

**IEEE 802.4L
THROUGH-THE-AIR TOKEN BUS PHYSICAL LAYER**

**Minutes of regular meeting of IEEE 802.4L on July 16, 1987 at 0900
at the Vancouver Hotel, Vancouver, B.C., Canada**

OPENING MATTERS

The meeting was called to order by Chan Rypinski, Vice Chairman, who announced that David Greentstein, Chairman, was unable to attend, and had asked him to chair this meeting.

The Chair noted that attendance was light, and he observed that there was a conflict with the main activity of 802.4, now at a critical phase of completing the revisions to the entire standard preparatory to a submission to ballot. Many individuals involved in this effort would have liked to attend the 802.4L meeting. This observation was later repeated by Bob Douglas, Chairman of 802.4, who attended parts of the 802.4L meeting.

The Chair asked those present to introduce themselves and to sign the attendance list. The Chair introduced, Michael Callendar, who is the international Chairman of CCIR Study Group 8, Interim Working Party 13 and who he had invited to attend. The mission of IWP 8/13 is to develop standards for future digital public land mobile radio services.

The Chair asked Ron Matthews to take notes on the decisions reached in the meeting.

The Chair announced that all present were eligible to vote excepting only those not participating in 802.4L.

The Chair passed out all available submissions and including the Minutes of the previous meeting, 87-006.

A motion was made, seconded and unanimously passed to accept the Minutes of the previous meeting as submitted.

The Chair announced that preparation and approval of a Project Authorization Request (PAR) was a critical responsibility for this meeting.

REPORTS ON ASSIGNMENTS

At the previous meeting, the Chair (D. Greenstein) had asked for contributions to be submitted and the Chair called for these to be presented:

1. Mr. T. Saito reported that he could find very little material on through-the-air optical data transmission at NEC. He submitted a publication from the NEC R&D journal on "Atmospheric Laser Communications Equipment" (which the Chair later marked 87-012).
2. Rick Formeister submitted a complete text of the FCC Rule-making (20 pages) on spread spectrum communication issued May 9, 1986. (which the Chair later marked 87-013).
3. The Chair offered his own submissions:
 - A. "FCC Rules and Possible Operating Frequencies" -- 87-007
 - B. "System Plan(s), Wireless LAN. . . .", for three different assumptions on frequency availability, bandwidth and modulation parameters -- 87-008, -009 and -011.
 - C. "Draft of Preparation for Counsel, Petition for Rule-Making, Industrial Wireless Automation Service" -- 87-010

DISCUSSION OF FCC CONSIDERATIONS

The meeting discussed the FCC aspect. One tentative conclusion was that it is possible that the IEEE group might need to petition the FCC for necessary Rule-Making to support a wireless LAN. The success of such a petition depends upon showing of need, a technical method suited to coexistence with some group of existing users of frequency space and a supporting constituency which as a group can validate a claim to improved economic efficiency for the institutional users.

**IEEE 802.4L
THROUGH-THE-AIR TOKEN BUS PHYSICAL LAYER
Report of the Vice-Chairman
Submission of the PAR to 802.4 and 802 Executive Committee**

SUBMISSION OF THE PAR TO 802.4

The edited draft PAR from the morning meeting of 802.4L was taken to the 802.4 plenary in exactly the edited, handwritten form from which it had emerged. 802.4 was much taken up with other important matters, but eventually Bob Douglas gave me the floor to present it with cautions on taking excess time.

The group was unsatisfied with poor wordsmanship in the scope section, and was dissatisfied with the purpose. I was instructed to leave the meeting, edit, and return with an improved text.

Working by myself, the text was edited to satisfy the objections of that meeting with the following result:

4. *SCOPE: To define an alternative physical layer for through-the-air communication which is part of a local area network using 802.4 media access technique and which is primarily for mobile environments.*

5. *PURPOSE: To provide LAN access to moving automatic machines and other stations for which wireless attachment is appropriate. To add description of standards criteria for through-the-air transmission parameters to support physical layer service. To prepare, if necessary, a petition to the FCC for Rule Making which authorizes use of radio spectrum for wireless LAN.*

Later in the afternoon, Bob Douglas asked me to present the revised PAR. He remarked on the FCC statement, the first of its kind in 802. The revised PAR motion was untabled and passed without dissent in seconds. He took the film for his use, and I kept the original. This PAR is attached and marked 87-014 (2 sheets).

I asked Douglas to poll the meeting to find out who would attend an 802.4L meeting on Monday of the next plenary week, but who could not attend on Thursday morning. There were at least 5 hands.

The PAR was not signed by anybody, and the blank for person delegated to receive communications was not filled in. Something will have to be done about these omissions.

SUBMISSION TO 802 EXECUTIVE COMMITTEE

Starting at 1900, the Executive Committee had a full agenda, much of which was taken up by the complaints of FDDI about overlap in scope with 802.6. Under New Business, 802.4 matters were 5.8 to 5.10. Bob Douglas came to the floor about 1100. He presented the new 802.4L PAR again calling attention to the FCC sentence. The PAR was passed without discussion, again in seconds.

RATIFICATION

I will ask the next regular meeting of 802.4L to ratify these actions and amend the Charter for consistency.

It is also my belief that it would be a good idea to call a Monday AM meeting on Plenary week for an exclusively technical discussion of the problems and solutions.

Respectfully submitted,

Chandos A. Rypinski,
Vice Chairman and Secretary of 802.4L

August 24, 1987

-5-

DOC: 802.4L/87-015

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IEEE 802-87*0.xx.A

AGENDA & MINUTES - IEEE 802 EXECUTIVE COMMITTEE MEETING

Thursday, July 16, 1987 - 7:00 p.m.

Hotel Vancouver Vancouver, B.C.

1. MEETING CALLED TO ORDER 7:00 p.m.
2. APPROVE OR MODIFY AGENDA 7:01 p.m.
3. ✓ TREASURER'S REPORT - Montague 7:05 p.m.
4. OLD BUSINESS
 - ✓ 4.1 TUTORIALS/SOCIAL HOUR - Rigsbee 7:10 p.m.
 - ✓ 4.2 FUTURE MEETINGS - Rigsbee 7:20 p.m.
 - ✓ 4.3 DOCUMENT LIST - Rigsbee 7:30 p.m.
 - ✓ 4.4 MEETING ROOM ASSIGNMENTS - Rigsbee 7:40 p.m.
 - ✓ 4.5 802.6 FUNCT. REQMTS & CHARTER - Mollenauer 7:50 p.m.
 - ✓ 4.6 MULTICAST MAC ADDRESSES - Lidinsky 8:20 p.m.
 - ✓ 4.7 CONFIRMATION BALLOTS - Graube 8:30 p.m.
 - ✓ 4.8 CONFORMANCE TESTING - Carlson 8:50 p.m.
5. NEW BUSINESS
 - ✓ 5.1 NEW 802.7 CHAIRMAN - Montrose 9:00 p.m.
 - ✓ 5.2 802.7 DRAFT H MAILINGS - Montrose 9:05 p.m.
 - ✓ 5.3 802.5 MOTIONS - Donnan 9:15 p.m.
 - 5.4 802 POSITION TRANSMITTAL TO X3 - Donnan 9:30 p.m.
 - ✓ 5.5 802.2 MOTIONS - Carlson 9:45 p.m.
 - ✓ 5.6 DADS - Loughry 10:00 p.m.
 - ✓ 5.7 FUTURE TCCC BALLOTING - Gibson 10:20 p.m.
 - ✓ 5.8 802.4 PARS - Douglas 10:30 p.m.
 - ✓ 5.9 BALLOTING EXPENSES - Douglas 10:40 p.m.
 - ✓ 5.10 NEW 802.4 CHAIRMAN - Douglas 10:50 p.m.
 - ✓ 5.11 LIAISON 802.0 TO X3T5 ON MANAGEMENT REQMTS - Lidinsky 11:00 p.m.
 - 5.12 PARTICIPATION IN WED. MORN. TECH. PLENARY - Lidinsky 11:20 p.m.
 - 5.13 - 11:30 p.m.
 - 5.14 - 11:40 p.m.
 - 5.15 - 11:50 p.m.

802 ARCHITECTURE & STANDARDS

AGEN802D

802.4L APPROVED AT 1100 PM

IEEE 802.4 WORKING GROUP
MEETING AGENDA
JULY 13-17, 1987 Vancouver, BC

Monday, July 13

3:30 - 802.4 Working Group Meeting - Room 227

Status of ISO IS
TG Interem Meeting Reports
Thru-Air Media Charter/PAR
Redundant Media PAR?
Distribute comments on Draft G
Phase-Continuous inclusion?
new business
Request for 802.4J4 from MAP

Tuesday, July 14

8:00 - 802.4H - Fiber Optic WG - Room 227
802.4J1/J3 - Eband/Carrierband Conformance - Garbal.
802.4J2 - MAC Conformance - Room 237

12:00 - Lunch

1:30 - 802.4H - Fiber Optic WG - Room 227
Draft G Physical Editing - Garbal.
802.4J2 - MAC Conformance - Room 237

Wednesday, July 15

8:00 - 802.4H - Fiber Optic WG - Room 227
Draft G Physical Editing - Garbal.
Draft G MAC Editing - Room 237

12:00 - Lunch

1:30 - 802.4H - Fiber Optic WG - Room 227
Draft G Physical Editing - Garbal.
Draft G MAC Editing - Room 237

Thursday, July 16

8:00 - 802.4H - Fiber Optic WG - Room 227
802.4L - Thru Air Media - Garbal.
802.4K - Redundant Media - Room 237

12:00 - Lunch

1:30 - 802.4 Working Group - Room 227

TG Chairman Reports
Editor Reports
Proceed to Draft H?

July 11, 1987

**AGENDA--IEEE 802.4L--JULY 16, 1987
THROUGH-THE-AIR TOKEN BUS**

**CHAIRMAN: DAVID GREENSTEIN
VICE-CHAIRMAN AND SECRETARY: CHANDOS RYPINSKI**

1. Opening
 - A. Attendance
 - B. IEEE Rules
 - C. Introductions
 - D. Receipt or announcement of new submissions
2. Minutes of last meeting at New Orleans
3. Report on presentation of Charter/Objectives to 802.4 and
Chair's update on current status - *PAR*
4. Presentation of Submissions
5. Summary and assignment of new tasks
6. Discussion of interim working meeting
7. Adjourn

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TO DEFINE AN ALTERNATIVE PHYSICAL LAYER
~~FOR~~ FOR THROUGH THE AIR COMMUNICATION
FOR ^{TO WHICH} MOBILE EQUIPMENTS AS PART OF A
LOCAL AREA NETWORK USING THE 802.4

MEDIA ACCESS TECHNIQUE THE SYSTEM DEFINED
MAY REQUIRE DEFINED BRIDGE FUNCTIONS
WHICH ARE PECULIAR TO THROUGH THE-
AIR COMMUNICATION

TO PREPARE +
TO ~~FOR~~ PETITION FOR RULE-MAKING
TO THE FCC COULD BE NECESSARY
TO PROVIDE AUTHORIZATION FOR
NEW OR ADDED USE OF RADIO SPECTRUM
FOR A SERVICE NOT NOW PART OF
THE RULES.

TO PREP. IF ACC. PETITION TO FCC FOR rule making ^{which authorizes} ~~authorization~~
USE OF RADIO SPECTRUM FOR WIRELESS LAN.

STANDARDS PROJECT AUTHORIZATION (PAR)

When completing this PAR refer to instructions in the PAR Submitter's Guide

239

1. <u>July 15, 1987</u> Date of Request		Revised PAR <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No		12. Standards Board Assigned Project No. _____ Approved: _____ (For Standards Office Use Only)	
2. <input checked="" type="checkbox"/> Standard <input type="checkbox"/> New		<input type="checkbox"/> Recommended Practice <input checked="" type="checkbox"/> Annexed To Revision of <u>802.4</u>		<input type="checkbox"/> Guide	
3. Project Title: <u>Through-The-Air Token Bus Physical Layer</u>					
4. Scope of Proposed Standard (use attachment sheet if necessary): <u>To define an alternative physical layer for through the air communication for primarily mobile environments as part of a local area network using the 802.4 media access technique.</u>					
5. Purpose of Proposed Standard (use attachment sheet if necessary): <u>To add description of standard criteria for through-the-air transmission parameters and formats with necessary functions to support 802.4 DTE/DCE interface and higher layers. The system defined may require bridge functions which are peculiar to through-the-air communication. To prepare, if necessary, a petition to the FCC for rule making which authorizes use of radio spectrum for wireless LAN.</u>					
6. Sponsor Technical Committee: _____ Society: _____					
7. Proposed Coordination: <u>IEEE Communications Society</u> <u>IEEE Vehicular Technology Society</u> <u>CCIR (IWP 8/13)</u>			Method of Coordination: <u>Distribution of minutes and requested documents.</u> <u>Joint membership US Advisory Group</u>		
8. Name of Group that will write the Standard: <u>IEEE 802.4L</u>					
9. Are you aware of any patent issues? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No (If yes, attach a sheet with a complete description.) Are you aware of any standards or projects with a similar scope? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No (If yes, attach a sheet with a complete description.)					
10. Person Delegated to Receive Communications and Conduct Liaison with Interested Bodies: Name _____ Company _____ Street Address _____ City _____ Telephone No. _____ Telex No. _____ State _____ Zip Code _____					
11. Submitted by: Name <u>Chandos Rypinski</u> Company _____ Street Address <u>130 Stewart Drive</u> City <u>Tiburon</u> Telephone No. <u>415 435 0642</u> Telex No. _____ State <u>CA</u> Zip Code <u>94920</u>					

Note: Copies of PAR Submitter's Guide and the IEEE Standards Manual are available from the IEEE Standards Office

11/13/85 :lg

IEEE 802.4 L CHARTER

THROUGH-THE-AIR TOKEN BUS PHYSICAL LAYER

To define an alternative physical layer for through-the-air communication for primarily mobile environments as part of a local area network using the 802.4 media access technique.

IEEE STANDARDS COMMITTEE 802.4L
THROUGH-THE-AIR TOKEN BUS ACCESS METHOD
MEETING NOTICE

The attendance of those interested in participating in the selection of a suitable method for providing a wireless environment for LAN access are requested to attend a meeting of 802.4L for technical discussions only:

November 9, 1987 at 0900
Room to be posted at Hotel
Embassy Suites Hotel (802 Plenary location)
Ft. Lauderdale, Florida

The proposed agenda:

Introduction: Current activities in digital radio
Report by C. Rypinski

1. FCC technical constraints
 - A. Frequency band assumptions
 - a. 902-928 MHz
 - b. 2400-2483.5
 - c. 5725-5850
 - d. other
 - B. Licensing or Certification
 - C. Transmitter power and energy spreading
2. System plan
 - A. Multiple radiation point coverage
 - B. Diversity techniques
 - C. Channelization and frequency reuse
 - D. Error correcting/detecting channel coding
 - E. Hierarchical or flat system control
 - F. Channel digital modulation
3. User requirements
 - A. Central administration
 - B. Installation compatibilities
4. Techniques supported by existing knowledge.

We hope to see you and any interested persons you may invite at this meeting.

For David Greenstein, Chairman



Chandos A. Rypinski, Secretary 802.4L
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SPECIAL ISSUE ON MOBILE RADIO COMMUNICATIONS

Guest Editor—J. H. Davis

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EDITORS' COMMENTS

- 469 Mobile and Personal Communications—Editors' Comments....J. H. Davis, J. J. Mikulski, and P. T. Porter

PAPERS

Physical Channel, Channel Coding, and Modulation

- 472 ARQ Schemes for Data Transmission in Mobile Radio Systems....R. A. Comroe and D. J. Costello, Jr.
482 Throughput Analysis for Code Division Multiple Access of the Spread Spectrum Channel....J. Y. N. Hui
487 Generalized Tamed Frequency Modulation and Its Application for Mobile Radio Communications....K.-S. Chung
498 Multilevel Decision Method for Band-Limited Digital FM with Limiter-Discriminator Detection....M. Hirano, T. Miki, and K. Murota

Diversity and Channel Access

- 507 Outage Probability in Mobile Telephony with Directive Antennas and Macrodiversity....Y.-S. Yeh, J. C. Wilson, and S. C. Schwartz
512 Performance of 16 kbit/s GMSK Transmission with Postdetection Selection Diversity in Land Mobile Radio....T. Miki and M. Hata
518 Diversity Improvement of Voice Signal Transmission Using Postdetection Selection Combining in Land Mobile Radio....K. Suwa, I. Shimizu, and T. Hattori
528 Optimum Combining in Digital Mobile Radio with Cochannel Interference....J. H. Winters
540 Switched-Diversity FSK in Frequency-Selective Rayleigh Fading....H. W. Arnold and W. F. Bodtmann
548 Commutation Signaling—An Antimultipath Technique....G. L. Turin
563 Slow Frequency Hopping Multiple Access For Digital Cellular Radiotelephone....D. Verhulst, M. Mouly, and J. Szpirglas
575 Multiple Accessing for the Collision Channel Without Feedback....J. Y. N. Hui
583 Analysis of Mobile Radio Slotted ALOHA Networks....C. Namislo

System Timing and Control

- 589 C 900—An Advanced Mobile Radio Telephone System with Optimum Frequency Utilization....K. Kammerlander
597 The Effects of Multipath and Fading on the Performance of Direct-Sequence CDMA Systems....G. L. Turin
604 Digital Portable Transceiver Using GMSK Modem and ADM Codec....H. Suzuki, K. Momma, and Y. Yamao

System Architecture

- 611 Design and Test of a Spectrally Efficient Land Mobile Communications System Using LPC Speech....M. McLaughlin, D. Linder, and S. Carney
621 Adaptive Mobile Access Protocol (AMAP) for the Message Service of a Land Mobile Satellite Experiment (MSAT-X)....V. O. K. Li and T.-Y. Yan



IEEE TRANSACTIONS ON COMMUNICATIONS

MARCH 1981

VOLUME COM-29

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A PUBLICATION OF THE IEEE COMMUNICATIONS SOCIETY



DUP

SPECIAL SECTION ON COMBINED MODULATION AND ENCODING

Guest Editors: J. B. Anderson and J. R. Lesh

- 185 Guest Editors' Prologue.....J. B. Anderson and J. R. Lesh
-
- 187 Power-Bandwidth Performance of Smoothed Phase Modulation Codes.....J. B. Anderson, C.-E. W. Sundberg, T. Aulin, and N. Rydbeck
- 196 Continuous Phase Modulation—Part I: Full Response Signaling.....T. Aulin and C.-E. W. Sundberg
- 210 Continuous Phase Modulation—Part II: Partial Response Signaling.....T. Aulin, N. Rydbeck, and C.-E. W. Sundberg
- 226 Correlative Phase Shift Keying—A Class of Constant Envelope Modulation Techniques.....D. Mulwijk
- 237 Quadrature Overlapped Raised-Cosine Modulation.....M. C. Austin and M. U. Chang
- 250 Power Spectra of Multi- h Phase Codes.....S. G. Wilson and R. C. Gaus
- 257 Demodulation and Carrier Synchronization of Multi- h Phase Codes.....B. A. Mazur and D. P. Taylor
- 267 A Simulation Study of Two Bandwidth-Efficient Modulation Techniques.....D. P. Taylor and H. C. Chan
- 276 Spectrally Efficient Communication via Fading Channels Using Coded Multilevel DPSK.....D. A. Johnston and S. K. Jones
- 285 Cochannel and Intersymbol Interference in Quadrature-Carrier Modulation Systems.....J. R. Cruz and R. S. Simpson

REGULAR SECTION

PAPERS

- 298 Teletraffic Analysis for Single-Cell Mobile Radio Telephone Systems.....S. H. Bakry and M. H. Ackroyd
- 305 Performance of Offset Quadrature Spread-Spectrum Multiple-Access Communications.....F. D. Garber and M. B. Pursley
- 314 A Method for Transponder Capacity and Link Performance Optimization in Preassigned Multilevel SCPC Systems.....L. N. Nguyen and O. Shimbo
- 329 An Evaluation of Local Path ID Swapping in Computer Networks.....G. Markowsky and F. H. Moss
- 337 Design and Performance of a DSI Terminal for Domestic Applications.....R. Maruta, A. Tomozawa, T. Nishitani, T. Okada, K. Nakano, T. Araseki, and M. Tajima
- 346 More on the Multipath Fading Channel Model.....W. D. Rummier
- 353 An Efficient Selective-Repeat ARQ Scheme for Satellite Channels and Its Throughput Analysis.....P. S. Yu and S. Lin

CONCISE PAPERS

- 364 The Effect of Phase Error on DPSK Error Probability.....N. M. Blachman
- 365 New LSI Digital Service Units and Office Channel Units Used for NTT Digital Data Networks.....T. Wakahara, S. Shimada, and F. Kanaya

proceedings OF THE IEEE



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january 1987

SPECIAL ISSUE ON PACKET RADIO NETWORKS

Edited by B. M. Leiner, D. L. Nielson, and F. A. Tobagi

3 SCANNING THE ISSUE

PAPERS

- 6 Issues in Packet Radio Network Design (*Invited Paper*), B. M. Leiner, D. L. Nielson, and F. A. Tobagi
- 21 The DARPA Packet Radio Network Protocols (*Invited Paper*), J. Jubin and J. D. Tornow
- 33 The Low-Cost Packet Radio (*Invited Paper*), W. C. Fifer and F. J. Bruno
- 43 The Application of Packet Switching Techniques to Combat Net Radio (*Invited Paper*), B. H. Davies and T. R. Davies
- 56 A Design Concept for Reliable Mobile Radio Networks with Frequency Hopping Signaling (*Invited Paper*), A. Ephremides, J. E. Wieselthier, and D. J. Baker
- 74 Crosslink Architectures for a Multiple Satellite System (*Invited Paper*), R. Binder, S. D. Huffman, I. Gurantz, and P. A. Vena
- 83 Future Directions in Packet Radio Architectures and Protocols (*Invited Paper*), N. Shacham and J. Westcott
- 100 Wide-Band Packet Radio Technology (*Invited Paper*), J. H. Fischer, J. H. Cafarella, D. R. Arsenault, G. T. Flynn, and C. A. Bouman
- 116 The Role of Spread Spectrum in Packet Radio Networks (*Invited Paper*), M. B. Pursley
- 135 Modeling and Performance Analysis of Multihop Packet Radio Networks (*Invited Paper*), F. A. Tobagi
- 156 Spatial Reuse in Multihop Packet Radio Networks (*Invited Paper*), L. Kleinrock and J. Silvester

PROCEEDINGS LETTERS

Electronic Circuits and Design

- 168 A Stray-Insensitive Single Switched-Capacitor Ladder Realization of an Arbitrary Order Low-Pass Filter, T. S. Rathore, S. M. Faruque, and B. B. Bhattacharyya

Miscellaneous

- 170 Electric Field of a Transmission Line over Multilayered Media, I. S. Moghram and D. J. Tylavsky

BOOK REVIEWS

- 172 *Recent Advances in Robotics*, G. Beni and S. Hackwood, Eds., reviewed by A. L. Pai
- 172 Book Alert

- 173 FUTURE SPECIAL ISSUES/SPECIAL SECTIONS OF THE PROCEEDINGS

- 174 INFORMATION FOR PROCEEDINGS AUTHORS

- 175 IEEE COPYRIGHT FORM

JANUARY

features

- 5 Measurement, Characterization and Modeling of Indoor 800/900 MHz Radio Channels for Digital Communications/Robert J.C. Bultitude**
This article reports continuous wave (CW) propagation experiments that were conducted at 910 MHz in order to determine the characteristics of indoor radio channels between fixed terminals. The measurement system and experimental procedures are described and analysis results are presented. Discussions regarding the physical interpretation of the results and their application are also included
- 13 Multipath Time Delay Spread in the Digital Portable Radio Environment/Daniel M.J. Devasirvatham**
Radio propagation in the digital portable communication environment is examined in this article. Time delay spread measurements are introduced and discussed in detail
- 22 Cellular Access Digital Network (CADN): Wireless Access to Networks of the Future/E.S.K. Chien, D.J. Goodman, and J.E. Russell**
This article examines the Cellular Access Digital Network (CADN), a wireless access network, which merges the wireless transmission and user location capability of cellular systems with the signaling and network control features of ISDN
- 32 Spread Spectrum for Indoor Digital Radio/M. Kavehrad and P.J. McLane**
Spread spectrum modulation is universally accepted in the hostile communication environments that occur in military applications. In consumer applications, spread spectrum is not widely accepted, in spite of recent FCC encouragements and rulings. We present a commercial application of direct sequence, spread spectrum modulation. This involves indoor digital radio for office, factory or laboratory based wireless PBX applications. Experimental results, as well as a discussion of the advantages of spread spectrum in harsh indoor, multipath environments, are included. Some sample calculations of multipath outage and a short description of a frequency hopping system complete the article
- 41 Multiple Access Communications Networks/Victor O.K. Li**
This article is an introduction to multiple access communications networks in which the terminals share common communication channels. Multiple access networks include satellite networks, local area networks, and packet radio networks. Various multiple access protocols will be described. We shall also describe how some of these protocols are used in different multiple access networks

departments

President's Message/F.T. Andrews	3
Guest Editorial/M. Kavehrad	4
New Products/K. Clark	49
Conference Calendar/R. Cupo	51
Solution to CommuniCrostic No. 57	53
CommuniCrostic No. 58/P. Green	55
News from the Board of Governors	56
Meeting Report/R. Cupo	56
Advertiser's Index/C. Jones	56

This month, we are pleased to present an article by Victor O.K. Li that links the Magazine and a forthcoming issue (July 1987) of the *Journal on Selected Areas in Communications* (JSAC). This is the first time that a guest editor for JSAC has placed an article in the Magazine to serve as a bridge between our Society's publications.

It is hoped that this "bridge" will continue in future issues, so that those members of the Society who do not receive JSAC will still benefit from its tutorial articles by reading a sampling of them in the Magazine. We encourage this cooperation and thank Dr. Li for his article.

As an example, the bit rate of a minimum bandwidth (zero-rolloff) QAM signal transmitted through a Gaussian channel was maximized.

The optimization can be extended to QAM signals with rolloff and the simpler case of one-dimensional modulations, e.g., PAM.

ACKNOWLEDGMENT

I would like to thank an anonymous reviewer for parts of the table.

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Performance of Quadrature Amplitude Modulation for Indoor Radio Communications

REINALDO A. VALENZUELA

Abstract—The performance of M -QAM for indoor radio communications is evaluated via a realistic model for indoor multipath propagation [1]. It is found that the outage (BER $< 10^{-4}$) is about 0.3 percent at 1 Mbit/s and 20 percent at 4 Mbits/s. Two-antenna predetection diversity reduces the outage from 1.2 to 0.04 percent at 2 Mbits/s. Increasing the signaling pulse rolloff factor from 0.5 to 1.0 reduces the outage by not more than 35 percent.

I. INTRODUCTION

Indoor radio may provide a very flexible support for voice and data services. Thus, it is of particular interest to evaluate, via a realistic channel model [1], what performance can be expected with conventional technology, such as M -level quadrature amplitude modulation (M -QAM), as a reference against which more elaborate systems could be compared.

System performance, in this space- and time-dependent channel is appropriately characterized in terms of *outage probability*, which is the fraction of locations for which, at a given instant, the bit error rate will be below a given threshold. This can be interpreted also as the fraction of time for which a moving terminal will have a bit error rate worse than required. In the work reported here, performance is evaluated for a reasonable "worst case" office which is located furthest from the transmitter and includes extensive multipath propagation, but is not completely in the shadow of a metal structure.

II. SYSTEM DESCRIPTION

A. Block Diagram

We consider a conventional M -level QAM system with a raised-cosine pulse shaping (rolloff factor α), coherent demod-

ulator, and timing derived through square-law envelope detection and narrow-band filtering, as outlined in the Appendix. For the AWGN channel, the detector signal-to-noise ratio can be written as [3]

$$\rho = \frac{3}{(M-1)} \text{CNR}_0 \quad (1)$$

where $\text{CNR}_0 \equiv P_{av}T/N_0$ is the unfaded carrier-to-noise ratio, the factor $3/(M-1)$ is the penalty associated with using $M > 4$, N_0 is the thermal noise power density times the receiver noise figure, P_{av} is the average symbol power at the detector, and T is the symbol period. The probability of a bit error is upper bounded by [7]

$$P_b = \frac{2}{\log_2 M} \left(1 - \frac{1}{L}\right) \text{erfc}(\sqrt{\rho}) \leq 0.5 \text{erfc}(\sqrt{\rho}). \quad (2)$$

In the experimental setup reported in [1], the worst case carrier-to-noise ratio is about 40 dB at 1 Mbaud, which is a typical value for a transmitter power of 200 mW and same floor propagation distance of 60 m from the transmitter.

III. THE CHANNEL MODEL

The indoor multipath propagation model, as presented in [1], is based on multipath delay spread (5 ns resolution) and attenuation measurements. In the model, rays arrive in clusters where the cluster arrival times and the ray arrival times are both Poisson processes with parameters Λ and λ , respectively. The complex, low-pass channel impulse response is given by

$$h(t) = \sum_{k=0}^{\infty} \beta_{k,l} e^{j\theta_{k,l}} \delta(t - T_l - \tau_{k,l}) \quad (3)$$

where T_l is the arrival time of the l th cluster and $\tau_{k,l}$ is the arrival time of the k th ray within that cluster. The ray phases $\{\theta_{k,l}\}$ are statistically independent uniform random variables in $[0, 2\pi)$, while their amplitudes $\{\beta_{k,l}\}$ are statistically independent Rayleigh random variables whose mean-square values $\{\beta_{k,l}^2\}$ decay exponentially with $\{T_l\}$ and $\{\tau_{k,l}\}$.

For the building considered in [1], appropriate values for the ray and the cluster mean interarrival times are estimated to be $1/\lambda = 5$ ns and $1/\Lambda = 300$ ns, respectively, while the ray and the cluster power-decay time constants are estimated to be $\gamma = 20$ ns and $\Gamma = 60$ ns. A typical worst case room would be located some 60 m away from the central station. With a power loss exponent of 3, the multipath power gain is about -55 dB. Moreover, the formation of clusters is related to the building superstructure (e.g., large metalized walls and doors), so that they do not change significantly within a given room. In fact, based upon the measurements presented in [1], the worst case office is reasonably described as having two clusters, with the first arrival of the second cluster occurring 120 ns after the first arrival of the first cluster. Additionally, the measured rms delay spread within rooms was found to have a median value of 25 ns. In order to obtain curves of outage probability versus required bit error rate, a large ensemble of channel impulse response was generated via Monte Carlo simulation, based on the statistical model, and the bit error rate associated with each realization was computed. The outage probability for a given bit error rate is found simply by dividing the number of times in which that bit error rate is exceeded by the total number of sample responses simulated.

A. Probability of a Bit Error

In the presence of intersymbol interference (ISI), the probability of a bit error is given by (2), but the detector

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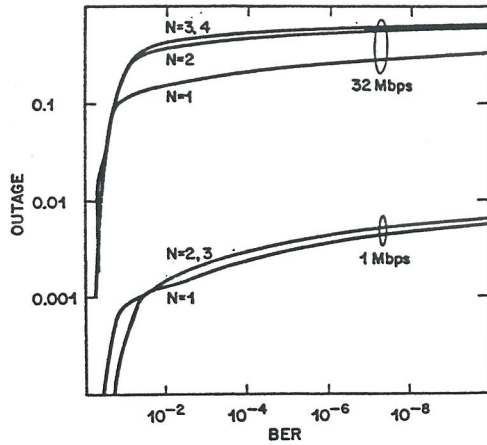


Fig. 1. Number of information symbols contributing to intersymbol interference.

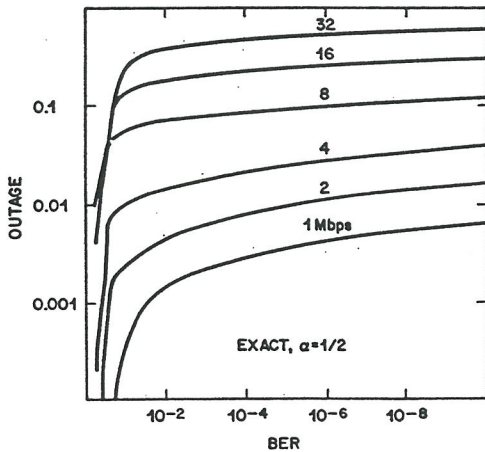


Fig. 2. Outages versus BER at signaling rates of 1–32 Mbits/s.

signal-to-noise ratio is conditioned on the information sequence

$$\rho\{\tilde{I}_n\} = \frac{3}{M-1} \text{CNR}_0 \left| 1 + \sum_{n \neq 0} (a_{m-n} f_{rm} - b_{m-n} f_{in}) \right|^2 \quad (2)$$

where $\{\tilde{I}_n\} = \{a_n + j b_n\}$ is the information sequence and $\{f_{rm} + j f_{in}\} = \{h(nT)\}$ is the complex-valued system impulse response, sampled at multiples of the symbol period. To remove the conditioning, the probability of a bit error has to be averaged over all information sequences contributing to intersymbol interference. Note that if N symbols on each side of the detected symbol contribute significantly to intersymbol interference, the averaging will have to be performed over M^{2N} information sequences.

IV. RESULTS AND DISCUSSION

A. Number of Interfering Symbols

It can be seen from the outage curves given in Fig. 1 ($\alpha = 0.5$) that at 32 Mbits/s, there is nothing to be gained from using N greater than 3. In fact, at $N = 2$, the error in the outage is still only 13 percent. At 1 Mbit/s, there is very little gain in choosing more than one interfering sample on each side of the desired symbol.

B. Effect of Signaling Rate on Outage

There is an approximate threefold increase in outage probability for every doubling in the signaling rate (Fig. 2). In fact, for a required bit error rate of 10^{-4} , the outage is 0.0029 at 1 Mbit/s, 0.021 at 4 Mbits/s, and 0.22 at 16 Mbits/s. These

figures are to be interpreted as the fraction of locations that, at a given instant, will have a bit error rate worse than required. The time-variant nature of the channel is essentially due to people or objects moving in the vicinity of antennas. Thus, there may be time-invariant channels, such as in buildings with large, open inner spaces, where static terminals communicate with a central unit located far about floor level. In such channels, the outage number could be translated directly into fraction of locations with unacceptable error rate. In this case, 0.1–1 percent outage probabilities may be tolerable and bit rates of up to 4 Mbits/s (with $M = 4$) at bit error rates not worse than 10^{-4} could be supported. In general, however, if people move while communicating or if the signal paths are likely to be disturbed, the outage number represents a fraction of time, such as seconds per hour, that a link will have an unacceptable bit error rate. In this case, outage could be understood as the fraction of lost bits or, indeed, the long-term bit error rate.

Fig. 3 compares the deterioration resulting from increasing the signaling rate for both, i.e., the indoor multipath propagation model and the flat Rayleigh channel, with identical unfaded carrier-to-noise ratios and a required bit error rate of 10^{-4} . For signaling rates of 1 Mbit/s or less, the channel performance is indeed the same as that of the flat Rayleigh channel. At this rate, the symbol period is about eight times the rms delay spread of the measured building. At lower rate, the outage decreases linearly with the bit rates, and even though it could be reduced to seemingly acceptable levels at very low data rates, the burstiness of the errors makes it more reasonable to attempt to reduce the errors by improving the channel.

C. Space Diversity Gain

For every trial, two samples from the ensemble of channel impulse responses were generated, and the one resulting in the largest in-band energy was selected. The diversity gain is depicted in Fig. 4. It is found that the outage probability is reduced from 0.15 to 0.05 at 8 Mbits/s and from 0.012 to 0.0004 at 2 Mbits/s. This is a factor of 2–3 worse than would have been attained with postdetection decisions, in which case the outage probability is the square of the single-antenna outage probability. This indicates that received energy, albeit simple to measure, is not always an ideal indicator of system performance.

D. Effect of Cosine Rolloff Factor on Outage

For indoor applications, the radio spectrum is not likely to be as tightly controlled as it is for wide coverage systems. Fig. 5 gives the outage probabilities at 2, 4, and 8 Mbits/s for cosine rolloff factors of $\alpha = 0.5$, $\alpha = 0.75$, and $\alpha = 1$. At $\alpha = 1$, a clear outage reduction is observed, resulting from less intersymbol interference associated with the narrower time domain pulse shape. However, the outage reduction is only about 35 percent, from 0.04 to 0.027 from a required bit error rate of 10^{-4} .

V. CONCLUSIONS

The performance of M -level quadrature amplitude modulation for indoor radio links has been evaluated using a realistic multipath propagation model. The outage probability, for a required bit error rate of 10^{-4} was found to be 0.0029 at 1 Mbit/s and 0.25 at 16 Mbits/s for $M = 4$. Selection diversity, with selections based on received energy, is found to reduce outage probability from 0.037 to 0.008 at 4 Mbits/s for a bit error rate of 10^{-4} where the more complicated postdetection approach would reduce outage probability to 0.0014. Finally, the outage probability reduction using pulses with a narrower time domain response (cosine rolloff factor of 1 rather than 0.5) was found to be 35 percent at 4 Mbits/s for a bit error rate of 10^{-4} .

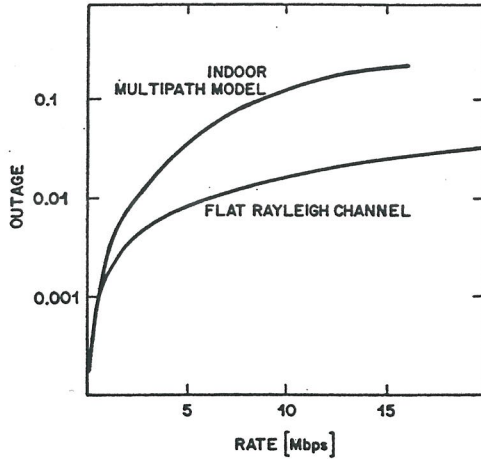


Fig. 3. Outages at required BER of 10^{-4} for flat Rayleigh channel and indoor multipath propagation model.

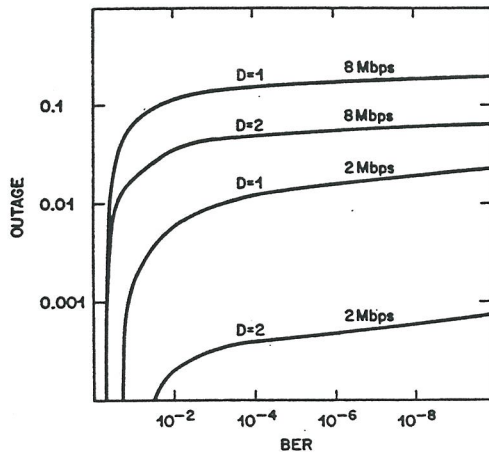


Fig. 4. Space diversity gain at 4 Mbits/s; two antennas, postdetection selection.

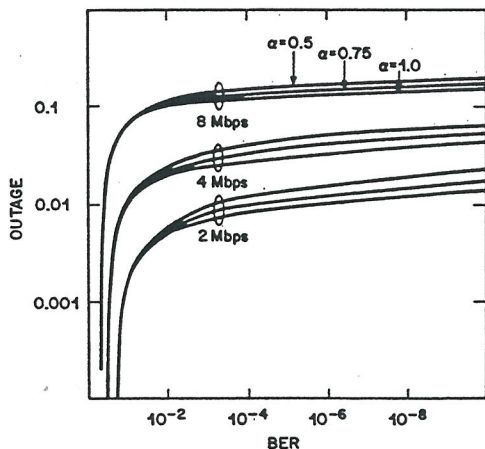


Fig. 5. Outages at 4 Mbits/s for cosine rolloff factor $\alpha = 0.5$, $\alpha = 0.75$, and $\alpha = 1$.

APPENDIX

The derivation of the timing instant t_d follows the analysis presented in [3] and [8], but applied to the indoor multipath propagation model of [1], and is summarized as follows. The received IF signal is

$$\tilde{v}(t) = k \sum_{n=-\infty}^{\infty} \tilde{a}_n \tilde{f}(t - nT) \quad (\text{A.1})$$

where k is proportionality constant. Squaring and averaging $\tilde{v}(t)$ yields, at baseband,

$$|\tilde{v}(t)|^2 = k^2 \sum_{n=-\infty}^{\infty} |\tilde{f}(t - nT)|^2 \quad (\text{A.2})$$

which is periodic with period T . The timing instant t_d is derived via narrow-band filtering of the first harmonic D_1 , the Fourier coefficient of $e^{i2\pi t/T}$, given by

$$D_1 = \frac{k^2}{T} \int_{-\infty}^{\infty} G^*(f) G\left(\frac{1}{T} - f\right) df \quad (\text{A.3})$$

with $G(f) = H(f) * CR(f)$. This is the overall channel transfer function where $CR(f)$ is the cosine rolloff function, with rolloff coefficient α , and the channel frequency response $H(f)$ is found by rewriting the channel impulse response, given by (7), as

$$h(t) = \sum_{k=0}^{\infty} \tilde{\beta}_k \delta(t - \tau_k) \quad (\text{A.4})$$

and taking the Fourier transform

$$H(f) = \sum_{k=0}^{\infty} \tilde{\beta}_k e^{-i2\pi f \tau_k} \quad (\text{A.5})$$

After some manipulation, D_1 can be written as

$$D_1 = \frac{\alpha k^2}{8T^2} \sum_k \sum_{l=0}^{k-1} \beta_k \beta_l^* \frac{\sin \pi \alpha (\tau_k - \tau_l)/T}{\pi \alpha (\tau_k - \tau_l)/T} \frac{e^{-i\pi(\tau_k + \tau_l)/T}}{1 + [\alpha(\tau_k + \tau_l)/T]^2} \quad (\text{A.6})$$

which is of the form

$$D_1 = |D_1| e^{i\phi} \quad (\text{A.7})$$

with the timing instant given by

$$t_d = -\frac{T}{2\pi} \tan^{-1} \phi. \quad (\text{A.8})$$

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I thank A. A. M. Saleh and L. J. Greenstein for many stimulating discussions and valuable suggestions.

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September 23, 1987

NOTICE:

POSSIBLE EXTRA MEETING 802.4L

DATES:

Monday, November 9, 0900, or
Friday, November 14, 1300

PURPOSE:

DETAIL TECHNICAL DISCUSSION
No business to be transacted

Please telephone me if you would be able and interested
in attending this extra meeting. If set, a new notice will be mailed.

Chan Rypinski

IEEE 802.4L--Through-the-air Token Bus Physical Layer

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