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A Survey on Picture Quality Degradation in Cable Television Links

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ABSTRACT: Video signals in communication links undergo various types of distortion. The most important among them is the cross and intermodulation distortion generated by the non-linearity of the transistors employed in the voltage and power amplifiers of the repeaters used in the links. In this paper an attempt is made to estimate the image quality degradation per link based on the transistor parameters.

KEYWORDS: Cable Television; Image degradation; Transistor; inter-modulation; IoT.

I. INTRODUCTION

A typical TV signal is characterized by a set of standard test signals. Out of these, the most important one is the signal generated by an image that results in a display of uniform brightness on the screen. The secondary test pictures are the bar patterns. The bright screen would generate a unit step function signal at the output of the camera. Test bar charts would give rise to square wave. Since the advent of television technology, test signals have not changed. However it is not possible to obtain a closed form output for a unit step input for a nonlinear system. Earlier this problemsurfaced in telephony, since a speech signal can be considered as a sum of sinusoids. The computation of the output of an amplifier fed with a speech signal poses a similar problem even though a step function is not involved. Volterra series was used to solve this problem [1].However we have to find a solution for television signals.

II. RELATED WORK

The first attempt to study the frequency dependent nonlinearities of a transistor was made in 1967 [1].This led to closed form expression for second and third order distortion coefficients in terms of transistor parameters. Subsequently, the results for cascaded configurations were reported [2]. The results highlighted the modulation performance of hybrid cascade configurations. The next paper [3] brought out the results on cross modulation performance of transistor amplifiers. The next work focused on the integral charge control model [4]. The merit of the charge control model (ICM) lies in the inclusion of high level effects.Hence ICM is a more accurate model to study the effects of nonlinearity. Later, the expressions for second and third order distortion coefficients for real and complex source and load impedance of a transistor amplifier, based on ICM and Volterra series, were published [5]. In this work, theauthors considered f_T nonlinearity, exponential nonlinearity and current gain(β) nonlinearity. The second and third order Volterra kernels of the common emitteramplifier found in this paper bring out certain physical aspects of this model. For example, the second order kernel can be represented by a cascade of a linear system, memoryless squarer and a linear system. The third order kernel can be represented by two parts. The first part consists of twoblocks. The first block represents a cascade of a linear system, a memoryless cuberand a linear system. The second block corresponds to a linear system followed by two parallel sections. One section consists of a memoryless squarer and a linear system. The other section is an identity system. The outputs of these sections are multiplied and are passed through a linear system. Another paper presented kernels of a different kind [3].

III. SIGNAL DISTORTION IN A LINK

In the case of cable television links, the signal passes through a series of amplifiers from the head end to the receiver of the subscriber. Hence the nonlinearity of the amplifier degrades the signal progressively. As a result the

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signal to noise ratio degrades. This leadsto the degradation of picture quality. When we consider a single link, the output voltage can be calculated by a computer simulation, based on perturbation technique. Here the nonlinearity can be modelled by power series expansion around the operating point. A typical computer simulation resulted in 0.87 % degradation per stage [6]. Hence for a long television link the degradation will be significant.

In the case of digital TV links, the repeater regenerates the information bits and the degradation depends on the bit error rate. In general the situation is much better in the digital domain.

IV. PROPOSED DISTORTION ESTIMATION SCHEME

Since a cable TV link includes many components in cascade, one should look at the overall distortion caused by all these components. Hence we need to express the signal degradation as a function of multiple variables. Hence we have

$$D = f(x_1, x_2, \ldots\ldots\ldots\ldots x_n) \qquad (1)$$

where, D represents the distortion and x_n represents the distortion generated in the n^{th} repeater.

Since it is difficult to obtain a formula for computing the distortion, one should look into other solutions. By carrying out extensive field trials one can get the distortion values with corresponding variation of other parameters. This was done earlier, in the 80's, in Europe. However, such experimental schemes did not throw much light on the distortion caused. The components and subsystems selection should be done in a proper manner. Traditionally two approaches were followed. The first one is to employ ultra linear transistors. The second approach is to include distortion correction circuits. Both approaches have been implemented in the past. Prior to the internet revolution we had a real problem of comparing the performance of cascaded subsystems. Presently we have advanced network technology that can be employed with IoT interface.

When setting up new cable television links, the IoT based measurement modules can be built into the subsystems and networked. In such a scenario, we can get the data in time and space on a continuous basis. An analysis of this data should give us more insight into the interdependence of various parameters of the amplifier. This should also lead us to the more realistic estimation of the picture quality degradation over a long link. The measured data can include temperature and other physical variables.

V. CONCLUSIONS AND SCOPE FOR FURTHER WORK

The fundamental problem of representing a TV picture as a signal suitable for computing the closed form expression in a nonlinear signal processing environment still remains. For a single stage TV amplifier, picture degradation is small. In the digital domain the picture quality degradation can be related to bit error rate and other measurable parameters. However the analog cable TV signal links still exist.

This work can be extended by active researchers along many fronts. Research workers keen to generate fundamental work can develop models for accurate computation of the output that appears in a nonlinear system that is fed with a unit step function or a modulated TV signal. Others can attempt to resolve the problem through IoT based approach leading to empirical results. More adventurous research workers can study the implications of this paper in a mixed signal hardware environment.

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BIOGRAPHY

M. S.Narayanan earned his B. E. degree in Electronics and Communication Engineering with university rank from National Institute of Engineering (Mysore University) in 1975. He got his M.Tech degree from IIT Bombay in 1977. He has 40 years of professional experience equally spanned between the academia and the industry. Presently he is a PG professor in the ECE department at Rajalakshmi Engineering College. His research interests include Image Processing, Data Compression, Information Theory, Rural Development, E-Governance, Transportation Systems and Energy efficient portable devices. He is a senior member of IEEE (USA), professional member of ACM (USA) and a life member of ISTE (India).