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**AUTOMATED NONLINEAR DISTORTION MEASUREMENT
IN NTSC RECEIVERS**

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Gary Lynn Ragsdale

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DEDICATION

I dedicate this work to my creator and to my family. To God and Jesus Christ, I offer praise for giving me life and for giving my life direction. To my wife, Joyce, and my daughters, Holly and Shannon, I give my deepest affection for filling my life with the richness of love.

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I take pride in my association with the University of Tennessee, its faculty, and its administration. I gratefully acknowledge the contributions of my fellow design team members: Sameer Shah, Eric Wrushen, Qin Wan, Baishali Raychaudhuri, and Keeratpal Singh.

ABSTRACT

This study develops automated nonlinear distortion measurement methods for NTSC televisions. The distortion measurements are the basis for further television refinements in a highly competitive product environment.

Prior research developed manual methods for compiling distortion measurements and these methods have become standard industrial practice. However, manual measurement methods do not fulfill the need for timely performance information across a large number of competing models. Application of GPIB test equipment, LabVIEW design tools, and Cleanroom development disciplines automates the measurement process in a manner compliant with industrial standards. The automated measurement system and popular competitive analysis tools exchange information using a common data format.

The study demonstrates that the application of automation to performance testing can produce distortion measurements compliant with industrial practice. The quantity and format of the measurements are substantially better than manual measurements permitting more effective analysis of competing models.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

The television market place is a highly competitive forum where customers define value as that pleasing combination of features, performance, and price. The customer's view of value increases in sophistication as new models are introduced. In this war of escalating value, manufacturers must continuously invest in television improvements or risk losing their position in the market place.

Manufacturers must act decisively and with precision in order to acquire and maintain market share. There exist nearly infinite opportunities for product change but not all lead to value enhancement. Excessive investment or wrong investment in product enhancements lead to development cost without corresponding television sales. Conversely, well chosen and timely investment of well-managed design resources yields market expansion in the face of stiff competition. Insightful product improvements are the result of good planning based upon enlightened market information.

Therefore, the compilation of competing product information is an important step in making high value design decisions.

The key to good design investment is regular product analysis based upon accurate, up-to-date performance information for all competing models. Competitive analysis gauges a manufacturer's relative strength within a given class of televisions. Decisions based upon sound analysis assign design resources for the greatest competitive advantage.

Competitive analysis supports the decision process by translating television behavior profiles into qualitative measures of product performance. The performance measures are the basis of objective investment decisions. Compilation of television behavior profiles is an important step in the analysis process.

A behavior profile may consist of sixty or more different television measurements. Industrial standards define metrics, measurement methods, and reporting formats [1]. The standards prescribe methods in a manner suitable for either manual or automated measurement techniques. Taken manually, a given measurement procedure may take from a few minutes to more than an hour to perform. A complete profile may take a skilled technician more than a day to complete. Manual test methods are sufficient to satisfy government regulations requiring performance profiles for

the manufacturer's product line. Competitive analysis takes the measurement process beyond a given manufacturer's product to all competing products.

Ideally, the competitive analysis process relies on a statistically sound compilation of behavior profiles for all competing models. The analysis should respond to immediate demands for information and should provide several perspectives on product competitiveness. Computerized profile compilations provide the greatest analytical benefit.

Each year, the many television manufacturers produce hundreds of new models. Therefore, compiling receiver performance profiles is a formidable task using manual methods. Processing of paper-based measurements further complicates competitive analysis. Fortunately, television performance measurement lends itself to an automated test system.

1.2 Prior Automatic Test System Development

Automated test systems exist in various forms within the television and other receiver industries. The forms address important aspects of product behavior and each system reflects different application goals.

Component test systems provide designers with integrated circuit performance profiles [2]. Automated tests provide greater accuracy and a broader range of performance measurements than previously feasible using manual methods. Component performance profiles lead to better application of integrated circuits within a receiver. However, component test systems do not examine the performance of the receiver incorporating the component. It does not necessarily follow that the receiver design will address the most important competitive challenges.

Automated production test systems replace manual test-point methods during television assembly [3]. Rapid examination of internal signals verifies television operation sufficient for final assembly, accelerates production, and lowers cost. However, production tests disclose nothing about the television's performance relative to other models.

Other radio frequency (RF) receiver manufacturers regularly apply automated test systems in their business activities. The goals and scope of these applications reflect particular industrial needs.

A broad range of automatic test systems operates within the microwave receiver industry [4]. For example, automated microwave test systems measure subassembly response across a wide frequency spectrum by accumulating thousands of

measurements. Like component testing, subassembly tests give insight into subassembly application. The tests do not describe the competitive stance of the composite receiver.

Diagnostic test requirements are similar to those of competitive analysis. Diagnostic test systems examine receiver performance in many different ways [5]. The variety and complexity of the measurements involve many different performance standards and several types of test equipment. Accuracy is essential, especially in military applications. Speed is important where a diagnostic system supports a large number of receivers. Even so, diagnostic tests only examine performance against the receiver design specification and draw no comparisons between a given microwave receiver and its competitors.

Competitive analysis guides strategic product design decisions and, therefore, must provide accurate, insightful investment information. Competitive analysis test systems must rigorously apply an array of equipment and a variety of standard measures across a large model population. An effective system should compile the measurements electronically, thereby supporting automated analysis. Finally, a competitive analysis test system must increase productivity by examining a much larger number of televisions for a given investment of manpower.

1.3 Automatic Test Facility Project Description

During the 1980s, the television industry initiated steps for improved international competitiveness. Better product performance through modern quality improvement techniques became a primary tool in achieving greater market share and lower production cost.

Manufacturers developed corporate quality standards consistent with applicable television measurement practice [1]. Quality standards prescribe methods for measuring performance and provide the means for monitoring performance trends through time. Analysis of the quality measurements provides management with a gauge of relative product strength.

Typically, manufacturers collect television measurements in a dedicated facility consisting of three test rooms. An RF-free Measurement Room provides an area isolated from external RF emissions. An Evaluation Room equipped with appropriate ambient lighting and acoustics creates a setting for observing video and audio quality. Technicians perform internal television measurements using equipment and work benches found in an Exploratory Test Room. In each room, skilled personnel measure television performance manually. As mentioned earlier, a technician may work a day or more to compile a full set of measurements.

Manual processes limit the volume and consistency of the measurement information. Individual technicians must properly attend to the details of test equipment configuration, account for environmental factors such as cable losses, and interpret measurement procedures. Technicians record measurements on paper, further complicating the information analysis process. Therefore, manual processes can not reasonably address a growing demand for competitive product information.

In 1993, the Communications, Information, and Signal Processing Group (CISP), University of Tennessee, Knoxville, began the Automatic Test Facility (ATF) project in cooperation with members of the television and test equipment industry. The Automatic Test Facility project expands upon accepted measurement methods by applying automatic test equipment techniques to the measurement process

The ATF project seeks to improve the consistency and efficiency of the television measurement. ATF project goals are to

- reduce the labor required for a performance profile
- increase the compilation rate of measurement profiles
- improve the accuracy of receiver measurements
- insure compliance with recognized measurement standards

- facilitate automated competitive analysis

The project combines computer-controlled test equipment, signal sources, switching matrices, and programmatic measurement methods to achieve increased measurement productivity. A Sun Sparcstation 10 workstation controls the test equipment and retains measurement records. Careful selection of the record format eases the transfer of receiver measurements to commercial analysis software. ATF software written in the National Instruments LabVIEW language embodies the measurement procedures and is the most complex portion of the project effort.

The ATF project addresses development complexity by adopting the Cleanroom software engineering methodology as described in [6]. Cleanroom methods promote software quality through a rigorous design process and comprehensively define user requirements through iterative development steps. The Cleanroom process boosts development productivity by virtually eliminating design rework.

This research expands upon earlier work in Cleanroom software engineering techniques by adapting the Cleanroom process and box definition methods to the LabVIEW visual programming language. Thus, this thesis explores the benefits of combining Cleanroom development disciplines with intuitive programming techniques.

1.4 Thesis Outline

The thesis consists of six chapters. Chapter 2 gives an introduction to television architecture, nonlinear distortion theory, and television measurement techniques. The chapter outlines the television signal composition and associated television sub-systems. It identifies the sources of nonlinear distortion, proposes mathematical models for predicting its occurrence, and presents accepted methods for observing nonlinear distortion in televisions.

Chapter 3 describes the methods used to create the Nonlinear Distortion Test procedure, Sierra Video Systems router, and Tektronix 2714 spectrum analyzer software. The chapter presents

- the techniques used to define functional requirements, user interfaces, and system design
- the measurement data collection format and retention process
- the Cleanroom techniques employed highlighting adaptations to a visual programming language
- the benefits and limitations of applying Cleanroom disciplines to the ATF project

Chapters 4 and 5 present the test procedure and equipment control design. Chapter 4 delves deeply into the Nonlinear Distortion Test functions, internal information

flow, and control logic. Chapter 5 discusses automated measurement and event processing from the perspective of test instrument control.

Chapter 6 summarizes the research, drawing conclusions about the methods employed and results achieved. It looks beyond the current work sighting opportunities for further automation of television distortion measurement.

CHAPTER 2

NONLINEAR DISTORTION MEASUREMENT THEORY

Color televisions receive a complex set of waveforms conveying a synchronized reproduction of verbal and visual information called a "scene." Ideally, a receiving television translates the information into a high fidelity reproduction. In practice, external impairments or impairments inherent to the television may distort the scene. The Automatic Test Facility measures television behavior during normal operation and in the presence of impairments gauging the reproduction fidelity to the original visual and audio information.

ATF measurement procedures fall in two categories -- optimum operation mode and disturbed operation mode. Optimum mode procedures gauge the fidelity of scene reproduction under nominal conditions. Scene distortions under optimal conditions are directly attributable to internal television malfunction. Disturbed mode procedures measure reproduction fidelity in the face of external impairments. External impairments may be signal attenuation, interference, or improper power supply and may induce distortions pointing to television design

limitations. The ATF applies its battery of test procedures to the television, compiling competitive analysis profiles.

Several ATF procedures focus on television reception under various operating conditions. For example, RF Sensitivity, RF Selectivity, and Nonlinear Distortion tests observe television behavior under sub-optimal conditions, each test from a different perspective. RF Sensitivity and RF Selectivity procedures measure a television's capability to overcome external reception interference (i.e., path losses and neighboring channel interference). RF Sensitivity measurements gauge the recovery of low-level signals reflecting upon the television's internal signal-to-noise ratio and radio frequency amplification. RF Selectivity measures television frequency discrimination in the presence of high-powered, adjacent channel interference. In contrast, the Nonlinear Distortion Test (NDT) measures interference generated within the television.

TV imperfections and the composition of the television signal may interact to produce scene distortion. The Nonlinear Distortion Test detects the internal distortions as another perspective on television performance. An understanding of the TV signal, the television architecture, and the sources of interference gives insight into nonlinear distortion measurement objectives.

2.1 The NTSC Signal

Televisions receive video and audio information in a signal envelope defined by the National Television System Committee (NTSC) and described in [7]. As shown in Figure 2.1, the NTSC envelope contains picture luminance, picture chrominance, display synchronization, and audio information. Prior to modulation, the information exists as separate baseband audio and video signals.

Audio signals are continuous waveforms with frequency range from 50 Hz to 15 KHz [8]. Television transmitters add audio to the envelope using a frequency modulated (FM) carrier. Federal Communications Commission regulation restricts NTSC audio signals to 25 KHz maximum deviation at 100% modulation. According to Carson's rule, the NTSC audio information occupies a bandwidth of approximately 80 KHz within the TV "channel" [9]. The FM carrier places the audio signal at the top of the channel spectrum, 4.5 MHz above the luminance carrier. Visual information requires a far more complex signal.

Video information rides upon an amplitude modulated (AM) carrier, also called the "picture carrier." Luminance modulation conveys gray-scale gradations ranging from black to white. The picture carrier and its luminance sidebands reside within the lower portion of the channel spectrum.

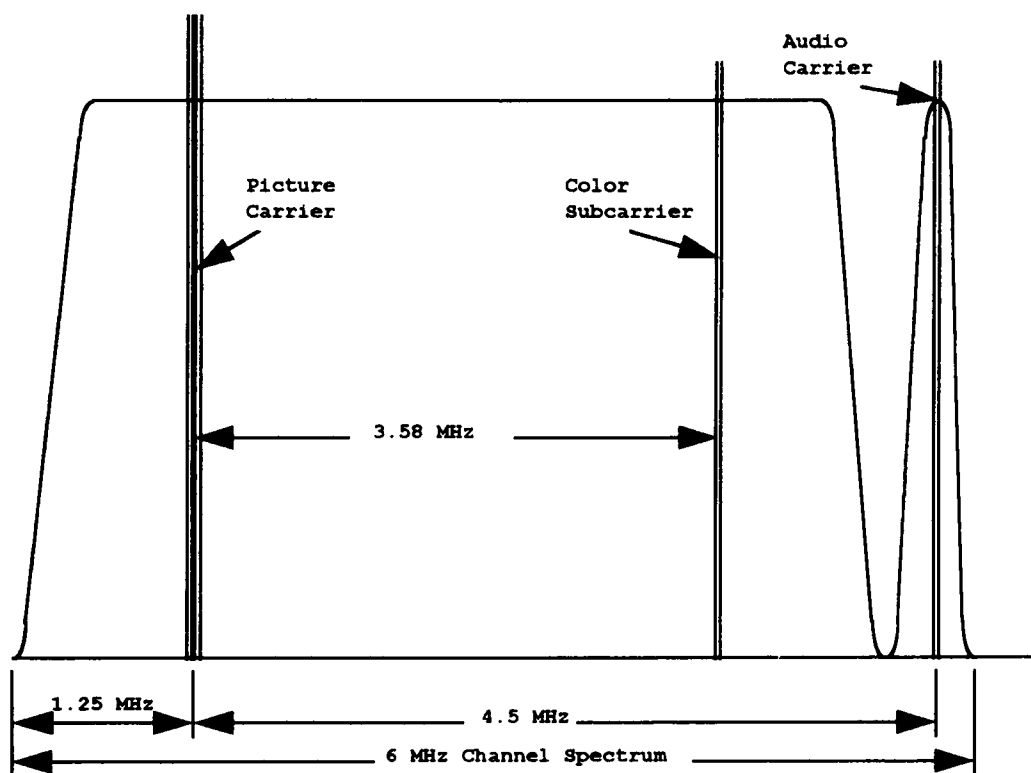


Figure 2.1 NTSC spectrum.

Color reproduction adds a subcarrier to the video signal. A chrominance subcarrier and its associated chrominance information reside in the upper portion of the spectrum just below the audio carrier. Chrominance information modifies the subcarrier with a phase-coherent, amplitude modulation technique. Chrominance amplitude and phase add color saturation and hue to an otherwise gray-scale image. In the time-domain, chrominance information appears superimposed upon the luminance information. Together, luminance and chrominance modulation make up a composite video signal.

The typical color television paints video images across a cathode ray tube (CRT) screen using three electron guns referred to by their color designation: red, green, and blue. Each gun contributes to the image luminance, hue, and saturation in proportion to the NTSC luminance and chrominance information.

The NTSC envelope conveys a scene as a series of sequential "picture" frames consisting of two alternating fields of interlaced raster lines. Each field consists of 262.5 lines staggered to present every other line in the frame. Televisions trace the raster lines across the face of the screen in left to right, top to bottom order. The presentation rate of 30 frames per second, the persistence of the screen phosphors, and the human visual response create a flicker-free video image.

NTSC signals contain vertical field, horizontal raster, and chrominance synchronization pulses. Vertical synchronization pulses return the electron guns to the top of the screen prior to each new field. The timing of the vertical synchronization pulses alternates the fields comprising a given frame. Horizontal synchronization pulses return the electron guns to the left side of the CRT screen prior to a new raster trace. A color burst, included in every raster line, synchronizes the television phase-coherent demodulator with the transmitter color oscillator.

Figure 2.2 presents a horizontal synchronization pulse and associated color burst. The figure depicts a single raster line forming a row of vertical color bars.

TV transmitters merge the composite video and audio signals into a contiguous, 6 MHz spectrum. A given transmitter modulates the NTSC spectrum to a frequency division multiplexed (FDM) channel assigned by the Federal Communications Commission (FCC). For example, Figure 2.3 demonstrates the combined video and audio spectrum for TV channels 9 through 13. Each channel consists of three carriers with associated sidebands: the picture carrier with vestigial luminance sidebands, the color subcarrier with vestigial chrominance sidebands, and the sound carrier with FM sidebands.

A television should accept the desired channel, reject all other channels, and reliably reproduce the scene. In reality, external and internal impairments may distort the reproduction.

2.2 Television Architecture

Televisions use a superheterodyne technique to select, demodulate, and amplify the desired channel from several possible selections in the VHF and UHF frequency bands [9].

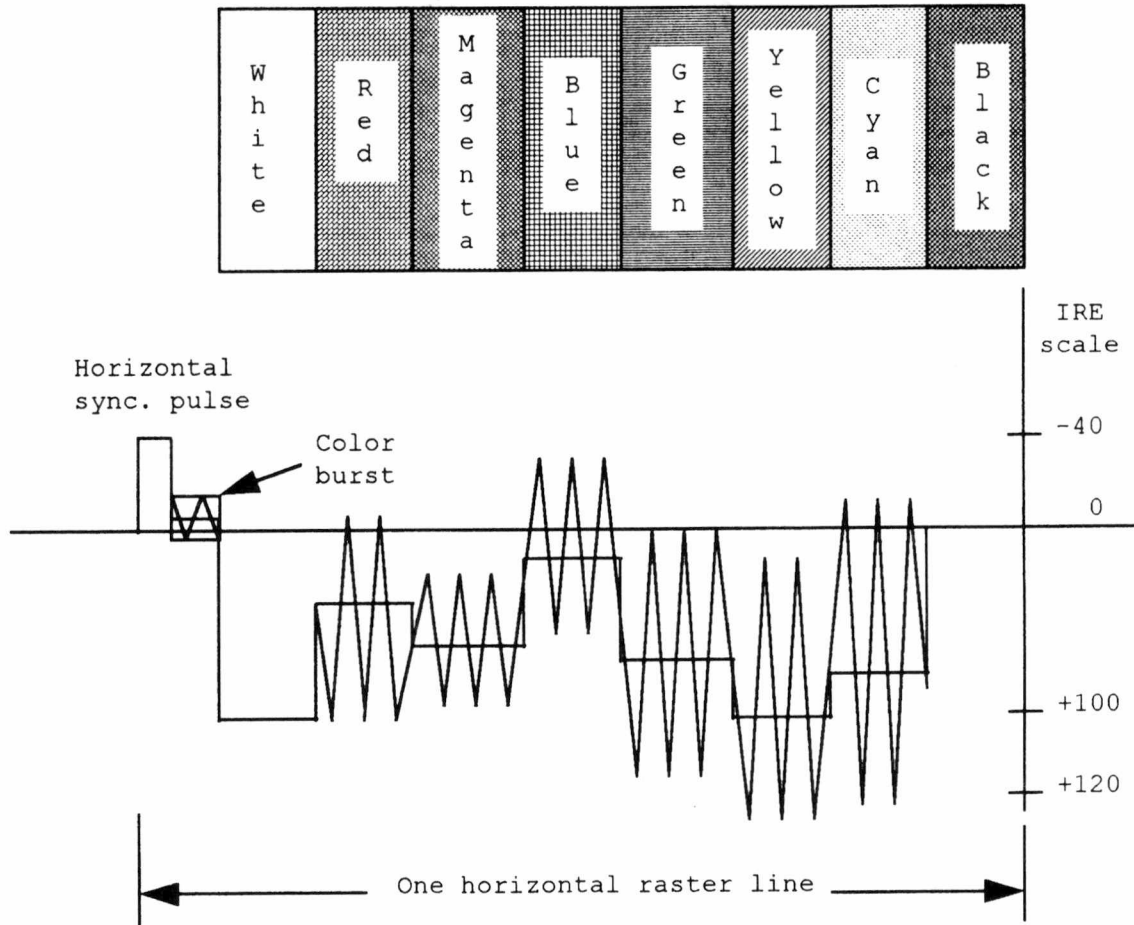


Figure 2.2 Color bar raster line

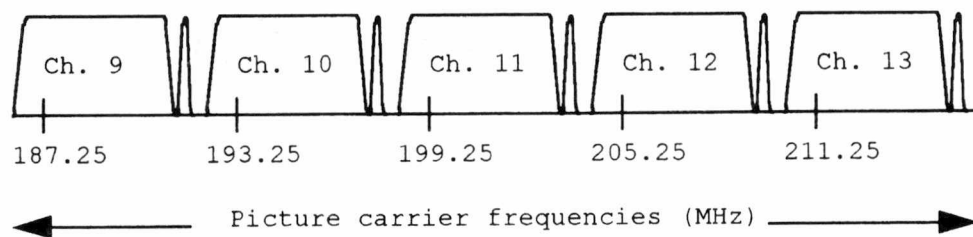


Figure 2.3 FCC channel assignments

Demodulation follows the same procedure in both bands except for differences in carrier frequency. Standard industrial practice prescribes the use of channels in the same frequency band when measuring nonlinear distortion. Given these considerations, the NDT study will focus on distortions occurring in the VHF band.

As illustrated in Figure 2.4, televisions consist of three major sub-systems: a superheterodyne receiver, a video monitor, and an audio amplifier section. TV receivers accept the entire spectrum of TV channels, select the desired TV channel, and demodulate the channel to a baseband NTSC signal. Baseband video and audio signals pass from the receiver into the video monitor and audio section. Within the video monitor, composite video signals decompose into luminance, chrominance, and synchronization components for control of the CRT electron guns. Amplifiers and an FM detector within the audio section demodulate the sound signal for reproduction via an electromagnetic speaker.

The TV receiver section is the primary source of nonlinear video distortion. Superheterodyne receivers consist of two signal processing stages called the tuner section and the intermediate frequency (IF) section. Components within both sections may contribute significantly to distortion.

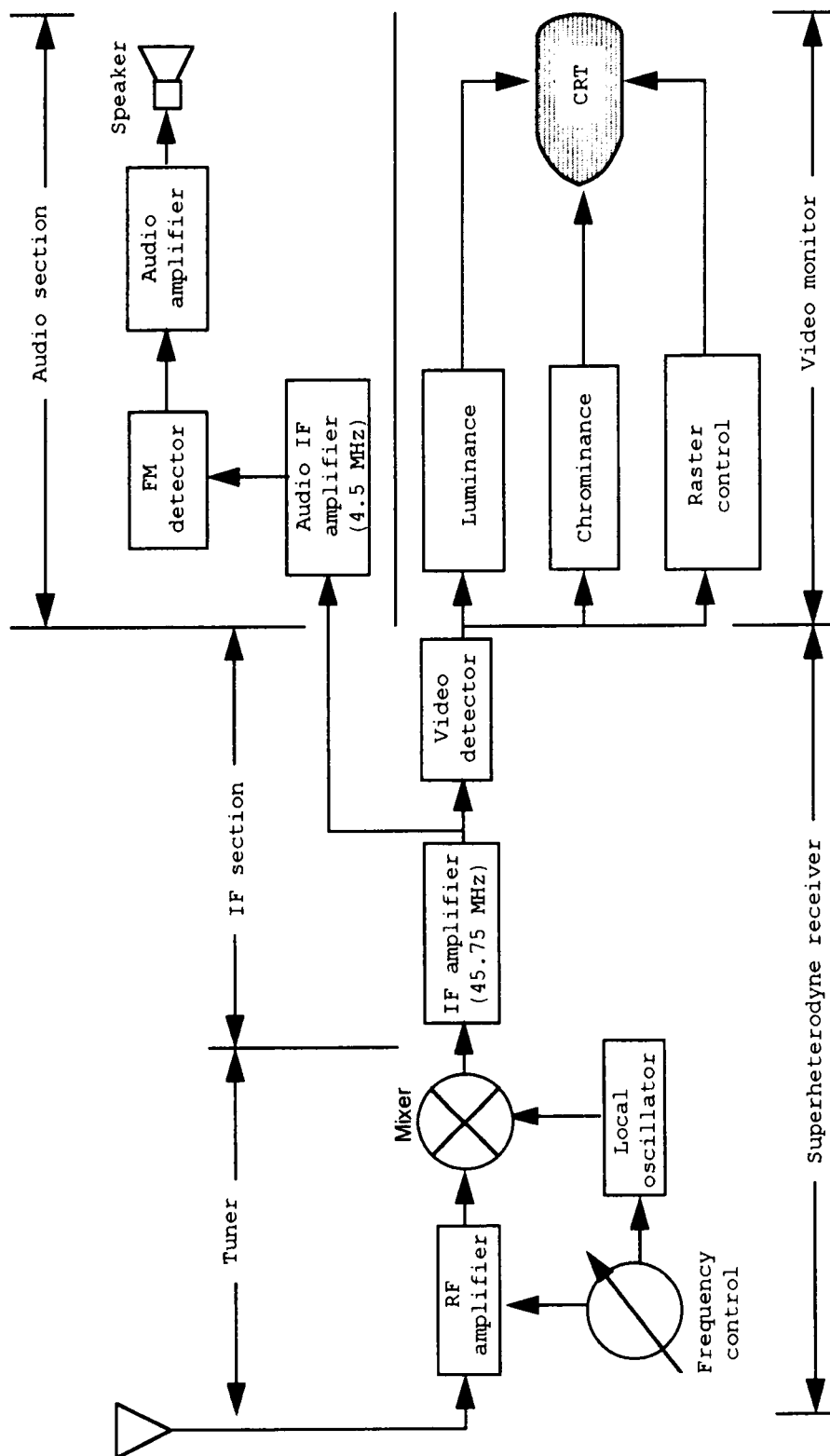


Figure 2.4 Television block diagram

Tuners consist of a wide-band, RF amplifier with variable band-pass filter, variable frequency "local oscillator," and an RF demodulator, also called a "mixer." Mechanical or electronic coupling coordinates the filter center frequency and oscillator frequency. Matching filter and oscillator frequencies select the desired channel spectrum while de-emphasizing other channels.

NTSC design strategically places the local oscillator frequency at 45.75 MHz above the desired channel. Mixers translate all combinations of desired picture carriers and associated local oscillator frequencies to the IF carrier frequency fixed at 45.75 MHz. All other combinations translate outside the IF section passband.

The format of the channel spectral envelope is unchanged by the tuner. Tuner output is the received NTSC signal translated to the IF carrier frequency. Thus, RF section design rejects undesired channels while preparing the desired channel for IF section processing.

IF sections consist of multiple amplifiers, bandpass filters, and an AM video detector. The filters provide additional adjacent channel rejection. Amplification increases the signal level in preparation for demodulation by the video detector. A baseband, composite video signal passes from the detector to the video monitor.

Perfectly designed televisions will select, demodulate, and decompose the desired TV channel without distorting the video signal. The NDT procedure measures television performance against the design goal.

2.3 Nonlinear Distortion Analysis

Theoretically, signals outside the desired channel spectrum introduce no video distortion. In practice, powerful signals located 12 MHz or more from the desired channel may distort video reproduction. Components within the TV receiver contribute to this undesirable behavior.

Superheterodyne receivers use two nonlinear devices as video signal demodulators -- the mixer and video detector. A perfect demodulator is a square-law device of the mathematical form [9]:

$$v_o = K_0 + K_1 v_i + K_2 v_i^2. \quad (2.1)$$

Practical demodulators have an input response resembling a power series with many more terms:

$$v_o = K_0 + K_1 v_i + K_2 v_i^2 + K_3 v_i^3 + \sum_{n=4}^{\infty} K_n v_i^n. \quad (2.2)$$

The series coefficients are real, constant, and decline in significance with higher order terms.

Only the first four terms produce significant distortion under normal operating conditions [10]. On the other hand, higher order terms become important considerations if high-

powered signals overload the RF section input. By industrial convention, nonlinear distortion measurement procedures consider receiver behavior prior to RF input overload. Therefore, this study will avoid overload conditions and treat the first four terms as the only significant distortion contributors.

In Eq. 2.2, the first term is a DC offset produced during the demodulation. Receiver design compensates for the offset and eliminates it as a source of distortion.

The first-order term of Eq. 2.2 is the linear gain component of the demodulator. Its sinusoids occur at the same frequencies as the received RF signal. Typical receiver RF selectivity is sufficient to eliminate the linear demodulation components. Consequently, the first order term is not a usual source of interference.

The second-order term is essential to video demodulation. Its nonlinear behavior yields the sums and differences of frequencies necessary for demodulation. For example, assume a picture carrier with monotone modulation of the form

$$v_i = V_c [1 + m \cos(\omega_m t)] \cos(\omega_c t), \quad (2.3)$$

where V_c , ω_c , m , and ω_m are the carrier level, carrier frequency, modulation index, and modulation frequency, respectively. Substitution of Eq. 2.3 into the second-order

term of Eq. 2.2 yields several sinusoidal terms including the demodulation term

$$V_{\text{de mod}} = \frac{1}{2} K_2 V_C^2 m \cos(\omega_m t). \quad (2.4)$$

All remaining terms are by-products of demodulation and represent various forms of second-order modulation, harmonic, and intermodulation distortion. Some interesting examples of second-order distortions appear in Table 2.1.

A similar expansion of the third-order term produces a multinomial combination of nonlinear sinusoidal sums and harmonics. Several possible distortion modes develop depending upon environmental conditions [10]. Particular combinations of desired and interfering frequencies emphasize one distortion mode over another. Table 2.1 presents some of the relevant third-order distortion modes. This study measures receiver susceptibility to any combination of third-order cross modulation, intermodulation, or modulation distortion as predicted by the last three table entries. NDT design draws upon industrial practice as a guide for conducting measurements.

2.4 Industrial Measurement Practice

Government and industry work together for improved TV reception by applying regulation and industrial practice to

Table 2.1 Nonlinear Distortion Modes [9,10,11]

Distortion Mode	Multinomial Expansion Term ^a	Interference Example
Second-Order Harmonic	$\frac{1}{2} K_2 A_1(t)^2 \cos(2\omega_1 t)$	$2f_6 \approx f_7^b$
Third-Order Harmonic	$\frac{1}{4} K_3 A_1(t)^3 \cos(3\omega_1 t)$	$3f_4 \approx f_{12}$
Second-Order Intermodulation	$K_2 A_1(t) A_2(t) \cos[(\omega_1 - \omega_2)t]$	$f_{30} - f_{23} \approx f_{IF}^c$
Third-Order Intermodulation	$\frac{3}{2} K_3 A_1(t) A_2(t) A_3(t) \cos\{\omega_1 \pm [\omega_2 - \omega_3]t\}$	$\omega_{P13} + (\omega_{P11} - \omega_{P9})d$
Third-Order Cross Modulation	$\frac{3}{2} K_3 A_2(t)^2 A_1(t) \cos(\omega_1 t)$	$\frac{3}{2} K_3 P_{13}(t)^2 P_{11}(t) \cos(\omega_{P11} t)$
Third-Order Modulation	$\frac{3}{4} K_3 A_1(t)^3 \cos(\omega_1 t)$	$\frac{3}{4} K_3 P_{11}(t)^3 \cos(\omega_{P11} t)$

Notes:

^a The distortion terms are selections developed through manipulation of Eq. (2.2). The modulated sinusoids $v_i = A_i(t) \cos(\omega_i t) + A_2(t) \cos(\omega_2 t) + A_3(t) \cos(\omega_3 t)$ produce a multinomial equation when substituted into the equation. Trigonometric expansion yields the listed term along with many other terms.

^b The symbol f_{xx} with numeric subscripts denotes the 6 MHz frequency spectrum associated with the indicated TV channel as assigned by the FCC for open-air broadcast.

^c The symbol f_{IF} denotes the 6 MHz spectrum associated with the 45.75 MHz, IF section carrier frequency.

^d Symbols $P_{xx}(t)$, ω_{Pxx} , and ω_{Sxx} denote the indicated TV channel video modulation, picture carrier frequency, and audio carrier frequency, respectively.

the sources of interference. The Federal Communications Commission and the International Telecommunications Union (ITU), the FCC's international counterpart, promote the public welfare by allocating the frequency spectrum to many services. These regulatory organizations carefully plan assignments of TV, land mobile radio, satellite, FM radio, and scientific-use channels avoiding interference within and between services. Regulators draw upon industry as a source of technical guidance during new regulation development.

The industrial sector, including television broadcasters and manufacturers, contributes to the management of the RF spectrum. Motivated by the need for a prosperous market place, industrial groups share research and develop standards for television practice. Standard publications improve the quality of regulation and foster the development of mutually beneficial technologies. Of these, standards for television performance play an important role in ATF design and in the measurement of nonlinear distortion.

An industrial standards group called the International Electrotechnical Commission (IEC) develops methods for measuring television performance by compiling recommendations into published measurement standards. Compliance with these standards is voluntary unless government agencies adopt the IEC recommendations as law. Whether voluntary or mandatory, IEC standards serve as a

metric for judging the merits of television design. Performance metrics for nonlinear distortion are of particular interest to the NDT study.

2.5 Nonlinear Distortion Measurement Practice

IEC standards prescribe methods for measuring cross modulation and intermodulation distortion within the television [1]. In particular, the Commission's recommendations guide considerations for the Nonlinear Distortion Test as they apply to

- selection of measured performance parameters
- definition of relevant nonlinear distortion modes
- definition of industrial terminology
- selection of desired and interference channels
- choice of video and audio modulation patterns
- arrangement of test equipment
- selection of signal voltage levels
- design of measurement procedures
- organization of measurement reports

Application of the recommendations yields measurements in a form comparable with those taken by other groups and at other times. Consistency in definitions, methods, and reporting creates meaningful information for new industrial regulation, product refinement, and competitive analysis.

IEC recommendations on cross modulation measurement are of special interest to the NDT study.

IEC Publication 107-1, "Methods of Measurement on Receivers for Television Broadcast Reception -- (Draft)," 2nd Edition, December 1993, Section 5.3.7, prescribes the standard method for nonlinear distortion under the heading "Cross Modulation." Careful examination shows the method may detect third-order intermodulation and modulation distortion as well.

A terminology discrepancy exists between industrial and classical definitions of distortion [9]. Industrial professionals define cross modulation as all disturbances created by one interference channel and intermodulation as disturbances created by two or more interference channels. Classical definitions describe the distortions in the following manner:

- Cross modulation adds modulation from one carrier to another carrier.
- Intermodulation creates a new sinusoid from two intermixed signals at different frequencies.
- Modulation distortion, or harmonic distortion, modifies signal modulation without altering the carrier frequency.

Despite the discrepancy, IEC standards provide a useful method for collecting and communicating nonlinear distortion

measurements involving a single interference channel. The NDT study applies the IEC standard while adhering to the classical definitions of distortion in its discussion.

This study applies the IEC "Cross Modulation" method to the detection of cross modulation, intermodulation, and modulation distortion as a metric for competitive analysis. The "Cross Modulation" method requires a controlled test environment involving an "observation" channel and a single "interference" channel. Many different combinations of channels may produce non-linear distortion.

As a guide to channel selection, IEC convention draws an important distinction between "Adjacent Channel" interference and "Cross Modulation" measurement methods. Both methods follow similar procedures but the Adjacent channel interference method, as its name suggests, uses interference channels adjacent to the desired channel. In contrast, the Cross Modulation method prescribes interference channels greater than one channel removed from the desired channel. In application, the IEC "Cross Modulation" method uses interference channels located 12 MHz above or below the desired channel. There are several possible combinations within the VHF band. In the NDT study, Channel 11 is the observation channel while Channels 9 and 13 act as interference channels.

The IEC recommends multiple performance measurements for each television under test. For each measurement, a test operator fixes the observation channel level within the range of 0.316 millivolts to 31.6 millivolts. Interference channels typically induce distortion at voltages 40 dB higher than the observation level. Available modulator power limits the NDT study to a maximum interference level of 200 millivolts. Therefore, NDT measurements will use observation channel levels of 1 and 4 millivolts, levels common to cable TV and urban, open-air antenna reception.

IEC standards specify the modulation content applied to the test channels. Interference channels carry monotone audio with either a color bar or a standard, black and white video pattern, called "monoscope." The observation channel bears a gray, flat field video with no audio modulation. Flat field modulation creates a uniform gray CRT screen upon which to observe interference. Application of an interference channel may create nonlinear distortion within the receiver. If so, combinations of distorted luminance, chrominance or audio modulation appear as disturbances in the flat gray observation display.

An IEC manual test arrangement shown in Figure 2.5 applies the observation and interference signals to a television under test (TUT). Two TV modulators produce the

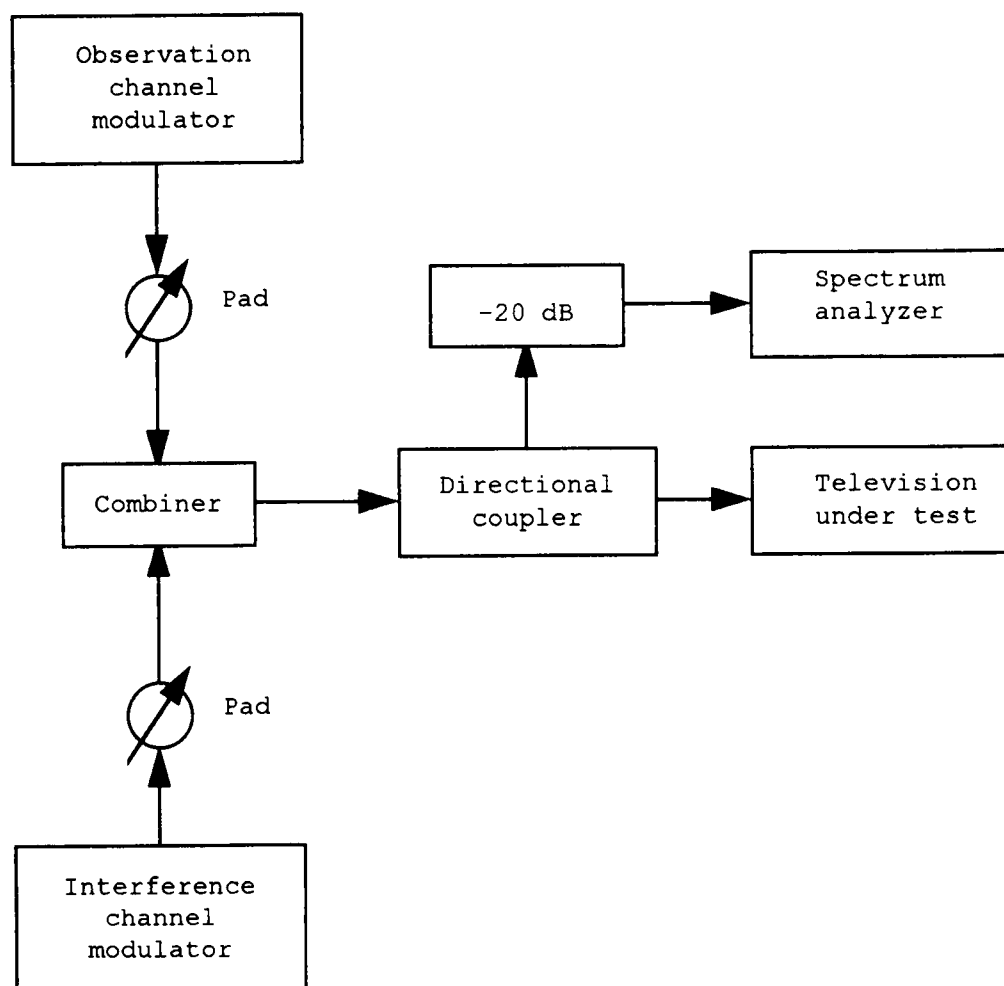


Figure 2.5 Manual test arrangement

observation and interference channels. Variable attenuation devices, called "pads," control the channel level. An RF combiner merges the two signals into a coaxial connection at the receiver and a spectrum analyzer. A 20 dB, directional coupler protects the spectrum analyzer from input signal overload. The pads vary the test signal levels, the spectrum analyzer measures the levels, and the television screen, with its flat gray field, is the means of detecting perceptible video distortion.

A distortion measurement consists of the following steps:

1. Set an observation level using the pads and spectrum analyzer.
2. Using the pads, vary the interference channel level until a video disturbance is barely perceptible upon the flat gray screen.
3. Record the interference level in dB relative to the observation channel level.

Operators repeat the experiment for several observation levels creating a profile of television behavior. The Nonlinear Distortion Test procedure, described herein, automates the manual measurement process.

CHAPTER 3

NONLINEAR DISTORTION TEST METHODS

3.1 ATF Test Goals

Competitive analysis seeks to enhance design investment decisions by gauging the relative performance of competing television models. Sound decisions call for a statistically valid data base containing performance profiles taken across a large population of competing television models. Manual efforts to collect TV profiles cannot keep up with the fast paced TV market. The ATF system resolves the profile collection problem by:

- automating the measurement process for maximum measurement speed and operator productivity
- rigorously applying IEC test procedures to competing models
- managing the automated test arrangement for maximum measurement accuracy
- compiling TV profiles electronically for efficient analysis
- offering an intuitive operator interface for ease of use

- lowering training costs by providing an interactive learning environment
- lowering software development costs through increased programming productivity
- reducing software maintenance costs through improved design quality

Achievement of the benefits listed above is a complex design problem requiring both sophisticated tools and good organization. Consequently, the ATF system represents a large investment in automated test equipment, software, and skilled labor. A team of engineers, project leaders, and managers developed the ATF in response to the need for a better TV measurement system. A battery of test procedure software and associated hardware is the outcome of their efforts.

The NDT is one of several procedures developed for the ATF. NDT design goals support the overall goals of the ATF system by adding distortion performance information to TV profiles. This study focuses attention upon the development of the NDT, associated utilities, and the ability to effectively measure distortion within the ATF using accepted industrial standards.

3.2 Nonlinear Distortion Test Procedure

The NDT procedure measures nonlinear distortion by recreating the "Cross Modulation" procedure within an automated process. It applies the IEC-prescribed test signals, records the presence of nonlinear distortion, and maintains a controlled test environment for measurement accuracy. In Figure 3.1, process steps accumulate measurements representing a distortion performance profile for one television. Under operator control, the NDT repeats the steps for many television models and compiles a data base of nonlinear distortion behavior.

The procedure tests for nonlinear distortion by applying stimulus to the TUT within a carefully controlled test environment. An NDT test environment, illustrated in Figure 3.2, consists of an RF-free test room, computer-controlled test equipment called "instruments," a SUN Sparcstation, and the NDT procedure software.

Televisions operating within the test environment will exhibit varying degrees of nonlinear distortion observed as disturbances in the TV display and unwanted spectral components within the superheterodyne receiver. Radiation from external sources (e.g., TV stations, unshielded equipment) may be mistaken for nonlinear distortion products. To avoid false measurements, the NDT procedure

Step	Description of Action	Test Equipment
1	Turn on all televisions, mute all audio, and tune all televisions to Channel 11.	Manual
2	Allow all televisions to operate for at least 15 minutes.	
3	Set the PM5640 video generator to produce a 50 IRE, flat field test pattern.	PM5640
4	Set the RE 540 audio generator to produce a 1000 Hz sine wave.	RE 540
5	Set all RF modulator pads to maximum attenuation.	TSI8150
6	Connect the color bar video and RE 540 audio signals to the Channel 9 RF modulator.	SVS router
7	Connect the monoscope video and RE 540 audio signals to the Channel 13 RF modulator.	SVS router
8	Connect the flat field video signal to the Channel 11 RF modulator.	SVS router
9	Adjust Channel 11 RF attenuation, designated the observation channel, to 1 mV at the TUT	TSI8150
10	Adjust Channel 9 RF attenuation, designated the active interference channel, to 200 mV at the TUT.	TSI8150
11	Adjust the Channel 13 attenuation, designated the inactive interference channel, to the same level as Channel 11.	TSI8150
12	Adjust the Channel 9 RF attenuation until Channel 11 flat field distortion is barely perceptible. Select "Record" to retain the "Channel 9 interference on Channel 11 at 1 mV." level. Repeat Step 12 for every TV under test.	TSI8150
13	Repeat steps 10 through 12 for "active interference" Channel 13 and "inactive interference" Channel 9 (i.e., reverse the roles of Channel 9 and 13 by changing their levels relative to Channel 11). Record the "Channel 13 video interference on 11 at 1 mV." level.	TSI8150
14	Adjust Channel 11 RF attenuation to 4 mV at the TUT.	TSI8150
15	Repeat steps 10 through 12 for "active interference" Channel 9 and "inactive interference" Channel 13. Record the "Channel 9 audio interference on 11 at 4 mV." level.	TSI8150
16	Repeat steps 10 through 12 for "active interference" Channel 13 and "inactive interference" Channel 9. Record the "Channel 13 video interference on 11 at 4 mV." level.	TSI8150

Figure 3.1 NDT test script

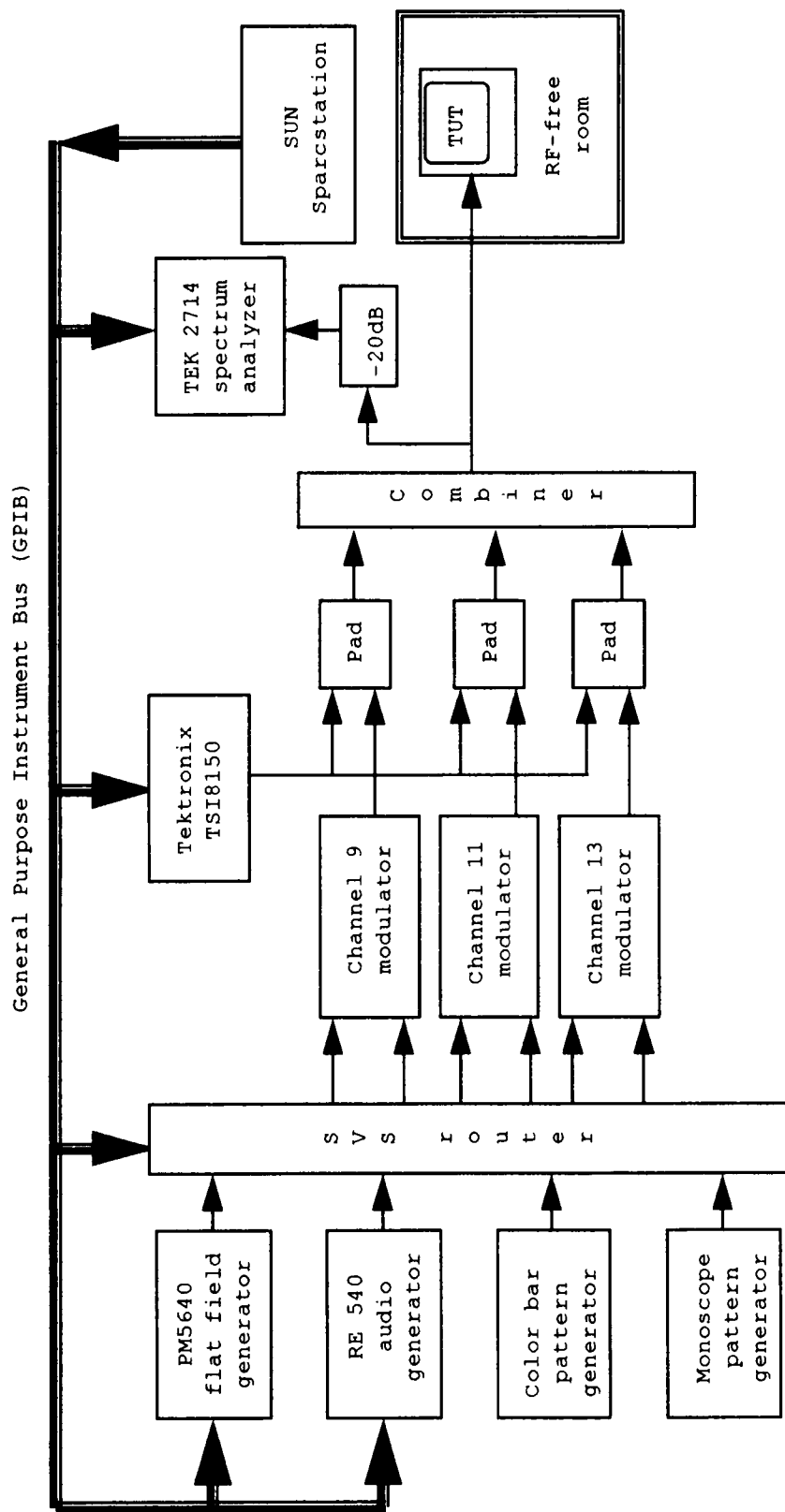


Figure 3.2 NDT equipment block diagram

places the TUT within the RF-free screen room, thereby shielding it from external RF interference.

ATF instruments construct a test stimulus, referred to as the "NDT broadcast," and consisting of three modulated TV channels, specifically Channels 9, 11, and 13. Each channel carries different video and audio modulation as described below.

<u>Channel</u>	<u>Video</u>	<u>Audio</u>
9	monoscope	1000 Hz
11	gray flat field	none
13	vertical color bar	1000 Hz

By definition, Channel 11 is the "observation channel" and represents desirable TV reception. Distortion induced by the presence of either Channel 9 or 13, referred to as the "interference channels," will appear as disturbances in Channel 11's display.

NDT broadcasts begin as a set of baseband video and audio signals as shown in the left-most portions of Figure 3.2. A SUN Sparcstation and the NDT software orchestrate the broadcast by issuing commands to ATF instruments over a General Purpose Instrument Bus (GPIB). Dedicated generators continuously produce the frequently used monoscope and color bar video patterns. Some of the NDT commands instruct

Philips PM5640 and RE 540 instruments to synthesize a flat field video pattern and 1000 Hz audio signal, respectively. Other NDT commands distribute baseband signals through a Sierra Video Systems (SVS) router to appropriate TV modulators transforming the baseband components into discrete TV channels. Pads, regulated by a Tektronix TSI8150 controller and NDT software, attenuate the modulator output to the desired signal level. The separate TV channels merge within an RF combiner to form a single, broadcast-format signal. Coaxial cables distribute the broadcast to one or more televisions under test.

Observation and active interference signal levels are important factors in the NDT environment. Only one interference channel is active for a given measurement. Computer-controlled attenuation reduces the inactive interference channel to a low level eliminating it as a source of distortion. NDT software holds the observation channel level at 1 mV for a full set of measurements, then repeats the measurements for an observation level of 4 mV.

With the observation channel level set to 1 millivolt, the software increases the level of one interference channel, Channel 9 for example, until the distortion is noticeable in the flat gray observation display. The NDT records the minimum distortion level for Channel 9, replaces Channel 9 with Channel 13 and records a Channel 13 minimum

distortion level. The process repeats with the observation level set at 4 millivolts and produces two more measurements, one for each interference channel.

Rapid distortion measurement across many televisions demands quick calculation of interference levels. Normal circumstances would suggest direct measurement using a spectrum analyzer. Unfortunately, each analyzer measurement takes up to one minute, slowing the procedure and making direct level measurement impractical. Instead, NDT software estimates the interference level by assuming ATF behavior changes slowly.

ATF components are subject to aging, thermal drift, and other variations in behavior. Modulator drift may vary carrier levels by several decibels over time. Modifications to the coaxial distribution system may cause signal attenuation changes. Occasionally, pads malfunction providing more or less signal attenuation than specified. Fortunately, most changes occur slowly, permitting periodic characterization of the system behavior.

Each evening, ATF operators take measurements of modulator power levels, distribution system losses, and attenuator values. After-hours behavior characterization provides a Tektronix 2714 spectrum analyzer the needed time for accurate measurements of variable system behavior. Some measurements initiate immediate repairs to critical

component malfunctions (e.g., faulty attenuaters, gross variations in levels). Other characterization measurements record normal variations in a behavioral model data base. For example, modulation drift and cable attenuation changes appear as updates to the ATF behavioral model.

NDT software achieves measurement speed by using the model as a reference for unattenuated signal levels. It adds pad attenuation to the reference computing the interference level at the TUT. By using the behavioral model, measurements progress rapidly, enhancing operator productivity.

3.3 NDT Operator Interface

The Nonlinear Distortion Test procedure creates a specially designed operator interface to achieve productivity, reduce training costs, and improve measurement accuracy. Many different possibilities exist for the operator interface, but careful consideration of NDT goals eliminates some of these possibilities. Final selection of the best design depends heavily upon a methodical interaction with the ATF operators.

A technique called a "story board" obtains important operator feedback. The NDT story board, shown in Figure 3.3, is a function tree diagram describing the progression

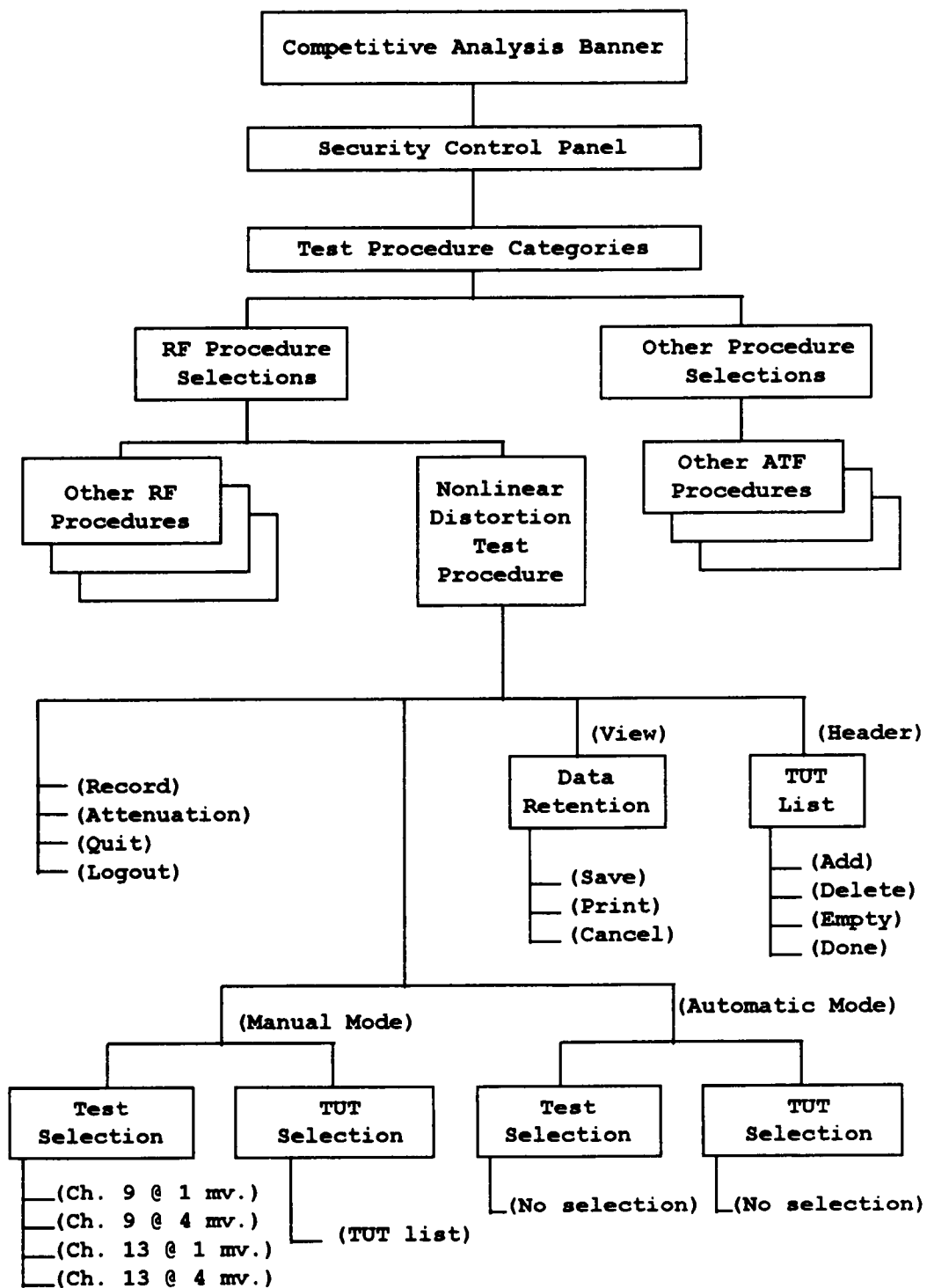


Figure 3.3 NDT story board

from the topmost operator interface panel downward to lower level panels. Each tree path represents a different NDT function. Tree blocks represent different interface panels with panel selections enclosed in parentheses. Movement along the path initiates the function and defines its operational parameters. For example, appropriate selections along the measurement retention path will create a measurement report on the Sparcstation printer. Erroneous selections invoke NDT panels displaying instructions for correcting the error.

NDT interface controls, shown in Figure 3.4, offer several test functions to the operator:

- automatic measurement mode
- manual measurement mode
- measurement retention control
- TUT addition and deletion control
- data accuracy protection

A given control selection takes the operator downward in the NDT story board tree and initiates a particular action (e.g., printing a measurement report) or returns the operator to a higher level within the tree. The design of each function strives for the goals of measurement productivity, accuracy, and intuitive operator interface.

Nonlinear Distortion Test

Test Selector: Ch. 9 Audio on 11 at 1 mV

TV Selector: 0

Current TV: UTK

Brand: UTK

Screen Size: 19.0

Serial Number: 1794-1994

Interference Level: -Inf

Time Stamp: 45249851

Test Mode: Automatic

Warm-up Indicator: ON

Model: Volunteer

Version: 3

Outlet: 31

Valid Data? Data Stored?: No

Test Name: Ch. 9 Audio on 11 at 1 mV

Quit: Logout

NDT Event: 9

View: ATF Header

Attenuation (dB): 0

Interference Level (dBmV): 40.0

RECORD

Figure 3.4 NDTmeas front panel

For example, NDT selections support two test modes: automatic and manual. Automatic mode takes four measurements for each member of a television list in the most efficient manner achievable with automation. In manual measurement mode, operators may choose the order of test by selecting the combination of TUT, observation level, and interference channel for each measurement. Manual mode is especially useful for cross-checking measurements taken in automatic mode. Thus, the two modes work together increasing productivity while ensuring accuracy and operator confidence in the measurements.

NDT software supports a variable list or "inventory" of televisions under test as shown in Figure 3.5. Operators may add or delete televisions from the TUT list at any time. As a data accuracy precaution, TV additions illuminate a "warm-up" indicator located on the NDT Control panel, thereby, alerting the operator to televisions added to the ATF within the last 15 minutes. Warning messages caution the operator against recording measurements for a "cold television."

Operators have control over measurement retention. Panel selections found in Figure 3.6 display the measurements, print reports, and save measurements to the competitive analysis data base. Once saved, error messages prevent the operator from taking duplicate measurements.

TUT List

TV Header

0	Brand	UTK
	Model	Volunteer
	Screen Size	19.00
	Version	3
	Serial Number	1794-1994
	Outlet	31
	Time Entered	4524981

Empty
Add
Delete
Done

Figure 3.5 TUT list front panel

Nonlinear Distortion Measurements

[illegible]

Figure 3.6 NDT measurements display panel

Measurements accumulate in a specially designed record organized in "data interchange format" (DIF). Each record contains a single distortion measurement and associated information sufficient to fully define the context of the measurement (e.g., operator name, date, time, observation level, interference channel). Figure 3.7 illustrates a set of measurements for a single TV model. Tab characters delimit information within the record (e.g., operator name, date, time) and carriage return characters separate DIF records. One television nonlinear distortion profile consists of four DIF records.

By selecting "Save" in Figure 3.6, an operator instructs the NDT procedure to add the distortion profile to a disk file. Competitive analysis programs readily process DIF records and produce a data base of investment information ready for use by decision makers. Because of the potential impact upon the data base and the analysis, designers solicit comments from competitive analysts, as well as operators, on those portions of the story board effecting NDT measurement retention.

As prospective users, ATF operators and competitive analysts interact with the NDT story board commenting on both normal operation and error behavior. Procedure designers observe user interactions and incorporate their

Date	Time	User	Test	Mfgr.	Model	Ver.	Serial No.	Size	Measurement Name	Intf. Lvl.	Intf. Ch.	Obs.	Level
11/7/94	19:30:25	Gary	NDT	UTK	Volunteer	3	1794-1994	19	Ch. 9 Audio on 11 at 1 mV	28	9	9	1.00E-03
11/7/94	19:30:25	Gary	NDT	UTK	Volunteer	3	1794-1994	19	Ch. 13 Video on 11 at 1 mV	25	13	13	1.00E-03
11/7/94	19:30:25	Gary	NDT	UTK	Volunteer	3	1794-1994	19	Ch. 9 Audio on 11 at 4 mV	35	9	9	4.00E-03
11/7/94	19:30:25	Gary	NDT	UTK	Volunteer	3	1794-1994	19	Ch. 13 Audio on 11 at 4 mV	33	13	13	4.00E-03

Figure 3.7 NDT record format

comments as refinements to the story board. Several story board iterations eventually converge into a general design consensus and NDT software development begins.

3.4 NDT Software Development

Software development translates the NDT story board into a working test procedure while striving for lower training costs, high development productivity, and low maintenance cost. Haphazard software design will not achieve these goals in a large, complex activity such as the Automatic Test Facility. Many megabytes of software make up its test procedures. To be successful in such a large endeavor, design engineers must work as a team following a development discipline called a "methodology."

A development methodology creates a disciplined environment by applying a set of principles, practices, and procedures to the design process. A good methodology provides direction, control, and feedback during important phases of the development. There are several popular methodologies within the software engineering profession.

A programming methodology called "design and debug" dominated software development for the past 20 years [12]. Its practice consists of:

- developing a system requirements specification through negotiation with the system users
- developing system software as a single, comprehensive design
- testing software using test methods developed by the designer
- delivering "tested" software to the system user
- budgeting design maintenance manpower to correct software errors discovered by the user

"Design and debug" methods make the following assumptions about the development environment:

- The user has complete knowledge of new system requirements.
- System requirements do not change during the design process.
- Design errors are inevitable.
- Post-design testing discovers all design errors.
- All error fixes improve the design.
- The "test and fix" process will converge to a fully correct design.
- Investment in quality control increases development cost.

Popular as they are, "design and debug" assumptions do not hold up under careful examination.

Software development studies document results contrary to the "design and debug" assumptions [13,14]. New systems, such as the ATF, are new business concepts and, as such, are evolutionary creations. System requirements change during system development reflecting an increased understanding of the business problem, increased user sophistication, and business paradigm shifts. A single-pass, all encompassing design step offers little opportunity to incorporate evolving requirements. Too often, new requirements lead to unanticipated redesign and major setbacks.

"Design and debug" procedures lack proactive quality controls relying, instead, upon post-design testing to add correctness to an incorrect design. Post-design testing finds errors, errors necessitate design changes, and, often, the changes introduce large numbers of new errors. Therefore, testing does not necessarily converge to a correct design. Sometimes, steady-state conditions develop where design changes equal the number of new errors introduced by the changes. Even worse, change-induced errors may be more serious than the oversights corrected by the change.

"Design and debug" methods assume post-design corrections are less expensive than design quality controls. This viewpoint overlooks the risk of design divergence, continuing design maintenance, and unpredictable support

costs. In practice, post-design testing seriously diminishes productivity by investing manpower in design rework and maintenance.

In contrast, processes operating within quality controls consistently exhibit lower overall costs compared to uncontrolled processes. Quality controlled development supports predictable design results, lower labor costs, and design correctness convergence. There are many alternative methodologies to "design and debug." The ATF project adopts a methodology consistent with its goals.

A software engineering methodology called "Cleanroom" provides the design disciplines used for ATF development [13,15]. Cleanroom methods promote language independent designs, increase design productivity, reduce design test failures, reduce design upkeep costs, adapt to evolving system requirements, and create design correctness through quality controls. All of these benefits are important to ATF development success.

ATF development adopts the National Instruments LabVIEW programming language as one of its tools. LabVIEW is intuitive, uses graphic techniques familiar to engineers, and comes with many useful functions such as GPIB support and interactive learning aids. It is a new, graphical programming language having little in common with traditional text-based languages (e.g., C, PL/I, Pascal).

Therefore, Cleanroom language independence is an important accommodation for LabVIEW programming.

Six design engineers construct the software defining the ATF test procedures. This small design team can ill afford large amounts of rework and maintenance activities. Cleanroom practices produce correct software from the onset creating greater design productivity and avoid costly redesign.

Cleanroom methods define a five-step procedure based upon design correctness principles. Within these steps, Cleanroom procedures communicate design concepts in a structured, mathematically rigorous manner. Design documents are a natural by-product eliminating the need for a separate investment in written specifications. Audits or "verification" of Cleanroom documents insure design correctness reducing testing, errors, and rework. Increased quality generates increased design productivity and lowers development cost.

The Cleanroom procedure, shown in Figure 3.8, consists of

- soliciting the latest system requirements
- planning a set of increments encompassing the latest requirements
- developing the next logical increment in the set

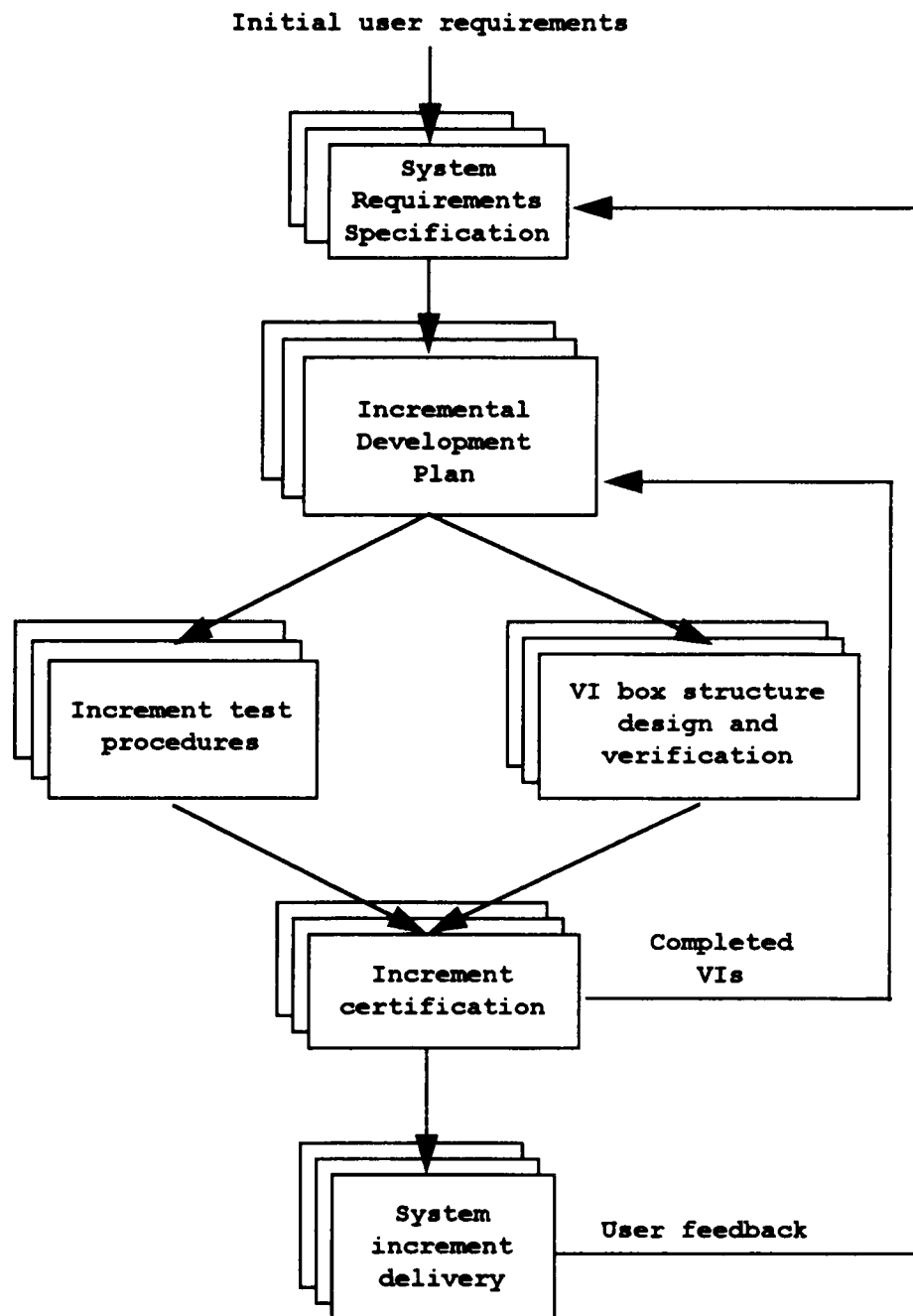


Figure 3.8 ATF Cleanroom model

- verifying the correctness of the increment components
- certifying composite system quality through testing of the entire increment
- deploying the latest increment to the system users
- collecting improvement feedback from the users

Cleanroom design steps repeat until the latest increment meets all system requirements.

Cleanroom procedures follow an iterative process that responds to an evolving understanding of system requirements. Each iteration, called a "design increment," captures new information about the ATF system. Successive increments expand upon prior understanding increasing the sophistication of each increment. New increments build upon the correctness of prior increments leading to reuse of earlier designs.

The process begins by collecting information through user interaction, story board design trials, examination of current business processes, and experimentation. Designers consolidate their findings into a System Requirements Specification. System users and designers revise the specification until its content achieves a consensus.

Note, the specification is not static. With each increment, new System Requirements Specifications develop reflecting the increased experiential understanding gained through user interaction with an evolving system. Thus,

Cleanroom development is a dynamic, highly responsive process reflecting the latest thinking of designers and users.

Cleanroom designers subdivide the latest system requirements and forecast a future sequence of design increments called an "Incremental Development Plan" (IDP). Each increment delivers a portion of the total requirement as described in the latest System Requirements Specification. If requirements converge to a static specification, then completion of all increments leads to a mature system design.

As in the requirements specification, the IDP encourages flexibility throughout the design without sacrificing productivity. Each Cleanroom process iteration revises the IDP taking into consideration changes in the System Requirements Specification and the products of past increments. An IDP distributes new requirements across the new set of increments and reuses past increment software consistent with the new requirements.

With new IDP in hand, ATF designers then divide the upcoming system increment into LabVIEW software modules called "virtual instruments" (VIs). VIs represent a logical abstraction of the new system into its component functions. Designers distribute the VIs amongst themselves according to some criteria such as workload and skill.

Virtual instrument development follows a three-step process referred to as "box structure design" using structures called "black box, state box, and clear box descriptions" [15,16]. A design begins simply as a black box description of VI stimuli and responses written in a procedural language called "box definition language" (BDL). Often, a VI must respond to stimuli based upon some history of past stimuli. If so, a state box description expands upon the black box by adding state machine variables and associated state logic. VIs derive responses from the current stimuli and the contents of the state variables in the clear box description. BDL functions map stimuli and state variables to appropriate responses. Adding BDL response derivations completes the VI design definition.

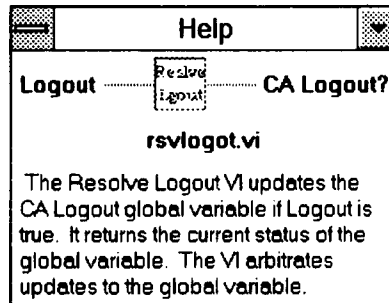
For example, the ATF requires a VI to resolve operator selection of a "Logout" button appearing on several panels. Selection of the button from any panel requires all ATF VIs to return control to the Competitive Analysis Banner panel. A VI called "Resolve Logout" arbitrates "Logout" selections by communicating the event throughout the ATF software. Figure 3.9 illustrates the progression through box structure design. The Resolve Logout black box description contains only the "Logout" stimulus and an arbitrated "CA Logout?" response. The VI recalls selections from other ATF panels

Black box description	State box description	Clear box description
<pre> define BB Resolve Logout stimulus Logout : logical response CA Logout? : logical enifed </pre>	<pre> define SB Resolve Logout stimulus Logout : logical response CA Logout? : logical state CA Logout : logical machine if Logout is selected then CA Logout := true fi end machine enifed </pre>	<pre> define CB Resolve Logout stimulus Logout : logical response CA Logout? : logical state CA Logout : logical machine if Logout is selected then CA Logout := true fi end machine proc if Logout is selected then CA Logout? := Logout else CA Logout? := CA Logout fi corp enifed </pre>

Figure 3.9 Resolve Logout box structures

using the state variable called "CA Logout" and "machine" logic shown in the state box description. A BDL "proc" block, appearing in the clear box description, describes the relationship between the stimulus "Logout," the state variable "CA Logout," and the "CA Logout?" response. The Resolve Logout clear box is a complete design description and translates directly into the LabVIEW VI shown in Figure 3.10. A set of box structures, a BDL description, and a LabVIEW VI constitutes a complete design ready for correctness verification.

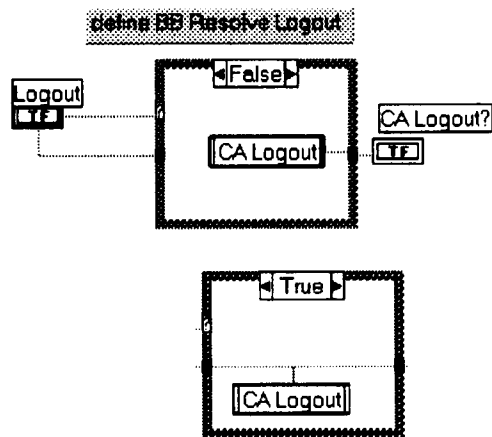
Figure 3.11 prescribes correctness criteria all VIs must pass before inclusion in an ATF increment. Some criteria represent design conventions adopted to accommodate operator preferences, insure the presence of interactive learning tools, or aid in design comprehension. For example, Verification Check List Item 3f verifies the quality of interactive tutorial panels. Other items, such as Verification Items 3a and 3b, check for VI design precision and accuracy. Design precision verification correlates the clear box design with the corresponding LabVIEW translation. Mismatches point to clear box translation errors. Design accuracy compares the clear box design with the System Requirements Specification. Inaccuracies point to misinterpretations of system requirements. In practice, VI



(a) Icon with "Help" description



(b) Front panel.



(c) Block diagram

Figure 3.10 Resolve Logout VI

ATF PROJECT
Verification Check List

Designer's name _____ VI name _____

<u>No.</u>	<u>Item</u>	<u>Comments</u>
1.	Colors	
a.	Black box: yellow	_____
b.	State box: green	_____
c.	Clear box: blue	_____
d.	Box elements	
i.	Block diagrams: light gray	_____
ii.	Text: black	_____
iii.	BDL: medium gray	_____
2.	Diagram organization	
a.	Vertical alignment	_____
b.	Horizontal alignment	_____
c.	Spacing within the diagram	_____
3.	Clear box design	
a.	BDL and code match (precision)	_____
b.	BDL accomplishes task (accuracy)	_____
c.	BDL box reduced to display only "define"	_____
d.	GET INFO: overview, instructions, I/O, author's name, modification history	_____
e.	Logic structure descriptions	_____
f.	Help descriptions	_____
g.	Data type conflicts	_____
h.	BDL describes state variables and shift registers	_____
i.	Wiring cleanliness	_____
j.	Descriptive icon	_____

Additional comments: _____

Figure 3.11 Verification check list

verification refers convention violations, translation errors, and design inaccuracies back to the designer for correction. Verified VIs become apart of the latest design increment and are ready for increment certification.

Cleanroom certification consolidates new VIs with reused VIs and tests the quality of the composite system. Ideally, designers and users create a certification procedure called a "usage model" consisting of statistically weighted stimuli patterned after expected system usage. Certification randomly applies model stimuli to the system at a rate proportional to its statistical weightings. Usage model tests produce statistically sound samples of system behavior and represent mathematically rigorous proofs of design correctness.

Unfortunately, ATF manpower constraints prevent formulation of ATF usage models. Instead, ATF quality controls rely upon the verification process and a less rigorous testing technique. Examination of past Cleanroom performance shows few design errors reach increment certification due, in large part, to the rigor of the box structure definition and verification steps. ATF development modifies the Cleanroom process by substituting traditional testing techniques for classical Cleanroom usage models, thereby, striking a balance between economy and rigor.

ATF certification follows increment test procedures prescribed by the designers. The procedures are designer estimates of likely failure conditions and, therefore, are not statistically rigorous. However, substitution of designer test procedures reduces manpower otherwise needed for preparing increment usage models. Potentially, ATF certification methods trade off lower modeling cost for higher maintenance cost. Experience supports the compromise based upon the low error rates achieved by the box structure and verification steps.

Increment certification readies a new set of functions for use by the system operators. Certification failures return an increment to the designers for correction. Successful certification of all functions permits deployment to the ATF users.

This study will now turn its focus upon three products of the ATF Cleanroom process: the Nonlinear Distortion Test procedure, Tektronix 2714 spectrum analyzer driver, and the SVS router driver VIs. These VIs contribute in different ways to the measurement of TV nonlinear distortion and to ATF project goals.

CHAPTER 4

NONLINEAR DISTORTION TEST PROCEDURE

The NDT procedure automates nonlinear distortion measurement with the goals of improved accuracy, productivity, and competitive analysis in mind. To achieve these goals, the procedure must accurately embody the industrial practice associated with the "Cross Modulation" measurement procedure. As shown earlier, a manual measurement procedure involves a well-defined process and a system consisting of equipment and human functions. Proper automation of distortion measurement requires the NDT to create an IEC-compliant process within a system composed of ATF equipment and the following software functions:

- pre-procedure ATF system reset
- test environment configuration
- TUT inventory tracking
- TUT selection
- interference channel selection
- observation level selection
- interference level adjustment
- measurement retention
- measurement accuracy safeguards

- post-procedure system reset

Many of these functions are not new to the manual "Cross Modulation" procedure. Instead, NDT software organizes distortion measurement into a highly repeatable process promoting measurement accuracy while freeing operators and analysts from drudgery.

The NDT is a part of a large ATF test procedure suite. Operators select the NDT procedure from a number of test options shown earlier in the NDT story board, Figure 3.3. The procedure software takes control of the ATF system and follows a logical sequence designed to recreate the "Cross Modulation" procedure.

NDT software consists of programmatic functions written in the LabVIEW graphical language and provides for the procedure control, test instrument control, NDT user interface, and measurement collection. A LabVIEW function, or "VI," consists of an icon, front panel, and block diagram as described in [17]. In the earlier example, Figure 3.10 illustrates the icon, front panel, and block diagram for the Resolve Logout VI. VI front panels offer a familiar user interface using buttons, numeric controls, lamps, dials, and other, graphically represented controls and indicators. Its block diagram describes program logic in a schematic form familiar to engineers. Icons represent functions embedded within the block diagram logic. Lines called "wires"

connect icons together relating the outputs of one function to the inputs of the next. Therefore, icons provide the means for a VI to use another function, referred to as a "sub-VI," within its block diagram. Using the wires connected to the icon, a "calling" VI manipulates a sub-VI's controls and receives results from its indicators

Given this relationship, the NDT exists as a collection of LabVIEW VIs and sub-VIs created within the Cleanroom discipline. Its design organizes the procedure into the hierarchical form shown in Figure 4.1. Names listed within each block associate a function with its primary VIs. A primary VI and its sub-VIs create the function by interacting with the operator, manipulating ATF instruments, and processing test information.

NDTmain, shown in Figure 4.2, sits at the top of the VI hierarchy and manages the flow of control through the NDT functions. Sub-VIs receive control from NDTmain, perform their designated task, and return status information. The sub-VIs are responsible for reporting errors to the operator and resolving non-critical error events; consequently, errors reported to NDTmain are serious and abort the procedure. In the absence of serious malfunctions, the procedure advances through the test script, passing control to the sub-VIs in its hierarchy. Operator selection of

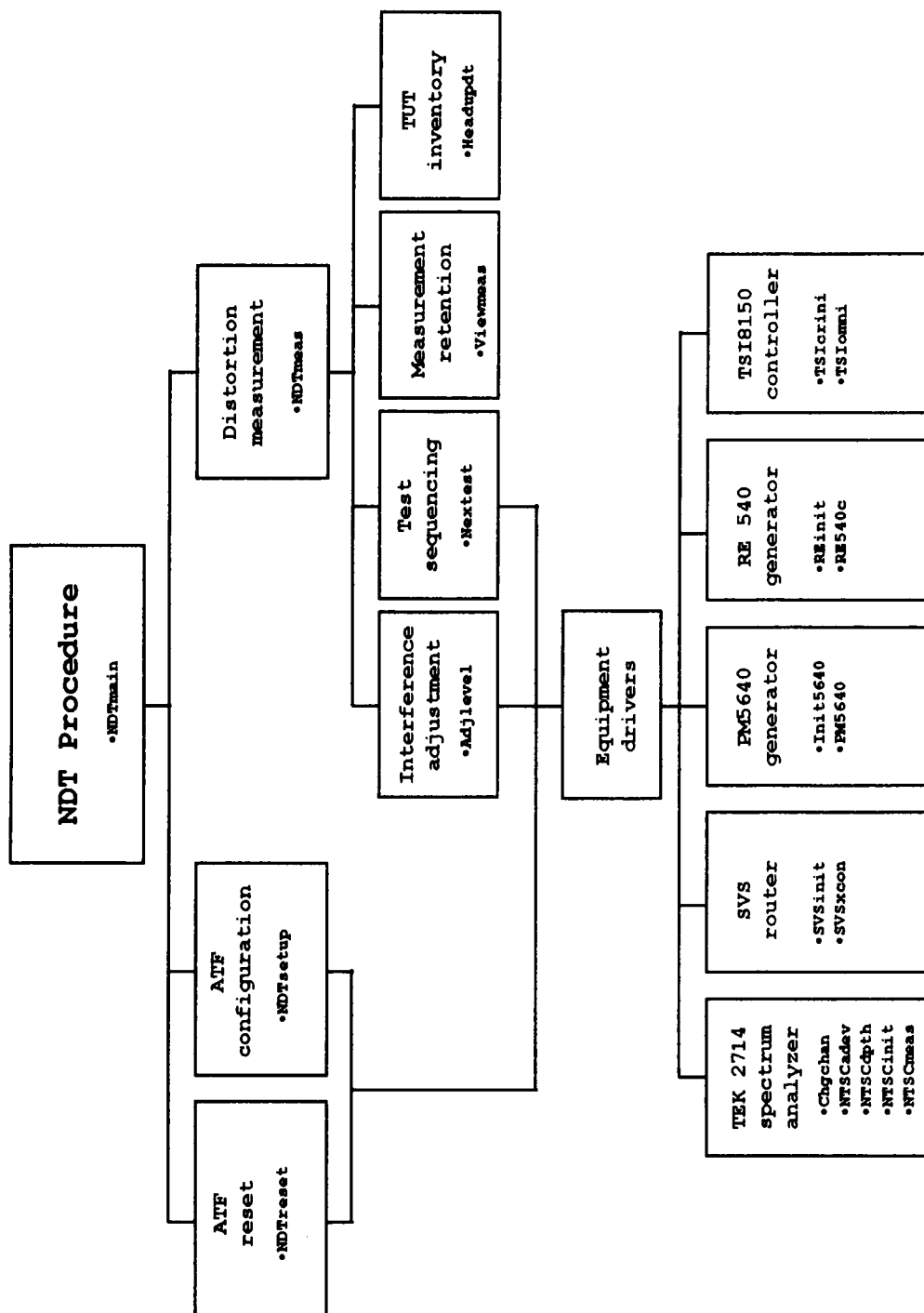


Figure 4.1 NDT function hierarchy

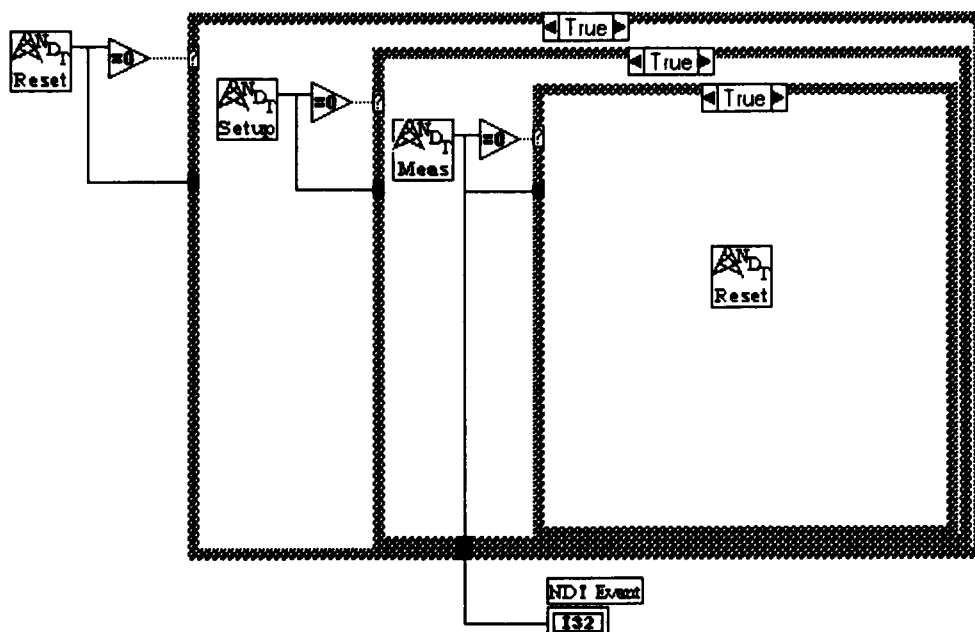
Nonlinear Distortion Test Procedure

Please stand by. The Nonlinear Distortion Test procedure is modifying the ATF system setting in preparation for distortion measurements.

NDT Event

0

(a) Front panel



(b) Block diagram

Figure 4.2 NDTmain VI

either "Quit" or "Logout," found in Figure 3.4, returns control to the ATF procedure selection menu.

Each NDT function consists of a set of VIs designed to work together to perform a desired task. User interface VIs detect operator selections, interact with other VIs for information, and respond to the operator with new displays and error messages. Instrument control VIs, called "drivers," adjust ATF settings, collect measurements, and assess equipment status. Procedure control VIs, positioned between the user interface VIs and the drivers, act upon operator selections, coordinate driver actions, and analyze measurement information in the manner prescribed by the NDT test script.

When NDT VIs take control of the ATF, the system executes Figure 4.3 placing the ATF in an idle state, creating the NDT broadcast environment, and recording four measurements for each TUT. Numerous cross-checks embedded with the VIs ensure orderly control flow, intuitive operator interaction, and rational responses to error conditions. Each step in the NDT procedure plays a role in reliable distortion measurement.

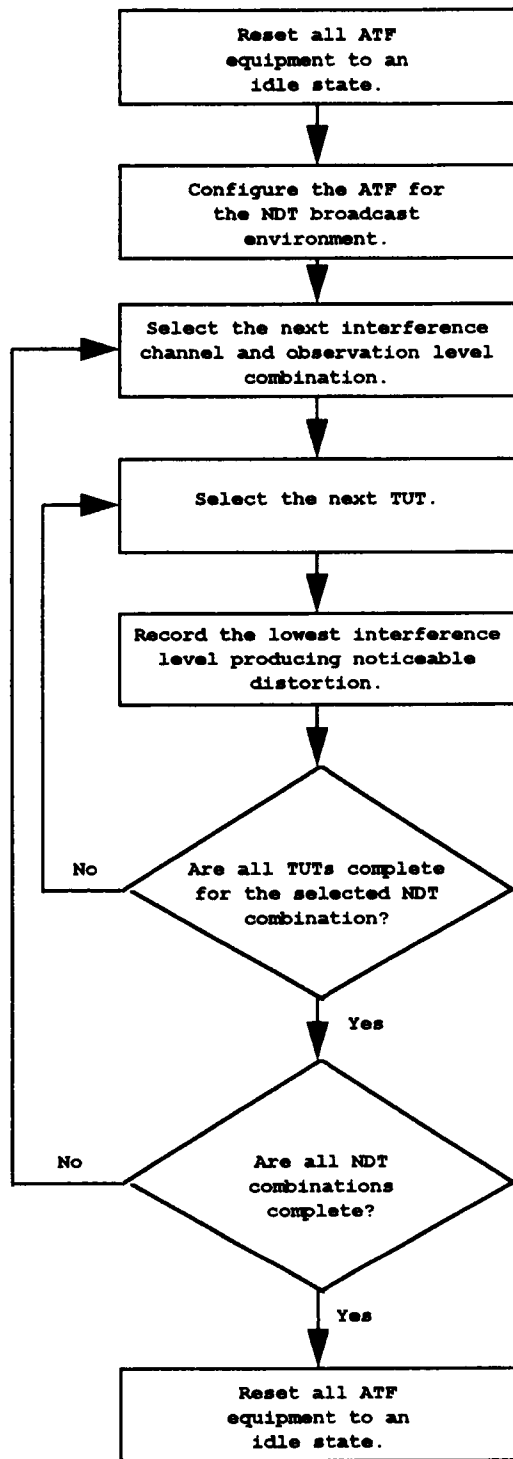


Figure 4.3 Test selection algorithm

4.1 NDT Environment Control

For instance, the NDT must be resilient to many possibilities when taking control of the ATF equipment. Power outages, maintenance actions, system malfunctions, and other events may place ATF instruments in undesirable states. A VI called NDTreset, Figure 4.4, calls upon instrument drivers to reset the ATF system to an idle state. Drivers SVSinit, Init5640, REinitc, and TSIcrini send GPIB commands to the SVS router, Philips PM5640 video generator, RE 540 audio generator, and TSI8150 controller, respectively, resulting in

- the RE 540 generating a 1000 Hz sine wave
- an SMPTE color bar pattern emanating from the Philips PM5640 video generator
- all modulators connected to unmodulated audio and video sources, referred to as "quiet" sources
- all modulator pads set to maximum attenuation

By convention, all procedures must return the ATF system to the idle state upon completing measurements. NDTmain complies with the convention by recalling NDTreset whenever the operator selects "Quit" or "Logout."

As soon as the system achieves an idle state, other NDT VIs prepare the ATF for distortion measurements. NDTsetup

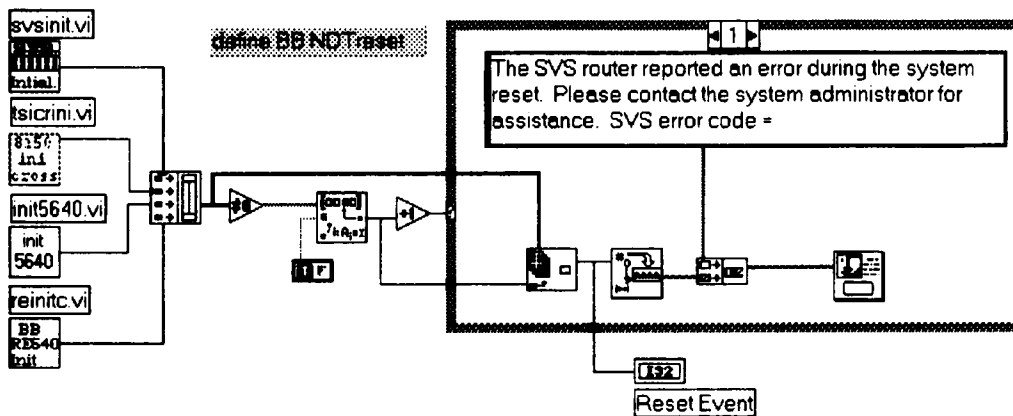
NDT Equipment Reset

Please stand by. The Nonlinear Distortion Test procedure is clearing prior ATF system setting in preparation for distortion measurements.

Reset Event

0

(a) Front panel



(b) Block diagram

Figure 4.4 NDTreset VI

VI, Figure 4.5, alters instrument settings by initiating the following driver actions:

- PM5640 VI creates a gray flat field video pattern.
- RE540c VI generates a 1000 Hz audio tone.
- SVSxcon VI connects the monoscope, PM5640, and color bar video sources to Channels 9, 11, and 13, respectively.
- SVSxcon interconnects the RE 540 audio tone to Channels 9 and 13.

The NDT broadcast environment is the result consisting of one observation channel and two interference channels with IEC-prescribed modulation. NDTsetup reports equipment malfunctions to the operator and to NDTmain.

4.2 NDT Measurement Control

NDTreset and NDTsetup create the NDT broadcast environment in preparation for distortion measurements by the NDTmeas VI. NDTmeas provides the user interface panel, shown earlier in Figure 3.4, and manages the following measurement functions:

- automatic TUT and test selection
- manual TUT and test selection
- measurement retention
- TUT inventory control

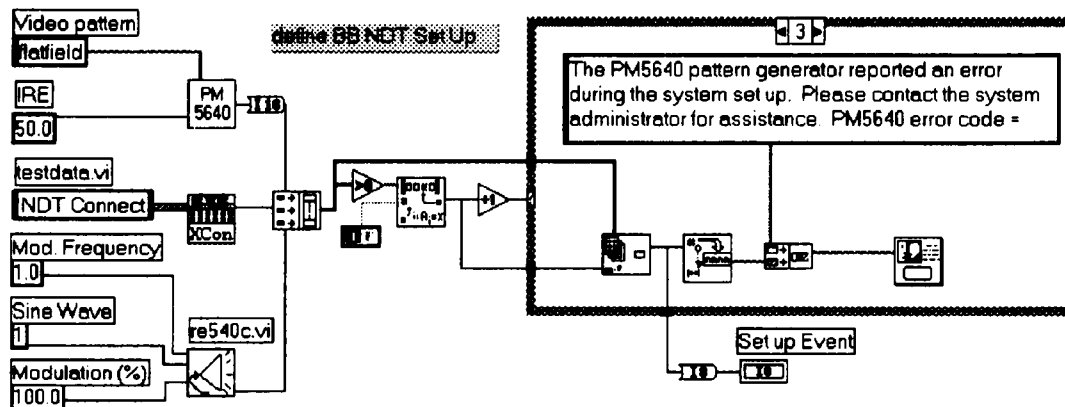
NDT Equipment Set Up

Please stand by. The Nonlinear Distortion Test procedure is modifying the ATF system setting in preparation for distortion measurements.

Set up Event

0

(a) Front panel



(b) Block diagram

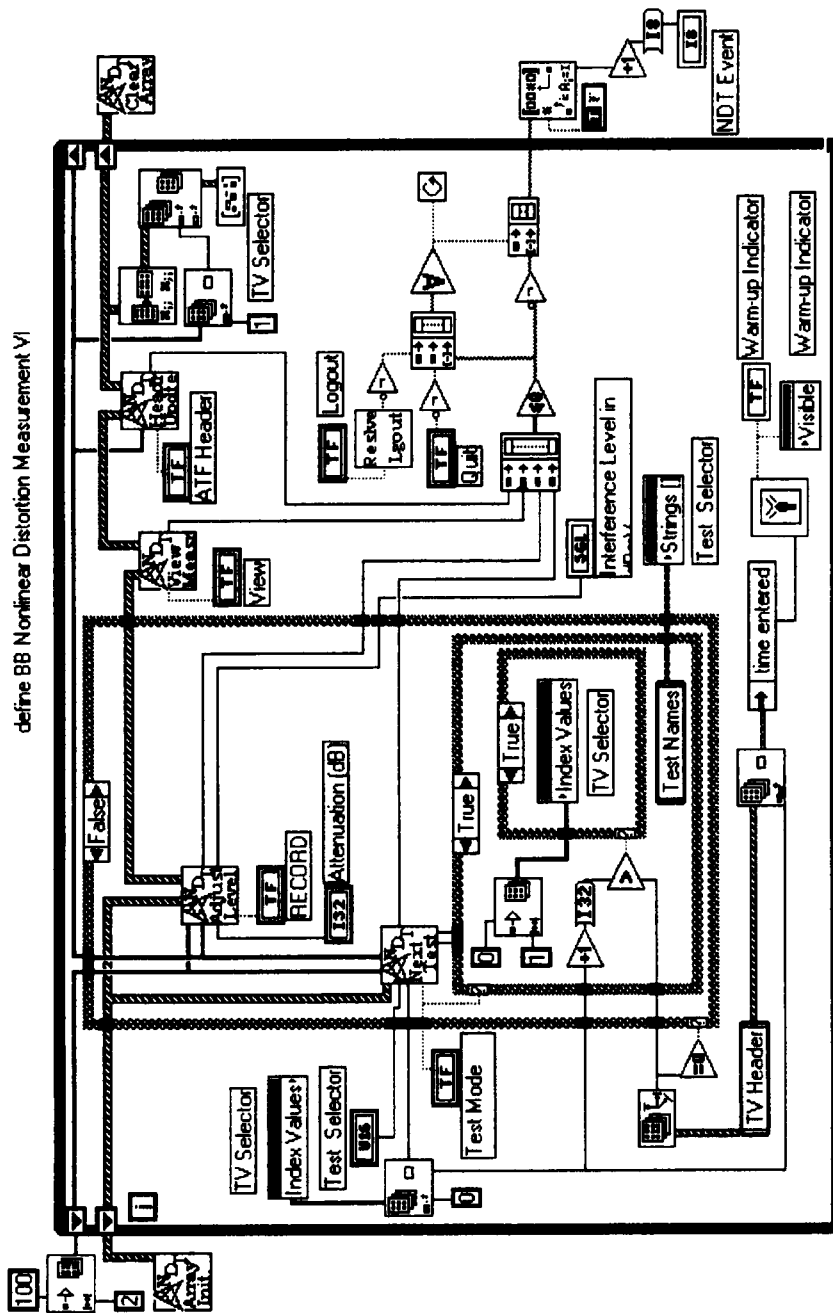
Figure 4.5 NDTsetup VI

- interference level adjustment
- measurement accuracy assurance

NDTmeas's block diagram, Figure 4.6, assigns each measurement function to a sub-VI.

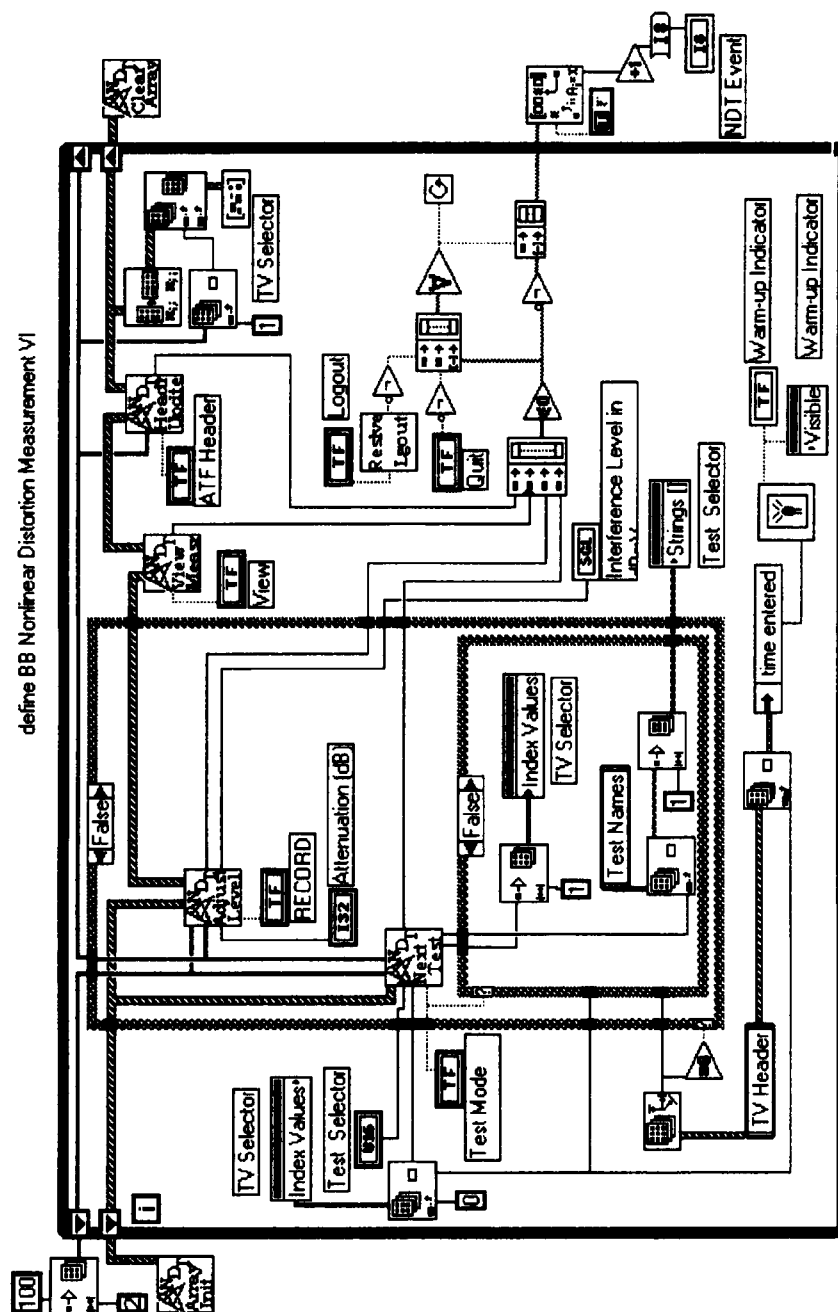
The sub-VIs exchange test information using graphical representations of shift registers. In the NDTmeas block diagram, two sets of shift registers appear as pairs of opposing arrowheads located on the left and right border of a "while loop" control structure. Information held in a shift register moves over a wire from the left arrow head, passes through intervening sub-VIs to the right arrow head, and replaces the earlier register contents. The shift register cycle repeats with each iteration of the while loop.

The lower shift register contains a two-dimensional data structure called Test Array, shown in Figure 4.7. NDT design defines a measurement as information collected for one combination of TUT, observation level, and interference channel. Elements of Test Array retain the distortion interference level and the associated measurement context (e.g., TV manufacturer, model, version, and serial number). Each array row contains four elements representing the four test combinations for a given TUT, i.e., two observation



(a) Manual mode

Figure 4.6 NDTmeas VI block diagram



(b) Automatic mode

Figure 4.6 NDTmeas VI block diagram (Continued)

Test Array

0	Brand	Model
0	UTK	Volunteer
	Screen Size	Version
	19.0	3
	Serial No.	Outlet
	1794-1994	31
	Intrf. Lvl.	Valid Data?
	-16.0	☐
	Data Stored?	Time Stamp
	☐	45249851
	Test Name	
	Ch. 9 on 11 at 1 mV	

Figure 4.7 Test Array control

levels and two interference channels taken in combination. There are as many rows as there are TVs in the TUT inventory.

The upper shift register holds a pair of indices, called Test Pointer, defining the measurement in progress and its associated Test Array element, referred to as the "active element." NDT sub-VIs use the Test Pointer to retrieve the active element, act upon operator selections and driver responses, and update the contents of Test Array. Test Array and Test Pointer information circulate from the shift registers, through the sub-VIs, and back to the shift registers so long as NDTmeas is active. Selections of "Quit" or "Logout" terminate the while loop and return control to NDTmain.

4.2.1 Experiment Selection

Under the NDT procedure, ATF operators perform four experiments, called "tests," for each TUT. Each test imposes different broadcast conditions and records the minimum interference carrier level creating noticeable distortion in the TV display. NDT software collects the four test measurements into a nonlinear distortion profile and enters the profile into the competitive analysis data base. Available modulator output power limits the number of

televisions under test at any given time; for instance, the modulators used in this study permitted observation of four TVs at one time.

An NDT "Mode" switch offers two options for conducting measurements across a set of TVs. Automatic mode takes control of test and TV selection advancing to the next combination after each measurement. During the course of testing, operators frequently re-examine results by comparing new observations with previous measurements. Manual mode permits the operator to suspend automatic measurement and select the TV and test combination. The measurement modes offer the efficiency of automation and the flexibility of selective testing.

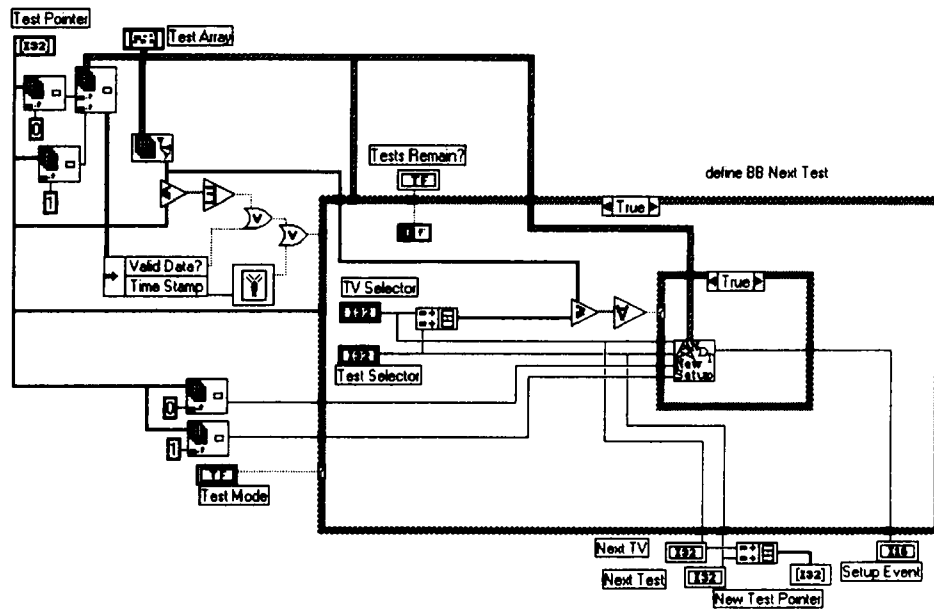
Nextest VI creates the automatic and manual modes offered by the "Mode" switch. "Mode" selections, the Test Pointer, and the Test Array enter Nextest through its front panel controls, Figure 4.8(a), and an updated Test Pointer returns via the "New Test Pointer" indicator. Within NDTmeas, "New Test Pointer" replaces the contents of the Test Pointer shift register, thereby advancing the measurement process to the next element in Test Array. Nextest uses different algorithms for computing New Test Pointer depending upon the "Mode" setting.

Next Manual or Automatic Test

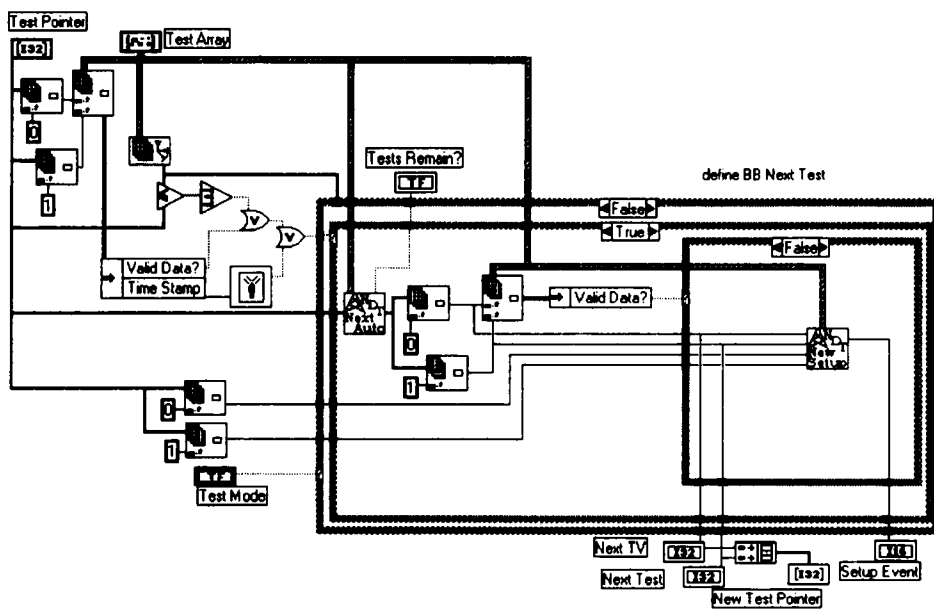
TV Selector	Test Pointer	Next TV																								
0	0 100	0																								
Test Selector	Test Array	Next Test																								
3	<table border="1"> <tr> <td>Brand</td> <td>Model</td> </tr> <tr> <td>UTK</td> <td>Volunteer</td> </tr> <tr> <td>Screen Size</td> <td>Version</td> </tr> <tr> <td>19.0</td> <td>3</td> </tr> <tr> <td>Serial No.</td> <td>Outlet</td> </tr> <tr> <td>1794-1994</td> <td>31</td> </tr> <tr> <td>Intr. Lvl.</td> <td>Valid Data?</td> </tr> <tr> <td>-16.0</td> <td>☐</td> </tr> <tr> <td>Data Stored?</td> <td>Time Stamp</td> </tr> <tr> <td>☐</td> <td>45249851</td> </tr> <tr> <td>Test Name</td> <td></td> </tr> <tr> <td>Ch. 9 on 11 at 1 mV</td> <td></td> </tr> </table>	Brand	Model	UTK	Volunteer	Screen Size	Version	19.0	3	Serial No.	Outlet	1794-1994	31	Intr. Lvl.	Valid Data?	-16.0	☐	Data Stored?	Time Stamp	☐	45249851	Test Name		Ch. 9 on 11 at 1 mV		0
Brand	Model																									
UTK	Volunteer																									
Screen Size	Version																									
19.0	3																									
Serial No.	Outlet																									
1794-1994	31																									
Intr. Lvl.	Valid Data?																									
-16.0	☐																									
Data Stored?	Time Stamp																									
☐	45249851																									
Test Name																										
Ch. 9 on 11 at 1 mV																										
Test Mode	New Test Pointer	Tests Remain?																								
☒ Automatic	0 0	☐																								
		False																								
	Setup Event																									
	0																									

(a) Front Panel

Figure 4.8 Nextest VI



(b) Manual mode block diagram



(c) Automatic Mode block diagram

Figure 4.8 Nextest VI (Continued)

In manual mode, operators specify the broadcast and TUT combination using the "Test Selector" and "TV Selector" controls, respectively. In Figure 4.8(b), operator selections create corresponding values for Test Pointer as computed by Nextest. As the operator's selections change, Nextest calls upon the Newsetup VI to alter the observation level and active interference channel combination.

Improved measurement efficiency is possible by observing the practical behavior of televisions. For a given observation level, i.e., 1 or 4 mV, competitive televisions exhibit nonlinear distortion within a relatively narrow range of interference level settings and are relatively insensitive to the interference channel selection. On the other hand, altering the observation level will cause the interference range to move significantly. Judicious ordering of TUT, observation level, and interference channel combinations reduces the number of large interference level adjustments and speeds the measurement process.

In Figure 4.8(c), Nextest's block diagram automates measurement selection by taking charge of the "Test Selector" and "TV Selector" controls. A VI called Nextauto computes the Test Pointer according to the steps listed below.

1. Nextauto selects measurements across all TUTs for a broadcast environment consisting of a 1 mV observation level and active interference Channel 9.
2. Measurements repeat across all TUTs for interference Channel 13 and the same observation level.
3. Steps 1 and 2 repeat for a new observation level of 4 mV.

Note, the algorithm steps match those in the NDT test script. As Nextauto advances through the test combinations, Newsetup alters the observation level and interference channel using the Test Pointer and Test Array as its guide. With each new manual or automatic mode selection, NDTmeas displays the active TUT in the "TV Selector" control and the test description in the "TV Selector" control.

4.2.2 Interference Level Control

During the procedure, operators direct their attention to the distortion patterns appearing in the TUT's gray screen. Adjusting the "Attenuation" slide control sends new values to the Adjlevel front panel, Figure 4.9. In its block diagram, Adjlevel computes a new interference level from the control setting and a reference level supplied by the ATF behavioral model VI called Losslvl.

Adjust Interference Level

Test Pointer

New Test Pointer

Attenuation

Record
☒

Intf. Level

Adjust Event

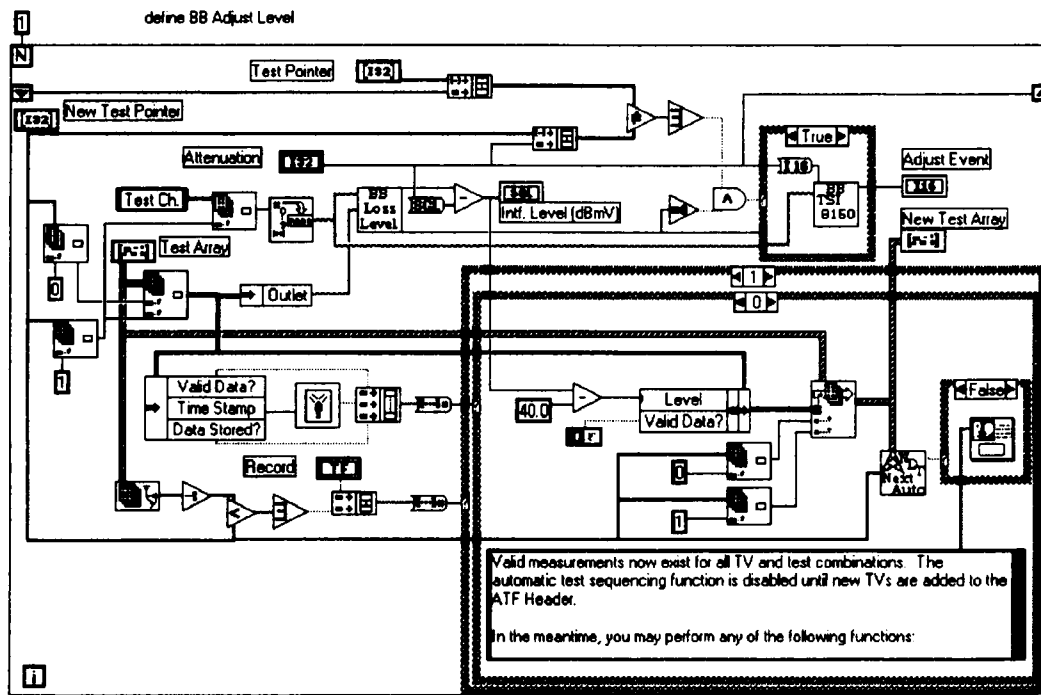
Test Array

Brand	Model
UTK	Volunteer
Screen Size	Version
19.0	3
Serial	Outlet
1794-1994	31
Level	Valid Data?
-Inf	☒
Date Stored?	Time Stamp
☒	45249851
Test Name	
Ch. 9 Audio on 11 at 1 mV	

New Test Array

Brand	Model
UTK	Volunteer
Screen Size	Version
19.0	3
Serial	Outlet
1794-1994	31
Level	Valid Data?
-Inf	☒
Date Stored?	Time Stamp
☒	45249851
Test Name	
Ch. 9 Audio on 11 at 1 mV	

(a) Front panel



(b) Block diagram

Figure 4.9 Adjlevel VI

Losslvl provides Adjlevel with the unattenuated reference level arriving at the TUT coaxial outlet. Adjlevel subtracts the "Attenuation" setting from the reference level displaying the result in the "Intf. Level (dBmV)" indicator. At the same time, Adjlevel sends "Attenuation" setting to the TSI8150 driver along with the interference channel number. TSI8150 adjusts the interference channel pad to the specified attenuation.

Adjlevel responds to the "Record" button by storing the interference level in the Test Array indicator labeled "Level." It notes the presence of a recorded measurement by setting the "Valid Data?" semaphore true. Many NDT VIs use "Valid Data?" and its counterpart "Data Stored?" to detect the presence of recorded measurements in the Test Array and in the competitive analysis data base, respectively. In the case of Adjlevel, the VI responds to the semaphores by

- asking for confirmation prior to overwriting previously recorded measurement as indicated by "Valid Data?"
- refusing attempts to duplicate entries in the competitive analysis data base as indicated by "Data Stored?"
- alerting the operator to add new TVs when measurements exist for all TVs in the TUT inventory

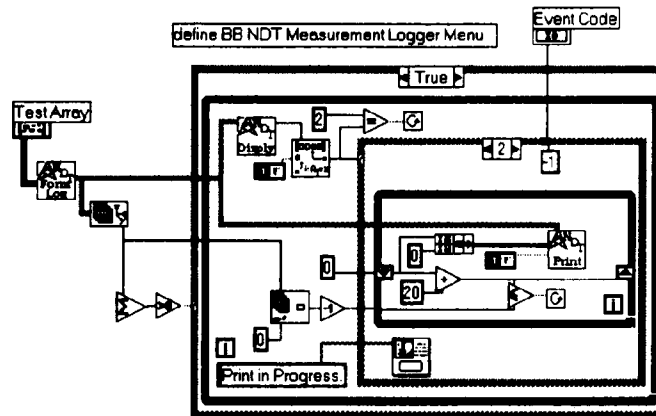
4.2.3 Measurement Retention

Every selection of "Record" creates new information ready for operator displays, printed reports, and entry into the competitive analysis data base. Selection of the "View" button activates the measurement retention VIs called Viewmeas and NDTloggr. Viewmeas submits the latest Test Array contents to NDTloggr's front panel, shown in Figure 4.10. Within the NDTloggr block diagram, Formlog VI extracts recorded measurements from Test Array and creates a two-dimensional array of measurement information. Each row represents a measurement containing one distortion measurement and its associated context. NDTview presents the records in the NDT measurement display, shown earlier in Figure 3.6. "Print" sends the records to NDTprint producing a report on the Sparcstation printer. Selecting "Save" activates the Logmeasr VI and enters the measurements into the data base. Upon receiving control back from NDTlogger, Viewmeas's block diagram, Figure 4.11, sets the "Data Stored?" semaphore true for all measurements entered into the data base. NDT VIs will reject attempts to duplicate measurements for a given TUT and broadcast combination once the "Data Stored?" semaphore is set. Selecting "Cancel" returns the operator to the NDTmeas front panel and readies the system for additional measurements.

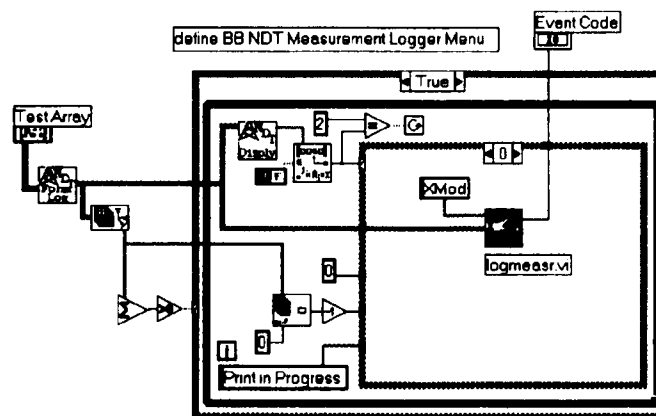
NDT Data Logger

Test Array		Event Code
0	Brand	0
0	Model	
	Screen Size	
19.0	Version	
	Serial No.	
1794-1994	Outlet	
	Level	
	Valid Data?	
	Data	
	Time Stamp	
	Test Name	
	Ch. 9 Audio on 11 at 1	

(a) Front panel



(b) "Print" block diagram



(c) "Save" block diagram

Figure 4.10 NDTloggr VI

View Measurements

View

Logger Event

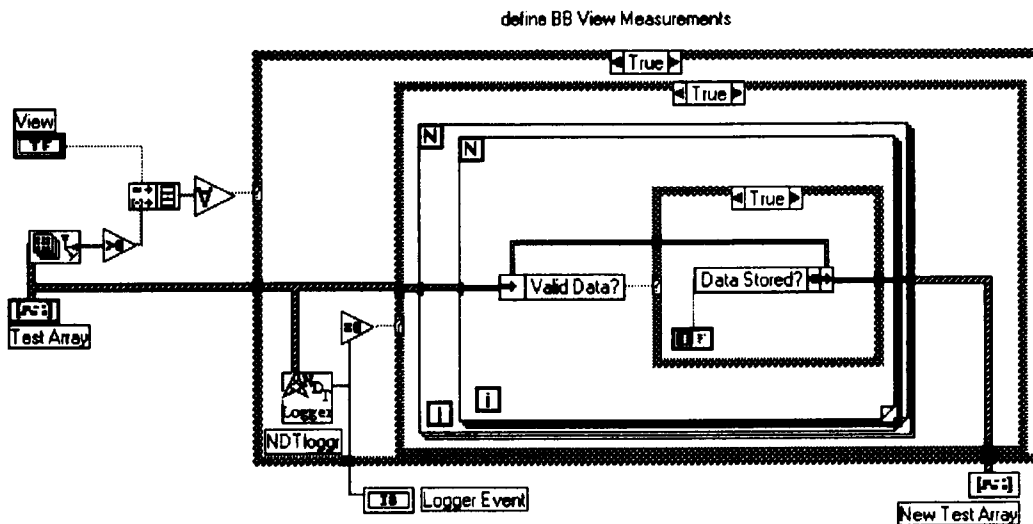
Test Array

Brand	Model
UTK	Volunteer
Screen Size	Version
19.0	3
Serial No.	Outlet
1794-1994	31
Level	Valid Data?
-Inf	☐
Data	Time Stamp
☐	45249851
Test Name	
on 11 at 1	

New Test Array

Brand	Model
UTK	Volunteer
Screen Size	Version
19.0	3
Serial No.	Outlet
1794-1994	31
Level	Valid Data?
-Inf	☐
Data	Time Stamp
☐	45249851
Test Name	
Ch. 9 Audio	

(a) Front panel



(b) Block diagram

Figure 4.11 Viewmeas VI

4.2.4 TUT Inventory Control

NDTmeas operates on an inventory of TUTs retained in an array called TV Header, shown in Figure 4.12. Periodically, ATF operators replace TUTs and must amend the inventory to reflect the new television complement.

Operators alert NDTmeas to TUT inventory changes by selecting the "ATF Header" button. Within NDTmeas's block diagram, Headupdt detects the selection and begins the process of amending the contents of TV Header. Headupdt accepts the latest Test Pointer and Test Array through its front panel connectors shown in Figure 4.13. In its block diagram, an ATF utility VI called Header presents the TUT inventory display shown in Figure 3.5. Operators add and delete TVs from the inventory by making the appropriate entries in the Header front panel. When operators select "Done," they initiate the following actions within Headupdt:

- Sortest VI updates Test Array by adding measurement elements for new TVs and extracting elements orphaned by deleted TVs.
- Orphaned Test Array elements pass to NDTloggr where the operator may view, print, and save measurements associated with TVs removed from the inventory.

TV Header															
0	<table><tr><td>Brand</td></tr><tr><td>UTK</td></tr><tr><td>Model</td></tr><tr><td>Volunteer</td></tr><tr><td>Screen Size</td></tr><tr><td>19.0</td></tr><tr><td>Version</td></tr><tr><td>3</td></tr><tr><td>Serial #</td></tr><tr><td>1794-1994</td></tr><tr><td>RF Outlet</td></tr><tr><td>31</td></tr><tr><td>time entered</td></tr><tr><td>45249851</td></tr></table>	Brand	UTK	Model	Volunteer	Screen Size	19.0	Version	3	Serial #	1794-1994	RF Outlet	31	time entered	45249851
Brand															
UTK															
Model															
Volunteer															
Screen Size															
19.0															
Version															
3															
Serial #															
1794-1994															
RF Outlet															
31															
time entered															
45249851															

Figure 4.12 TV Header array control

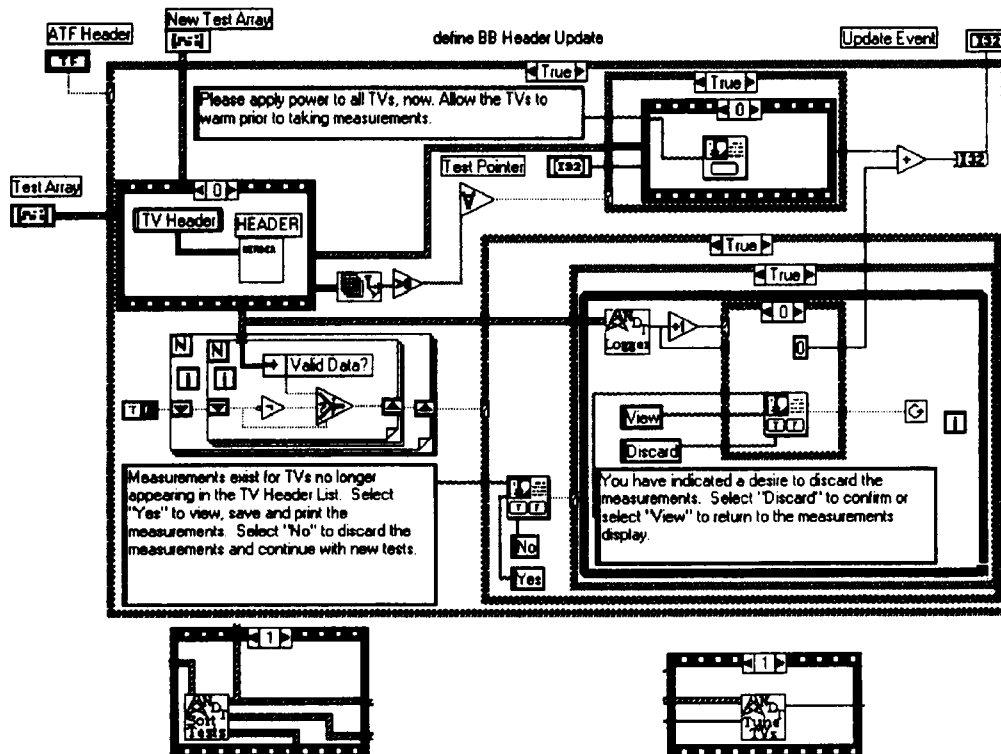
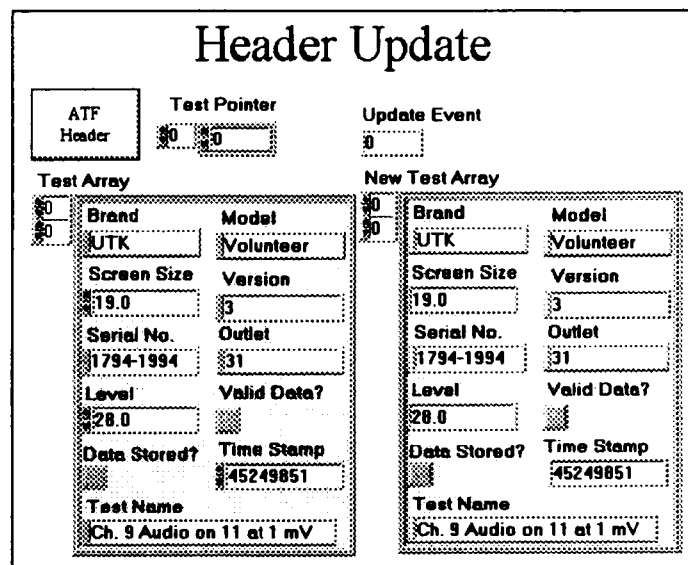


Figure 4.13 Headupdt VI

- Headupdt instructs the operator to apply power to recent additions and to wait fifteen minutes before taking measurements.
- TuneTVs requests new TVs be tuned to Channel 11, the observation channel.

Headupdt returns a new complement of elements through the indicator "New Test Array." "New Test Array" replaces the contents of NDTmeas's Test Array shift register, thereby, notifying all NDT VIs of the new TV configuration.

Thus, the NDT procedure and its sub-VIs manage an inventory of TUTs, select a TV from the inventory, prepare it for distortion tests, and collect the resulting measurements. Many of its sub-VIs are unique, such as those defining the automatic test selection algorithm. On the other hand, the NDT and other ATF procedures have common functional needs creating an opportunity for reusable sub-VIs.

CHAPTER 5

ATF DRIVERS AND UTILITIES

ATF procedures generally call for similar functions for frequently performed tasks. Designers could recreate these functions within all of the test procedures. However, the ATF goal of improved design productivity suggests the procedures draw from a common resource of utility VIs and equipment drivers. Therefore, ATF test designers identify recurring functions during the course of procedure development, reduce the functions to generic VIs useful across more than one procedure, and collect the VIs into a common pool called a "VI library."

In the broadest sense, National Instruments (NI) supplies a library of frequently used functions with the LabVIEW language [18]. NI's library includes several VIs facilitating communication with test instrument via the GPIB bus [19]. National Instruments describes GPIB and other library functions in manuals accompanying the LabVIEW language.

ATF system designers augment NI's libraries by creating a pool of generic VIs used in many of the ATF test

procedures. Figure 5.1 describes the generic VIs created for various ATF procedures and used by the NDT procedure. NDT development adds Sierra Video System router and Tektronix 2714 spectrum analyzer VIs to the ATF library. For the sake of brevity and to assign appropriate authorship, the remaining sections will limit detailed discussion to those VIs created by the NDT research.

5.1 Sierra Video Systems Router Driver

IEC test procedures prescribe unique broadcast environments requiring dissimilar combinations of baseband and RF equipment. For instance, the "Cross Modulation" broadcast environment requires three different baseband signal combinations to be broadcast simultaneously upon three different NTSC carriers. Test engineers create the broadcast environments by interconnecting the needed instruments into the desired broadcast configuration. Frequent reconfiguration of the environment becomes a manpower intensive and error prone activity. Sierra Video Systems routers automate instrument reconfiguration by connecting baseband signal sources to corresponding baseband sinks under ATF software control [20].

VI Name	Functional Description
Init5640	resets the Philips PM5640 video generator and produces a standard color bar pattern.
PM5640	Sets the Philips PM5640 video generator to the specified video pattern and modulation level.
REinit	Resets the RE 540 Stereo Audio Generator and produces a 1000 Hz, sine wave at a level equivalent to 100% NTSC audio modulation.
RE540c	Sets the RE 540 audio generator to the specified wave form and audio modulation.
TSIcrini	Sets all modulator pads to maximum attenuation.
TSIomni	Varies individual modulator attenuation to levels specified in dB.
Warm	Detects "cold" televisions by comparing the Test Array "Time Stamp" with the Sparcstation internal clock.
Header	Displays, adds, and deletes TVs from the TUT inventory as directed by the operator.

Figure 5.1 Shared VI descriptions

As shown in Figure 5.2, SVS routers consist of up to three independent switching matrices called levels and provide virtual connections from any input to any output on the same level. Each level has an equal complement of input and output ports constructed for interconnecting baseband audio or video components. For example, appropriate commands might connect a Channel 2 modulator attached to router output 2, level 1, and a monoscope pattern generator attached to input 5, level 1, thereby, transmitting a monoscope pattern upon the Channel 2 picture carrier. Router design does not permit interconnections between levels (e.g., level 1 outputs can not connect to inputs on level 2 or level 3). By default, router design connects all outputs to input 1 on the corresponding level unless specified otherwise by GPIB commands or manual entries made through the router's control panel. An input will accept only one signal source. On the other hand, router outputs will drive multiple signal sinks as constrained by the maximum router output power.

Internally, an SVS router refers to a port by its level and input or output number (e.g., level 1, input 12; level 3, output 5). ATF convention eases operator training by assigning names to all ATF signal sources, signal sinks, and by associating each router port with its corresponding

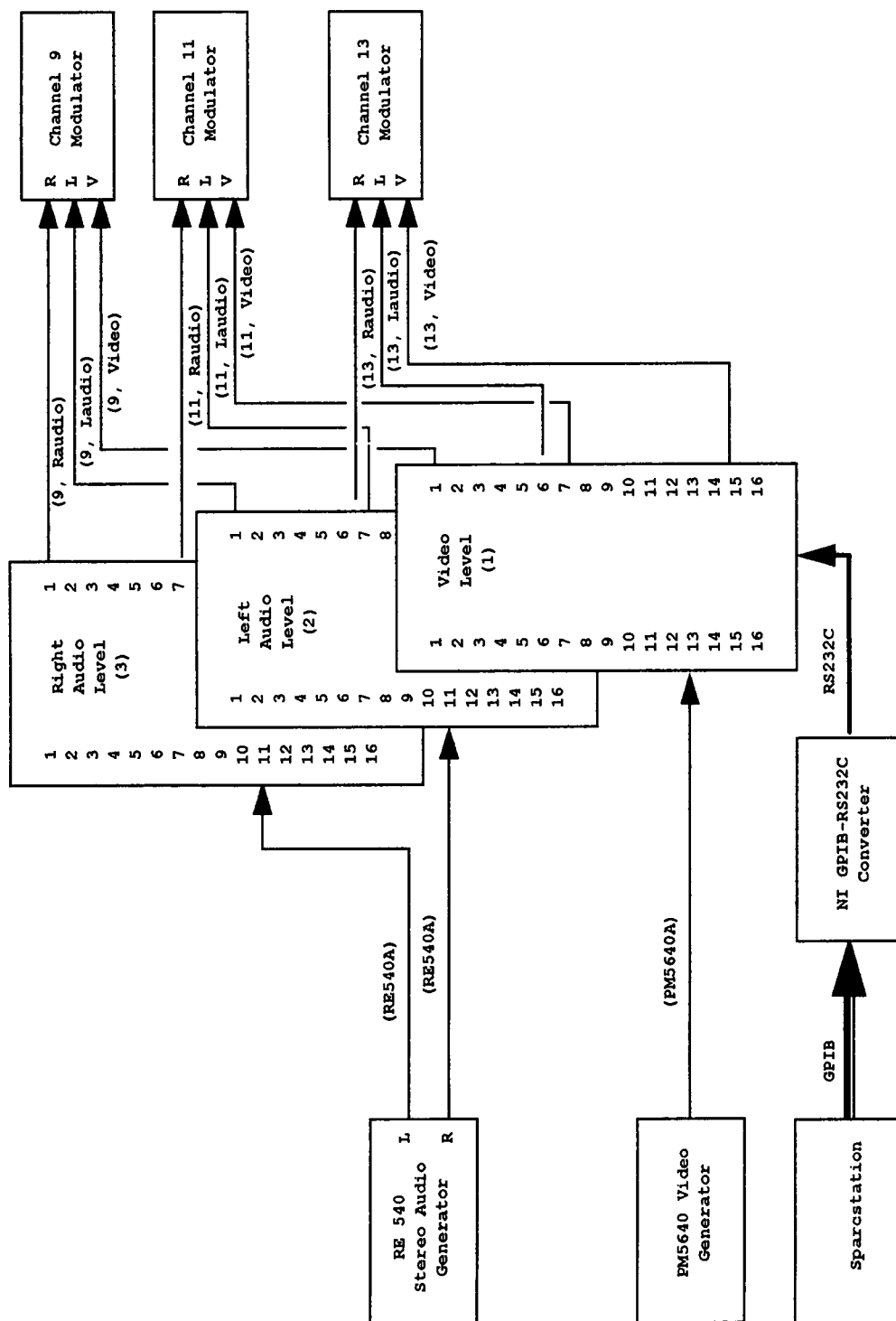


Figure 5.2 SVS router architecture

signal source or sink. For example, suppose a router receives Philips PM5640 video patterns on level 1, input 3. ATF convention might assign the router input port the name "PM5640A, Video." Note the letter "A" appended to "PM5640" permits more than one Philips PM5640 video source within the ATF. The name "Video" identifies the PM5640 as a baseband video component.

SVS software design incorporates the naming assignments into programmatic control of one or more SVS routers. ATF convention assigns router level 1 to baseband video, labeled "Video"; level 2 to left stereo channel audio or monaural audio, labeled "Laudio"; and level 3 to right stereo channel audio, labeled "Raudio." SVS router VIs, collectively referred to as the "SVS driver," translate the component and level names into the equivalent combinations of level and port addresses.

Addition of new procedures often adds new broadcast requirements and may lead to more than one SVS router within the ATF. Software design accommodates multiple routers by assigning each one a name (e.g., SVSA, SVSB).

SVS VIs use the names to direct commands to a particular router via its serial, RS232C-standard interface. The ATF communicates with the router via an NI GPIB-to-RS232C converter. Driver VIs send router commands clearing prior port interconnections, making new interconnections, and

returning router status to the Sparcstation. The interchange allows test procedures to

- restore the router to the idle broadcast configuration, i.e., all outputs connected to input 1 on their corresponding levels.
- interconnect input and output pairs as specified by their ATF names.
- report router malfunctions to the ATF operator.

A hierarchical driver design organizes the functions listed above into primary and sub-VIs as shown in Figure 5.3.

5.1.1 SVS Router Event Processing

While performing their functions, SVS VIs interact with the ATF procedures, Sparcstation UNIX software, GPIB, GPIB-RS232C converter, and SVS router. Each transaction produces feedback referred to as "events." An event may indicate successful completion of a designated task, a change in system status (e.g., application of power, operator intervention), or a router malfunction.

Events vary from instrument to instrument both in format and in the degree of detail. Events may be in the form of numeric values called "codes," text called "responses," or logical bits called "status." Instrument manufacturers do

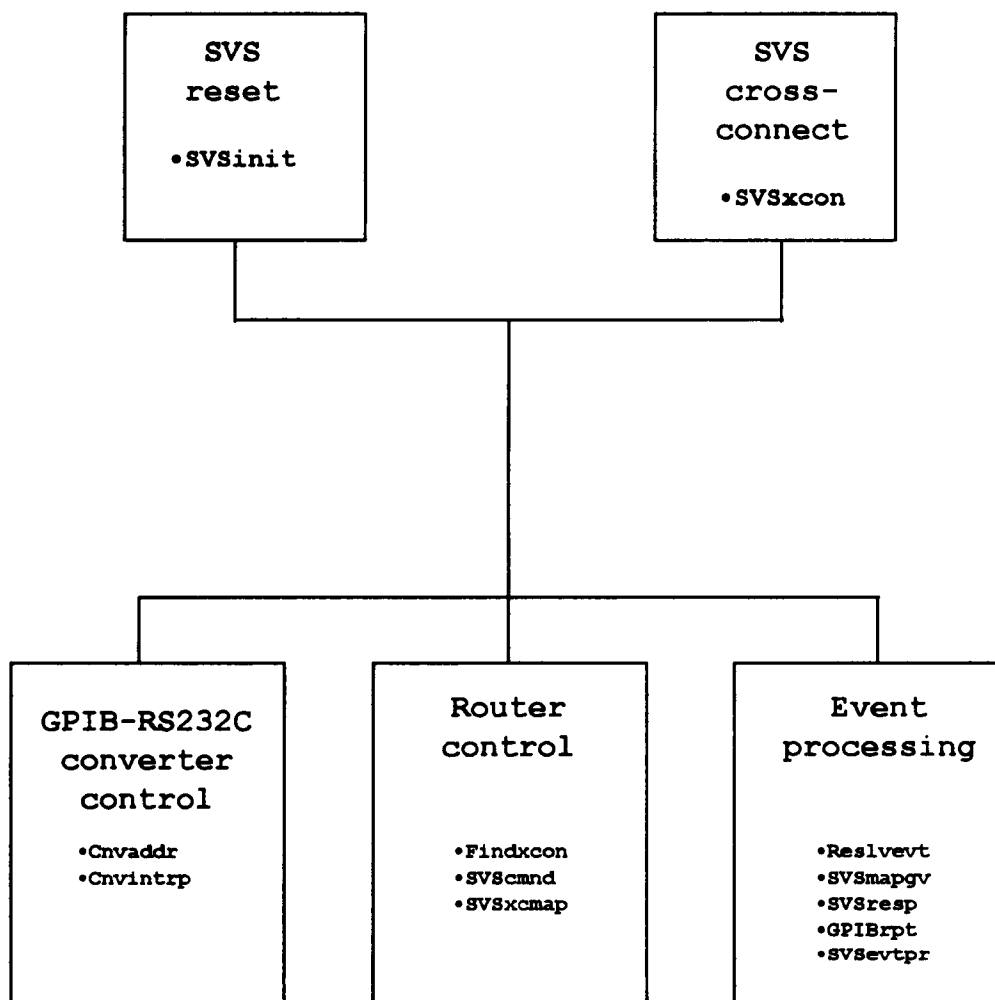


Figure 5.3 SVS router VI hierarchy

not coordinate their event formats, leading to overlapping events in one instance and disparate events in another instance. Collecting and reporting equipment status is an important part of an instrument driver's function.

Consequently, the SVS driver devotes several VIs to organizing event information into a rational form.

Driver design maps codes and responses from the converter, router, and GPIB into a coordinated set of SVS event categories using the Reslvevt VI. In Figure 5.4(a), Reslvevt accepts the UNIX codes, SVS textual responses, and GPIB status arrays as sources of events. Within its block diagram, Figure 5.4(b), a modified National Instruments VI called GPIBrpt converts GPIB status arrays into a set of GPIB codes. SVSevtpr VI translates the GPIB and other event codes into event categories using the event map VI SVSmapgv, Figure 5.5.

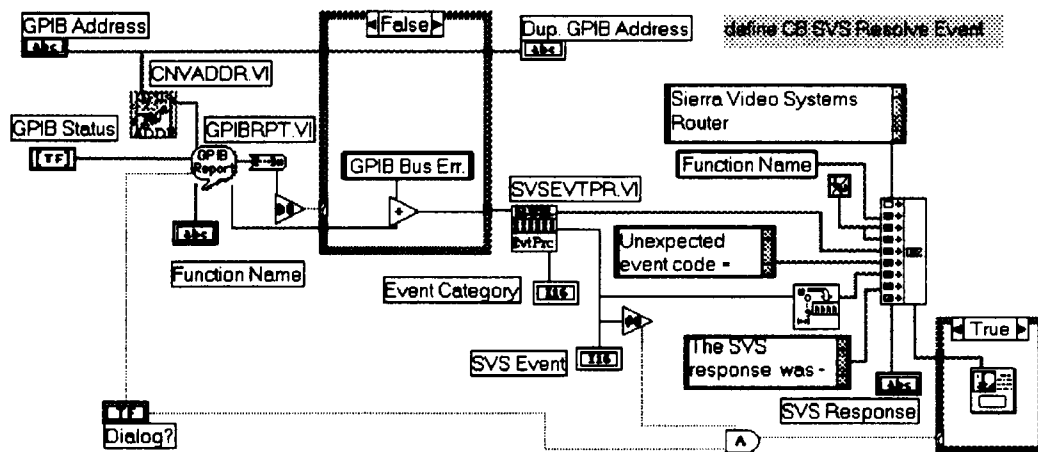
SVSmapgv groups similar events into a single category. Event categories are contiguous and relatively few in number easing the complexity of event processing by ATF procedures. For example, GPIB-RS232C converter command and argument errors span a non-contiguous range of codes from 200 to 299 [21]. SVSmapgv maps all converter command and argument events into event category 3. SVSmapgv associates a description with each category code further easing the display of operator messages.

Sierra Video System Router

Resolve GPIB, Converter and Response Events

GPIB Address 3	GPIB Status 0	Dup. GPIB Address 3
Dialog? ☐	Function Name No Name Specified	SVS Event 0
SVS Event 0		Event Category 0
SVS Response *** OK !!		

(a) Front Panel



(b) Block Diagram

Figure 5.4 Reslvevt VI

SVS Router Event Map G.V.

SVS Event Map

9	Lower 401 Upper 401 Category 8 Event Text SVS driver detected an invalid cross connect request - output,
---	---

Normal Comp.	Func. In Proc.	SVS Power-On
0	2	6
SVS Cmnd. Err.	GPIB Bus Err.	Conv. Cmnd. Err.
7	100	200
Conv. Serial Err.	SVS Driver Err.	Inv. Xcon. Req.
300	400	401
Inv. Router ID		
402		

Figure 5.5 SVSmapgv VI

Reslvevt relays the event category to test procedures as router status information. Malfunctions detected by Reslvevt produce operator messages containing the event code, category, and description. Together, Reslvevt, GPIBrpt, SVSevtpr, and SVSmapgv create a general framework for processing events as the router performs its function.

5.1.2 SVS Router Reset

By ATF convention, drivers must provide a method for returning test equipment to a known state. In the case of the router, Sierra Video Systems defines a default condition consisting of all outputs interconnected to input 1, i.e., all outputs on the Video level interconnect to Video input 1, all outputs on the Laudio level interconnect to Laudio input 1, etc. ATF convention reserves input 1 for a "quiet" signal source, that is, a source having no active video or audio signal. TV modulators connected to input 1 transmit carriers without modulation sidebands, representing an idle ATF broadcast environment.

Test procedure VIs, such as NDTreset, call upon SVSinit VI, thereby, returning the router to the idle broadcast state. Within Figure 5.6, SVSinit issues commands to the GPIB-RS232C converter clearing its internal buffers,

Sierra Video Systems Router Reset

GPIO Address

28

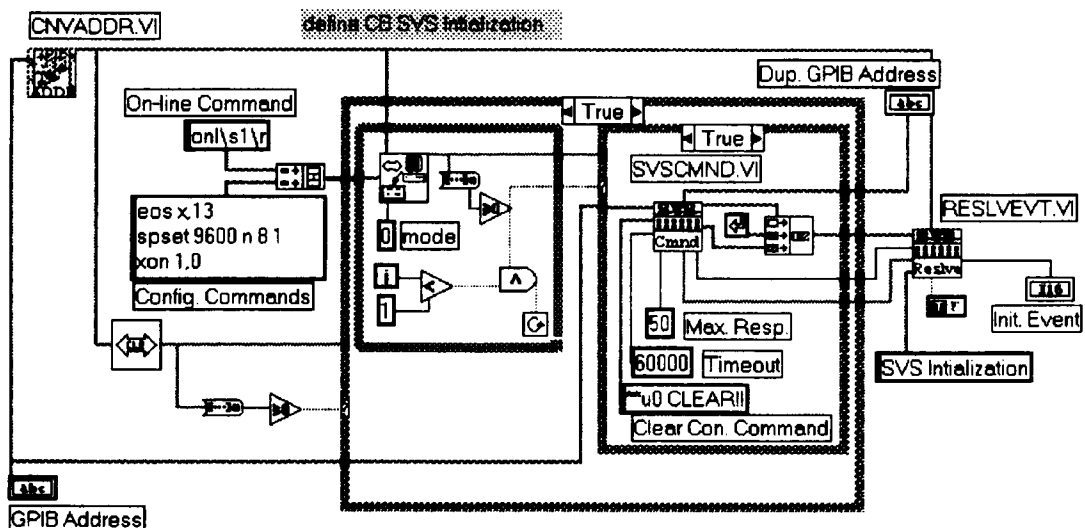
Dup. GPIO Address

28

Init. Event

0

(a) Front panel



(b) Block diagram

Figure 5.6 SVSinit VI

resetting the RS232C serial bus, and readying the converter for use by other SVS VIs. SVScmd VI sends a "***u0 CLEAR!!" command instructing the router to switch all outputs to input 1 on the corresponding levels. Reslvevt collects events from the converter, GPIB, and router producing the "Init. Event" code and operator messages as appropriate to the situation. SVSinit relays the "Init. Event" code to test procedures as router status. Typically, router malfunctions reported in this manner will abort the test procedure and request router repairs. Normal completion of SVSinit readies the router for use by a test procedure.

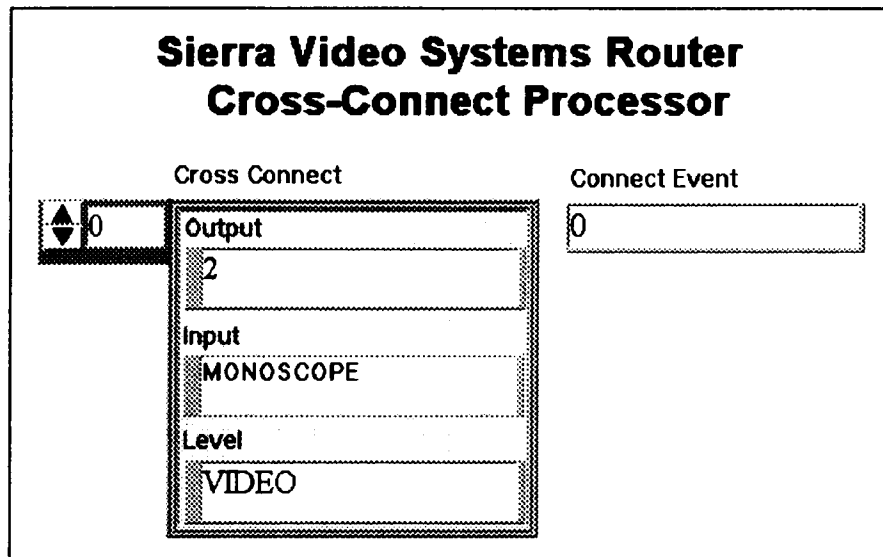
5.1.3 SVS Router Interconnection

As mentioned earlier, ATF convention assigns names to system components and ATF software adopts the convention by referring to instruments by their name. For example, convention assigns the names "10" to TV Channel 10 modulator, "RE540A" to the primary RE 540 audio generator, and "Monoscope" to the dedicated monoscope pattern generator. Some instruments deal with more than one type of baseband signal. For example, an ATF video CD player, named "VideoCD," produces baseband video, left audio, and right audio signals. Test procedures request broadcast interconnections by specifying the component name and signal

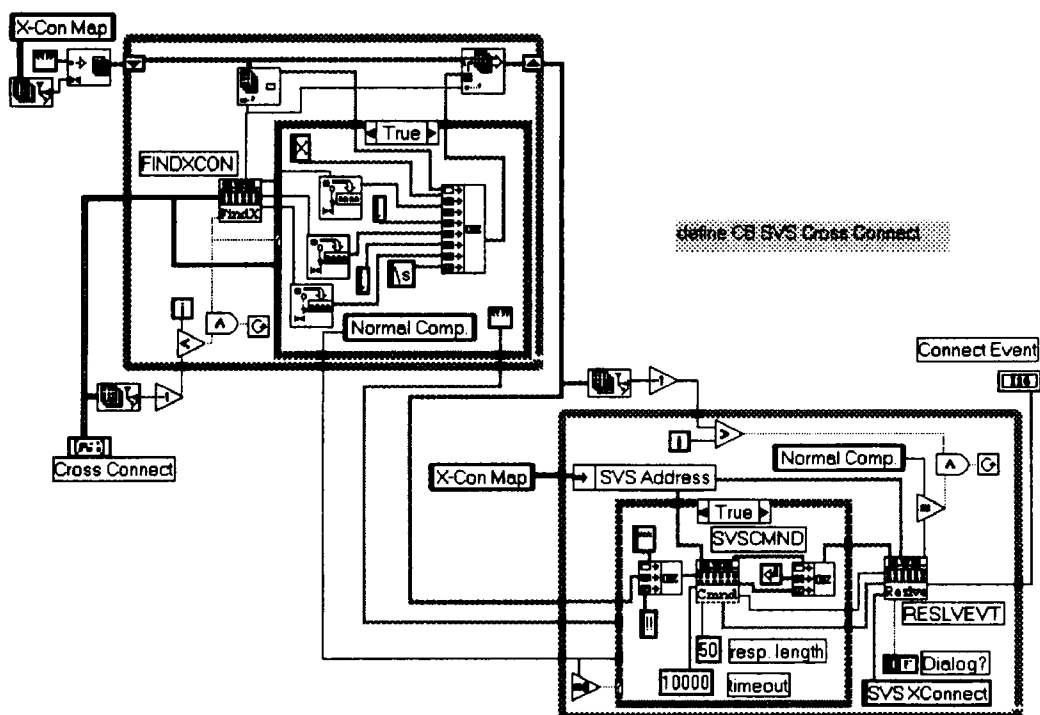
type (e.g., "VideoCD, Laudio" refers to the CD left audio source).

SVSxcon VI accepts one or more interconnection requests, commonly referred to as a "Cross-connect," through its front panel, Figure 5.7(a). Test procedures create interconnections by entering one or more elements in the array control labeled "Cross-connect" specifying the router output, input, and level by using the corresponding signal source, sink, and type names. A "Connect Event" indicator reports the progress of the interconnections to the requesting procedure. For example, the front panel in Figure 5.7 requests a cross-connect between a monoscope video source and Channel 2 modulator sink.

Within the SVSxcon block diagram, Figure 5.7(b), Findxcon VI translates each "Cross-connect" element into the corresponding router level, input, and output numbers using an interconnection map called SVSxcmap, Figure 5.8. "Level Map" control contains an array element for every SVS router in the ATF and each element defines the name assigned to the router, its GPIB address, and the names assigned to its ports. In Figure 5.9(b), Findxcon searches SVSxcmap for the input and output specified by a "Cross-connect" element returning the corresponding router, output, input, and level number in its indicators as shown in Figure 5.9(a).



(a) Front panel



(b) Block diagram

Figure 5.7 SVSxcon VI

Sierra Video Systems Router Cross Connect Map

X-Con Map

0

SVS Router Element

SVS Name
SVSA

SVS Address
28

Level Map

1

Map Names

Level
VIDEO

Output Map

2

Output
2
69

Input Map

5

Input
MONOSCOPE

Figure 5.8 SVSxcmap interconnection control

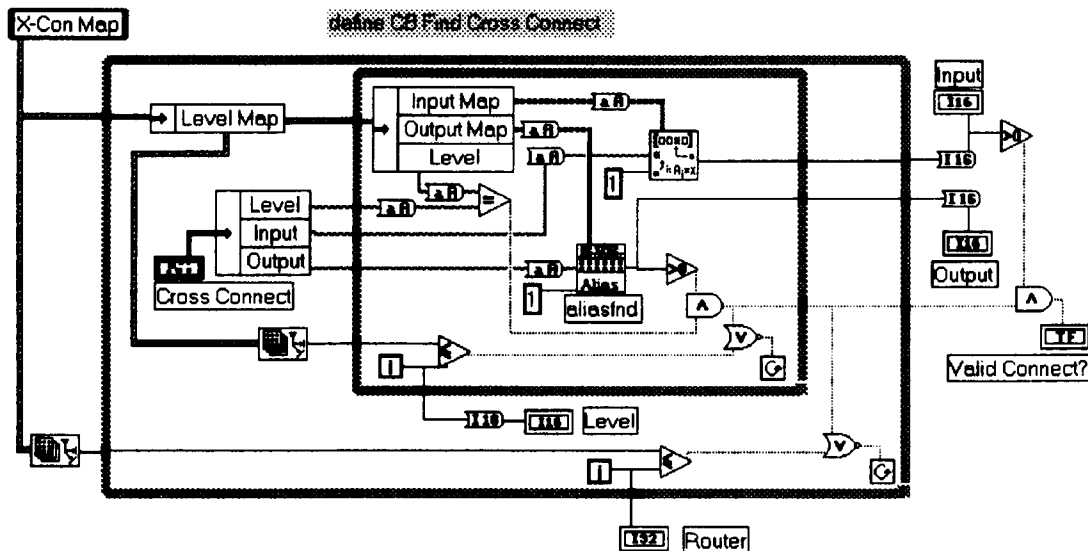
Sierra Video Systems Router Find Cross Connections

Cross Connect Output 2 Input MONOSCOPE Level VIDEO	Router 0 Output 2 Input 5 Level 1
---	--

Valid Connect?

ON

(a) Front panel



(b) Block diagram

Figure 5.9 Findxcon VI

The earlier example requests an interconnection from Channel 2 modulator video sink to a monoscope video source. Findxcon translates the request into an interconnection from output 2 to input 5 within router 0, level 1. SVSxcon constructs the router command "**X2,5,1!! using the Findxcon response as the command parameters. SVScmd sends the command to router 0, also referred to as router "SVSA," and relays all of the events produced by the command to Reslvevt for translation and reporting.

SVSxcon supports an unlimited number of commands to an unlimited number of routers. However, all component name and signal type combinations must be unique to produce the desired interconnections. For example, the combination "Video" and "Monoscope" must occur in only one SVSxcmap element. Findxcon ignores duplicates and produces interconnections to the first combination appearing in SVSxcmap.

More than one sink may share a router output port, thereby, creating a potential for ambiguity between ports and instruments. Within SVSxcon, Aliasfnd VI, Figure 5.10 resolves the ambiguity by searching a list of sink names held in the SVSxcmap "Output" indicator. This "alias" list associates a given output port with more than one instrument name.

Sierra Video Systems Router Shared Port Alias Finder

Name List

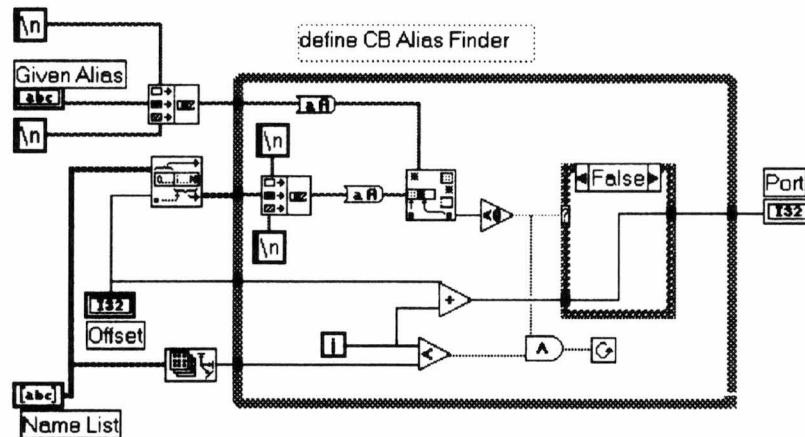
Port Aliases
 INVALID OUTPUT

Given Alias

Port

Offset

(a) Front panel



(b) Block diagram

Figure 5.10 Aliasfnd VI

ATF operators add routers, delete routers, and reassign router ports to new components by making corresponding entries in SVSxcmap's "X-Con Map." In so doing, they change the behavior of the SVS driver without altering its design. Therefore, SVSxcmap and its associated VIs create a degree of independence between SVS software and the ATF hardware composition.

5.2 Tektronix 2714 Spectrum Analyzer Driver

As mentioned earlier, the ATF behavioral model is essential to the speed and accuracy of the NDT and other test procedures. Test procedures use reference levels taken from the model's database to compute attenuation settings and signal levels. Therefore, database entries must accurately reflect the current transmission characteristics of the ATF. If not, test measurements may lead to incorrect analysis and poor investment decisions.

Regular measurement of system characteristics is an important part of ATF maintenance. At the time of this writing, ATF operators manually revise the database using measurements collected with a Tektronix (TEK) 2714 spectrum analyzer and an analyzer driver developed during this research. During subsequent research, special ATF test

procedures will assume the task of measuring system behavior and revising the database.

Whether taken manually or under computer control, spectral analysis provides an effective method for measuring ATF transmission characteristics and a spectrum analyzer is a good tool for the task. Specifically, the TEK 2714 offers voltage magnitude measurements as a function of frequency and other features common to most analyzers. However, ATF designers chose the TEK 2714 over other models for its ability to

- select the display center frequency by specifying the TV channel number (e.g., a reference to Channel 2 selects 55.25 MHz as the display center frequency).
- measure NTSC picture and audio carrier levels.
- measure video modulation depth.
- measure audio FM deviation.

Software may access these features by using the GPIB commands described in [22]. Development of a TEK 2714 driver makes these functions accessible to the ATF behavioral model and future test procedures.

Cleanroom methods naturally organize complex functions into a software hierarchy. Examination of the NDT and SVS driver structure, Figures 4.1 and 5.3, reveals a structure placing primary functions at the top of a tree structure and sharing sub-VIs placed along its lower branches. This "top-

down" design is the natural outcome of the black box, state box, and clear box definition steps.

A design begins at the highest abstraction with a general, black box description of a primary function. The design evolves downward with increasing detail as the definition of a top-level function points directly to necessary sub-VIs, sub-VI definitions identify lower-level VIs, and so on until the Cleanroom process completely describes the design. Therefore, it is not surprising to find a hierarchical relationship within the TEK 2714 VIs and in Figure 5.11.

The driver design parallels that of the SVS router with similar event processing and system reset functions present in both designs. The designs diverge in matters relating to their primary functions, i.e., baseband signal switching versus spectral measurement.

5.2.1 TEK 2714 Event Processing

Like their router counterparts, TEK 2714 VIs interact with the UNIX software, GPIB, and the spectrum analyzer during the performance of driver functions. TEK 2714 driver design adopts the earlier strategy of reorganizing the

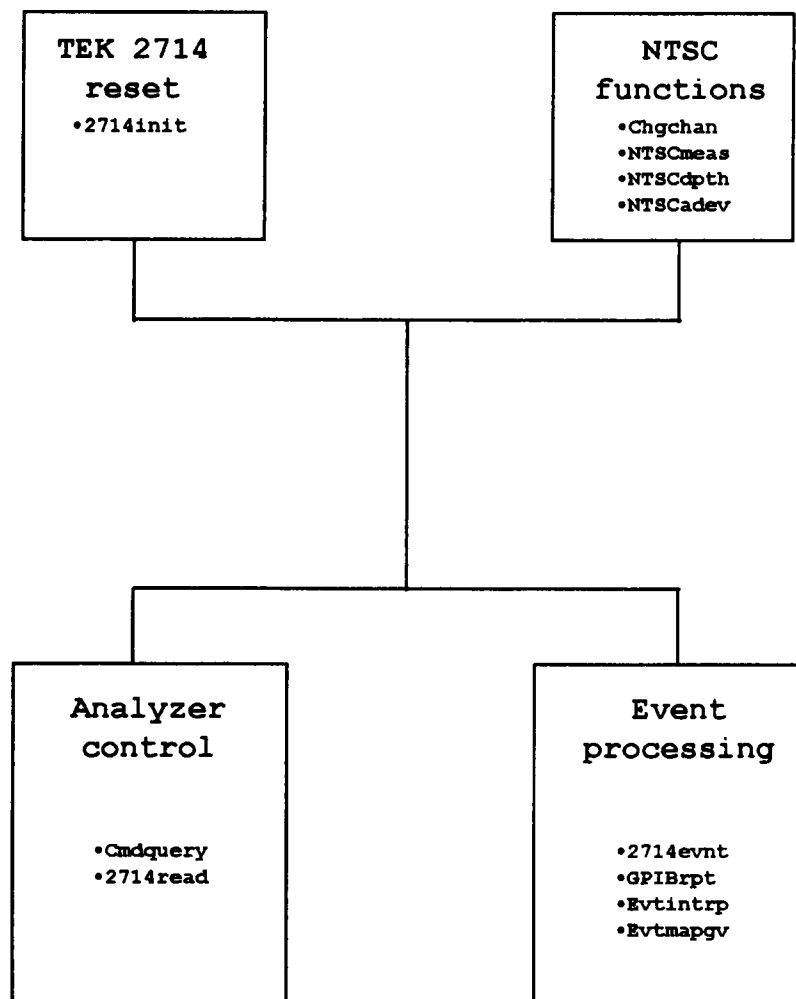


Figure 5.11 TEK 2714 VI hierarchy

diverse events into a coordinated set of categories and associated descriptions.

The 2714evnt VI receives analyzer responses and arrays of GPIB status through its front panel shown in Figure 5.12(a). Within its block diagram, Figure 5.12(b), a VI called Evtintrp processes the GPIB and TEK 2714 responses into event categories and descriptions using the "2714 Event Map" control, Figure 5.13. Like its router counterpart Reslvevt, 2714evnt relays numeric event status to ATF software via the "Event Category" indicator and displays descriptive messages to ATF operators. Consolidating event processing into a few, specially designed VIs frees the rest of the design to focus upon the primary driver functions.

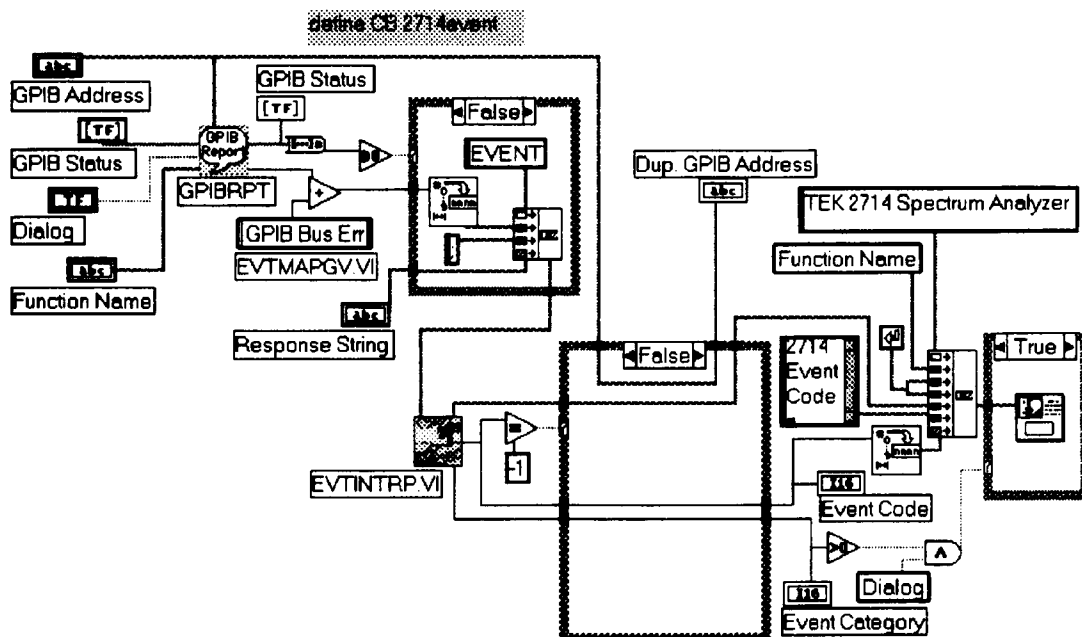
5.2.2 TEK 2714 Reset

As with other drivers, the TEK 2714 driver must return the spectrum analyzer from a number of possible conditions to a known state. A VI called 2714init, Figure 5.14(a), supports more than one ATF analyzer by requiring the GPIB address of the desired instrument. Within its block diagram, Figure 5.14(b), 2714init sends commands instructing the analyzer to discard prior GPIB commands and return to its factory default settings. A VI called 2714read monitors

**TEK 2714 Spectrum Analyzer
Event Reporting**

GPIB Address 1	Dup. GPIB Address 1
Response String 	GPIB Status 0
Function Name No Function Specified	Event Code 0
GPIB Status 0	Event Category 0
Dialog 	

(a) Front panel



(b) Block diagram

Figure 5.12 2714event VI

2714 Event Map

15

Event Map Element

Lower

2000

Upper

2000

Category

14

Event Text

The 2714 is not responding to EVENT? queries. Check the 2714.

Event? Err

2000

CATV? CLVL Err

2001

GPIO Bus Err

1000

Command Timeout

2002

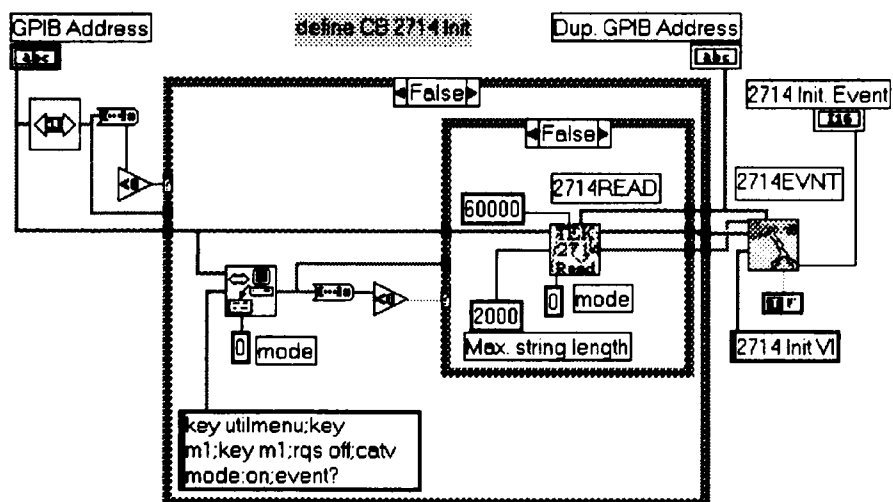
Figure 5.13 2714 Event Map control

TEK 2714 Spectrum Analyzer

System reset in progress. Please wait

GPIB Address 1	Dup. GPIB Address 1
2714 Init. Event 0	

(a) Front panel



(b) Block diagram

Figure 5.14 2714init VI

the analyzer's progress and returns its textual response. The 2714evnt VI collects GPIB status arrays and the response, translates the events into a category, and reports the summarized event as a numeric code and descriptive messages. Under normal system operation, 2714init prepares the analyzer for use by other VIs.

5.2.3 TEK 2714 NTSC Channel Selection

As mentioned earlier, ATF designers chose the TEK 2714 spectrum analyzer for its ability to work directly with NTSC transmissions. The TEK 2714 driver exploits this decision by giving ATF procedures direct access to frequently used NTSC functions.

Industrial practice deals with NTSC broadcasts as 6 MHz spectral channels referenced to a picture carrier frequency. FCC regulation associates channel numbers and carrier frequencies in a manner consistent with the employed broadcast medium. For open-air broadcast, FCC frequency allocations distribute TV channels over discontinuous portions of the VHF and UHF frequency bands. Cable broadcasts distribute TV channels over the coaxial cable bandwidth using STD, HRC, or IRC frequency assignments. Therefore, industrial practitioners naturally refer to TV

channels by their broadcast format and channel number, not by their carrier frequency.

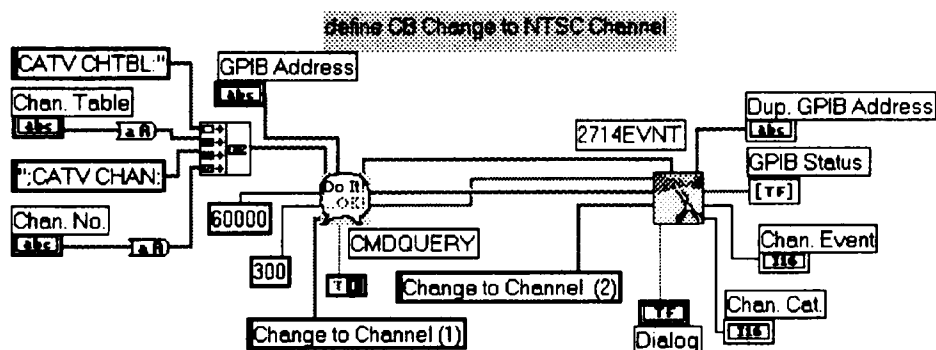
As an accommodation to industrial practice, TEK 2714 spectrum analyzers retain several broadcast translation tables, called "channel tables," in its nonvolatile memory. The analyzer uses a specified table (e.g., STD, HRC) and channel number to compute a display center frequency. For example, ATF spectrum analyzers have channel tables for open-air, STD, HRC, and IRC broadcast formats. Analyzer operators display a particular carrier and its modulation by specifying the channel table and number. TEK 2714 software follows industrial practice by using the channel tables when selecting the display center frequency.

The Chgchan VI directs a spectrum analyzer, as designated by its GPIB address, to display the 6 MHz spectrum assigned to the specified broadcast format and number. For example, Chgchan's front panel in Figure 5.15(a) requests the analyzer at GPIB address 1 to display Channel 12 transmitted in STD broadcast format. In response, the 6 MHz spectrum associated with a 205.25 MHz picture carrier will appear on the TEK 2714 display and the "Chan. Event" indicator will return an event code as status to the requesting VI. Within its block diagram, Figure 5.15(b), Chgchan issues TEK 2714 commands selecting the

TEK 2714 Spectrum Analyzer Select CATV Format and Channel

GPIO Address 1	Dup. GPIO Address 1
Chan. Table STD	GPIO Status 0
Chan. No. 12	Chan. Cat. 7
Dialog 	Chan. Event 7

(a) Front panel



(b) Block diagram

Figure 5.15 Chgchan VI

desired channel table (e.g., the STD table) and channel number. A VI called Cmdquery sends the command and retrieves the analyzer's response. The 2714evnt VI translates the response into the corresponding event categories and descriptive messages. Once displayed on the analyzer screen, test procedures may employ other VIs to conduct spectral measurements.

5.2.4 TEK 2714 NTSC Measurements

TEK 2714 analyzers process the channel spectrum appearing in their displays and quantify the following NTSC envelope characteristics:

- picture carrier level expressed in dBmV
- audio sub-carrier level expressed in decibels relative to the picture carrier level (dBC)
- picture carrier modulation depth expressed as a percentage of the picture carrier level
- FM frequency deviation from the audio sub-carrier expressed in Hertz

The TEK 2714 driver gives the behavioral model and other software access to these functions.

For instance, the NTSCmeas VI simultaneously measures the picture and audio carrier levels. ATF VIs select a particular analyzer by specifying its GPIB address in the

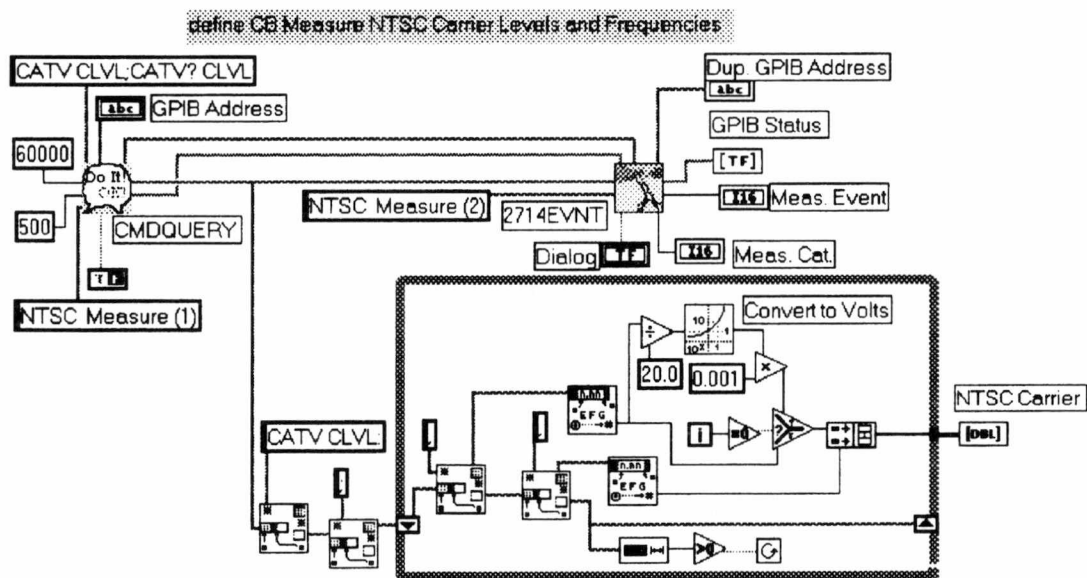
front panel shown in Figure 5.16(a) and receive results in an array indicator labeled "NTSC Carrier." The first pair of elements present, from left to right, the picture carrier level, expressed in volts, and its frequency. The second pair of elements contain the audio sub-carrier level, in dBC, and its frequency displacement from the picture carrier. "Meas. Event" and "GPIB Status" indicators give detailed information on the success of the measurement attempt.

Internally, NTSCmeas follows nearly the same programmatic flow as Chgchan. In Figure 5.16(b), Cmdquery requests the measurement by issuing the command "CATV CLVL;CATV? CLVL." The 2714evnt VI processes analyzer responses and GPIB status producing "Meas. Event," "GPIB Status," and operator messages, as necessary. Logic located at the bottom of the diagram extracts the measurement results from the analyzer response. The analyzer response is of the form "CATV CLVL: level 1, frequency 1, level 2, frequency 2;" where level 1, frequency 1, level 2, and frequency 2 are the picture carrier level, picture carrier frequency, audio sub-carrier level, and sub-carrier frequency, respectively. NTSCmeas translates the picture carrier level from dBmV to volts, collects all four measurements into a two-dimensional array, and presents them

TEK 2714 Spectrum Analyzer NTSC Carrier Measurements

GPIO Address 1	Dup. GPIO Address 1						
GPIO Status 0	Meas. Cat. 0						
Dialog 	Meas. Event 0						
NTSC Carrier <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%; text-align: center;"> 0 </td> <td style="width: 40%; text-align: center;">4.0300E-3</td> <td style="width: 40%; text-align: center;">2.0525E+8</td> </tr> <tr> <td style="text-align: center;"> 0 </td> <td style="text-align: center;">-1.2100E+1</td> <td style="text-align: center;">4.5020E+6</td> </tr> </table>		0	4.0300E-3	2.0525E+8	0	-1.2100E+1	4.5020E+6
0	4.0300E-3	2.0525E+8					
0	-1.2100E+1	4.5020E+6					

(a) Front panel



(b) Block diagram

Figure 5.16 NTSCmeas VI

in the "NTSC Carrier" indicator. As can be seen by comparing Chgchan and NTSCmeas, hierarchical VI organization and Cleanroom disciplines create opportunities for repeated use of sub-VIs.

Video modulation measurement repeats the architecture and uses the same sub-VIs. The NTSCdpth VI, Figure 5.17, issues the modulation depth command and processes events using the Cmdquery and Evtintrp sub-VIs. Analyzer responses reduce to a single value displayed in the "Mod. Depth" indicator as shown in Figure 5.17(a).

The audio frequency deviation measurement VI, NTSCadev, follows the same design with differences in the commands issued, the extraction of the maximum FM frequency deviation, and its display as shown in Figure 5.18(a). Figure 5.18(b) is nearly identical to the other TEK 2714 measurement VIs. Therefore, Cmdquery and Evtintrp reduce analyzer function design to extracting the results from the analyzer response. Taken together, 2714init, Chgchan, NTSCmeas, NTSCdpth, and NTSCadev provide a suite of useful NTSC measurement functions to ATF software, especially the behavioral model.

The NDT, SVS router, and TEK 2714 software developments demonstrate the feasibility of automated television measurement. It is possible to recreate manual processes

TEK 2714 Spectrum Analyzer NTSC Video Modulation Depth

Dialog 	Meas. Cat. 0 Mod. Depth 90.0 Meas. Event 7
--	--

Dialog

Meas. Cat.

0

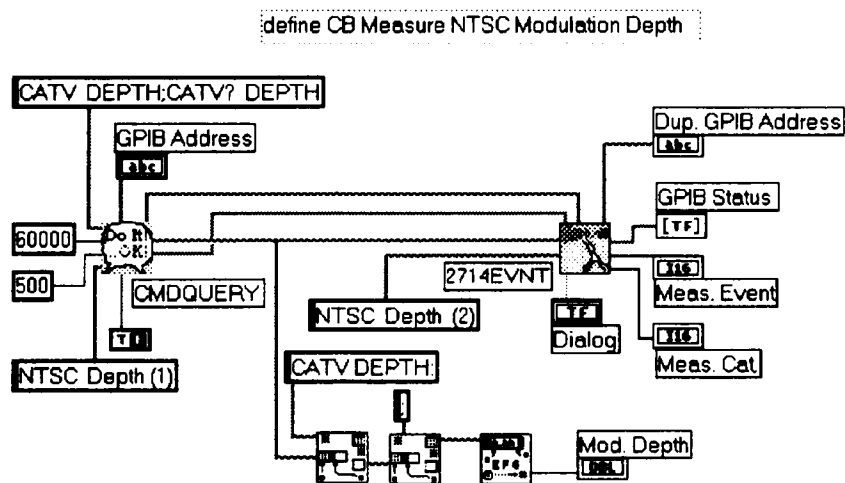
Mod. Depth

90.0

Meas. Event

7

(a) Front panel



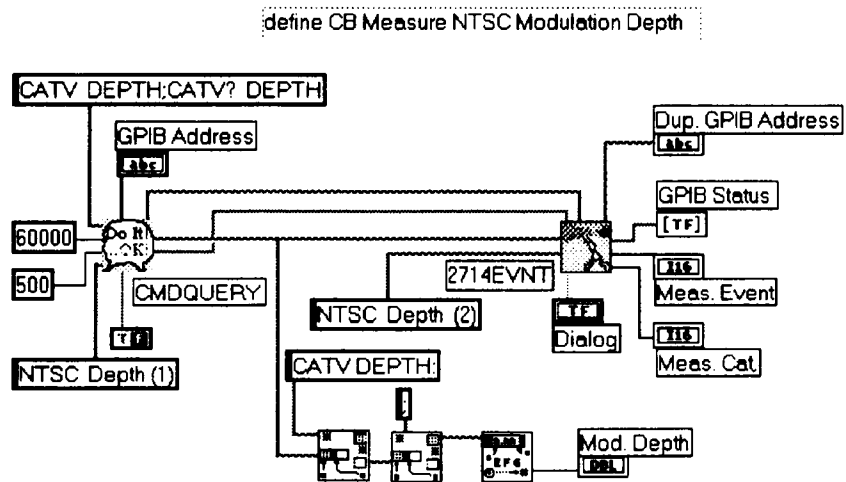
(b) Block diagram

Figure 5.17 NTSCdpth VI

TEK 2714 Spectrum Analyzer
NTSC Aural Deviation Measurement

GPIO Address 1 Dialog	Dup. GPIO Address 1 GPIO Status 0 Meas. Cat. 0 Aural Dev. 2.50E+4 Meas. Event 0
--	---

(a) Front panel



(b) Block diagram

Figure 5.18 NTSCadev VI

within an automated test environment, regulate the test instruments, and reliably collect measurement information in an electronic form. Therefore, the ATF demonstrates through this research that major improvements in competitive analysis and product design decision making are achievable.

CHAPTER 6

DISCUSSION

6.1 Conclusions

Through the course of its discussion, this study relates the reasons and methods for observing nonlinear distortion in NTSC televisions. Its justification lies in the need for better gauges of relative product strength as a guide for design decisions in the highly competitive television market. From past experience, manual television performance measurement provides limited, sometimes inconsistent information in a form not readily usable for competitive analysis. These shortcomings lead to the development of the Automatic Test Facility. Its battery of test procedures, instrument drivers, and measurement collection VIs provide a greater resource of television performance information, better measurement accuracy, and higher labor productivity. Within the context of this larger effort, the Nonlinear Distortion Test procedure applies automation to the IEC "Cross Modulation" method producing distortion information in greater quantity and in an electronic format ready for competitive analysis.

The NDT's improvements in distortion measurement are consistent with the broader goals of the ATF project. Automatic performance measurement improves productivity by mechanizing the creation of the NDT broadcast environment, eliminating written records of TV distortion behavior, and organizing the test progression in a manner requiring the least operator intervention. Automatic cross-checks ensure the accuracy of the measurements and focus the ATF operator's attention on the behavior of the television under test.

NDT software and ATF hardware recreate the "Cross Modulation" test method producing nonlinear distortion modes like those observed under manual procedures. When subjected to the NDT procedure and its manual counterpart, televisions exhibit the same combinations of cross modulation, intermodulation, harmonic, and modulation distortion.

The organization of the NDT software and its drivers demonstrates the benefits of Cleanroom disciplines in ATF development. Cleanroom methods and LabVIEW design tools create well-organized test procedures, instrument drivers, and utility VIs. Box definition and verification techniques build quality into VI design during the early stages of development. Improved quality reduces software testing and maintenance costs permitting designers to focus on new test procedures. Procedure development adds common functions to

VI libraries, as in the case of the SVS router and TEK 2714 drivers. VI libraries become a common resource for new procedure development improving design productivity and quality. Therefore, NDT, SVS, and TEK 2714 VI developments lay foundations for further automation of television performance measurement.

6.2 Opportunities for Further Research

IEC standard 107-1, Section 5.3.7.2, suggests a further enhancement in distortion measurement [1]. The standard describes an "objective test" method eliminating the need for operator observation of TV behavior. The alternative method introduces a slightly different broadcast environment and employs a spectrum analyzer to detect distortion. Spectral analysis VIs might recognize the presence of distortion components within a TEK 2714 display and automatically record the interference level inducing the distortion.

Spectral analysis might go beyond the requirements of the IEC standard by determining the distortion modes and their relative contribution. Additional analysis may provide new feedback to designers on factors contributing to poor TV performance.

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VITA

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