AUTOMATED BIT ERROR RATE TESTING

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ABSTRACT

An automated bit error rate (BER) test system has been developed for an environment that requires repetitive testing. This system acquires data by the IEEE 488 interface, performs all BER and CNR calculations, and plots and stores the results for further processing and references. An important usage of such an automated system is to monitor the receiver's performance over a prolonged period of time to record its response to the varying transmission characteristics of the channel.

INTRODUCTION

For a CATV scrambling system employing encrypted digitized audio, the live audio is first digitized and then encrypted in the encoder. The digitized audio can be transmitted through the cable system either by pulse amplitude modulation (PAM) within the horizontal blanking interval of the video or by means of other RF modulation techniques. In either case, after demodulation and detection in the CATV decoder, the digital bit stream containing audio information is recovered but not without errors. The BER after detection, but before decryption, is referred to as the raw BER. In order to provide high audio quality, the raw BER should be kept low over the range of subjectively acceptable video carrier-to-noise ratios (CNR). Thus numerous BER tests are required for quality control. A specific automated BER test system for decoders in a CATV environment will be discussed. The paper also considers some general philosophy in automating BER tests.

DIFFERENT BER TEST METHODS

A communications system can be tested by transmitting a pseudorandom bit sequence and comparing the detected bit stream bit by bit at the receiver with a locally generated replica of the transmitted sequence. For systems without explicit ports for inputting the data sequence, this method requires interfacing the pseudorandom bit sequence at both the transmitter and receiver. In many TV applications, data bit is usually inserted during the horizontal blanking intervals (HBI) or vertical blanking intervals (VBI) of each frame, making burst synchronization necessary before bit-by-bit comparisons can commence. This method is fine for accurate laboratory tests but cumbersome in the field. Furthermore, this method cannot be used to continuously monitor the performance of a system without disrupting services.

A simpler BER test method can be devised if the information bits of the system are encoded for error checking. For example, in linear block codes, a nonzero syndrome indicates an error in the received block. This error checking can be accomplished either by software or by hardware. Other techniques use the violations of signal format for error monitoring as in bipolar and correlative partial response systems. In either case, an external pulse can be generated whenever a bit error is detected. By averaging the number of error pulses per second over a sufficiently long time, the BER of the system can be estimated quite accurately. The required averaging time T is approximately given by

$$T \geq \frac{1}{\varepsilon^2 pR} \qquad (1)$$

where p is the desired bit error probability, and R is the bit rate of the system. ε is the ratio of the standard deviation of the measured probability to the desired probability. ε should be of the order 0.1 to provide a high-confidence estimate. The advantages of this method are that live information can be sent so that no disruption of services is incurred while monitoring the BER performance of the system, and it is relatively simple to implement. The shortcoming of this method is that there will be undetected bit errors, the number of which depends on the block codes being used. For example, assume that odd parity checking is used and there are 26 bits per block or word, then the probability of two random errors per block is given by $\binom{26}{2} p^2 (1 - p)^{24}$ where p is the bit error rate and $\binom{n}{x}$ denotes the combination of n items taking x at a time. These double errors do not cause much sacrifice in accuracy; for example, if the true raw bit error rate is 1×10^{-4} then the probability of double errors is 6.5×10^{-6}. For systems where double errors are likely, e.g., in a differentially encoded system, counting the odd number of parity errors may underestimate the BER of the system. In essence, system-dependent errors should be considered in devising the correct BER test.

SOURCES OF BER DEGRADATION

There are system-dependent and transmission-dependent parameters that affect the BER of a communications system. Some system-dependent factors are the front-end noise figure, the bandpass filters' delay distortion, the timing jitter, etc., of the receiver. The transmission parameters are the inherent noise in the channel, the channel amplitude and delay distortion, co-channel and adjacent channel interferences, etc. In this paper only the channel characteristics and noise are considered as the factors affecting BER.

In a CATV environment, the noise is the cable noise measured at the input to the decoder. This noise can be measured by demodulating the video signal to baseband and using a Tektronix 1430 in noise insertion mode. The actual cable noise and the inserted noise are matched to within 0.5 decibel by comparing the displays on a Tektronix 1480R waveform monitor. The noise figure of the video demodulator can be factored out to get a more accurate estimate of the input video signal-to-noise ratio. The equation governing the input carrier-to-noise ratio to the output carrier-to-noise ratio, after passing through a linear device with noise figure F, is given by

$$\left(\frac{C}{N}\right)_{in} = \frac{1}{1/(C/N)_{out} - \frac{(F-1)kTB}{P_i}} \tag{2}$$

where P_i is the input power, the product kTB is the noise power at temperature T°K, and bandwidth B.

The channel can be modelled by a two-path transfer function[1]

$$a\left[1 + be^{j\phi}e^{j(\omega-\omega_o)\tau}\right]$$

where a and b are scale and shape factors, respectively; ϕ, τ, and b are the phase, delay, and attenuation, respectively, of the second path compared to the main one. ω_o is the frequency of the fade minimum, and $(1+b)/(1-b)$ is fade depth of the channel. In a CATV environment b can be as strong as -10 to -15 decibels and the delay T can be between 150 to 1000 nanoseconds.

Each BER test should be qualified with the attenuation b and the delay T of the second path of the channel.

AUTOMATING A BIT ERROR RATE TEST SYSTEM

In many cases numerous BER tests are required to evaluate a product. It is convenient to utilize a microcomputer to perform all the repetitive functions in BER testing. In order to ease the communications with other data acquisition equipment, the microcomputer should have the IEEE 488 interface. HP-IB is one trademark that conforms to the IEEE 488. The microcomputer's language should be simple to use and flexible enough to control and communicate with different equipment that may be required in the test. Furthermore, the whole system should be fast enough to compute mathematical functions for algorithmic branching purposes in real time.

At a minimum, the electronics counter for counting the error pulses should be able to "listen" to the IEEE 488 commands. Error pulses are then counted over a selectable duration, e.g., 1-second interval, and then averaged by repeating the trial. In monitoring the BER performance of a communications system over an extended period of time, it is important to record the input carrier power variation with time. One way to accomplish this is to sense the ALC or AGC level. An autoranging digital voltmeter with the IEEE 488 interface can acquire the ALC level and the computer stores the data for future plotting and references.

The philosophy of BER testing is to stress the system so as to produce bit errors. One way is to increase the noise power into the system by injecting noise. A noise generator with a 1-decibel step attenuator should be used so that carrier-to-noise ratio can be varied 1 decibel at a time. Attenuators programmable through IEEE 488 are available if total automation is desired. Other methods of stressing the system, like decreasing the threshold and/or jittering the bit timing of the data detector, can also be devised for BER testing.

AN AUTOMATED BER TEST SYSTEM

To efficiently test and survey the performance of a cable product, an automated BER test system has been developed at Oak. The test system's setup is shown in Figure 1. The microcomputer we have chosen is the HP 9816S. This computer has a clock rate of 8.0 megahertz and has both HP-IB and RS-232 interfaces. The RAM memory is expandable to 1024 kilobytes. It has a built-in real-time clock, essential for data logging when the time durations of tests are important. The computer language chosen is HP BASIC with extensions. It has a rich set of commands for equipment control and is simple to use. The test system further consists of an HP 9121D dual disc drive and uses 3.5-inch, semi-rigid discs with 256 kilobytes of storage per disc. This provides an additional 512 kilobytes of storage for gathering long-term statistics of the system under test. The printer used is HP 82906A. It accepts direct graphics dumping instructions and has programmable font control. Both HP and Fluke counters can be used. HP 5316A electronics counter can both "talk" and "listen" to the microcomputer through the IEEE 488 interface. The Fluke 7220A counter can only listen and requires a translator Fluke 1120A to convert codes and signals of IEEE 488 to the corresponding codes and signals compatible to the counter.

An extensive interactive, user-friendly BASIC software package has been developed at Oak for the HP 9816S microcomputer. This package has a manual for choosing test routines for both short and prolonged BER tests. These routines prompt the operator step by step for necessary inputs and information, like carrier power, filename, etc., for BER testing and allows the operator to choose what information to store, plot, and print. It also allows retrieving and previewing of stored data on the CRT before printing and plotting. Furthermore, stored BER files can be retrieved and further processed to include the noise figure of the device under test for

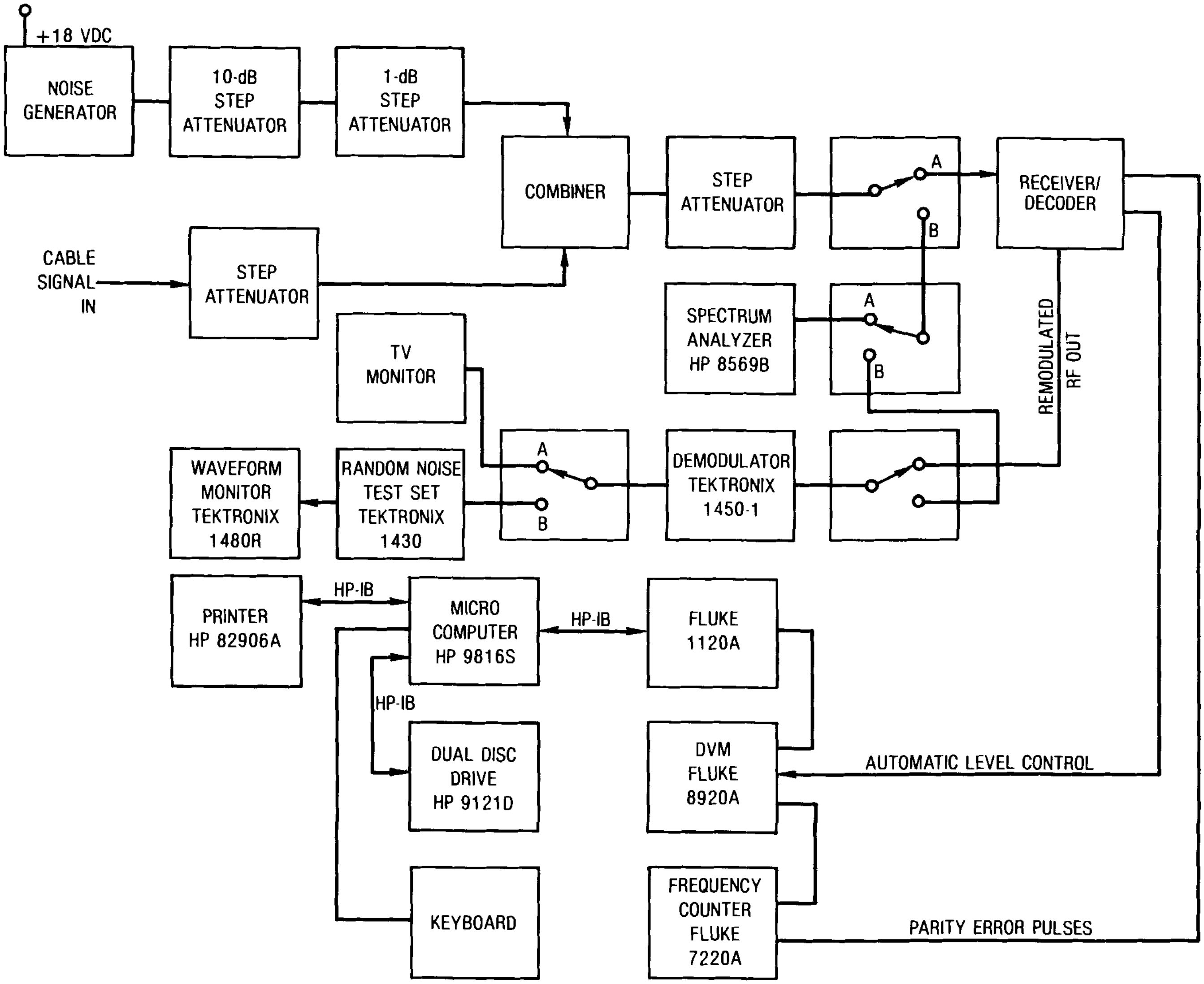


Figure 1. CATV Survey and BER Test Setup

CNR computations. In addition, a routine allows a number of BER curves from different files to be plotted together for comparison purposes.

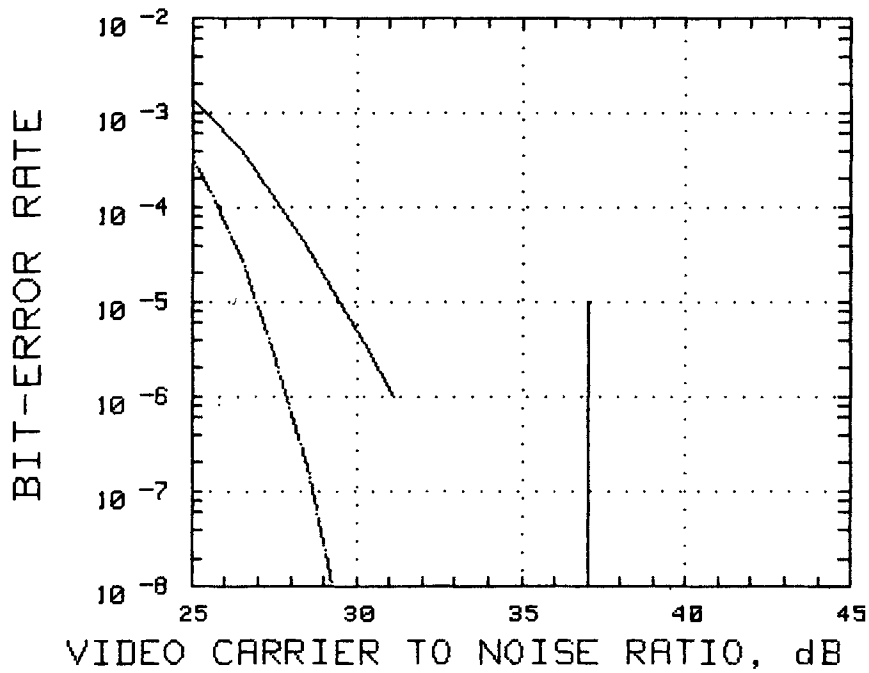
SHORT BER TEST

A single BER curve is a snapshot of the system's performance under different carrier-to-noise ratios given the transmission characteristics of the channel during the test. The noise is the sum of the thermal noise, the channel noise if measurable, and the injected noise. To run a BER test with this automated system in a CATV environment, the operator only requires the video carrier power and the cable SNR of the test channel at the site. The attenuator setting of the noise generator is then varied to change the resultant CNR.

The computer automatically sums the thermal noise, the cable noise, and the injected noise to arrive at a resultant video CNR. It continuously acquires the parity error counts every second from the HP-IB counter and averages the BER accordingly. The total averaging time is controllable by the operator and should be proportional to the bit error rate as per Equation 1 in order to form a statistically high-confidence estimate. The final averaged BER can be manually changed by the operator, if desired, and stored. The BER curve can be plotted immediately after the run so that any errors can be corrected at the site. The multipath and delay information at the site can be appended to the BER file at the users' convenience.

Figure 2 shows the printout of a typical BER run. "CNR INJ." is the CNR with the injected noise. "CNR TOT." is the resultant CNR when the cable noise is included. Figure 3 is a plot of multiple BER runs at different sites of the same amplitude modulated link (AML).

AML HE



Leftmost curve: PAM Theory for 60-IRE p-p HBI DATA. NO VIDEO, NO MULTIPATH.

SERIAL # = 115
VIDEO LEVEL AT CAL = +8.00 dBmV
ATTEN AFTER COMBINER = 14 dB
WEIGHTED CABLE SNR = 41.1 dB
TEK DEMOD NOISE FIGURE = 15.00 dB

CHANNEL # =M DISC FILE : BROOHE3
REF NOISE POWER = +1.43 dBmV(4.2 MHz)
INPUT VIDEO POWER = -6 dBmV
LIMITING CNR = 41 dB

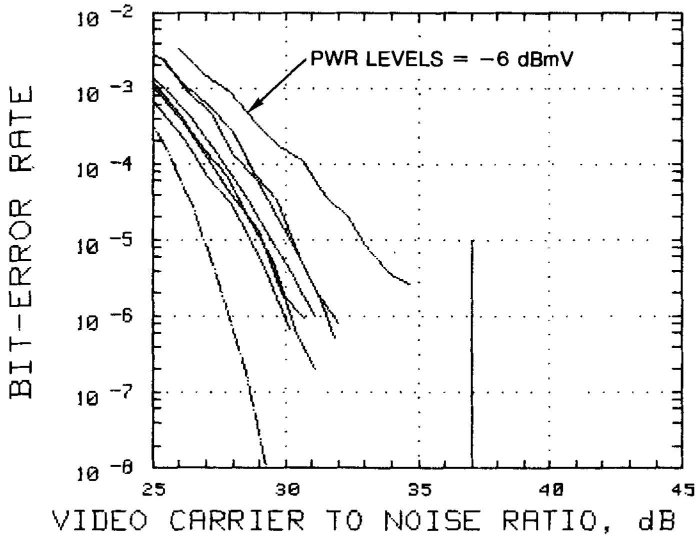
CABLE SIGMA PC FIELD BOARD, AUDIO CHANNEL TEST BY PARITY COUNTING
THE DELAY IS APPROX. 200 NS. THE ANGLE IS 180 DEG. NO GHOST OBSERVABLE
LIVE AUDIO, 5 STEP VIDEO IN SCRAMBLED MODE, DATA SWING ON, INVERT & NONINVERT

TEST BY USING C. WONG'S PROGRAM

BER DATA SUMMARY

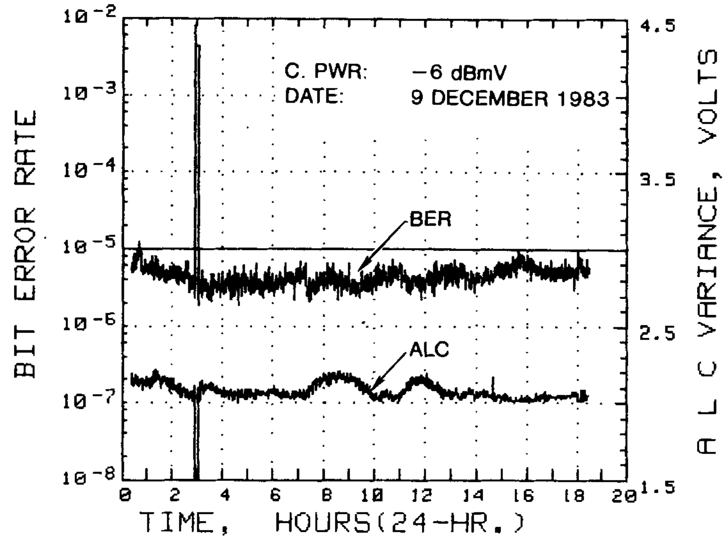
CNR	TOT:	23.5	24.5	25.5	26.4	27.4	28.3	29.3
	BER:	4.48E-03	2.10E-03	9.75E-04	4.08E-04	1.37E-04	4.42E-05	1.33E-05
	SNR:							
CNR	INJ:	23.6	24.6	25.6	26.6	27.6	28.6	29.6
CNR	TOT:	30.2	31.1					
	BER:	3.82E-06	9.89E-07					
	SNR:							
CNR	INJ:	30.6	31.6					

Figure 2. Printout of an Automated BER Run



Leftmost curve: PAM Theory for 60-IRE p-p HBI DATA.
NO VIDEO, NO MULTIPATH.

Figure 3. BER Multiple Plots



PROLONGED BER TEST, C. PWR = -6.0 dBmV

Figure 4a. Prolonged BER Test

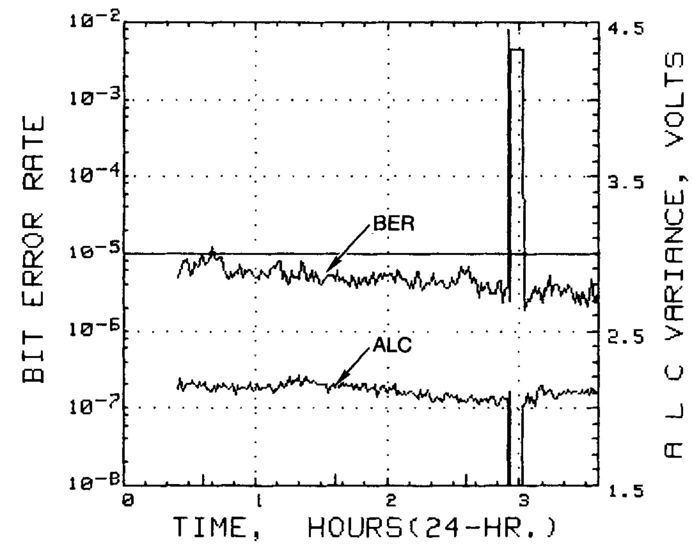


Figure 4b. Expanded View of Error Event

PROLONGED BER TEST

A prolonged BER test is performed to detect and record the duration between events which causes the BER of the receiver to increase above a preset threshold. It is a test on the varying transmission characteristics of the channel over time. It can be used to gather relevant statistics about the channel, e.g., mean time between fades and noise bursts, etc.

In this test, the operator sets up the injected noise level to attain a certain desired BER. The computer continuously logs in error counts every second so that any instantaneous BER and ALC level variations can be monitored. The ALC level is proportional to the input signal power. No operator supervision is required during the test. The program contains error traps so that minor momentary instrument malfunctions will not disrupt the operation. To conserve storage, not all the data acquired in each second are recorded. An algorithm was written so that only BER variations above a certain magnitude will be stored. This allows extended testing of 48 hours or more to be conducted easily with the present system. The program is further capable of zooming in on an error event of interest and plots an expanded view of the BER versus time for easy diagnosis. Figure 4a shows the results of a prolonged BER test. Figure 4b shows the expanded view of the error event. Both the BER and ALC values versus time are plotted. Note the simultaneous decrease in carrier power and the increase in BER. This test shows the decoder's response to the carrier power outage.

CONCLUSION

This paper discusses some aspects and problems in automatic BER tests. An automated system has been developed that utilizes a microcomputer for data acquisition and control. This system has been used extensively in cable system performance surveys.

A further enhancement of this system could be to add an intelligent spectrum analyzer with IEEE 488 interface which can tune to different channels and change resolution bandwidth under computer control. Such a system could then perform peak search for video and audio carrier power measurement, noise averaging for CNR measurement, etc., in a routine way to survey a whole cable system accurately and expeditiously.

REFERENCE

1. C. Siller, "Multipath Propagation," IEEE Communication Magazine, Vol. 22, No. 2, pp 6-15, February 1984.