Minutes of the IEEE p802.4L Working Group

Fort Lauderdale, Florida
November 5-7, 1989

Intermediate part on November 5 and 6.

Chairman. Vic Hayes

Secretary & Editor. Michael Masleid, Chuck Thurwachter, Tom Phinney.

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Vic Hayes called the meeting to order at 1:20 PM on 5 November 1989. 11 people were in attendance, who introduced themselves.

The minutes of the Chicago meeting were amended as follows:

Page 2, second line:	add "(delay spread)" following "σ",
Page 2, fifth line	add "Line-of-sight"
Page 2, sixth line	add "obstructed path"
Page 2, paragraph of "conclusion":	replace "the modulation" by "a receiver without equalization"
Page 3, sentence starting with 3):	replace "10.2" by "4".

Tom Phinney moved adoption of the minutes as amended. Bruce Tuch seconded, carried unanimously.

Six new contributions were accepted in various media (Styrofoam, plastic, wire, B-size sheets and 35 mm slides as well as 8.5x11" and A4 paper (see list of temporary documents at the end of this report).

Larry van der Jagt stated that he did not have a proposal for his alternative modulation scheme and that he will drop further pursuit because the receiver, although simple to make, had no resistance against delay-spread.

Bruce Tuch presented the outline for his 90-minute Monday night tutorial.

Analysis of Oshawa Data

Larry van der Jagt presented his further analysis of the Oshawa data. Analysis of 35 different sequence-position data sets gave a pathloss exponent of $R^{2.2}$. and a deviation of 9.5 dB. The data showed that the channel varied only very slowly in time, but changed substantially with motion of just 2.5 mm (1."). The mean delay spread was 286 ns with a standard deviation of 99 ns. The presence of narrow band interfering emitters in the channel may require that the system have more processing gain than afforded by the Barker-11 sequence. Larry suggested that longer M-sequences used with CDM (code division multiplexing) may provide a more robust solution. A part of his analysis is distributed as doc:IEEE p802.4L/89-19

At 5:30 PM, Don Johnson moved to adjourn for the day. Tom Phinney seconded, carried.

6 November 1989

Vic Hayes called the meeting to order at 9:03 AM on 6 November 1989. 14 people were in attendance. (This grew to 16 before the meeting ended)

Analysis of Retail environment Data

Don Johnson presented results of delay-spread measurements made in a large department store in a shopping mall near Atlanta, GA. The rms delay spread was usually 50-100 ns. The worst case obstructed-path measurement, within a tool department, showed a delay-spread of 144 ns.

A detailed analysis of the path losses showed free-space attenuation (6 dB/octave) for short distances (7-13 m) followed by higher attenuation (10-12 dB/octave).

A number of discrete interferers were detected, both in-band and near the band edges, with levels up to -50 dBm near the store entrances.

Don then presented his analysis of the affect of a single impulse, or of a large number of impulses due to uncorrelated emitters. Refer to doc:IEEE p802.4L/89-20.

Characterization of the environment

Vic Hayes tried to characterize the loss, delay-spread and noise statistics observed so far.

environment	slope dB/octave	standard deviation dB	exp	Delay spread (within 20 dB from max peek) ns	Noise
retail	10-13	4-6	3-4	80	
factory	5.5-7	8-10	1.8-3.3	100-110	
office	7-8	3-7	3.3-3.7	<50	

Table 1. Channel characteristics

Tom Phinney moved to adjourn until 8:00 AM Tuesday morning. Joel Love seconded. Carried.

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Fort Lauderdale Florida
November 7-8, 1989

Regular part on November 7 and 8.

Chairman. Vic Hayes

Secretary & Editor. Michael Masleid, Chuck Thurwachter, Tom Phinney.

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Vic Hayes called the meeting to order at 8:29 AM on 7 November 1989. There were 10 people in attendance, growing later to 14.

Vic Hayes started with a review of the last interim meeting. This included a summary of contributions and of the matrix with the characteristics of the office, retail and office environments (Table 1 above).

Characterization of environments

The discussion continued with the completion of the last column of the matrix, called noise. It was pointed out that on one hand real-time waveform recordings were required, and on the other hand the statistics of the number of hits per second above a certain level, for many levels, would be more valuable. We decided that it would be more important to obtain the data as a function of the noise generating device rather than as a function of the environment. Consequently the last column of table 1 above was removed.

Vic attempted to make a new table with columns for device type, impulsive noise and narrow band emission. After some discussion it was concluded to request contributions to fill in the charts as depicted in tables 2 and 3 below as well as on a request to improve the lay-outs of the charts and any other matter for improving the usefulness of the data.

Device	Band	Power *)		Number of hits per second			
		distance	level	Threshold			
		from source		-10 dB	-20 dB	-30 dB	-40 dB
		m	dBm				

Table 2. Characteristics of impulsive noise generators

Device	Band	Power		Bandwidth	Duty cycle
		distance	level		
		m	dBm		

Table 3. Characteristics of Constant Wave Interferers

NOTES:
* reference antenna : dipole for the appropriate band
distance from source > 1 m
vary measurements over a sphere with at least 10 measurements
for impulsive noise measurements: make the measurements in the time domain
for CW measurements: include a graph of frequency versus time behavior for sweeping devices, e.g. microwave ovens.

The discussion went on with the question how these characteristics would be standardized in test suites. Is the classification to be done by environment or by receiver design? Since it is possible to record a transmission and to synthesize an environment it is practical to simulate standard environments. It is more in line with p802.4 practice to standardize performance in environment than it is to specify a design.

In realizing the current specification of noise from devices, it was discussed whether there was a need for the FCC to restrict on the generation of impulsive noise. Toy helicopters, hall effect fans and cash registers of the electromechanical type all produce noise at the GHz level.

Definition of the transmitted signal

Bruce Tuch introduced his contribution on the definition of the transmitted signal and the mathematical proof that the scheme contains sufficient information for a receiver to demodulate. The hand-out was numbered IEEE p802.4L/89-15; this had to be changed into IEEE p802.4L/89-16. On page 11, equation 26 "cos (2πf.." had to be changed into "cos (4πf.. ". These changes will be made prior to distribution.

The contribution was accepted as the basis for the definition of the standard. The nice spectrum of the Barker-11 sequence was stressed; this may not be the case for the M-sequence codes, however. A long discussion ensued on the possible breakdown to a line spectrum due to the data pattern correlating back to a repetitive pattern after the scrambler and the ruling of the FCC. It is felt that the intent of the FCC is to avoid interference with other services and that the momentary line spectrum will cause only minimal interruption to the other users.

Analysis of System Parameters

A long discussion began concerning the advantages of long codes. There are trade-offs between data rates and noise immunity. The discussions were interrupted for lunch at 12:17 PM.

7 November 1989, PM

Vic Hayes called the meeting to order at 1:30 PM on 7 November 1989. 14 people were in attendance.

A number of new items were added to the issues list:

1) trade-offs in data rate vs noise immunity (long vs short codes)
2) long codes vs short codes at higher frequencies (wider bands) and multiple channels (FDM vs CDM)
3) Noise characteristics for various devices.

In exploring the possibilities the guidelines from the Running objectives and directions list were reiterated:

1. Regulatory environment
2. Noise and interference rejection
3. Want high data rate at required BER and outage.
4. Want to support multiple nearby LANs
5. Robust with respect to multipath
6. Want to accommodate relative motion between Transmitter and Receiver
7. For a given operating band (900 MHz, 2.4 GHz, 5.7 GHz), want the interoperability relationship of differing modems to form a direct inclusion relationship (full and not partial ordering).

<u>Components of a solution</u>

A) CDM vs FDM vs TDM
B) Spreading code length
C) BPSK vs QPSK vs DBPSK vs DQPSK
D) Symbol duration compared to delay spread.

With these parameters in mind we started to make a chart with the inter-dependencies of these parameters. The result was further discussed and changed on the Wednesday morning meeting. Please continue reading there for the resulting charts. The meeting continued with the last, mostly domestic, items on the agenda.

Next Meeting

Next meeting 22-26 Jan 1990 at TARA Hotel near Newark, NJ. Tom Phinney and Paul Eastman volunteered to host the meeting in Phoenix AZ instead.

(Note from the chairman: In the plenary p802.4 meeting these dates and places would be changed. Refer to the venue paper for the eventual details).

The meeting's objectives will be to solve issues and work toward the first draft. The last mailing date for the meeting is 23 December 1989.

4 half day sessions will be requested for the meeting at the next plenary of IEEE p802, and may include the Sunday PM and Monday AM.

Tom Phinney moved to adjourn until Wednesday AM. Gunther Martin seconded. Carried unanimously.

8 November 1989

Vic called the meeting to order at 8:35 AM, 12 people were in attendance.

Analysis of System Parameters (continuation)

The implications of spreading amount and bandwidth on the required dynamic range and the ability to reject CW interference, single and multiple impulses, and other types of noise was discussed at length.

The number of useful M-sequences of length 2^n-1 was enumerated for N=5-10.

3 @	31	=	2^5-1
3 @	63	=	2^6-1
9 @	127	=	2^7-1
8 @	255	=	2^8-1
24 @	511	=	2^9-1
30 @	1023	=	$2^{10}-1$

An attempt was made to look at the pros and cons of the Barker-11 sequence, the length 31 M-sequences, and the length 127 M-sequences.

A number of basic relationships among some of the variables in the modulation design space were enumerated/elucidated

Assumptions: No equalizer and a symbol time of 500 ns while the (disturbing) delay spread is smaller than the symbol time

Band MHz	902-9281	2400-2483	5725-5850
	capacity in	capacity in	capacity in
	kbit/s	kbit/s	kbit/s
11 chips			
DQPSK	2000	3 x 2000 (FDM)1)	5 x 2000 (FDM)1)
31 chips	--	--	--
127 chips DQPSK	173	520	870
127 chips PSK	87	260	435
127 chips QPSK + CDM	1557 (CDM) 2)	4680 (CDM) 2)	7830 (CDM) 2)

Table 4. Capacity of the various bands depending on the modulation and spreading methods

Note 1: 3 channels or 5 channels available

Note 2: 1 channel but with 9 bits sent simultaneously in a symbol

The following list with dependencies among the various parameters was provisionally established:

Without multi-symbol equalizer, the symbol time can not exceed the peek delay spread of the channel.. As a consequence, larger delay-spread mean lower symbol rates. In such environments it is useful to consider higher dimensionality of the symbol space.

For a Power limited transmitter the energy per bit varies inversely with the data rate.

Long sequences give higher dimensionality

a) for the same symbol rate they require higher bandwidth

b) for fixed power per symbol, power per bit varies inversely with the number of bits per symbol

c) using CDM to increase the data rate by simultaneous transmission of multiple codes creates interference due to cross correlation.

d) if noise power density decreases with increasing dimensionality, the increasing dimensionality increases resistance against interferers.

f) changing the frequency bandwidth does not necessarily change the density of the interference

g) longer chipcodes increase the dimensionality per symbol which can be used for:

1. increase the bits per symbol
2. and/or increased dimensionality per bit.

I. Keeping the data rate the same, long codes may have the following advantage (+) or disadvantage (-) with respect to the Barker-11 sequence against solitary impulse

- a) increased bandwidth brings in power equal to bandwidth or power equal to bandwidth ^{2}
+ b) processing gain
+ c) nonlinear clipping
1. CDM makes Gaussian voltage distribution which increases the clipping limit
2. CW interferers (which must not be clipped) increase clipping limit

II. Keeping the data rate the same, long codes may have the following advantage (+) or disadvantage (-) with respect to the Barker-11 sequence against CW interferers

+ a) peculiar characteristics of moderate length M-sequences may cancel CW interferers.

NOTE for the analysis of the above criteria receiver models must be given.

Table 5 was was drafted to summaries the gains in immunity depending of the amount of spreading and showing the effects of various noise types.

Comments are requested on any of the tables and statements drafted at the meeting.

Amnt of Spread	Effect of Gaussian noise				Effect of Line interferers				Effect of impulsive noise			
	constant chiprate 5.5 Mchip/s		constant data rate 1000 kbit/s		constant chiprate 5.5 Mchip/s		constant data rate 1000 kbit/s		constant chiprate 5.5 Mchip/s		constant data rate 1000 kbit/s	
	gain	data rate	gain	chip rate	gain	data rate	gain	chip rate	gain	data rate	gain	chip rate
chips /symbol	dB	kbit/s	dB	Mchip/s	dB	kbit/s	dB	Mchip/s	dB	kbit/s	dB	Mchip/s
11	0	1000	0	5.5	0	1000	0	5.5	0	1000	0	5.5
127	10.6	87	0	60.5	10.6	87	0....10.6	60.5	0....10.6	87	0?	60.5
							⇑		⇑			
255	13.7	43	0	121	13.7	43	0....13.7	121	0....13.7	43	0?	121
							⇑		⇑			

Table 5. Gains in noise immunity depending on the amount of spreading
11 chips/symbol is the reference
DQPSK modulation

Note: The arrows point to the most likely value. Further analysis is required.

At 11:50 Tom Phiney moved adjournment "until we meet again". Chuck Thurwachter second, carried unanimously.

List of temporary documents

Temp.	Source	Title	Document number
F.4L/1	Hayes	Document list	
F.4L/2	Hayes	Agenda	
F.4L/3	Hayes	Attendance list	
F.4L/4	Masleid	Impulse response conformal maps and model	
F.4L/5	Storoschuk	35 mm slides of factory and plant lay-outs	
F.4L/6	van der Jagt	Statistic analysis of Oshawa analysis	doc: IEEE p802.4L/89-19
F.4L/7	Johnson	Impulse noise effect on 4 level QAM Spread Spectrum Signal	doc: IEEE p802.4L/89-20
F.4L/8	Johnson	Retail measurement results	doc: IEEE p802.4L/89-21
F.4L/9	Tuch	Slides for tutorial	
F.4L/10	Tuch	Hand-outs for tutorial	

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