BiLAN Audio Tester for Audio Quality Evaluation of Digital Signal Processing Systems

Quick overview:
BiLAN is a universal bidirectional audio tester for functional test and quality evaluation of PCs, embedded systems, electro acoustic components and signal processing software

BiLAN provides programs for simple quality evaluation of wave files up to the quality evaluation of a product at the far end during a real time network connection. Bidirectional standard IP-RTP audio streaming is supported.

Representative statements about quality influencing measures, real time indication of signals and spectra and automatic error tracing support research, development and customer service in getting on with up to ninety percentage less effort compared with conventional methods.

The implementation of the core algorithms of BiLAN concerning diagnostic, quality evaluation and error tracing into audio products for improved product release, maintenance and service might lead to a remarkable high increase of reliability and cost reduction.

Remark: The abbreviation BiLAN means Bidirectional LAN

Sound acoustics research
Waldhäuser 9
D 92549 Stadlern
E-Mail:contact@sound-acoustics.eu

Ingenieurbüro für digitale Signalverarbeitung
Geschäftsführer: Michael Walker
USt-IdNr.: DE230286469
Gerichtsstand Schwandorf

Content:

1. Introduction

Up to now a reliable statement about the quality of an audio product is only possible with very high effort as to time consuming listening tests and preparation of measurement techniques for objective quality measures. Real-time observation of the signal, its transfer characteristics and quality evaluations are not possible in most cases. Hence simulations are recorded and “offline” examined.

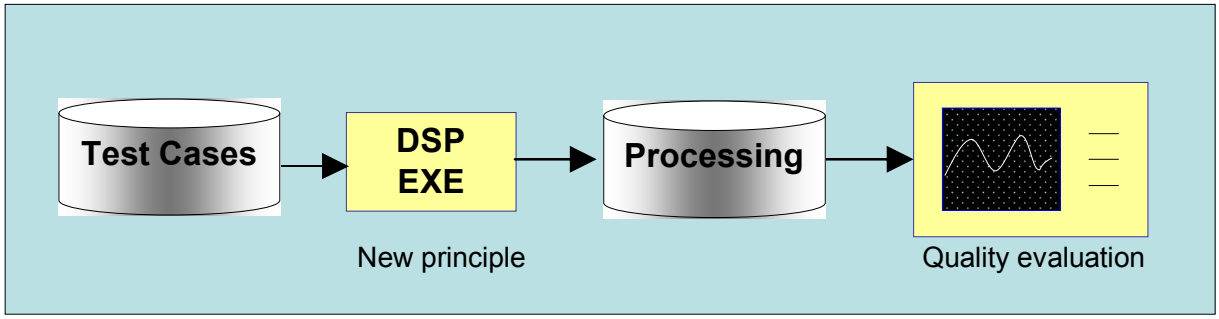

Fig1: Quality evaluation of processed test cases

A frequently applied procedure for the examination of the quality enhancement with a new signal processing principle is based on quality comparison acc. to Fig1.
A researcher compares actual test cases with processed test cases by subjective listening tests and examines quality influencing measures with the aid of audio editors and standardized objective test principles. However a standardized test principle as e.g. PESQ [2] does not correlate with the perception of the human hearing system [4] and shows unsatisfactory contrary results if the test cases exceed the very limited scope of such principles.

In spite of the high effort for quality evidence, the question about quality remains if the new principle is to be implemented on a hardware platform with limited computational power and low cost consumer components as audio devices, loudspeakers, microphones or headsets.

A real time test must follow the hardware platform of the intended product as it is mandatory to check not only the implemented principles but the quality of the product itself.

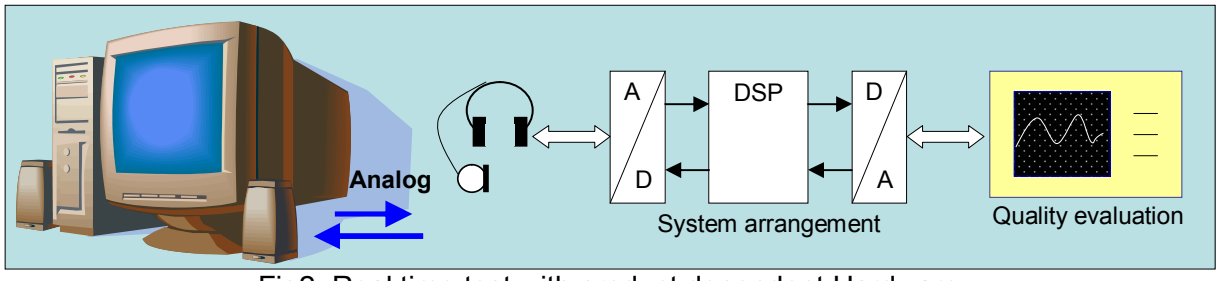

Fig2: Real time test with product dependent Hardware

The real time test acc. to Fig2 is more complex, since the audio devices and the electro acoustic components influence the quality in addition to the software. Usually quality evaluation of systems acc. to Fig2 is carried out with time consuming listening tests, some simulations with recordings and long term tests with individual and expensive hand made examination of recordings and error tracing results.

The effort for quality evaluation is further increasing if a product shall transmit and receive signals over a network [5, 6]. The quantization of Codecs and quality of the network connection showing jitter and packet losses must be taken into account in addition to local hardware and software properties.

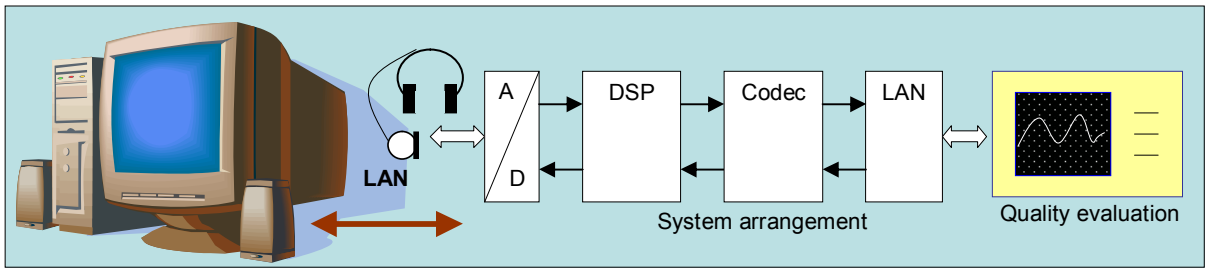

Fig3: Real time test over LAN interface

The audio quality of systems according to Fig3 depends now on the properties of network, local hardware and signal processing software.

Hence engineers are forced to carry out lots of listening tests and must examine many recordings and quality measurements. The quarrel who is responsible for quality impairment between network providers, product engineers and software designers normally leads to time consuming and difficult tests and endless discussions.

2. Requirements

A new measurement and test tool is needed in order to enhance the current situation. The new tool should be able to carry out all tests as discussed in Fig1-Fig3 and must provide the following features:

1. Facilities are needed for interfacing to the unit under test
2. Offline simulation is very useful for quality evaluation of simulated test cases which are frequently used by researchers and development engineers for proof of quality evidence of their new signal processing principle.
3. Real time operation is mandatory for every signal processing product. Recognizing sporadic distortions requires true real time conditions.
4. Objective quality measures with psycho acoustic properties [7, 8] are urgently recommended as the end user is evaluating the product subjectively. New distortion analysis principles are needed in order to adapt to frequency resolution, bandwidth and time resolution for any sampling rate.
5. Use of real time oscilloscopes is most important for signal observation in the time domain for error diagnostics and error tracing.
6. Real time spectrum analyzers are needed for the observation of the transfer function and non linear distortions during operation.
7. Test signal generators and external test case readers are needed for various tests. Special test signals are helpful for quick and efficient quality evaluation showing the quality properties of the test object at a glance.
8. An error tracer is needed for automatic searching for sporadic distortions which appear from time to time. This saves manpower and costs.
9. Documentation support is needed for error tracing and significant statements for measurement reports.

These features are combined in the BiLAN Audio tester as described in the following.

3. BiLAN - A Universal Audio Tester

Overview

BiLAN is a bidirectional audio streamer for functional test and quality evaluation of PCs, embedded systems, electro acoustic components and signal processing software.
It is used for easy and fast hardware and software test of audio devices, LAN interfaces and digital signal processing principles.

BiLAN is suitable for all sampling rates featuring the following functions:

- Interface adaptation
  - Various controllable RTP – protocols [5,6]
  - Audio device selection
- Software parameterization, packet loss concealment and jitter compensation
- Real time and simulation tests
- Various signal generators for different test conditions,
- Real time oscilloscope,
- Spectrum analyzer with indicated frequency distribution which correlates with the perception of the human hearing system.
- Quality measures which reflect subjective perception taking the masking effect and the frequency dependency of the human hearing system into account [8].
- Adaptive distortion analysis,
- Quick manual recording of wave files
- Playback on different interfaces
- Error tracer with new controllable sensitive thresholds, automatic recording and error reporting with time stamps.
- Text and vector graphic output for documentation

These functions and some add-on features are combined in one tool, making functional tests and quality evaluation of various audio systems possible within a few minutes.

Quality evaluation of far end hardware and software is possible with the same measures available as applied for local real time and simulation tests.

The following chapters explain some features in more detail:

Objective QualityMeasures

Subjective listening tests will never be totally replaced by objective quality evaluation but many listening tests can be saved if reliable objective quality measures are available. Objective quality measures are not only needed for significant statements but also for reliable adaptive quality test principles.

In consideration of typical product quality problems, which are introduced by hardware and software impairments, the following general quality influencing measures are provided by BiLAN:

- *Signal to Noise Ratio.
- *Distortion factor
- *Transfer function
- *Signal level
- *Level deviation
- **Jitter

*Signal quality influencing measures are computed in frequency and time domain according to psycho acoustic rules [7, 8] in order to receive hearing adequate objective quality measures. Hearing adequate means a high correlation between subjective perception and objective measures.
The averaging process is continuously adapted to the selected time window of indicated diagrams for optimal time resolution. .
The spectrum analyzer uses the same algorithms for averaging the spectral absolute magnitude. Hence the frequency representation is smoothed dependent on the selected time axis providing best possible approximation to the perception of the human hearing system.

**The statistics of voice packet transfer can be indicated in the status bar of BiLAN if a product applies signal streaming over IP (e.g. VOIP). Jitter is indicated if signal packets are not received in isochronous time intervals because of variable delays which are observed at multiple points in a network.

Listening Test Simulation

Objective quality evaluation of speech and distorted speech as proposed in [2] is too specific and can only be an optional extension for a general measurement and test tool.
Due to the different sampling rates and individual quality requirements of various applications, a hearing adequate listening test simulator as described in [3] with controllable threshold of acceptance should be preferred if such an optional extension is desired.

BiLAN can be extended with an objective listening test simulator on request.

Product Dependent Quality Properties

The requirements for a narrowband radio set differ strongly from wide band applications in time and frequency resolution. Telecommunication systems use different Codecs with more or less quantization errors.

Hence, adaptation to product dependent quality criterions must be considered. For instance G.711 introduces non linear distortions which are equally distributed in the frequency domain leading to a distortion factor to which the threshold "Max. distortion" (fig4) can be adapted.

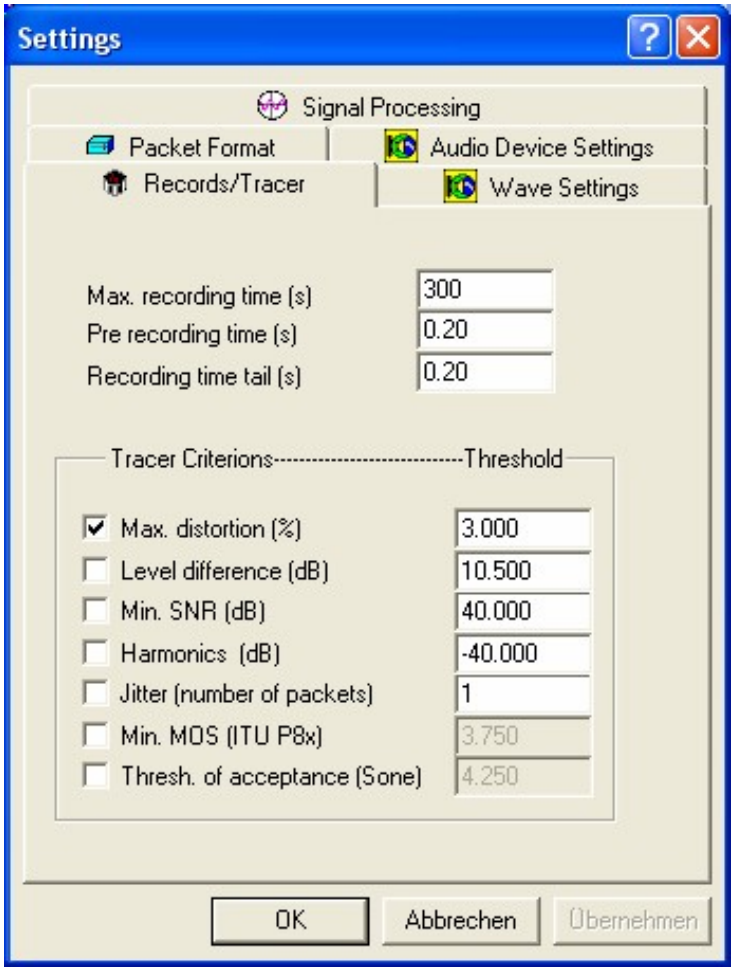

Fig4: Product dependent thresholds of quality

BiLAN provides product dependent adaptation of different thresholds, which determine the maximum accepted degradation.

Thresholds are available for each quality measure as e.g. minimum SNR, maximum distortion or the maximum level deviation.

For network operation, the threshold of the maximum number of consecutive packets (jitter) can be determined.

With the determination of these thresholds, a red flag for unacceptable quality degradation indication in the status bar is activated (fig6).

Test Signals

A distortion analysis needs sinusoidal wave form for the determination of the relationship between harmonics and the whole spectral composition.
Determination of the signal to noise ratio is only possible using signal bursts as known from natural speech which includes speech pauses, too.
White noise and pulses are used for the determination of the transfer function of a system. Test signals can also be a composition of different scenarios in order to cover e.g. the worst and best case conditions of an application.

BiLAN provides for this reason various synthetic test signals, the ability to apply recordings with individual test cases and to apply the analog input as input signal for the excitation of the test object to be examined.

Special test signals as e.g. the butterfly impulse or butterfly sine wave are provided for fast quality tests covering all necessary excitations for the determination of SNR, distortion factor and level within few seconds of real time operation.

Real Time Tests

BiLAN supports real time tests for all system configurations (Fig1-Fig3) at every sampling rate. Every available audio device can be selected. The following real time operating modes are available:

- Wave file test: Standard conformant wave files are replayed in a loop. The continuous repetition of a selected wave file facilitates real time and long term evaluation with external test cases.
- Audio device test is used for the evaluation of the PC- hardware including electro acoustic components like loudspeakers, microphones and analog interfaces. The analog input signal or alternatively the microphone signal is evaluated.
- Connection tests use the network for audio streaming with the standardized IP protocol with RTP header [5, 6]. The quality evaluation of the far end hardware and software including electro acoustic components like loudspeakers, microphones and analog interfaces is possible. The received signal is evaluated. Additionally parameters like packet loss and jitter can be indicated and evaluated.

Quality Evaluation over Network

The following real time tests were carried out over the network (2 PCs bidirectional connected over LAN interface). Far end diagnostic in real time is possible during a running network connection with the aid of new self adaptive distortion analysis and special test signals.

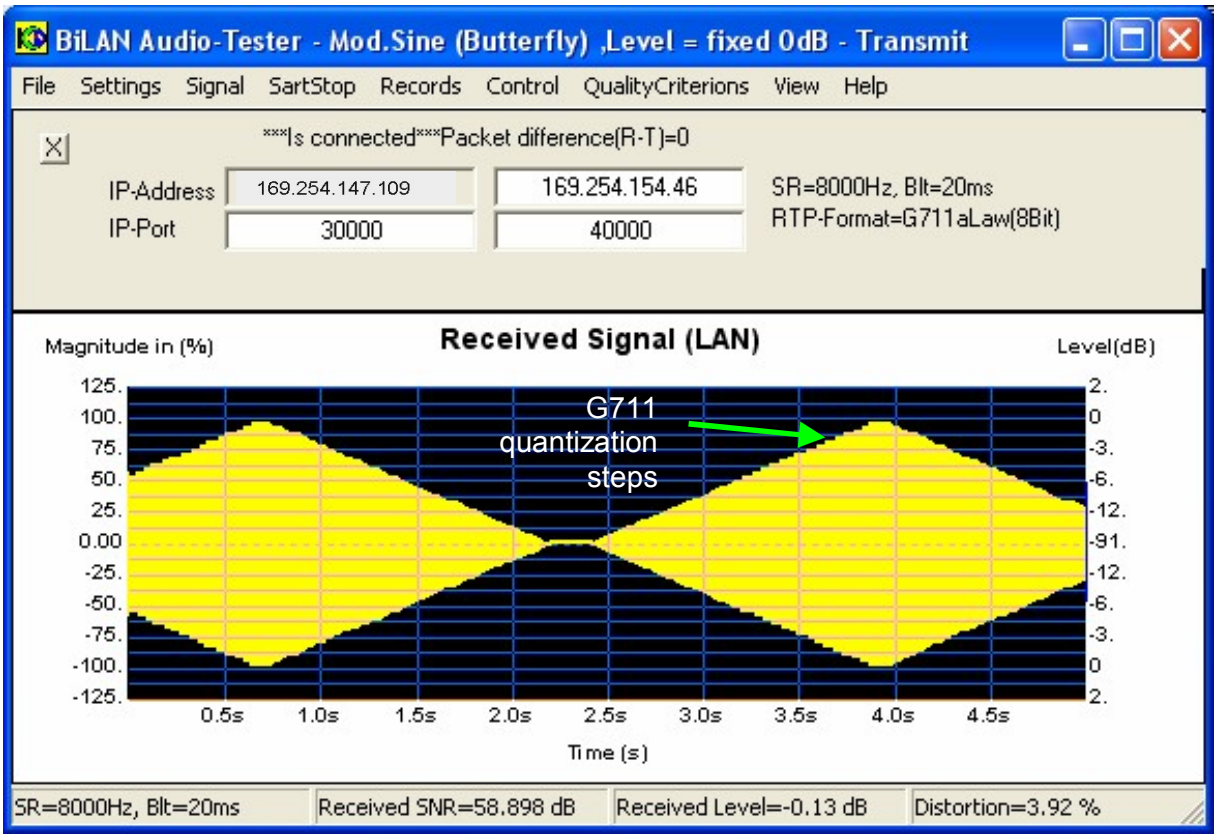

Fig5: Quality evaluation over network.

The “Butterfly Test” in Fig5 shows the signal distortions, the signal to noise ratio and the gain or attenuation introduced by the far end partner’s terminal after a few seconds measurement time. The quantization of the G.711 Codec is also visible in this diagram.

The indicated quality criteria in the status bar can be selected according to the desired test procedure as shown in the following figures.

Fig 6 shows what we hear in time domain. Quality degradation of signals is indicated by the status bar, which turns to red color, if quality impairment exceeds the product dependent threshold.

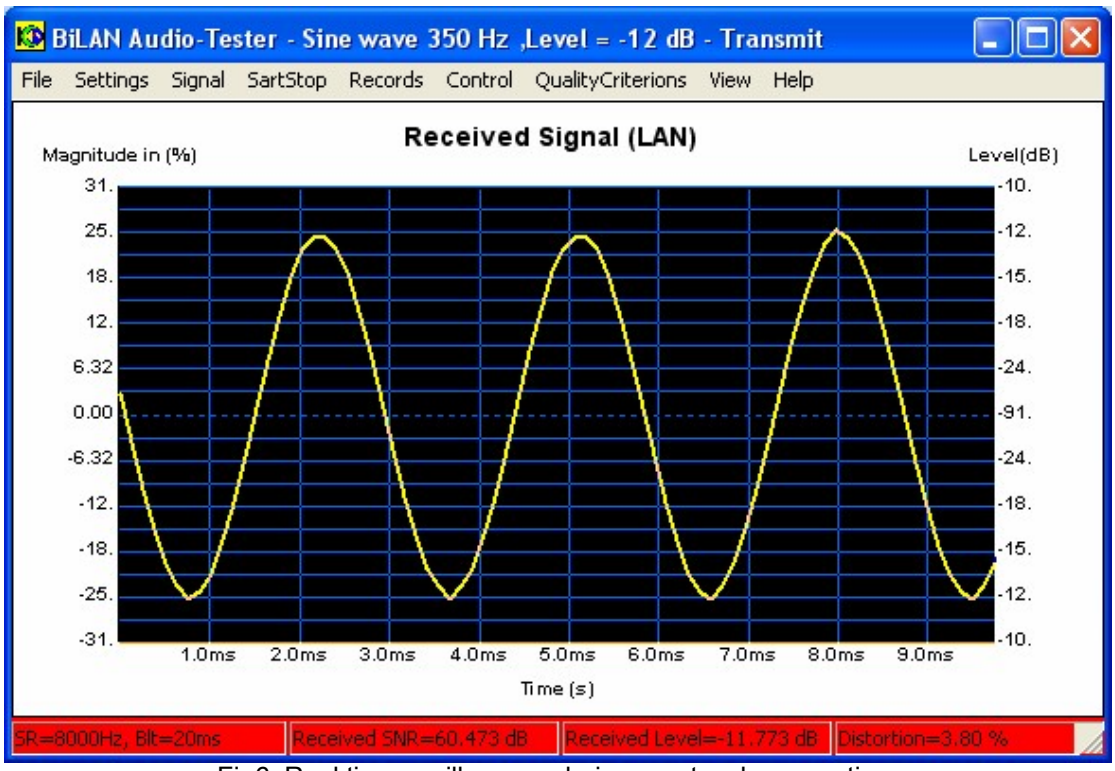

Fig6: Real time oscilloscope during a network connection.

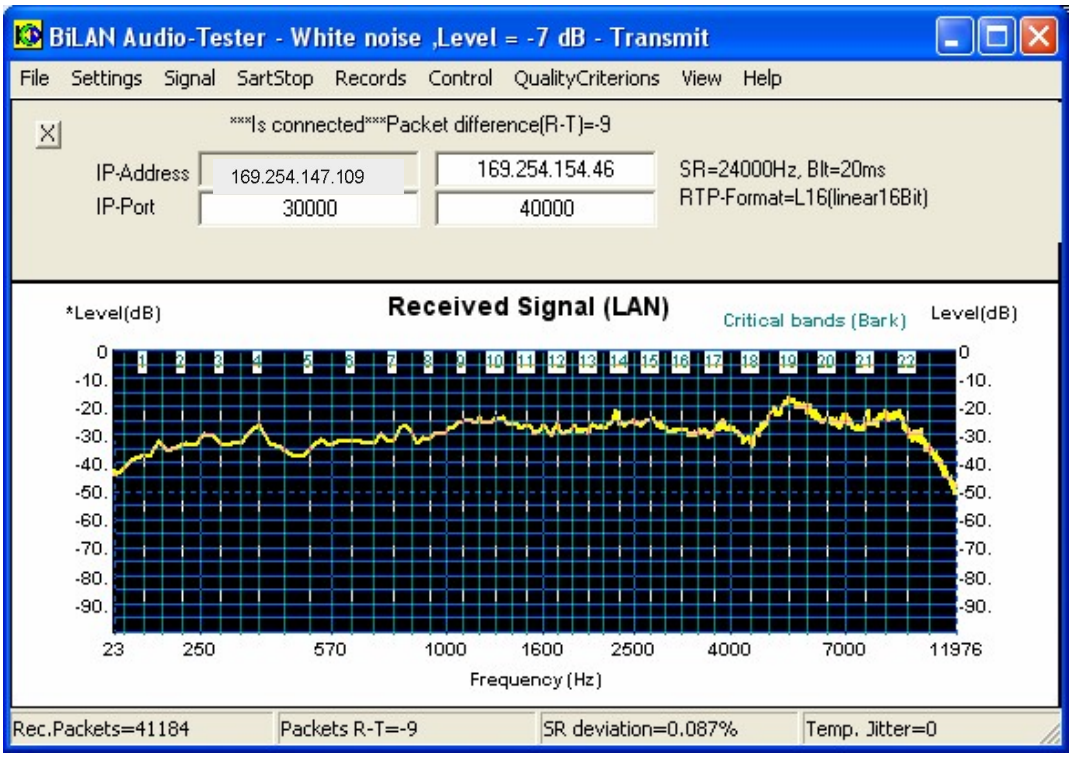

Fig7: Evaluation of the electro acoustic transfer functions at far end terminal.

Fig7 shows the received spectrum with hearing adequate frequency distribution. The status bar informs about sampling rate deviation between receiver and transmitter and other network properties.

Error Tracer

One of the most expensive tasks is the search for sporadic distortions, which can only be detected during a long term stability test. Typical problems can appear if software parameters diverge or if the software exceeds the maximum available computational power.
Sporadic distortions occur from time to time and might be only faint but audible.

BiLAN replaces time consuming error tracing by only a view minutes for some presets. The implemented error tracer is equipped with new measurement principles providing sensitive thresholds for the start and stop conditions of automatic recordings.
The upper limit of the recording time and the time before and after the error occurred can be determined in order to catch the error in a perfect time window.

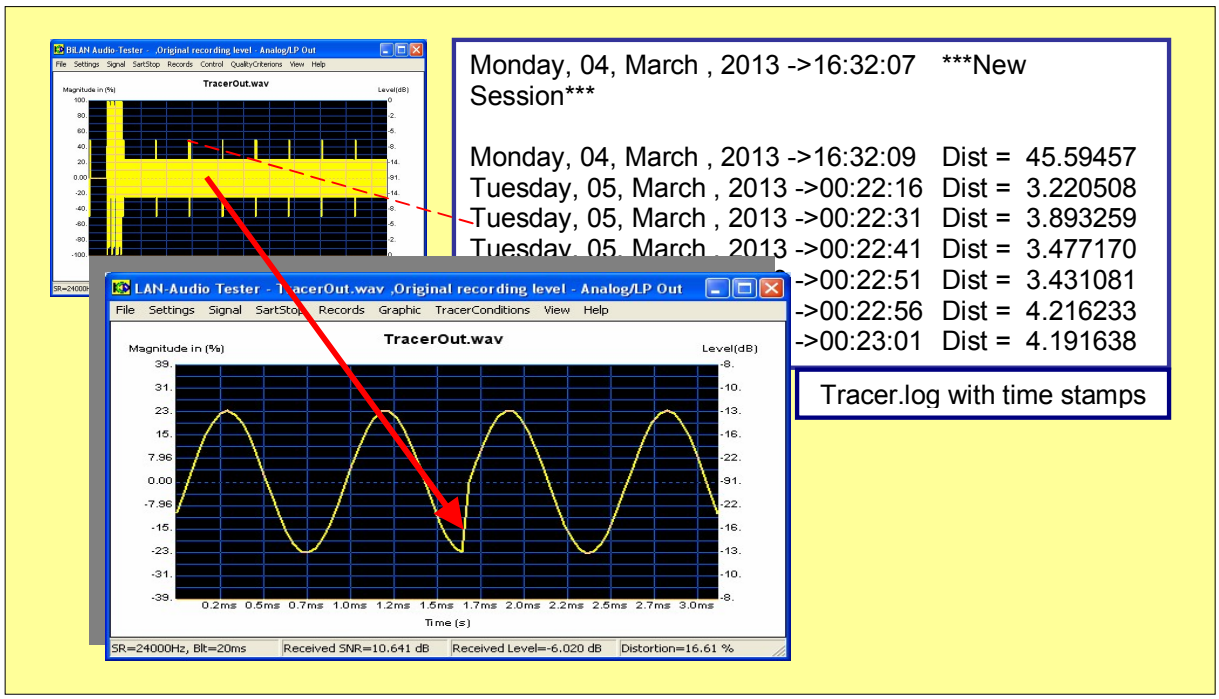

Fig8: Automatic recording of sporadic faint distortions

The error tracer carries out automatic recording of wave files and reports about detected distortions with corresponding time stamps fig8. Synthetic bursts indicate the occurrence of a new degradation.

The evaluation of the error tracer's recording is supported by mouse controlled zooming and keyboard controlled time shifting. Fig8 demonstrates a faint audible distortion caused by a phase error which was introduced after several hours of error free operation.

Quality Evaluation of Processed Test Cases

Research and development frequently start with simulations. Test cases before and after signal processing with a desired principle are compared and evaluated.

BiLAN provides test results directly after opening a recorded test case.
The examination of details within a recording is supported by adaptive time resolution of the implemented level estimators.

A new distortion analysis facilitates evaluation of unknown sinusoidal wave forms.

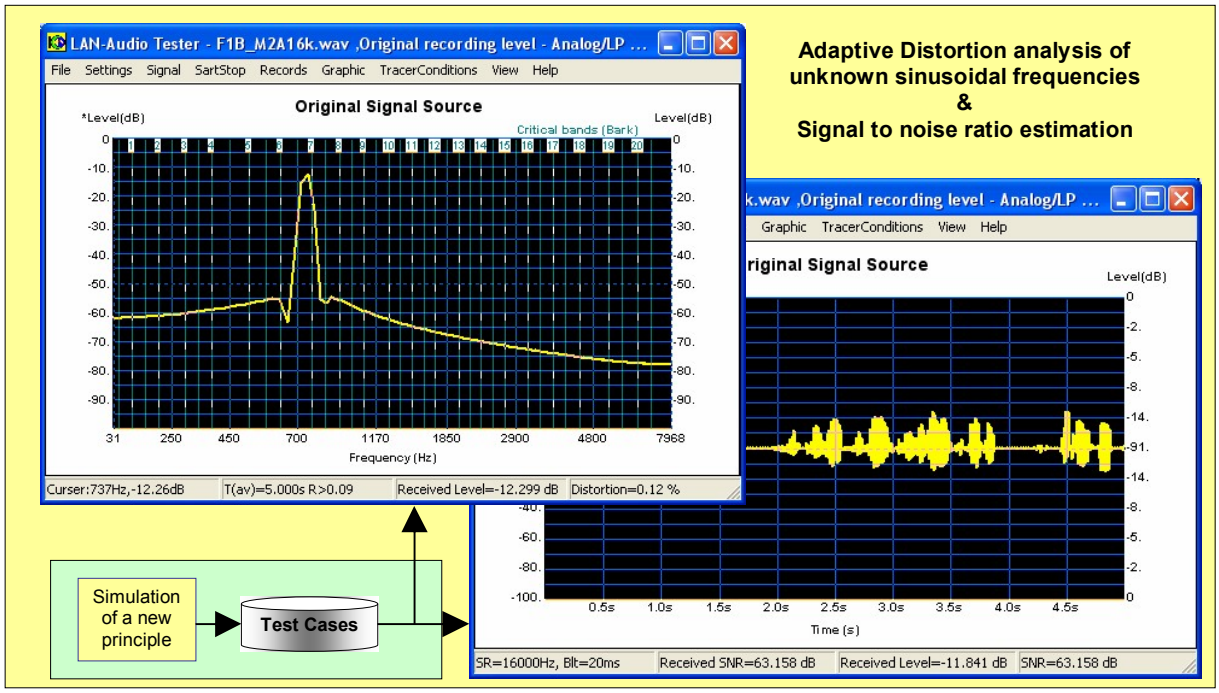

Fig9: Quality evaluation of recorded and processed test cases. Quality measures like signal to noise ratio, distortion factor and transfer function are immediately available.

Documentation

Diagrams and measurement results can be saved as enhanced metafiles. Enhanced metafiles are using vector graphics and hence the size of a diagram in a report doesn't matter concerning possible data loss by size reduction. Each Windows operating system supports this format. The conversion to other desired formats is possible with the aid of all Windows Office packages.

BiLAN provides protocols and graphics for measurement report and documentation as follows:

- Measurement reports about errors found created automatically by the error tracer,
- Recorded wave files are used for creating vector graphics (fig10) in frequency and time domain.
- During real time operation every diagram can be saved as vector graphic.

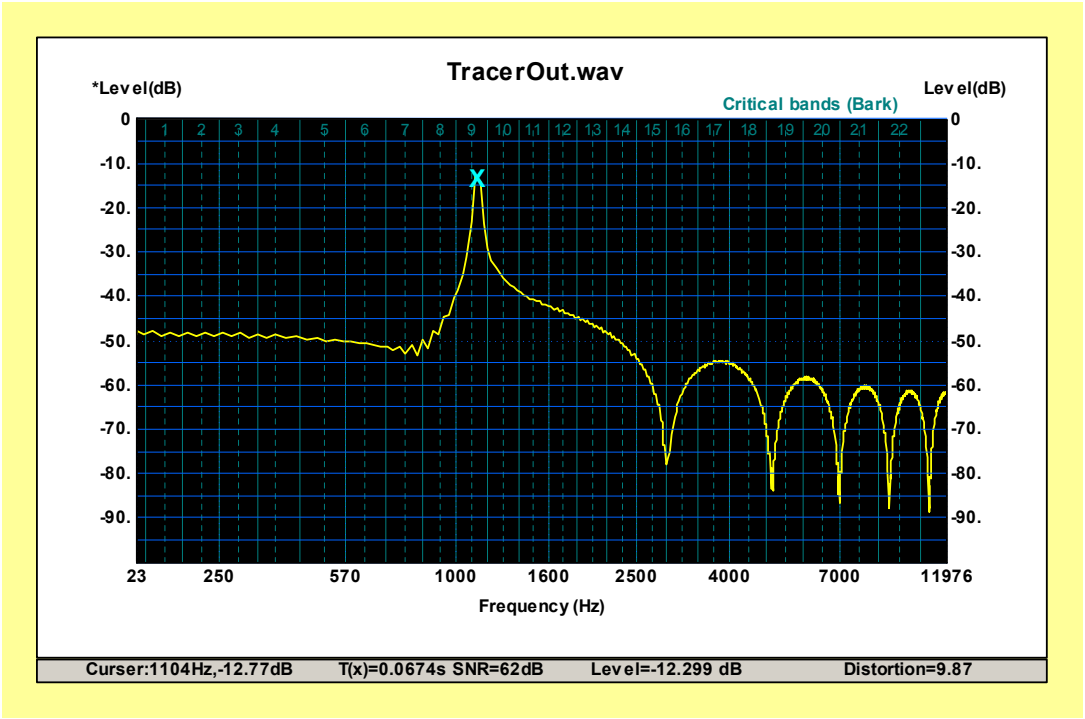

Fig10: Diagrams and test results for measurement reports

Measurement results are indicated in the gray bar at the bottom of each diagram.

4. Outlook and Optional Extensions:

BiLAN is designed for all 32 Bit Windows operating systems (XP, Vista and W7) and can be made available for any other operating system on request. It can be seen as an independent robust and reliable test tool for the evaluation of audio systems as described in this report.

This test tool is ready for new extensions with e.g. an objective listening test simulator, adaptive fine tuning or other desired automatic procedures and can be adapted to other formats like different RTP packet - , wave - or graphic formats if desired.

Sound acoustics offers consulting and development of optional extensions against cost sharing.

Quality evaluation over the network might become a very important feature which can be further improved with a control port for automatic analysis and test procedures over the network.

The implementation of the core algorithms of BiLAN concerning diagnostic, quality evaluation and error tracing into audio products for improved product release, maintenance and service might lead to an up to now remarkable high increase of reliability and cost reduction.

Fixed product dependent tolerance margins like SNR, distortion factor or level deviations are easy to control with BiLAN. Complex tolerance margins like e.g. three dB bandwidth of a transfer function or the maximum accepted frequency dependent attenuation can be visualized.
A further step towards automatic product evaluation and product release can be achieved with a few extensions for the computation of the complex margins.
However a more comprehensive statement about quality is that of the human who evaluates quality subjectively according to his perception and taste. Objective test principles which try to simulate subjective listening tests [2, 4] need reference and test cases for the computation of MOS measures.
A real great challenge is the development of a new unidirectional listening test simulator which might be a combination of BiLAN's core algorithms, particular new test cases and the examination of signal compositions with new code books – a pending research topic which is currently being developed at Sound acoustics.

5. Conclusion

The BiLAN Audio tester replaces the effort for up to now manually carried out tasks by automatic procedures and reduces the effort for test-preparations drastically. Interface adaptations, archiving of listening tests and preparation of documents for measurement reports are supported.

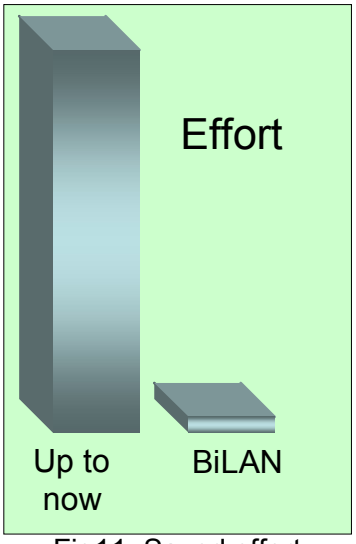

Fig11: Saved effort

The estimation of the saved effort in Fig11 is based on the required effort for quality evidence in various former developments. More than 90% effort for quality evaluation, long term stability tests and error tracing can be saved with BiLAN.

The general quality measures with BiLAN facilitate easy comparison between new software principles and the whole system arrangement of a product.

Subjective listening tests according to [1] with hundreds of test persons and various test cases show a standard deviation of 0.68 on the 5 point MOS scale [4]. In most cases only a few listening tests and test cases which can be carried out in a company are too little for deriving reliable MOS statistics. Under these circumstances the reliability for the estimated quality amounts less than 35%. Uncertainties during manually carried out error tracing impair this estimation in addition which can be reduced with the BiLAN error tracer.

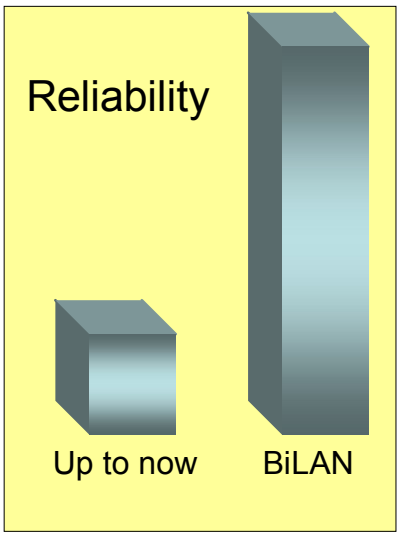

Fig12. Enhanced reliability

Both, enhanced reliability and saved effort aid in bringing the product to market without headache, time consuming tests and difficult discussions.

BiLAN is suitable for a wide range of use:

- Universal usage
  - Research
  - Development
  - Customer service
  - Receiving Hardware and SW-Release
- Products
  - PC- Hardware and Software
  - Embedded Systems
  - Signal-Processing systems
  - Telecommunication systems
- Cost and time saving > 90%
- Enhanced reliability 100% versus subjective tests
- Easy adaptation to individual requirements

6. Acknowledgements

The frame work of this new development tool was supported by discussions with project partners who pointed to up to now unsolved tasks. We would like to thank all partners for their contributions but especially

Dipl. Ing. Reinhard Mehner – THALES Deutschland for his valuable hints and suggestion making the realization of this tool possible.

7. Literature

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