IEEE 802.11
Wireless Access Method and Physical Layer Specification

Title: **Frame Length Recommendation for Frequency Hop Block Coding as Specified in 94/069**

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Abstract: This paper presents simulation results for the block coding algorithm adapted by the frequency hop ad hoc group. The simulated data makes clear the conclusion that the frame length of the block code is not as critical as perhaps some had anticipated and comes to the conclusion that a frame length of 64 bits is suitable. In addition, it is clear from this paper that the standard specification under preparation should address the quality of the eye pattern transmitted by a compliant transmitter and the ability of a compliant receiver to receive a worst case complaint transmissions.

Introduction

The packet format coding technique described by Dean Kawaguchi in submissions 94/69 and 94/129, called block coding here, has been recognized by the frequency hop subgroup of IEEE 802.11 Physical Layer Working Group as an effective means to prevent killer patterns from occurring. Killer patterns are data patterns that result from a short term plurality of ones or zeros that cause a baseband bias shift to the extent that errors will result even if there is no additive channel noise. These are considered killer patterns since a repeat of these patterns would not correct the situation and thus could never be successfully communicated through the channel of the system. It may be possible to avoid killer patterns by a technique of reencrypting repeat messages with a different key. Convincing statistical arguments, however, have not been forthcoming and the proposal of Dean Kawaguchi is thus appropriate since its effectiveness in eliminating killer patterns is not at question.

The packet formatting technique of 94/69 has been formally accepted by the frequency hop subgroup in a motion during the May 1994 meeting with only the frame length left for further consideration.

The block diagram of Figure 1 is presented as a means to focus attention on the principle issues of this submission. From Figure 1 it is apparent that there is an equivalent high pass filter stemming from the modulator in the transmitter. This is typically the result of a phase locked loop, pll, used in conjunction with a voltage control oscillator, VCO. In addition, the baseband signal may be influenced by a high pass filter in the receiver.

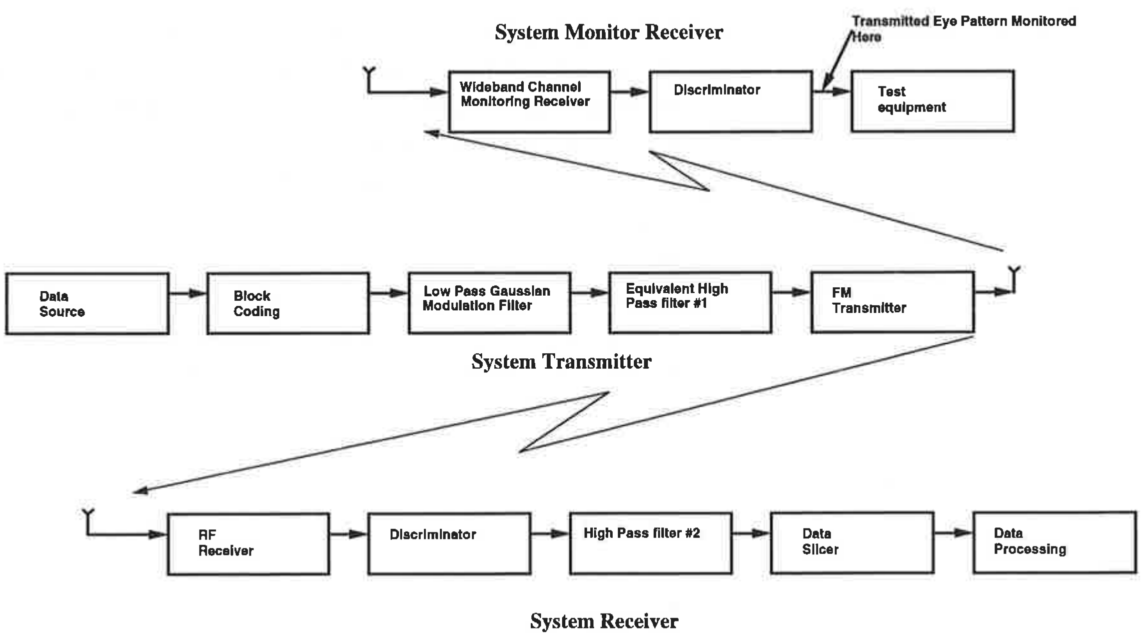

Figure 1. System Block Diagram

For the purpose of this submission the channel will be considered to have one high pass filter and that is typically the one resulting from the transmitter pll. The principle issue of this submission is the impact of the channel baseband high pass filter on the performance of the system and the impact of frame length of the block coding on overall system operation.

To do this, the submission will first address the simulation study. Based on the simulation results, certain conclusions are presented, recommendations made and motions proposed.

The simulation study first considers a model of the system. It is important to point out that data depicting an actual Saw filter is used for the channel filter and that this filter cuts the eye opening to about 50% as shown in figures A1 and A2. This conservative model provides conservative results. This model is then evaluated for performance with random data for a range of effective channel baseband high pass filter cut off frequencies. This is done for no block coding and for block coding with frame lengths of 16, 32 and 64 bits. It is evident from this aspect that good practice would indicate that the channel high pass filter should be not greater than 1 kHz. The next phase of the simulation addresses the worst case killer pattern scenario where the encrypted (or whitened) data is all zero's (or all one's). With this input it is evident that block codes of 16, 32, or 64 bits will prevent killer patterns.

Simulation Model

The algorithm described in 94/069 was implemented in SPW by the system shown in Figure 2. Frames of random data are separated by stuffing a zero bit before every N bits. If the next frame is the same sense as the entire previous transmission (including inverted data and stuffed bits), the next frame and stuffed bit are inverted.

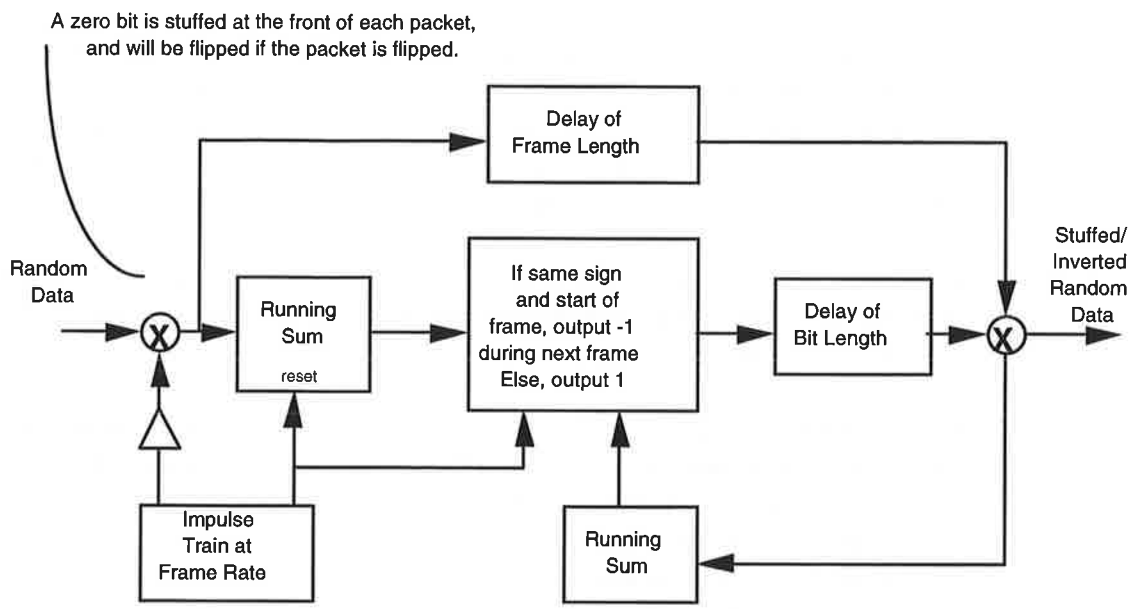

Figure 2. System for Implementing Packet Stuffing Algorithm

Bit Error Rate Performance

Theory

The simulation results are based on a different analytical approach than described in 94/069. The 94/069 method of frame size validation was by calculating standard deviations and variances based on long statistical simulations. These results do not easily translate to system performance measures such as bit error rate (BER). Here the decision was made to simulate BER directly for the actual system shown in Figure 3. The IF filter is shown in Figure 4. The BER is determined quasi-analytically rather than using a Monte Carlo analysis to reduce the simulation time. In the quasi-analytical approach, the data is detected without noise, and at every bit, a BER curve is calculated analytically based on phase shift and assuming AWGN. These bit-wise BER's are averaged to determine the overall BER.

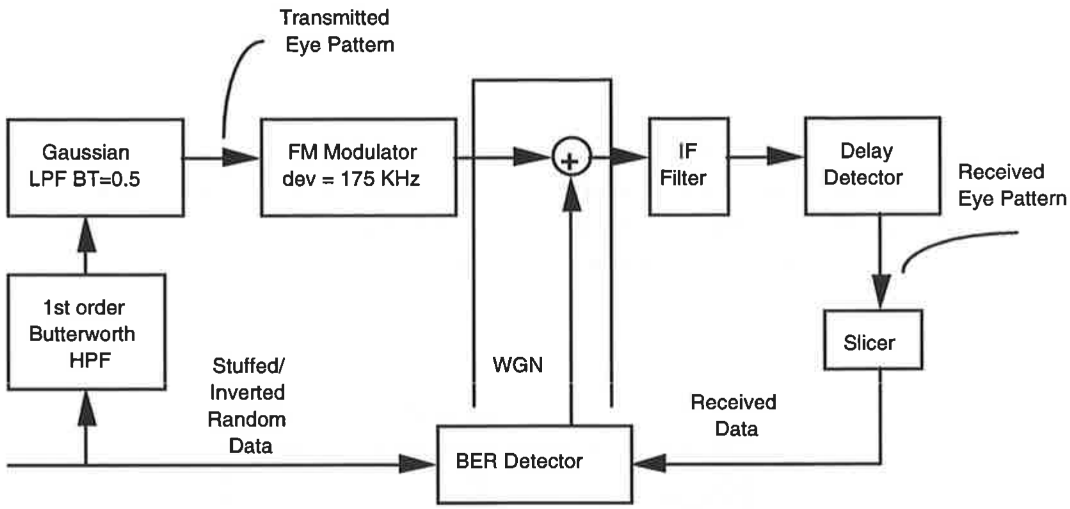

Figure 3. 1 Mbps RLAN System

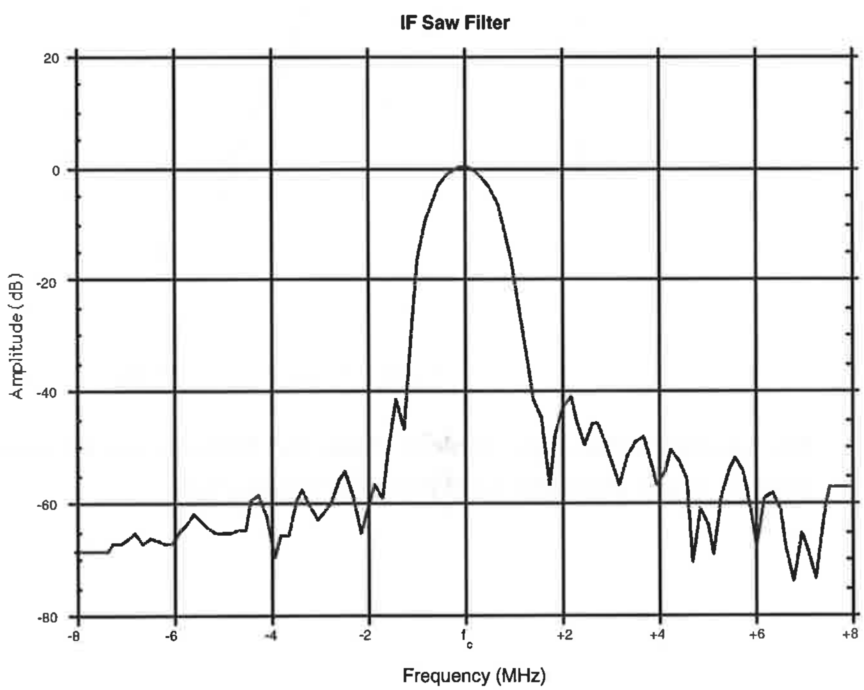

Figure 4. IF SAW Filter

Results

Figure 5 shows the BER vs. Eb/No for two choices of effective baseband high pass filter cut off frequencies (1 kHz and 5 kHz) and four choices of frame length (16, 32, 64, and infinite). As a sanity check, the BER was calculated using the Monte Carlo method at two points on the 5 kHz, length 32 curve.

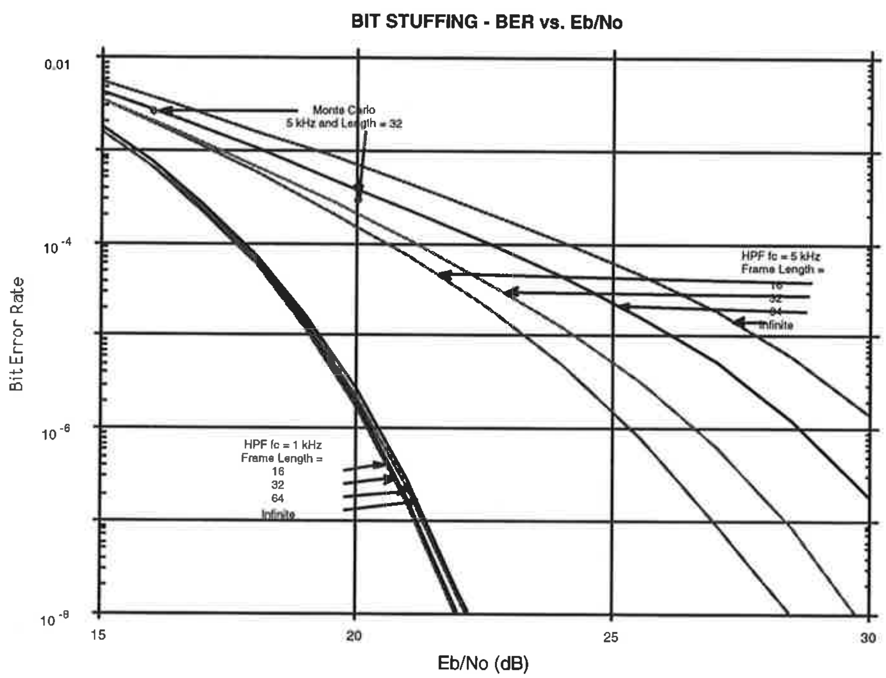

Figure 5. BER vs. Eb/No

For random initial data, Table 1 shows the Eb/No's at a bit error rate of 10^{-5} for various frame sizes and high pass filter front ends.

High Pass Filter Cut Off Frequency

Frame Length		500 Hz	1 kHz	2 kHz	5 kHz	10 kHz
	16	18.9 dB	19.1 dB	19.5 dB	23.3 dB	> 50 dB
	32	19.0 dB	19.1 dB	19.7 dB	24.3 dB	> 50 dB
	64	19.0 dB	19.2 dB	21.0 dB	26.2 dB	> 50 dB
	Infinite	19.0 dB	19.3 dB	22.8 dB	27.8 dB	never

Table 1. Eb/No at BER = 10^{-5} for Random Data

Table 2 shows the same data as table 1 except that the transmitted data is all zeros. For the infinite length case (no stuffing), the input to the high pass filter is dc, and therefore, the data is completely attenuated. As mentioned earlier, this is a killer pattern. All zeros (or all ones) would lead to a BER of 0.5 over the long run for the infinite case in Table 2.

High Pass Filter Cut Off Frequency

Frame Length		500 Hz	1 kHz	2 kHz	5 kHz	10 kHz
	16	14.2 dB	14.4 dB	14.9 dB	17.2 dB	22.9 dB
	32	13.9 dB	14.8 dB	15.8 dB	22.4 dB	BER 0.03 @ 40 dB
	64	14.1 dB	15.5 dB	19.3 dB	BER 0.08 @ 40 dB	BER 0.08 @ 40 dB

Table 2. Eb/No at BER = 10^{-5} for All Zeros

Attached are these additional supporting graphs (not available in electronic form): Figure A1 is the transmitted eye pattern with no high pass filter, Figure A2 is the received eye pattern with no high pass filter, Figure A3 through A6 are the periodograms of the transmitted data with frame lengths equal 16, 32, 64, and infinity, Figure A7 is the transmitted eye pattern for the 1 kHz, length 64 case, and Figure A8 is the transmitted eye pattern for the 2 kHz, length 64 case.

VCO turn on and acquisition time

An important aspect of the total system design is VCO acquisition time following a period of power down or sleep. Power down is not turned off, but a state of non operation where bias may be present at critical points. Motorola has implemented a design that has a effective high pass filter cut off of less than 1 KHz. This same VCO has a rapid turn on time following a period of power down or sleep. Following a period of power down of 10 seconds the VCO/synthesizer had settled to within 50 KHz of steady state in less than 1.0 mSec.

Conclusions

The simulation demonstrated that the block coding proposal of Dean Kawaguchi is effective in eliminating the possibility of killer patterns at any of the frame lengths under consideration, 16, 32, or 64 bits.

The simulation exercise was quite effective in illustrating that some control over effective high pass baseband filtering is required. It is apparent from Figure 4 that if the cut off frequency of the effective high pass baseband filtering of the channel is 1 kHz or less, then there is no problem with receiver sensitivity or system range. This is true with or without the proposed block coding *at any of the frame length* under consideration. This is not true if the cut off frequency is 5 kHz.

It is quite appropriate therefore that the nominal cut off frequency for the effective baseband filter of the channel be considered as 1 kHz.

With these considerations the choice of 64 bits for the frame length does not impose a system performance penalty, it provides manufacturing margin, and the overhead penalty associated with shorter frames is avoided.

It is quite evident from the block diagram of Figure 1 that manufacturers may have different effective implementations of the high pass filter responses of their transmitters and receivers. One could envision a low pass boost in a receiver to compensate for a high pass filter in a transmitter. It is therefore incumbent on the IEEE 802.11 committee to require a minimum degree of flat frequency response in both the receiver and transmitter sections. It is proposed below that the transmitter be tested for flat frequency response by requiring that a minimum eye opening be maintained and that the receiver be tested with an RF input signal that represents a worst can modulation high pass filter.

Motions

It is moved that the frame length for the block code adopted by the frequency hop group in its May 1994 meeting be 64 bits.

It is moved that compliant transmitters be tested with a standard test signal and that the eye pattern, as determined by a test receiver as in Figure 1 of this submission, verify that the absolute value of the deviation at the center of each bit period be at least 140 kHz. The test receiver should have a flat baseband response, +/- 1 dB from 100 Hz to 1 MHz.

It is moved that compliant receivers be tested with a standard digital test signal which has been filtered by a 2 kHz high pass filter before being coupled into the modulation port of a test RF signal generator. The receiver shall be required to provide 10^{-5} BER at -80 dBm input and better than 10^{-6} BER at -77 dBm. input.

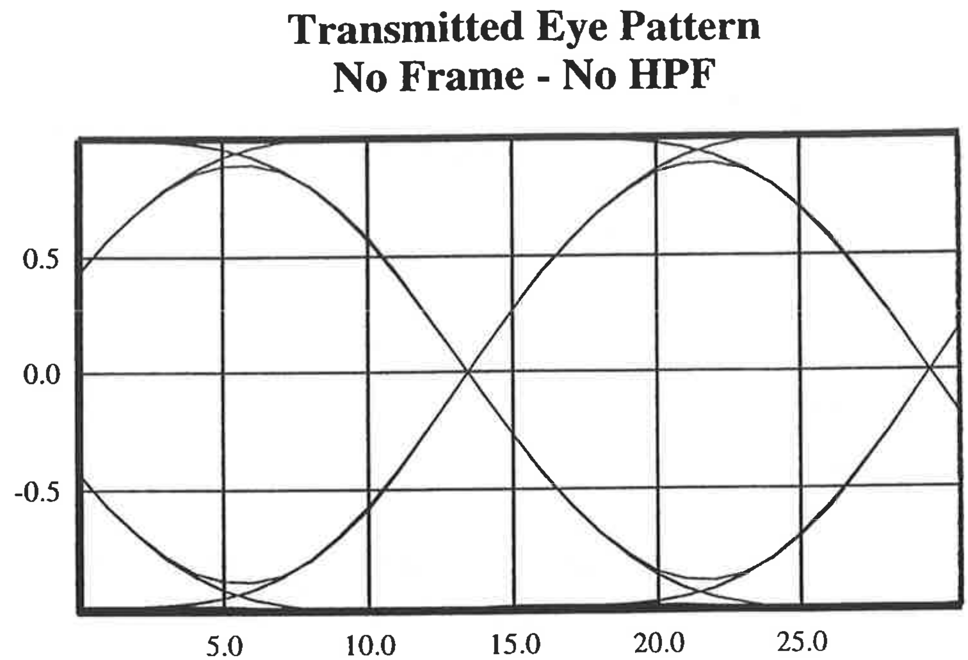

Figure A1. Transmitted Eye Opening

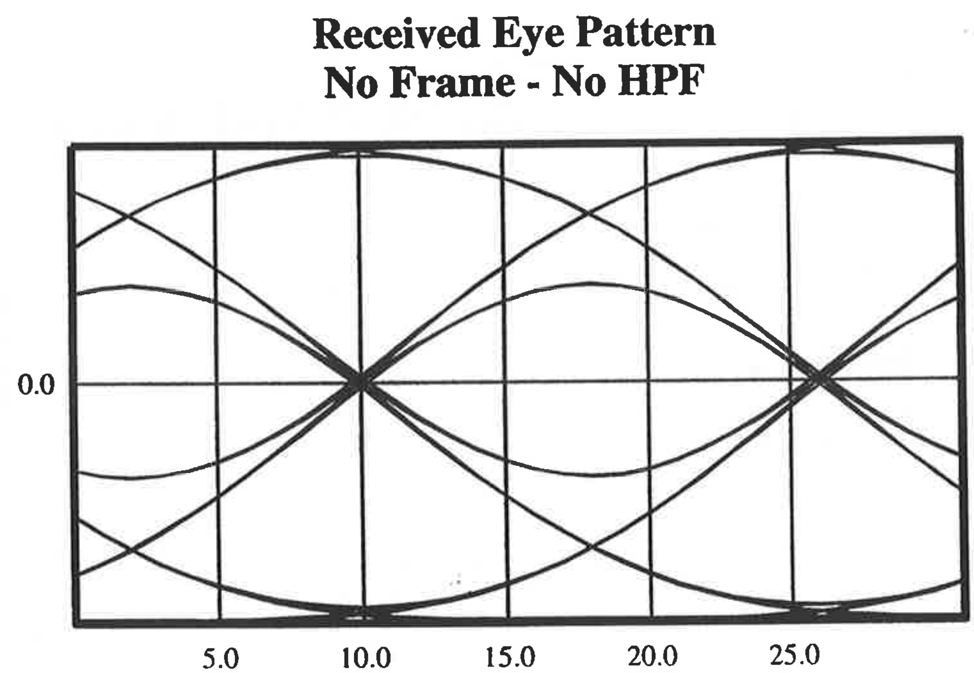

Figure A2. Received Eye Opening

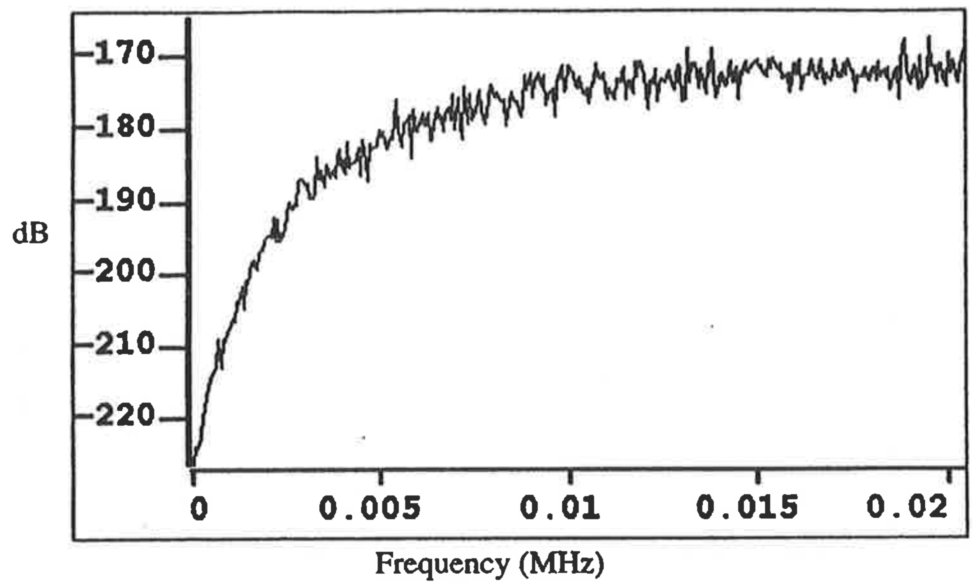

Figure A3. Periodogram of Frame Length 16 Data

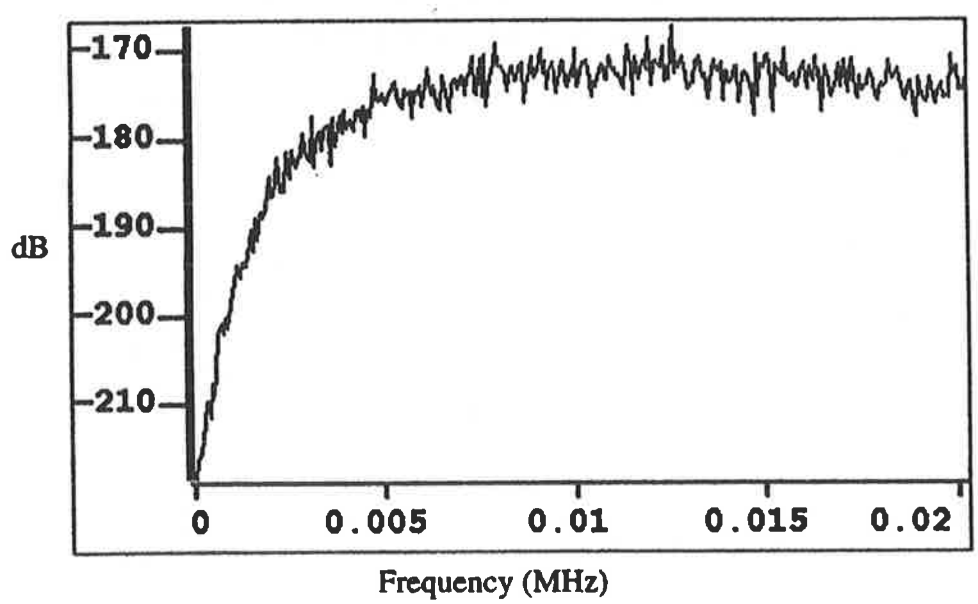

Figure A4. Periodogram of Frame Length 32 Data

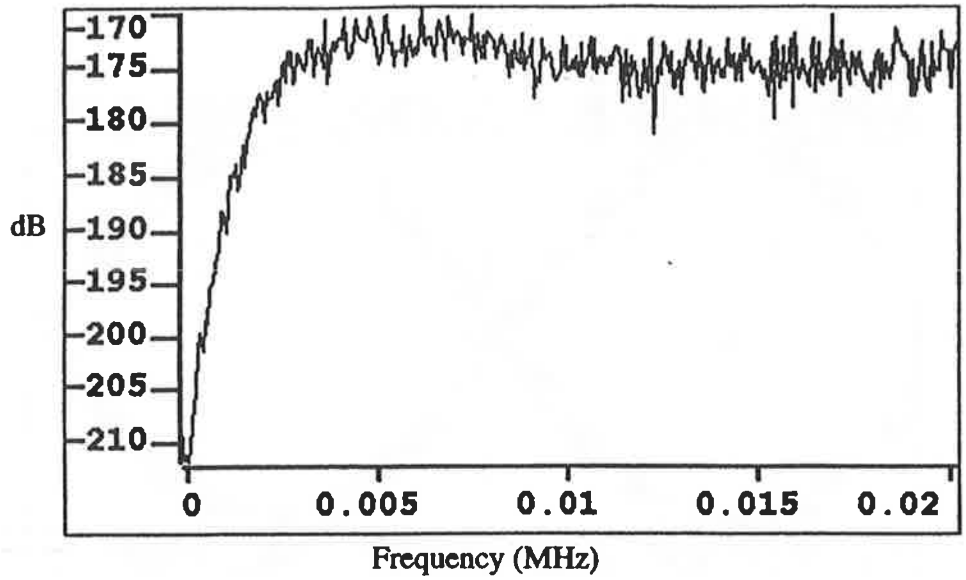

Figure A5. Periodogram of Frame Length 64 Data

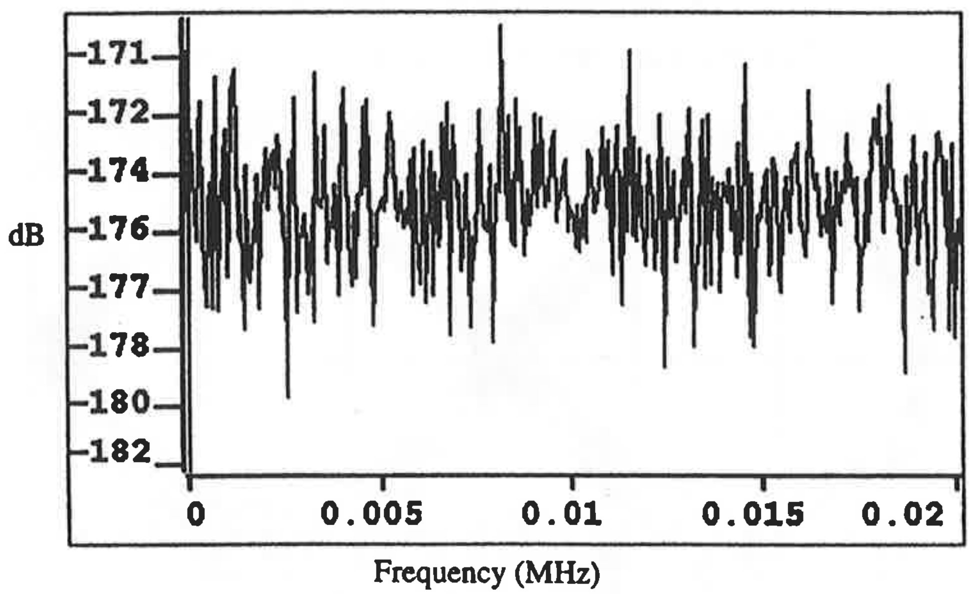

Figure A6. Periodogram of Random Data

Transmitted Eye Pattern
Frame Length = 64 - HPF fc = 1 kHz

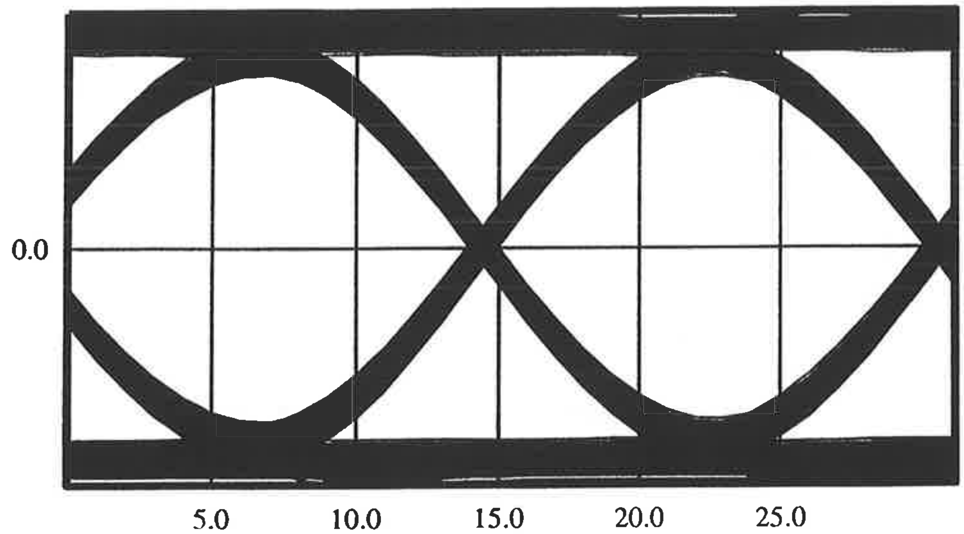

Figure A7. 80% Transmitted Eye Opening

Transmitted Eye Pattern
Frame Length = 64 - HPF fc = 2 kHz

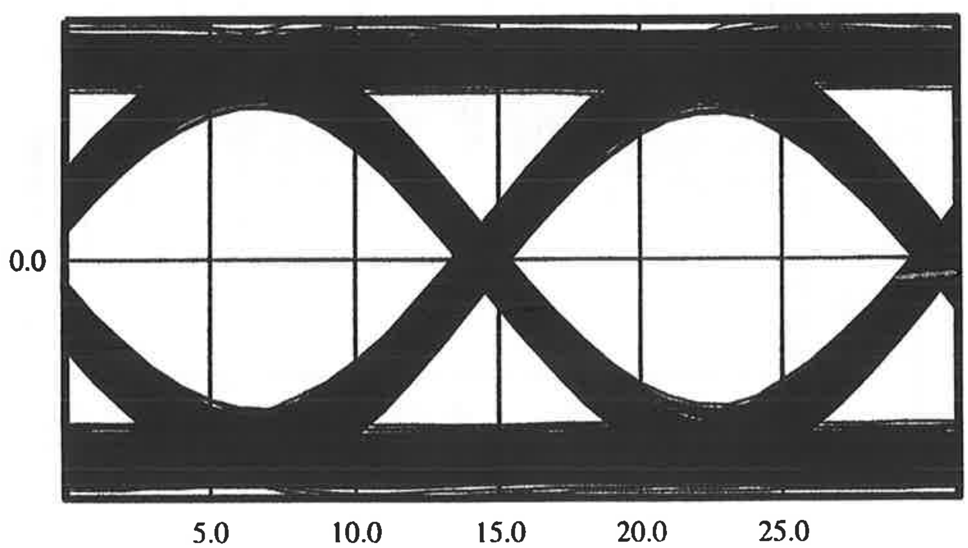

Figure A8. 71% Transmitted Eye Opening