Quality Verification of Digital TV Signals in Production Line Environment

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***Abstract*—Production lines normally present a verification step, which is responsible for warning about defective devices, which should not be released for commercial use. That step, in digital television (DTV) production lines, often includes a tuning and decoding check, which basically verifies if DTV devices are capable of presenting audio and video. However, poor signal conditions may cause unnecessary rejections, which happen due to very hostile environments. Because of that, the present paper proposes a verification methodology that reports poor signal conditions during tuning tests, with the goal of reporting that the associated check must be executed again. Tests in a real environment showed that the proposed approach is effective and efficient, while revealed that less than 40% of the obtained rejections were indeed caused by hardware problems.**

I. Introduction

Production lines are commonly responsible for assembling commercial products, according to a predefined execution flow. In summary, components are added while a partially complete product moves through workstations, until a final assembly is obtained. Nonetheless, as the instantiations of a product manufacturing process, they normally provide some verification/testing step, which is in charge of warning about defective or nonconforming devices.

As widely known, production processes must be as accurate as possible, in order to provide a small rejection rate, 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) products [1], such as terrestrial and satellite set-top boxes and integrated DTV receivers, the associated verification procedures often include a tuning and decoding step, which then confirms or not the primary device's purpose. However, a correct result is only obtained if the provided signal can be decoded, *i.e.*, for example, the signal level is above the tuner sensitivity figure and the carrier-to-noise ratio is above the minimum acceptable limit, which depends on code rate, modulation type, etc. In addition, such parameters must also be configured according to what is expected to be tested, in the target device.

A common problem faced in DTV production lines is the device rejection caused by poor signal conditions, which may happen due to the transmission infrastructure (*e.g.*, air or cable) and not hardware or software problems. At a first glance, that may seem overestimated; however, given that production lines are normally hostile environments, due to temperature, machine operation, and interference from other devices, such a verification becomes necessary.

The problems discussed in the last paragraphs are the inspiration for the present work, which proposes a simple verification methodology regarding product rejection, during tuning tests. In summary, the transmitted DTV signal is monitored, analyzed, according to standardized parameters and previously collected data, and, as a result, an automatic evaluation system warns when a product is rejected during poor signal conditions. As a consequence, the most obvious approach is to retest the related device, in order to confirm the obtained result or at least provide stable signal conditions.

II. Digital TV Signal Quality Parameters

When a DTV signal is received and decoded, the most direct indication of reception problems is the presence of artifacts in the decoded video [1]. Those artifacts, in turn, are linked to the impossibility of acquisition of transport stream packets [2], [3] without errors, due to the performance of error-correcting codes [1], [2]. Traditional DTV standards, such as Digital Video Broadcasting [4], Integrated Services Digital Broadcasting (ISDB) [5], and Advanced Television Systems Committee [6] normally employ a concatenated strategy, based on two encoders: an inner encoder, which is often based on convolutional codes, and an outer encoder, which normally relies on BCH codes, such as Reed-Solomon.

The mentioned strategy is able to provide quasi-error-free (QEF) reception after the Reed-Solomon decoder, when the bit error ratio (BER) after the convolutional decoder (viterbi algorithm) is below 2×10^{-4} [4]. In addition, error visibility is considered to happen for BER values above 3×10^{-6} [7], after the Reed-Solomon decoder. It is worth noticing that such a performance is directly related to the signal input level (sensitivity) and carrier-to-noise ratio (C/N).

In summary, one may infer about signal conditions by directly measuring BER values, after the inner and outer decoders, or radio frequency (RF) parameters, at system input. BER measurement could be done through the device itself, but that has the potential to mask other problems. A reference system could also perform that task, but, if not carefully chosen, it may 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.

III. The Proposed Methodology

Given what was discussed in sections I and II, a complementary signal evaluation is necessary, during tuning tests, in order to indicate the repetition of verification processes, when poor signal conditions are detected.

The proposed methodology is based on the measurement of two RF parameters, computed with the input signal: level and C/N. In summary, such parameters are obtained and used in a classification procedure, in order to warn about a possible verification error due to signal conditions. The following steps describe the final algorithm:

- System initialization and calibration;
- Acquisition of level and C/N;
- Classification according previous measurement data;
- Indication of signal conditions.

It is worth noticing that such a classification must be done according to standardized figures and previously measured data. Regarding that matter, one may notice that the standards themselves already suggest such values, according to the chosen configuration parameters. For instance, it is often assumed that when measuring the sensitivity of a receiver compliant with the Brazilian Digital Television System (BDTS), 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].

As a consequence, during the development of the present work, a great amount of tests was performed, in order to raise curves regarding signal level and C/N. The latter, along with standardized values, for all handled transmission standards and configuration parameters, were then used for signal quality classification. Before performing analysis, it is only necessary do indicate the current setup, *i.e.*, which standard and configuration is being used.

The proposed methodology can be easily integrated into any tuning verification procedure, in order to provide signal quality indications, as long as suitable equipment is employed. Besides, given that all steps can be performed automatically, there is no need for additional human interaction, which may result in financial savings.

IV. Tests in a Real Environment

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 production lines. That company estimated that fails related to poor signal conditions represent a loss of at least 1% and, in table I, one can see the statistics regarding annual rejection rates for three of its products.

TABLE I
ANNUAL REJECTION RATES FOR THREE PRODUCTS OF TECHNICOLOR BRAZIL.

Model	Production in units	Rejection rate (%)
Product A	1365953	1.19
Product B	1105919	5.25
Product C	893984	1.51

The chosen production line was used for assembling set-top boxes, according to BDTS [8]. The problem mentioned in section I, regarding verification failure due to signal conditions, was identified and handled, as described in section III. Figure 1 shows the employed system setup.

Fig. 1. System setup for real tests.

As one may notice, the tuning verification has an integrated signal condition evaluation (the proposed approach) and, if poor condition is detected, the proposed methodology indicates that another test must be performed.

It is worth noticing that the proposed methodology was implemented through the 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.

With the mentioned system up and running, the rejection rate was measured and it was verified that less than 40% of the non-conforming devices, due to signal decoding problems, actually presented a defect. As a result, a considerable financial saving was noticed, which made the mentioned production line more efficient and cost effective.

V. Conclusion

This paper proposes a methodology for monitoring DTV products rejected due to signal decoding problems, in order to verify if there really is a hardware/software problem or a poor signal condition caused the non-conformity. Test results, in a real environment, showed that the proposed methodology is efficient and effective, when verifying signal conditions during signal decoding tests, and revealed that less than 40% of the observed rejections were really due to non-conforming devices. As future work, state-of-the-art classifiers will be employed, in order to make the proposed methodology more robust and easily extendable, through the adoption of other signal parameters (characteristics).

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