Digital TV signal evaluation for functional tests

Rogério Caetano, Eddie B. de Lima Filho and Carmina Porto.

Abstract— **Verification process in digital television (DTV) production often includes a tuning and decoding check, which ensure that assembled devices are capable to reproduce audio and video. Poor test signals conditions, however, may cause device rejection, leading to losses of time and money for the manufacturer. This work proposes a real time DTV test signal monitoring and evaluation that assess signal conditions during tuning tests aiming to report if the associated check must be rerun. Tests, in a real manufacturing environment, showed that the proposed methodology is effective and revealed that only less than 40% of the rejected devices presented nonconformances.**

Keywords— **Digital television, signal testing, verification process, real time monitoring.**

I. Introduction

Production lines are organized structures used for assembling commercial products. While a partially complete product moves through workstations (WSs), components are continuously added, until a final assembly is obtained and packed. In addition, as production processes are not flawless, verification/testing steps are often needed, which are in charge of detecting defective or nonconforming devices, working as an insurance policy against losses and fines.

As widely known, production processes must be as accurate as possible, in order to provide a small rejection ratio, which then reduces resources spent in problem correction or even financial losses, due to product return. In addition, a correct analysis depends on correct parameters and measures; otherwise, conforming products may be rejected (false positive) and also defective devices may be approved (false negative).

In production lines developed for digital TV (DTV) set-top boxes (STBs) and integrated receivers [1], a tuning and decoding step is almost mandatory. The main purpose of this step is to check if the most important feature of those devices is working properly: channel presentation.

Indeed, that is only possible if the input DTV signal (e.g., terrestrial or satellite) can be acquired and decoded. For instance, the input signal level and the carrier-to-noise ratio (C/N) must be higher than the tuner's sensitivity and minimum expected quality, respectively; however, the latter depends on parameters such as code rate and modulation type, which must be configured according to what is expected to be tested or transmitted to the target device.

In DTV production lines, devices may be rejected due to poor signal conditions, which often happens when the employed transmission infrastructure (e.g., air or cable) is somehow compromised. Regarding that, one may argue that such consideration is overestimated; however, given that common production lines are hostile environments, due to temperature, machine operation, and interference from other devices, such a verification becomes a necessary procedure, in order to ensure a suitable operation.

However, despite video signals interference problems observed in all companies that manufacture decoders, televisions, receivers and set-top boxes may have an impact on company productivity there is a lack of research around this phenomena. Companies do not normally have indicators that points out the impact of such interference on their productivity, and these problems are often confused with other efficiency problems.

The discussion presented in the last paragraphs is the inspiration for this article, which proposes a simple signal verification methodology. In summary, the transmitted DTV signal is monitored and goes through a classification procedure, according to standardized parameters and previously collected data. Then, if a product is rejected during poor signal condition, an automatic evaluation system reports that and triggers a retest. In this way, the obtained result may be confirmed or not, but now with acceptable signal quality.

II. DTV Signal Reception Parameters

During the presentation of DTV signals, the most direct indication of transmission or reception problems is the presence of artifacts, which appear in the decoded video [1]. Such elements instantly reveal difficulties regarding the reception of transport stream packets [2], [3] with no error indication, due to the performance of error-correcting codes [1], [2]. Current DTV standards, such as the digital video broadcasting (DVB) [4], the integrated services digital broadcasting (ISDB) [5], and the advanced television systems committee [6] normally employ a concatenated error-correction strategy, which relies on two different encoders: an inner encoder, which is often based on convolutional codes, and an outer one, which normally relies on BCH codes (e.g., Reed-Solomon).

That approach is able to provide quasi-error-free (QEF) reception after the Reed-Solomon decoder, when the bit error ratio (BER) after the convolutional one (viterbi algorithm) is below 2×10^{-4} (two errors in 10, 000 bits) [4]. In addition, the error visibility threshold is considered to be 3×10^{6} after the Reed-Solomon decoder [7]. It is worth noticing that such a performance is directly related to the signal input level (sensitivity) and C/N values.

Based on what was explained, it is possible to infer about signal conditions by directly measuring BER values, after the inner and outer decoders, or radio frequency (RF) parameters, at system input (tuner). BER measurement could be done through the device itself, but that has the potential to mask other problems, such as circuit nonlinearities and bad RF coupling.

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A reference system could also perform that task, but, if not carefully chosen, it could also suffer from other issues. As a consequence, the measurement of RF input parameters, through certified equipment, presents itself as an interesting choice and is suitable for use in production line environments, as long as correctly configured.

III. Methodology

Considering what was discussed in sections I and II, when functional tuning tests are performed, a complementary signal evaluation is necessary in order to indicate if the verification processes must be rerun. Indeed, that happens when poor signal conditions are detected, which may easily occur in manufacturing environments.

The methodology presented in this work consists of continuously monitoring the signals used in the set-top-boxes test process and evaluate its quality. This evaluation is based on test signal classification regarding the measurement of two RF parameters: level and C/N. Such attributes are obtained and used as input to a classifier that indicates the signal quality in order to warn about a possible verification error due to signal failure. The proposed algorithm can be described by four simple steps (Figure 1):

- System initialization and calibration;
- Acquisition of level and C/N parameters;
- Signal Calssification;
- Indication of signal status.

Fig. 1. Proposed method

During the development of this work, video signals samples were acquired in order to create a robust database. We sought to catalog pure signal samples (without interference), and samples with different types of interference, both at the target frequency to meet the company's needs. A great amount of tests was performed, in order to raise curves regarding signal level and C/N.

The obtained parameters, along with standardized values, for all handled transmission standards and configuration sets, were then used for classifying signal quality. Before performing an analysis, it is only necessary do indicate the current setup, i.e., which standard and configuration is being used (e.g., DVB-T, ISDB-T, 64-QAM, etc.).

It is worth noticing that such a classification must be done according to standardized figures and previously measured data, as implicit in the third step. Regarding that matter, one may notice that some standards already suggest such values, according to the chosen configuration parameters. For instance, when measuring the sensitivity of a receiver compliant with the Brazilian digital television system (SBTVD), which uses the terrestrial ISDB as air interface, for a 64-QAM modulation and 3/4 code rate, QEF reception can be obtained if a minimum C/N of 19 dB is provided at system input [8].

Nonetheless, that is an approximation and different receivers may require C/N figures as high as 19:5 dB [11]. Regarding DVB systems, the same configurations would require a minimum simulated C/N of 18:2 dB (see table A.1 of ETSI EN 300 744), for Gaussian channels [4]. Finally, such results are also affected by the current environment. All the parameters configurated in this projected were defined respecting both the brazilians laws and standards and the company needs.

The proposed methodology has the potential to be easily integrated into any tuning verification procedure, in order to provide signal quality indications. Besides, given that all steps can be performed automatically, there is no need for additional human interaction, which may result in budget saving. Actually, consequences of test automation are not restricted to execution speed and reliability, but also include the reduction of human operators.

IV. Tests in a Real Production Line

The industrial pole of Manaus, in Brazil, has many industries specialized in producing DTV equipment and, among them, Technicolor Brazil was selected for integrating the proposed methodology, into the verification procedure of one of its STB production lines.

That company estimated that fails related to poor signal condition represent a loss of at least 1% and, in Table I, one can see statistics regarding annual rejection ratios for three of its products.

TABLE I

Failure rates detected in test lines related to the transmitted signal in the most-produced models

Model	Anual Production (units)	Rejection Ratio (%)
Product A	1365953	1,19
Product B	1105919	5,25
Product C	893984	1,51

The chosen production line was used for assembling SBTVD set-top boxes [8]. During the project implementation, the poor signal condition problem was identified and handled, as described in section III. Figure 2 shows the employed system setup.

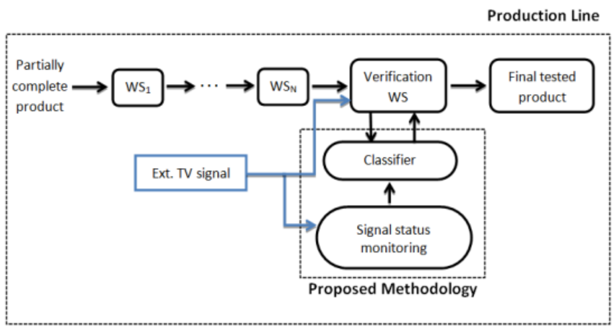

Fig. 2. System setup for real tests

In the mentioned production line, devices are manually tested by human operators, who tune a specific channel and formerly decide if the audio and video content is correct. With the introduction of the proposed methodology, this decision is up to the classifier.

To enable the implementation of this methodology in the factory, we have created a friendly interface where the test responsable can easily set up the parameters related to the monitored signal just by indicating which device is being tested and which standard configuration must be used.

With the aim to continuously analyse the video signal, a supervisory system composed of a web application that allows managing and controlling the results of real-time video signal tests of several verification WS in the production line has been developed.

The test stations were arranged in a tree configuration in which the root represents the place from which the signals are distributed, and the branches are located in the production line, totaling 7 monitoring points. In this way, the maintenance team can take quick action when the region affected by the interference is identified.

When devices arrive at the verification WS, the mentioned tuning test is performed and the monitoring module then decides if the input signal can be decoded. Based on the responses from the production line's verification procedure and the monitoring module, a classifier then judges if the tuning verification must be rerun or was correctly performed.

In addition, if the signal status remains unsuitable for a long time (many adjacent devices are reject), a warning signal is issued, indicating that the external test signal must be checked. In summary, a signal condition evaluation is integrated into the tuning verification and indicates if a test must be repeated, but now under suitable signal condition.

It is worth noticing that the proposed methodology was implemented through a spectrum analyzer PXIe-1073, produced by National Instruments, which was used as acquisition front-end. The acquired RF parameters were then read with a monitoring system developed in Labview, which also includes the classification algorithm.

V. Results

Among the results achieved during the implementation of this project, we highlight: automation of the detection of physical interference in the video signal used in the tests of the Technicolor decoders, continuous monitoring of video signals allowing a fast identification of the regions (test stations) that are being affected by interferences and therefore a reduction in the search time of the points of origin of the interferences.

With the mentioned system up and running, the rejection ratio was measured and, consequently, it was verified that less than 40% of the non-conforming devices, due to signal decoding problems, actually presented a problem (hardware or software). Table 2 shows a comparison between the percentage of failure rates due to inappropriate test signals estimated by the company before and after the use of the system.

In order to evaluate the performance of the presented solution, a statistical analysis (test t) of the products weekly rejection rate averages of the products was performed, leading to a $p < 0{,}05$ which indicates that our solution really has an influence in the device verification process. As a consequence, a considerable financial saving was noticed by the company, which made the mentioned production line more efficient and cost effective.

TABLE II

Comparison of failure rates detected in test lines related to the transmitted signal in the most-produced models before and after the use of the system

Model	Annual Rejection	
	Before	After
Product A	1,19%	0,47%
Product B	5,25%	2,09%
Product C	1,51%	0,6%

VI. Conclusions

The main innovative feature of this project is a test of an in-vivo controlled scientific experiment to investigate, develop and evaluate an innovative solution for automatic detection of physical interference arising from connection problems such as: partially or totally broken cables, deffective connectors and amplifiers installed at different points in the cables that may interfere the video testing of Technicolor products leading them to classify conforming products as non-compliant.

The proposed methodology provides an additional check during set-top boxes tunings tests in order to verify if the signal used for the tests meets the standars, thus, avoiding false negative results during product quality evaluation. Tests, in a real manufacturing environment, showed that this scheme is effective, when verifying signal conditions during signal decoding tests, and revealed that less than 40% of the obtained rejections were indeed due to nonconforming devices.

VII. Further work

As future work, state-of-the-art classifiers will be employed, in order to improve robustness and extendibility, through the use of other signal parameters to compose the features vector. The feasibility of creating learning rules that identify the origin of the failure, which can assist the maintenance team to shorten time taken to fix the problem, will be evaluated.

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