGC	Automatic Gain Control
DCME	Digital Circuit Multiplication Equipment
FFT	Fast Fourier Transform
IUT	Implementation Under Test
LR	Loudness Rating
RMS	Root Mean Square (value)
SLR	Sending Loudness Rating
SPM	Signal Processing Method
TCL	Terminal Coupling Loss
VAD	Voice Activity Detection

4 Derivation of requirement and selection of test method

4.1 General Principles

When defining new test standards or practices it is essential to separately consider the two following processes:

- the derivation of a well-defined objective requirement which is linked as closely as possible to a basic quality (auditory/subjective perception);
- selection and description of the most appropriate method(s) to assess the relevant decision variable.

This separation may not seem necessary when testing products based on conventional technology, but it is crucial for proper evaluation of products with properties and characteristics not foreseen in the standard and for the possible later acceptance of alternative, typically more advanced, measurement methods.

NOTE 1: In some cases a telephone terminal containing non-linear or time-varying circuitry may be tested against the standard requirement by modifying the test method slightly e.g. to ensure that the IUT is in a well-defined state. Such a modification can essentially be justified by technical arguments. In other cases it may be necessary to re-evaluate the requirement as such in view of the acclaimed technology. This will typically require psycho-acoustic considerations as to whether one quality parameter can be traded in for another, e.g. lower echo in return for higher distortion.

It is necessary to consider carefully the range of conditions under which the requirement has to be fulfilled to satisfy the basic purpose. In most cases practical testing has to be restricted to a scarce sampling of these conditions. Nevertheless, it is essential for the obligations of the equipment manufacturer whether such a limitation of conditions is specified as part of the requirement or as part the test specification.

NOTE 2: The underlying assumption for the sampling: that the result sampled at 1 kHz would be representative for the whole range of frequencies specified by the requirement, would clearly not be fulfilled. If a requirement for third harmonic distortion is only applicable at 1 kHz, the equipment manufacturer may ensure the necessary performance of his product by integrating a 3 kHz notch filter (possibly triggered by the 1 kHz signal only) in his product. If alternatively, the requirement is stated to cover a wider range of frequencies, and the actual frequency is specified in the test specification, such a solution would not be acceptable.

The present document is meant to help "concerned parties" (manufacturers, test laboratories, standards body etc) in enhancing standards and to ensure and/or improve the speech quality of systems using complex signal processing techniques.

4.2 Basis for Requirements

The items mentioned below summon all the application specific knowledge, including the psycho-acoustics aspects, necessary to derive a specific requirement, which can be objectively evaluated. A clear understanding of these items is essential for both the standards engineer and the designers ability to implement improvements to the product.

- Purpose;
- assumptions;
- relevant Standards and Recommendations;
- test Arrangement;
- decision Variable(s);
- mapping between objective and subjective evaluation;
- expression of the Requirement.

An explanation and discussion of the individual items is given in subclause 4.2.1 to subclause 4.2.7.

4.2.1 Purpose

Each specific requirement shall be justified in terms of a test purpose, i.e. a description of the nature of the supposed impact on the speech transmission as well as the documentation for the relationship between this impact and the subjectively perceived quality of the object to be tested.

EXAMPLE: The need to optimize the use of the limited dynamic range of the network and the need to have a somewhat uniform listening level for receivers not having a volume control justifies the requirement for Sending Loudness Rating.

4.2.2 Assumptions

The assumptions shall contain information specific to the particular implementation of the functionality of the test object or its application. Often such assumptions can lead to dramatic simplifications of the test procedures and the requirements for specific instrumentation. When a requirement and the consequent test specification are based on such assumptions, however, a means for a test engineer to check the validity of the assumptions should be annexed to the test specification.

EXAMPLE 1: If a test object is required to have (and separately tested for) an amplitude linear performance, the requirements for frequency sensitivity and loudness ratings may be limited to be applicable to excitation at nominal level.

EXAMPLE 2: If a telephone is intended to be used with a band-limited network, there is no need to specify its telephony characteristics in a wider frequency range.

4.2.3 Relevant standards and recommendations

There are several groups of standards relevant to the definition of a test. By relying on relevant standards specifying general testing methods, as well as to specific standards dealing with e.g. physical test arrangements, when defining a test, exhaustive definitions of specific tests can be avoided. Simultaneously this allows to the widest extent possible the use of general commercially available measurement equipment. The standards specifying the general functionality and operation of the object to be tested may also contain valuable information for defining an optimum testing strategy for the telephony aspect of its use.

EXAMPLE: By specifying overall weighting filters and frequency selective filters by reference to general international standards (e.g. A-weighting, 1/3 and 1/12 octave filters) a wide choice of commercial instrumentation becomes available, elaborate definitions are avoided, and calibration as well as calculation of measurement uncertainty can be unambiguously performed.

4.2.4 Test arrangement

The test arrangement should simulate as closely as possible the real use conditions with due respect, however, to existing standards and to the use of commonly available laboratory facilities. In cases where the real use conditions are expected to have a significant influence on the behaviour of the test object, it should be considered to include the test arrangement as a separate variable in the requirement or to define a worst case condition.

EXAMPLE: The Terminal Coupling Loss which is essential for the echo experienced by the opposite party in a conversation, may vary depending on how tight the handset is held against the ear. Positioning the handset in a free field will typically represent worse conditions than those occurring during normal handset telephony with the earpiece tightly coupled to the ear.

4.2.5 Decision variable(s)

The test definition shall contain a precise definition of the decision variable to be determined. To the widest extent possible, the decision variable should only reflect the basic performance of the telephone under test. The decision variable may be a complex function. In this case it will not be the decision variable itself, but one of its time and/or frequency domain representations or a calculated (set of) value(s) based on one of these, which will be compared to the requirement values. The definition of the decision variable and the choice of its representation should always reflect considerations relating to the determination of measurement accuracy and, where relevant, to the additivity of transmission related parameters.

NOTE: Non-linear distortion may be evaluated from the level of individual order components or as a total level excluding the fundamental. Selective assessment has more advantages. It allows components to be weighted individually according to their audibility as well as enables the distinction between non-linearity and noise, which again simplifies the calculation of measurement uncertainty.

4.2.6 Mapping between objective and subjective evaluation

For optimum consistence with subjective evaluation, the decision variable will often be explicitly weighted by data reflecting the properties of human speech and perception. Without proper consideration, however, test result will often be unintentionally biased by the practical definition of the test, e.g. by the choice of the test vector. Therefore, the desired overall mapping of the data should always be clearly stated in the test definition.

EXAMPLE 1: Loudness Ratings are intentionally based on frequency weighted data to simulate the human loudness experience.

EXAMPLE 2: Receiving frequency responses as traditionally measured on a closed volume coupler, are not individually corrected for the real ear loss. Consequently, they significantly lack correlation to subjective evaluation.

EXAMPLE 3: When sampled on a logarithmic scale, group delay calculated from phase changes are inherently subjected to a 1/f weighting. If determined from the magnitude of the impulse response, the result reflects a basically flat weighting.

4.2.7 Expression of the Requirement

The requirement shall contain (an) upper and/or lower limit value(s) against which the determined decision variable or value(s) derived from this may be calculated. The conditions under which the requirement shall be fulfilled shall reflect the test purpose and where relevant provide an indication of the subjective performance evaluation corresponding to the limit value(s).

NOTE 1: It is often forgotten to specify the range of conditions under which the requirement is applicable, or to confuse this range with the test vector, which is adopted to minimize the assessment time for each test object.

NOTE 2: Current tests often individually relate so poorly to the subjective performance evaluation that it is not possible to argue seriously for specific limit values. An improvement in this respect should, however, be addressed in future work.

4.3 Guidelines for Test Procedure Specification

On the basis of the application specific knowledge mentioned above (subclause 4.2), every test engineer with a general solid measurement experience should be able to derive test procedures yielding comparable results. Regulatory standards still need to address some or all of the items listed below in detail to eliminate any ambiguity in the verdict. In all other standards, however, such definitions should be of an informative nature and include proper guidance on the basic restrictions within which the average test engineer may design his own implementation of the test.

With regard to specific test signals and testing methods more information can be found in ITU-T Recommendation P.501 [2].

- Test vector;
- result presentation;
- conditioning signal;
- measuring signal;
- analysis principle;
- validation.

An explanation and discussion of the individual items is given in subclause 4.3.1 to subclause 4.3.6.

4.3.1 Test vector

While the requirement shall normally be fulfilled for all combinations of parameters within the specified operating conditions, a limited number of test points may be specified for practical tests, when it can be justified that the results obtained can be regarded as representative for the full range of the parameter. Under this assumption, the test vector shall normally be designed for minimum measuring time and/or to allow the use of generally available test equipment.

EXAMPLE: For the measurement of sensitivity frequency response functions, the requirement is often expressed as a continuous function. Nevertheless, modern telephone characteristics generally allow a sampling of the requirement at 1/12 or even 1/3 octave intervals.

4.3.2 Result presentation

Whenever the requirement depend on an independent variable (e.g. frequency, time, or level) and is only provided in terms of "knee points", it is essential for the consistence between the verdict and a visual presentation that the interpolation of the requirement as well as of the measured values reflect a preferred graphical format. For easy comparison of results, the preferred axis ratios and absolute size for the graphs should also be given.

EXAMPLE: A frequency response which passes against a mask which is linearly interpolated on a graph with linear frequency axis, may easily fail against a mask obtained by linear interpolation on a graph with logarithmic frequency axis.

4.3.3 Conditioning signal

If the performance of a test object may vary as a function of the operating conditions typical of real use, these conditions have to be properly simulated for a period prior to and during the actual measurement. When the performance depends on the characteristics of the test signal itself, it has to be ensured that this is suited for the evaluation of the specific performance aspect. Alternatively, the conditioning signal shall be constructed to allow the application and analysis of a separate measuring signal, which can be added in time or frequency without affecting the acquired performance of object under test. Proper activation of the object under test always need to be insured. Important conditioning signal aspects are: long and short term spectra, amplitude distribution, voiced/unvoiced structure, temporal envelope and auto-correlation function.

EXAMPLE: For evaluation of test objects featuring speech detectors, the signal has to have a temporal envelope simulating that of real speech.

4.3.4 Analysis principle

In the choice of analysis principle it has to be considered, whether the output of the telephone under test is coherent to the input. If this is the case, the use of complex analysis techniques may provide faster and/or more accurate results than may otherwise be obtained. In general, however, simple, device independent, and generally standardized measurement methods are to be preferred.

NOTE 1: Coherence between input and output may be lost when signals are transmitted through low bit rate coders, thus eliminating the use of complex dual channel analysis techniques.

NOTE 2: The subjective perceived behaviour of adaptive echo cancellers and other time varying devices can only be estimated but not measured correctly by standard dual channel block processing methods (e.g. FFT) if the characteristics are not stable during the block acquisition time.

4.3.5 Measuring signal

The actual measuring signal shall reflect the selected analysis principle. It may be discrete or continuous in the frequency domain, with serial or parallel application of the signal relating to each frequency (band). For analysis of systems which have been brought into a volatile quasi-stationary state, parallel (or broadband) excitation may be advantageous, while serial excitation is inherently better suited for measurement of non linear distortions and temporal variations. In order to obtain accurate results, it is essential that the measuring signal contains energy throughout the frequency range of interest. When a repetitive signal is being used, the delay between repetitions needs to be longer than the total decay time of the system under test (object under test + environment) in order to avoid time domain aliasing (= frequency domain under-sampling). When used in combination with a separate conditioning signal, the duration and/or level of the measuring signal itself needs to be low enough in order not to interfere with the adaptation of the object under test.

NOTE 1: Use of pseudo-random signals for the analysis of non-linear objects may lead to severe measurement errors, as the distortion products cannot be distinguished from the linear response.

NOTE 2: Use of ordinary or simulated speech samples for excitation may give problems with the signal to noise ratio in the high end of the frequency range.

NOTE 3: When activating the object under test by a parallel sequence, care has to be taken that the measuring signal does not influence the behaviour of the test object. The behaviour of the object should only depend on the conditioning (activation) signal, which normally requires the amplitude of the measuring signal to be small compared to the amplitude of the conditioning signal.

4.3.6 Validation

Whenever the choice of testing methodology has been based on one or more assumptions about the behaviour of the telephone under test or its environment, a separate test with the ability to disclose a possible deviation from these assumptions shall be included in the test suite.

EXAMPLE: If, due to an assumption of amplitude linearity, the frequency sensitivity responses are performed at the nominal level only, it will be appropriate to include a simple test for variation of gain versus level.

5 Descriptions of terminals considered as systems

This clause gives in general terms a description on how to treat a terminal as a system. By subdividing the system into different parts (inclusive different types of detectors), a model is made in order to describe Signal Processing Methods (SPM) implemented in the terminal. Also a "black-box" approach, making the basis for the descriptions, is discussed. Finally short definitions of specific detector types are listed.

In clause 6 this system description is used as the basis for a model to describe the testing problem and in that way help to devise an appropriate testing method.

5.1 Classification and Coverage of terminals

The present document is concerned with the problems arising when dealing with time variant (non-stationary) and/or non-linear systems. Please refer to table 1 in the following. Time variant systems may be grouped in deterministic systems (i.e. systems with predictable time-varying characteristics), and systems with memory of the past (i.e. the current transmission characteristics depend on the pre-history). As systems with memory adapts to the circumstances they are sometimes also referred to as adaptive systems.

Table 1: Example of SPMs and their most likely Classification

Classification of Telephony Terminals		Time In-variant	Time variant	
			Deterministic	**Memory**
Linear		Traditional Terminals	a, b	f, g, h, i, j, k, l, m, n, o
Non-Linear	**Undesired**	Traditional Terminals		
	Intentional	a, d, e	(a, b)	n, o

a: Frequency Shift
b: Frequency Multiplication
c: Centre Clipping
d: Peak Clipping (soft or hard) Peak limitation 1
e: Recoverable Non-linearity (e.g. instantaneous companders such as A and μ-law)
f: Threshold Amplifier
g: Squelch
h: Compander
i: Compressor Peak limitation 2
j: Automatic Gain Control (AGC)
k: Adaptive Directivity
l: Dynamic Frequency Response Characteristics
m: Signal Activated Gain Control
n: Echo cancellation
o: Noise Cancellation/Reduction

NOTE 1: The SPM's "Frequency shift" and "Frequency multiplication" a) and b) in table 1 do mathematically belong to the group "Linear, Deterministic Time Variant" as the phase of the transfer function is a linear function of time. However, it contradicts the intuitive feeling of time variance, as the frequency shift/multiplication does not vary with time.

NOTE 2: One example of a deterministic system is a frequency shift of the transmitted signal. An example of a system with memory is an AGC (Automatic Gain Control), where the gain in the transmission path depends on the level of the received signal in the recent past.

NOTE 3: Transmission systems where the transmission parameters are user controllable are not considered as non-stationary as they can be put into a well-defined stationary state and measured as such. One example of such a system is a telephone with receive volume control. Neither are "catastrophic" behaviour covered in this document, for example if the telephone suddenly fails to operate.

For both time in-variant and time variant systems non-linearity are usually an undesired side-effect. Often, however, non-linearity are introduced deliberately. It is therefore useful to distinguish between undesired and intentional non-linearity.

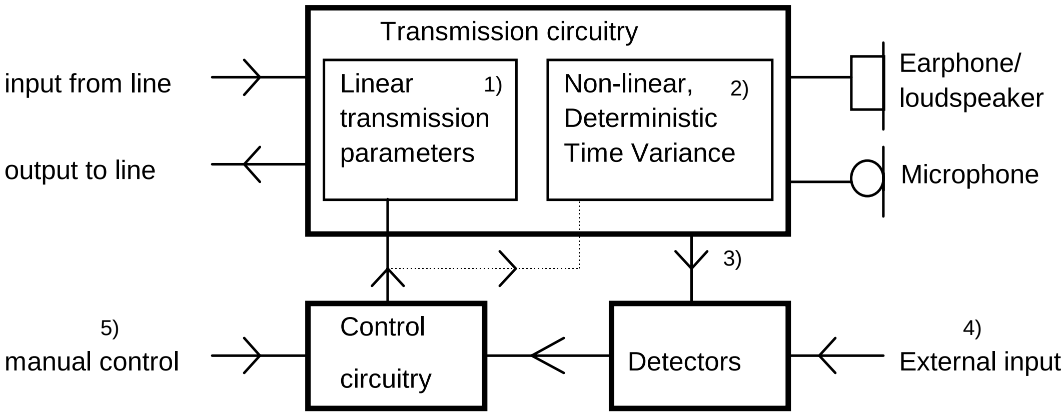
NOTE 4: Examples of undesired non-linearity are the distortion introduced by an amplifier or the low frequency distortion caused by an AGC with a short time constant. Examples of intentional non-linearity are peak clipping and centre clipping.

Time invariant systems are covered by many existing handset standards, at least the linear performance, but also to a large extent the non-linear performance.

5.2 Description of a SPM as a subdivided system

Obviously simple linear and time in-variant telephones also perform signal processing. In this context, however, the signal processing in mind is the often sophisticated and sometimes digital signal processing essentially implemented in time variant and intentional non-linear systems. Despite this ambiguity the words Signal Processing Method (SPM) will still be used to describe the latter group, i.e. the term refers to:

- any signal processing that takes place in the control path;
- only time-varying processing that takes place in the transmission path, i.e.;
- the processing that gives the terminal its non-stationary characteristics;
- any intentional non-linearity in the signal path.



NOTE 1: Normally the Control Circuitry controls only the linear transmission parameters, i.e. usually gain and sometimes also frequency response in both directions.

NOTE 2: The non-linear behaviour (static transfer characteristic) and the deterministic time varying transmission properties are usually independent of the transmitted signals. One could, however, imagine sophisticated SPM's where that is not the case.

NOTE 3: The detector may monitor the transmitted signals anywhere in the signal paths.

NOTE 4: The external input is input that does not relate directly to the desired transmitted signals, e.g. input from a dedicated microphone for monitoring background noise.

NOTE 5: Telephones are often equipped with manual controls such as a receive volume control. Such controls often complicates the test procedures and the amount of testing. In this context, however, any manual controls are assumed to be left unchanged during a single measurement.

Figure 1: Illustration of a telephone terminal with SPM (numbers on the figure refer to notes above)

The classification of Telephony Terminals in the previous clause was based on theoretical considerations. In the following an operational description (from a measurement viewpoint) of a telephone terminal with an SPM is given. In figure 1 the deterministic time variance is grouped with the non-linear part, the reason being that usually none of these are signal dependent. It should be stated clearly that non-linearity in this context refers only to the static transfer characteristics, and not to e.g. a non-linear regulation characteristic in an AGC. In subclause 5.4 the most common detector types are described, while control circuitry are described in clause 6 and annex A where individual SPMs are described.

It is the intention that based on this model and knowing the type of detector(s) and control mechanism(s) implemented in the terminal, it should be possible, combined with information about test methods and signals ITU-T Recommendation P.501 [2], to device suitable test procedures for various contemporary SPMs.

5.3 Black-box approach or use of prior knowledge

Ideally the IUT (Implementation Under Test) should be considered as a black-box. From a test view-point, however, it is convenient to use any prior knowledge about the IUT. For instance, which detection algorithms are used, and which transmission parameters are controlled (see figure 1).

If no or limited prior knowledge of the IUT is available, e.g. from the supplier or manufacturer, it is desirable to devise methods to detect which Signal Processing Methods (SPMs) are implemented.

NOTE: For instance a frequency shift can be detected by feeding a single frequency through the transmission path and analysing the output. If the output frequency is different, the type of shift (linear or logarithmic) may be detected by feeding another frequency through the system.

5.4 Detector Types

In this subclause contemporary types of detectors are listed. The various types may be grouped both according to the (intended) detected properties and the detection algorithm. The distinction is not quite clear, as the detector types may be combined with filtering of various kind. For example a primitive speech detector may be made by combining a level detector with a band-pass filter that filters out the speech-band around 400 Hz. Often the detection is done by highly non-linear signal processing followed by a low-pass filter.

5.4.1 Level Detection

Linear Rectifier

The Signal is rectified and low-pass filtered. Usually a simple 1st order filter is used, but higher order filters may be used for fast and ripple-free detection. The inverse of the cut-off frequency determines the time constant. The filtered signal may be followed by a log conversion to express the level in dB. The relation between this level, and the RMS level depends on the signal shape.

RMS Detector

The signal is squared and low-pass filtered. Otherwise as for the linear rectifier.

Peak Detector

Signal peaks are used to detect the presence of a signal. Time constants and thresholds are depending on the application.

Spectral Detection

Detection is made by characteristics found in the frequency domain. Parameters extracted depend on the application.

5.4.2 Speech Detection

Amplitude modulation

Fast level detection followed by further analysis. The post analysis may take several forms.

Spectral comparison

Spectral analysis followed by a comparison with a typical speech spectrum. The parameters extracted to detect speech depend on the application. Typically the characteristics of speech like distribution of harmonics, envelope etc are used.

Formant detection

Spectral envelope comparison.

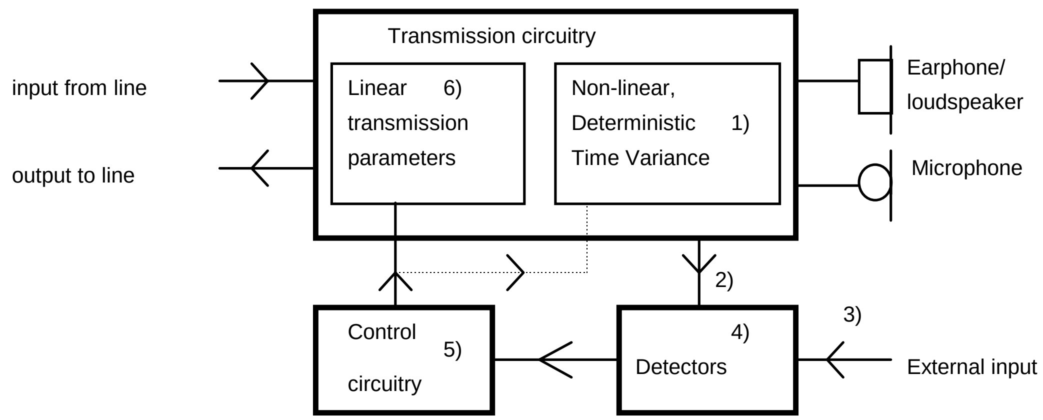
5.4.3 Response Detection

Used for instance in echo cancellers to detect the impulse response of the echo.

Cross-correlation techniques using the transmitted signals. Other techniques using dedicated test signals.

6 Generic Signal Processing Method

The generic SPM described here is based on the model presented in subclause 5.2. Figure 2 below is essentially identical to figure 1, however, with new and more operational notes, with respect to specify appropriate test procedures. The idea behind figure 2 and the commented template is to serve as a check list when describing specific SPMs and appropriate objective test methods.



NOTE: Delete elements that are not relevant for the SPM in question

NOTE 1: Specify the type of Deterministic Time Variance and/or the type of non-linearity and where it is positioned in the signal path.
NOTE 2: Indicate which signals that are monitored.
NOTE 3: Specify the external input which parameters are monitored and where.
NOTE 4: Specify the type(s) of detector(s).
NOTE 5: Give the functional relationship between the detector output and the controlled parameters.
NOTE 6: Indicate the controlled parameters.

Figure 2: Schematic description of generic SPM (numbers on the figure refers to notes above)

6.1 Commented template

The following commented template or generic SPM has been used for the descriptions in the examples in annex A, and as can be seen the SPM have been grouped in three types. The purpose is manifold:

- a uniform description of SPMs is obtained;
- the template and model serves as an internal working tool;
- the template serves a guideline when developing test methods for specific SPMs not covered by the examples.

Table 2: Template

Definition	Short definition of the SPM
Purpose (benefits)	The reason for implementing the method in the telephone, i.e. what are the benefits.
Side-effects (drawbacks)	A description of the expected type of degradation of the transmission quality. This may lead to additional tests (see “influence on test” below) Information on how to minimize the degradation should also be given.
Description	In addition to the definition above a detailed description should be given stating which signals are monitored, which properties are detected, which transmission parameters are controlled, and how (what are the functional relationship between the detected and controlled parameters including the time constants involved). To extend the understanding, figures should be included showing signal paths and processing, steady state input/output characteristics, time behaviour, etc. (i.e., a dedicated schematic description based on figure 2 could be included). If possible, relationships should be given in specific mathematical terms.
Influence on tests	With reference to an existing standard, if any relevant exists, the following 4 items should be used as a check-list when evaluating the influence on test: • Additional measurement parameters including requirements and test methods; • The type of tests on which the SPM will have an influence, stating whether **requirements and/or test methods** have to be changed. Both change in test signals and/or analysis methods should be stated. (Which tests that are not relevant if any); • Supplier Statements; preferably for the selection of testing methodology in the form of a detailed testing specification. In the absence of detailed testing specification, a description of the implemented SPM should be given, including detector mechanisms time constants etc; • In the case of insufficient information from the supplier it will be desirable to devise how to validate the existence of the SPM, and determine critical parameters that are important for the selection of test methods. NOTE 1: For example, in order to select adequate excitation signals for the measurement of frequency responses it may be necessary to measure attack and release times of certain types of AGC's. NOTE 2: It can however not be expected to reach the above level of details for all SPMs.
Recommended Test Method	Description of the most obvious/simple test methods for the test cases not covered by the standard referred to above. NOTE 3: In the future it would be helpful make the description in the form of an ATS (Abstract Test Suite).

Annex A (informative): Examples of SPM descriptions

In this annex detailed descriptions of the following SPMs are given:

- frequency Multiplication;
- centre Clipping;
- automatic Gain Control (AGC).

A.1 Frequency Multiplication

Definition	The input frequencies are multiplied by a constant factor, resulting in a logarithmic frequency shift of the output.
Purpose (benefits)	To avoid howling when the open loop gain exceeds 1.
Side-effects (drawbacks)	A subjectively experienced change in pitch. Wow and Flutter or mirror frequencies around half the sampling frequency (depending on the implementation – see below). The recognition may suffer.
Description	Linear/Deterministic Time Variant signal processing. The log frequency shift may be both up or down, and implemented by an analogue tape recorder with a rotating tape head, or by analogue or digital sampling and re-sampling.
Influence on Tests	If coherent and/or selective measurement techniques are employed, the coherence has to be re-established by multiplying the generator frequency by the same factor as in the SPM, and/or shifting the analysis filter by the same amount, or widening the filter to encompass the shift. The presence of the SPM may be detected by applying a single frequency to the input and measuring the output frequency - if the frequencies are the same, the SPM is not present. If not, another frequency has to be applied and the output frequency measured again, in order to establish the type of shift (linear or logarithmic).
Recommended Test Method	Pure sine excitation. The output is either measured broad-band, or suitable measures should be taken as mentioned above to ensure coherence. If frequency response is measured, it has to be clearly be stated whether the response refers to the input or output frequency. If loudness ratings are being calculated preference should be given to the output frequencies as the LR algorithms are designed to operate on the received spectrum. Furthermore, the frequency multiplication factor or the logarithmic shift in octaves or decades (with sign) should be given.

A.2 Centre Clipping

Definition	Zero gain in the static transfer characteristic in a region near the zero crossing. At higher levels the output is a linear function of the input.
Purpose (benefits)	To reduce gain at low input levels, e.g. to reduce low level noise.
Side-effects (drawbacks)	Increased low level distortion (cross-over distortion). This type of distortion is particularly annoying to the human ear as it, contrary to the distortion created by the human ear itself, increases as the level decreases. For symmetrical transfer characteristics the distortion will be purely odd-order; again a type of distortion foreign to the human ear. The on-set of the distortion may be softened by introducing a smooth transition from the linear region to the region of zero gain. With increasing asymmetry of the transfer characteristic the even order distortion will also increase, partly masking the odd-order distortion to the human ear, which in itself has an asymmetrical transfer characteristic.
Description	Non-linear (intentional)/Time In-variant signal processing. The SPM operates on the instantaneous signal level, and may be described by its static transfer characteristic. The key parameter is the threshold level above which the differential gain approaches a constant (non-zero), and below which it approaches zero. The transition may be abrupt (hard clipping) or gradual (soft clipping). The SPM may be positioned in the transmit and/or receive path.
Influence on Tests	Care has to be taken that the range of excitation levels encompasses the transition region around the threshold level, so as to determine the gain variation as function of input level. Distortion measurements around the threshold level also become essential, and even and odd order distortion should be measured separately in order to establish the degree of asymmetry. By nature the distortion is frequency independent. To test the presence of the SPM, however, the distortion should also be measured at low frequencies. If the level test indicates reduced gain at low input levels, and the odd-order distortion is essential level independent and increases uniformly towards low frequencies (6 dB/octave), then the SPM is more likely of the Threshold Amplifier type involving a detector with a fast time constant (see subclause 5.3.1).
Recommended Test Method	Pure sine excitation. The level dependence may be measured by measuring the gain at 1 kHz as function of input level. The input level should range from nominal preferably to near or below an audible level. As low level measurements are likely to be disturbed by background noise, selective measurements are to be preferred. The 2nd and 3rd order harmonic distortion should also be measured selectively at 1 kHz in the same level range. In order to detect the presence of the SPM the 3rd order harmonic distortion should be measured from 100 Hz to 1 kHz at nominal level.

NOTE: Frequency dependent variations can be integrated into the Centre Clipping.

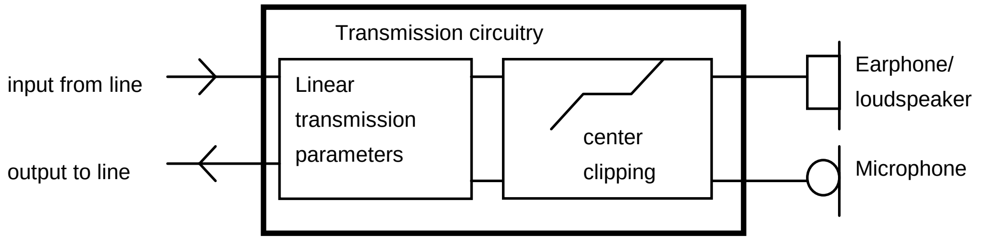


Figure A.1: Centre Clipping - hard or soft

A.3 Automatic Gain Control (AGC)

Definition

Gain control that keeps a constant output level within a certain range of input levels.

Purpose (benefits)

To achieve an output level which is optimized regarding a subjective opinion or optimized regarding the needs when input to other equipment.

Side-effects (drawbacks)

Increased noise in speech pauses. This effect may be reduced by increasing the release time Tr, and/or reducing the maximum gain.
Bursts at start. May be reduced by decreasing attack time Ta and detector time constant Td, and/or decreasing the maximum gain.
Pumping effects on speech. May be reduced by increasing the attack and release times (Ta, Tr) and detector time constant Td, and/or decreasing the range of gain adjustment.
Unwanted level limitation. May be reduced by increasing the attack time Ta and detector time constant Td.
Increased low frequency distortion as Td approaches one period of the signal frequency. May be reduced by increasing the detector time constant Td.
As can be seen from the above, reducing the side-effects is a delicate balance of choosing proper values for Td, Ta, Tr, and the range of gain adjust, yet maintaining the purpose of the SPM. In general the time constants involved should be chosen so that Td < Ta < Tr and the range of gain adjustment should not be higher than necessary in order to encompass normal ranges of transmitted signal levels.

Description

Linear (with undesired non-linearity's)/Time Variant with Memory. The signal may be monitored at either:

- the input. In this case the gain is adjusted, within chosen limits of gain or signal level, inversely proportional to the detected level so as to keep a constant output level;

- the output. In this case the gain is adjusted differentially, within chosen limits of gain or signal level, with the amount that the desired level differs from the detected.

In both cases a level detector is involved. The detector may be of a simple type (linear rectifier or RMS), or more sophisticated such as speech detector types. The key parameter of the detector is its time constant Td.
The control characteristic is essentially characterized by its stationary input/output characteristic in terms of gain or output level versus input level, the key parameters being maximum and minimum gain (or range of input levels). Furthermore the dynamic behaviour of the control circuitry is characterized by an attack time Ta (the time it takes to reduce the gain by a certain amount), and a release time Tr (the time it takes to increase the gain by a certain amount).
The AGC may be placed in both the receive path and/or the transmit path.

Influence on Tests

For types of detectors not sensitive to variations in crest factor and frequency response most types of excitation signals are suitable for measuring transfer characteristic and time constants.
The static transfer characteristic should be measured using excitation signals extending well above and below nominal levels.
The detector time constant can most likely not be determined directly without interfering with the IUT. The side-effects can, however, be determined indirectly by measuring odd-order distortion at mid and low frequencies, as the low frequency distortion will increase when the Td approaches one period of the signal frequency.
Ta and Tr can be determined by shifting the input level from a low to a high level and back.
Frequency response with subsequent LR calculation cannot in general be measured with stepped or swept sine excitation as the response, due to the regulation, most likely will come out flat. Instead broadband excitation should be used.
The supplier should state nominal values of Td, Ta, Tr, and regulation characteristics as well as detector type.

Recommended Test Method	Pure sine excitation for determining time constants in case of simple detectors (for other detector types other types of signals may be necessary). The level dependence may be measured by measuring the gain at 1 kHz as function of input level. The input level should range from well above to well below nominal. As low level measurements are likely to be disturbed by background noise, selective measurements are to be preferred. In order to detect the presence of the SPM, and the side-effects of a short Td, the 3rd order harmonic distortion should be measured from 100 Hz to 1 kHz at nominal level. Ta and Tr are determined by shifting a 1 kHz input signal from a low to a high level and back within or encompassing the regulation range. The time constants are determined as the time it takes to reach the steady state gain within a certain limit. The frequency response may be measured using e.g. pseudo-random pink noise excitation, band-limited to 100 Hz to 8 kHz, and subsequent analysis of the output spectrum in 1/3 or 1/12 octaves.

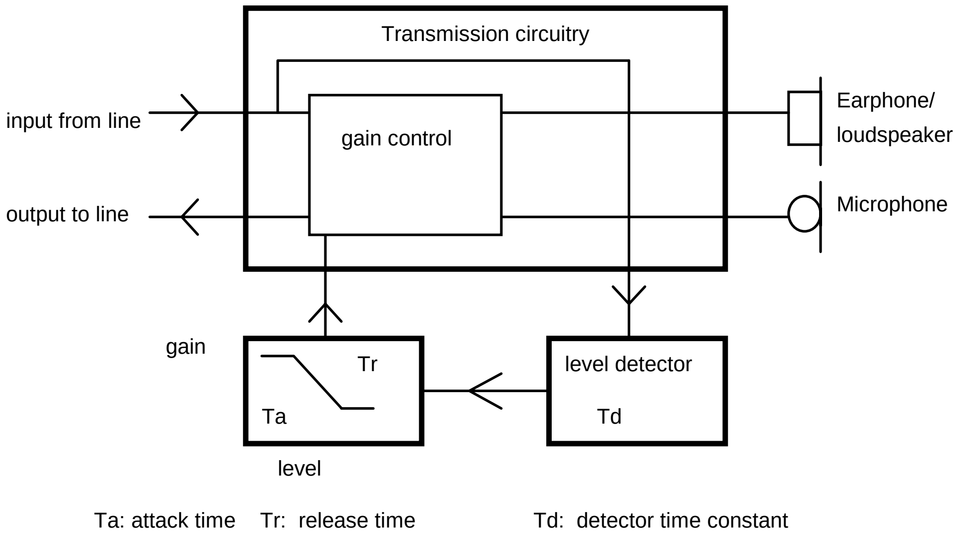


Figure A.2: Automatic Gain Control (AGC)

The example shows a receive AGC that monitors the input. The detector may monitor the output instead, and the AGC may also operate on the transmit path.

History

Document history		
V1.1.1	January 1999	Publication

ISBN 2-7437-2736-5
Dépôt légal : Janvier 1999