IEEE ELECTROMAGNETIC COMPATIBILITY GROUP

NEWSLETTER

ISSUE NO.85 SPRING 1975

EDITOR: ROBERT D. GOLDBLUM

Electromagnetic Compatibility Symposium & Exhibition

Montreux, May 20-22, 1975

SPECIAL ONE WEEK PACKAGE

Since round trip air fare to Switzerland from New York costs over $700, Swissair has assembled a special one week package tour for $747.00. Tour price includes:

- Economy-class air ticket New York/Geneva/New York (minimum 10 passengers).
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- Five Continental breakfasts in your hotel in Montreux.
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- Five nights hotel accommodations in the Montreux Palace Hotel
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- Two Continental Breakfasts in Geneva at hotel

The rates are based upon double occupancy whereas the single supplement is $50 additional or $797.00

The flight departs from New York on Saturday evening, May 17, 1975, and returns on Sunday, May 25, 1975. For more information, contact the Newsletter editor or submit the coupon located on page 3.

THE DEADLINE FOR RESERVATIONS IS

APRIL 28, 1975

IEEE ELECTROMAGNETIC COMPATIBILITY GROUP NEWSLETTER is published quarterly by the EMC Group of the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017. Sent automatically and without additional cost to each member of the EMC Group.

Second class postage paid at New York, N.Y., and additional mailing offices.

NEW IEEE STANDARDS CATALOG AVAILABLE

New York, N.Y. - The new 32 page IEEE Standards 1975 Catalog is now in print. Copies may be obtained without charge. The new catalog lists more than 350 standards publications by subject as well as in numerical sequence. Included in this new set of listings are the many American National Standards published by IEEE.

Standards developed within the IEEE cover test methods, practices for electrical installations, units, definitions, graphic symbols, letter symbols, and applications methods. Engineers in such widely varied fields as antenna design, communications, power generation and distribution, microwave measurement, industrial applications, electromagnetic compatibility, and rotating machinery will find many authoritative documents that have received recognition both nationally and throughout the world.

Single copies of the new catalog may be obtained free from the IEEE Standards Department, 345 East 47th Street, New York, N. Y. 10017.

NEWSLETTER STAFF

EDITOR:
Robert D. Goldblum
R&B Enterprises
P.O. Box 328
Plymouth Mtg., Pa. 19462

ASSOCIATE EDITOR:
(Chapter Chatter)
Charles F. W. Anderson
2 Bauer Avenue
Oakhurst, N. J. 07755

ASSOCIATE EDITOR:
(EMC Personality Profiles)
William G. Duff
Atlantic Research Corp.
8601 Greeley Blvd.
Springfield, Va. 22150

ASSOCIATE EDITOR:
(Book Reviews)
James S. Hill
6706 Deland Drive
Springfield, Va. 22150

ASSOCIATE EDITOR:
(Sequency Union)
Dr. G. Robert Redinbo
153 Stoney Ridge Drive
Longwood, Florida 32750

CONSULTING EDITOR:
Rexford Daniels
P.O. Box 129
Concord, Mass. 01742

The following standards are listed under EMC:

Recommended Practice for Measurement of Field Intensity Above 300 Megahertz from Radio-Frequency Industrial, Scientific, & Medical Equipments (IEEE Std 139-1952) .....$ 3.00

Recommended Practice for Minimization of Interference from Radio Frequency Heating equipment (IEEE Std 140-1950).....$ 3.00

Open Field Method of Measurement of Spurious Radiation from Frequency Modulation & Television Broadcast Receivers (IEEE Std 187-1951).....$ 3.00

Radio Interference: Methods of Measurement of Conducted Interference Output to the Power Line from FM and Television Broadcast Receivers in the Range of 300 kHz to 25 MHz (IEEE Std 213-1961).....$ 3.00

Radio Interference: Construction Drawing of Line Impedance Network (IEEE Std 214-1961).....$ 4.00

Measurement of Radio Noise Generated by Motor Vehicles and Affecting Mobile Communications Receivers in the Frequency Range of 25 to 1000 Megahertz (IEEE Std 263-1965)..... $ 3.00

Recommended Practice for Measurement of Shielding Effectiveness of High Performance Shielding Enclosures (IEEE Std 299-1969).....$ 4.00

Standard for the Measurement of Impulse Strength and Impulse Bandwidth (IEEE Std 376-1975).....$ 6.00

The following standards should be of interest to the EMC communities:

Definitions of Terms for Radio Wave Propagation (IEEE Std 211-1969).....$ 3.00

Standards Report on Measuring Field Strength in Radio Wave Propagation (IEEE Std 291-1969).....$ 4.00

Methods for Measuring Electromagnetic Field Strength (Below 1000 MHz) (IEEE Std 302-1969).....$ 4.00

Standards Report on State-of-the-Art of Measuring Field Strength, Continuous Wave, Sinusoidal (IEEE Std 284-1968).....$ 3.00

Standards Report on Measuring Field Strength in Radio Wave Propagation (IEEE Std 291-1969)..... $ 4.00

Methods of Measuring (Below 1000 MHz) Electromagnetic Field Strength (IEEE Std 302-1969.....$ 4.00

Recommended Practices for Burst Measurements in the Time Domain (IEEE Std 257-1964) (Reaff 1971).....$ 3.00

Recommended Practices for Burst Measurements in the Frequency Domain (IEEE Std 265 1966).....$ 3.60

Techniques and Instrumentation for the Measurement of Potentially Hazardous Electromagnetic Radiation at Microwave Frequencies (ANSI C95.3-1972).....$ 5.00

When ordering, IEEE members who include their membership number will receive a 25 per cent discount.

DOT/TSC, CAMBRIDGE, MA, COMPLETES L-BAND EM NOISE MEASUREMENTS PROGRAM FOR SHIPS

Mr. John M. Clarke of the U.S. Department of Transportation, Transportation Systems Center (DOT/TSC), Cambridge, MA 02142 recently announced the availability of Report No. CG-D-50-75.

"Clarke, J.M., Cantor, S.R., Winchus, J.J., Caporate, A.L., Measurement and Analysis of L-Band (1535-1660 MHz) Electromagnetic (EM) Noise on Ships, Final Report, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA 02142, December, 1974"

The technical content of this report is directly related to the same maritime satellite applications as the report announced by Mr. Ralph E. Taylor of NASA, Goddard Space Flight Center, MD 20771 on page 13 of Issue No. 84, Winter 1975, EMC Group Newsletter.

The report (CG-D-50-75) is available through the National Technical Information Service, Springfield, VA 22161.

Accession No. NTIS NO. AD-A-005-653.

The following is the abstract from the report:

A program of L-band (1535-1660 MHz) electromagnetic (EM) noise measurements conducted on ships is described in this report. The magnitude and duration of EM noise on ships is of particular significance in terms of potential radio frequency interference (RFI) to future Marine Satellite (MARSAT) receiving systems on ships. The program involved the measurement and identification of EM noise levels originating at internal sources on the ships selected, and external sources at coastal locations within radio line-of-sight. The instrumentation and measurement procedures employed are described and illustrated. The predominant EM noise sources identified are discussed and illustrated graphically, and the potential RFI signal amplitude and bandwidth parameters are related to a typical MARSAT receiver sensitivity, and the communications link quality ratio C/N_o . The predominant sources of L-band noise were found to originate at ports and the adjacent cities. These sources are continuously present when the ships are docked, and can be characterized as a combination of continuous city ambient noise and intermittent broadband impulsive ignition noise from dockside unloading apparatus, automobiles and trucks. Some RFI levels 20 to 30 dB above receiver thermal noise were evident which would result in unacceptable degradation to the satellite-to-ship link C/N_o.

WALSH FUNCTION PROCEEDINGS AVAILABLE

The Proceedings of the "1974 Symposium on Applications of Walsh Functions" held at The Catholic University of America in Washington, D.C. are now available. Published as a text book (460 pages, case bound) by R&B Enterprises, limited quantities are available through the IEEE, 345 East 47th Street, New York, N.Y. 10017. Order as catalog number 74CH0861 - 5EMC at $13.50 for non-members and $10.00 for IEEE members.

Copies of the 1970 through 1973 Proceedings of the "Symposium of Applications of Walsh Functions" can be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA. 22151. Order these proceedings by title and AD number:

1970 Proceedings AD707431 (274 pages,$3.00)
1971 Proceedings AD727000 (218 pages,$3.00)
1972 Proceedings AD744650 (401 pages,$6.00)
1973 Proceedings AD763000 (298 pages,$6.00)

NAVY EMC/EMI FILMS AVAILABLE

Fred Nichols has three of the Navy's film on EMC/EMI in his custody. They are available on request to any of the Chapters for presentation. From what we have heard about these, they are well worth the viewing! To arrange loan, get in touch with Fred at: LectroMagnetics, Inc., 6056 W. Jefferson Blvd., Los Angeles, CA. 90016.

ITEM 1975 ISSUED

The 1975 edition of ITEM - Interference Technology Engineers Master Directory & Design Guide has been published and mailed. This year's publication contains 186 pages of tutorial material and advertisements on EMC instrumentation, filter, shielding, EMP, TEMPEST and many other related subjects. For a free copy, write to R&B Enterprises, P.O. Box 328, Plymouth Meeting, Pa. 19462.

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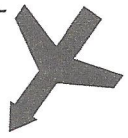

Jim Hill
6706 Deland Drive
Springfield, Va. 22152

Dear Jim: Please enter _____ reservations in my name for the special EMC '75 trip. I have enclosed a $100 deposit for each reservation requested. I also need domestic air transportation from _____.

Name (print)_____ _____
Company_____
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APPOINTMENT OF KENNETH W. BACH

Mr. H. Dean McKay, President, AH Systems, Incorporated, announced the appointment of Kenneth W. Bach to the position of Director of Operations, Atlantic Region. The position, which is newly created, includes responsibility for coordination of all AH Systems' programs and contracts in the newly defined Atlantic Region. The region includes the eastern United States, eastern Canada, Europe and the Middle East.

Initially, it was indicated, Mr. Bach will establish a new office in upstate New York. A permanent office location has, however, not been selected.

Mr. Bach holds BSEE and MSEE degrees from the University of Maine. He has held several technical and management positions with the Sprague Electric Company, Fairchild Camera & Instrument Corporation's Electro-Metrics Division and with Randtech Corp.

Mr. Bach's initial responsibilities will include the support and expansion of AH Systems' consulting services in LSI, microprocessor and secure-communications technology. Support for AH Systems' microprocewsor-controlled RF/EMI data collection system installations will also be provided by Mr. Bach's Atlantic Region Office.

AH Systems provides systems engineering, analysis and software in the area of microprocessors and LSI systems for the government and industry.

FELLOW GRADE GROUP MEMBERS

Four members of the Group on Electromagnetic Compatibility (G-27) have been elected to Fellow Grade as of January 1, 1975. These members and their citations are listed as follows:

Mr. Robert D. Briskman - for contributions to the development of communications satellite systems - 02,08,10,19,27.

Dr. George S. Eager, General Cable Corp.- For development of an industry-accepted method of corona detection in extruded dielectric power cables - 03,09,13,17,19, 27,31,32,34.

Dr. Richard C. Johnson - For contributions to and leadership in antenna measurements and rapid-scan microwave antennas - 03,10, 17,27.

Professor Jean G. Van Bladel, University of Ghent, Belgium - For contributions to electromagnetic theory - 01,03,04,17,20, 27.

REX DANIELS HAS STROKE

Corresponding editor, Rexford Daniels, is now convelesing from a stroke suffered in his home in mid-December. Rex has been very active in G-EMC AdCom activities, including serving as editor of this newsletter for over ten years. Those who wish to join your editor in wishing him a speedy recovery should address cards and letters to Rex at P.O. Box 129, Concord, Ma. 01742.

IEEE EMC PUBLICATIONS AVAILABLE FROM:

IEEE
445 Hoes Lane
Piscataway, N.J. 08854
Attn: SPSU

EMC TRANSLATIONS (Hard Copy or Microfish)
$3.00/issue Members; $6.00/issue Non-members.

YEAR	VOL;	ISSUES	
1967:	9;	1,2,3	(hard copy only)
1968:	10;	1,3,4	(hard copy only)
1969:	11;	1,2,3,4	(hard copy only)
1970:	12;	1,2,3,4	
1971:	13;	1,2,3,4	
1972:	14;	1,2,3,4	
1973:	15;	1,2,3,4	
1974:	16;	1,2,3,4	

EMC CONFERENCE RECORDS:

1961 Symposium	CHO-087-7	$4.00
1965 "	CHO-188-3	$7.50
1966 "	CHO-217-0	$5.00
1968 "	CHO-284-0	$12.00
1969 "	CHO-308-7	$12.00
1970 "	CHO-429-1	$ 9.00
1971 "	CHO-573-6	$12.00
1972 "	CHO-638-7	$12.00
1973 "	CHO-751-8	$14.00
1974 "	CHO-803-7	$16.00

OTHER EMC PUBLICATIONS:

1972 Bibliography on EMC - CHO680-9 $6.00
1974 Applications of Walsh Functions - CHO-861-5 $13.50

PLEASE SEND ONE EACH OF CIRCLED PUBLICATIONS

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EMC PERSONALITY PROFILES

by William G. Duff

J. PAUL GEORGI

Deputy & Technical Director

Electromagnetic Compatibility Analysis

Center

Paul is a senior member in the IEEE and has been very active in the EMC Group. He is currently a member of the AdCom. During his busy career, he has published a number of reports and has served on several panels. His honors and awards include numerous Air Force Letters of Commendation and Outstanding Performance Awards and the Exceptional Civilian Service Award, the highest award given to a civilian.

Paul Georgi was born in Antwerp, Ohio, on April 5, 1921, and spent his youth in Fort Wayne, Indiana. After graduation from high school he qualified through competitive examination for a U.S. Army Signal Corps program in electrical engineering (RADAR) at Fenn College and Case Institute of Technology, in Cleveland, Ohio.

Upon completion of the 18 month program, Paul was assigned to the U.S. Army Air Force Aircraft Radio Laboratory (ARL), Wright Field, Dayton, Ohio. His duties at ARL included basic design improvements in radio altimeters, control systems for glide bombs and the design of automatic altitude controls for low flying aircraft, all of which led to the U.S. Army Signal Corps filing for several patents in his name. He remained at Wright Field until 1943 when he was sent overseas where his duties consisted of the establishment of communications links between Command Posts and field fighting commands. Paul served in the New Guinea and Phillipine campaigns until wounded in April 1945. After release from active duty he returned to ARL at Wright Field. In the Fall of 1947, he took leave to return to college and received his B.S. degree in June 1949. He again returned to ARL and the design of C&E equipment for post-war aircraft and missiles.

Paul was called back to active duty with the Air Force in 1950. He remained at ARL, and founded a requirements analysis group which established state-of-the-art requirements for electronic equipment under the cognizance of the Laboratory. He served as Chief of this organization throughout the Korean War and for three years thereafter. In 1955, he was selected for the position of Assistant Chief of the New Developments Office of the Bombardment Missile Division, ARDC, in which capacity he served until selected to serve as staff electronic engineer on the staff of Major General Howell Estes, Commander, Detachment #1, ARDC.

During his tenure as staff electronic engineer, he was instrumental in focusing the Air Force's and Department of Defense's attention on the present and future electromagnetic compatibility program. In recognition of his effort, Paul was selected to attend the Air Force Institute of Technology. He graduated from AFIT in August 1960 with a Master's Degree. Upon graduation from AFIT, he was assigned as Chief, Standardization and Criteria Branch, of the Plans and Program Control Office Directorate of Systems Management, ARDC Wright Air Development Division.

In April 1961, Paul was invited by Headquarters USAF to consider the position of Technical Director of the Electromagnetic Compatibility Analysis Center. He accepted this position in June 1961, and continues in it to date. In January 1962 he was promoted to the highest grade obtainable in Civil Service, that of PL-313. This is a rank reserved for outstanding individuals in the sciences, and authorized by Congress and appointed by the Civil Service Commission.

Paul is a devoted family man married to the former Doris K. Henschen, of Fort Wayne, Indiana. The Georgi's have two children, Karen and Craig. He is an outdoor enthusiast having hunted and fished over most of the United States and Canada. In addition, he has indoor interests of radio experimentation, reading and listening to light classics in the music field.

CHAPTER CHATTER

by Charles C.W. Anderson

San Francisco

The Chapter's February meeting featured a demonstration of Watkins-Johnson equipment which can be used for Tempest testing. Fred Nichols will present a talk on management considerations in EMC at the Bay Area Chapter's March 19 meeting. This gathering will also feature presentation of the awards for contributions to the Symposium last year and election of officers.

The Chapter, as previously reported is sponsor of a session at the International Conference on Communications this coming June (at which your Column Editor has been invited to present a paper. Title: "Some Pages from the Case Book of an Interference Detective (with apologies to Mr. Sherlock Holmes)".

Washington

Tom Doepner, Secretary of the Chapter, sent in a fine report on Delmer Ports' talk at their January meeting. A verbatim quote from the talk:
"Don't call it 'radiation', call it 'leakage'; and you avoid many questions which shouldn't have been asked in the first place."
Delmer's talk was well-illustrated with viewgraphs and dealt with harmonic, spurious and intermod components produced in multichannel operation, and with other design problems associated with cable TV. According to Tom, the post talk discussion was so lively that Chapter Chairman John Leopold had to cut it off to "give those of us who still have to work for a living a chance to go back to work."

Al Paul informed me that Bill Green's planned talk on TEMPEST matters had to be withdrawn, so their February meeting had to be cancelled.

In March, Captain Jack Weatherford (USN Ret'd.), of General Research Corp., spoke on EMC and the 1979 World Radio Administrative Conference. Speaking on the basis of over 30 years in frequency management, Captain Weatherford covered such topics as national and international band-edge protection considerations and the present and potential conflicts associated with allocations to discrete systems as technology proceeds to more sophisticated systems.

New Jersey Coast

The January meeting, which was to have featured Mr. Miles Merkel of Ft. Huachuca, was instead addressed by Seymour Krevsky of USAECOM, Ft. Monmouth, who ably substituted. He described the Army's world-wide EMC/EMI responsibilities, emphasizing the problems engendered by the great variety of operational environments which are encountered.

In February, Bill Bakker (a former Chapter member, by the way) spoke on "Design, Manufacture and Evaluation of EMI, EMP and TEMPEST-protected Cables." He described the latest developments in these areas, with particular emphasis on forming techniques which contribute to improved shielding efficiency.

The March luncheon meeting featured Mr. Glen Sundberg of Hughes-Fullerton. He described the program for investigations of techniques and limits for EMI measurements in the millimeter wave region..Some innovative methods were developed during the program. Recommendations for limits for millimeter equipments have been worked out, for the ranges below 10 GHz, as well as for the 10 to 100 GHZ range.

Programs for the remainder of the season are as folbws:
17 April: Electromagnetic Compatibility Considerations in Heart Pacemakers; Dr. Emanuel Goldberg of Beth Isreal Hospital, NYC.

15 May: Near-field Probes Using Fiber-optic Transmission Lines; Mr. Ezra Larson of NBS-Boulder.

19 June: Topics Related to Telecommunications Policy and Spectrum Management; Mr. D.M. Jansky of OTP/EOP Washington, D.C.

Jersey Coast Chapter is attempting to get eligible members to up-grade to SM status.

Pacific Area

Bob Ford wants a volunteer to arrange the next PAC Area G-EMC meeting. Sounds like a good "professional activity" for somebody out there!

Only personal-type item is that Dick Snell, formerly in the PAC area, and now at USAFIT (I believe) is now a Major. Congratula-

tions! Dick Snell is also doing book reviews for the PAC Area NL. He is very high on the new "Manual of Linear Integrated Circuits: Operational Amplifiers and Analog ICs" by Prensky, published by Reston Publishing Co., Reston VA.

Bob is also interested in obtaining tape recordings of some of the papers which this column reported as having been presented at various Chapter meetings. If you want to volunteer in a good cause, send your tapes to Bob. I'm sure he would arrange to copy and return them in good condition. Bob's address is: Robert R. Ford, 1268 Mokapu Blvd., Kailua, HI 96734.

Philadelphia

Steve Garcia reports that the Philadelphia Chapter is "moving along at a reasonable pace". In January, Dr. Salati, Director of Continuing Engineering Studies at the Moore School of Electrical Engineering of the U. of Pennsylvania, spoke on grounding problems, with particular emphasis on solid-state circuits. Fred Nichols will address the Philadelphia Chapter on 9 April on: "Management Outlooks for the EMC Engineer". Also, in April, the Philadelphians will join with the Communication Society Chapter for a meeting at which Dr. Lewis Claibourne of Texas Instruments will speak on applications of surface acoustic wave devices to comm systems.

Congratuations to Steve on his election as a Senior Member of the Instrument Society of America.

Boston

The following letter has been received from Chapter Chairman, Robert J. Berkovits:

Since 1970, the EMC group Boston Membership has been near 50 even though this is the second largest section in the U.S. It seems that the EMC groups in a few large companies are primarily involved in MIL spec and Tempest work. It seems that they have their heads stuck in black boxes. They have been unwilling or too busy to communicate. However, this year many of them showed up at our September and December meetings. The other group that attends the meetings is made up from systems oriented engineers including representation from the government, non-profit and small consulting firms. They are more systems oriented.

For the 1975 - 1976 year we will continue to hold joint meetings with the other IEEE group-societies. We have inquired about holding an EMC session at Electro 76 in Boston. Ernie Witschi the business manager for the Boston section IEEE is unable to give us information about the program set up until Intercom 75 is finished.

Our officers for next year will probably be John Clarke - Chairman, Stephen Cantor - Vice Chairman and Dale Samuelson - Secretary. We will send more information after our last meeting in May.

The following is a list of meetings held since September, 1974 and the planned meeting for May of this year:

Joint with AES; Att. 21: "New Specifications and Measuring Techniques CISPR, ANSI, FCC, Military" William S. Lambdin, General Manager, Electro-Metrics Div., Penril Corp. 9/24/74.

Joint with AES; Att.11: "Interference Between Pulse-Compressing Radars", J.J.G. McCue, MIT Lincoln Lab. 10/17/74

Joint with Communications Society; Att. 22: "Marisat - Sattellite Communications for the Maritime Industry", D.W. Swearingen COMSAT General Corp. 11/7/74.

One Day seminar organized by Dale Samuelson, Electro-Modular Systems; Att. 41: 12/4/74.

1. "The Hospital Environment, Radiation Hazards, etc." Albert R. Kall, Ark Electronics Corp.
2. "New Specs and Measuring Techniques", Bill Lambdin (Same as Sept. 24th talk).
3. "Modern Susceptibility Testing Methods; Automatic Power Leveling, Pulse Generation, Crawford Cells," Ralph Logan, Instruments for Industry.
4. "Using a Universal LSI Controller for EMC." Dr. Gary Nelson, A. H. Systems, Inc.

Joint with AES and AP; Att. 26: Surface Scattered Multipath" Dr. J.K. DeRosa, CNR Inc. 2/11/75.

5/13/75 Joint with VT:"Wide Band Noise and Urban Channelization in Mobile Communications", Richard Buck, DOT/TSC and Howard Salwen, Proteon Assoc.

CHARLIES' CORNER

GRUNDIG DESIGNS INTERFERENCE-FREE COLOR TV RECEIVER

Dr. Theodore Cohen, of the ARRL RFI Task Group, has forwarded a copy of an article which appeared in the German magazine FUNKSCHAU which describes the design and testing of a new color TV receiver featuring excellent rejection of interference from external signals in the MF, HF and VHF ranges. The author, Egon Koch of Grundig, presents details of the new TV tuner, including a schematic, and discusses the measures required to obtain the desired freedom from interference. To illustrate the degree to which Herr Koch was able to interference-proof the new sets, they were subjected to 100V rf in the HF range at the antenna terminals without adverse effects on picture or sound reception.

(continued)

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A summarized translation of the article appeared in the February issue of World-radio News. A limited number of copies of another translation, with the tuner schematic, are available on a one-person basis from Associate Editor Charlie Anderson by sending him 50¢ in stamps to cover repro and mailing costs. Address: C.F.W. Anderson, 2 Bauer Ave., Oakhurst NJ 07755.

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AMERICAN RADIO RELAY LEAGUE TO HAVE RFI/EMC SESSION DURING NATIONAL CONVENTION

Dr. Ted Cohen, of the ARRL RFI Task Group, has forwarded an announcement of the RFI/EMC session to be presented as part of the Technical Symposium at the ARRL National convention to be held in Reston VA on 12 September 1975. The G-EMC has been invited to present a paper. The announcement and letter have been forwarded to Gene Cory. If you have a paper (previously unpublished) in any of the following areas and, preferably, are an amateur, please get in touch with Charlie Anderson, who will coordinate with Dr. Cohen on this.

Analysis and Modeling
Cleaning House
Designing for EMC
Field Modifications
Legislation and Regulations
Measurements
Resolving Complaints
Standards

Obviously, the papers should be slanted towards interference from communications/electronics emitters to equipment operated by the general public, particularly home entertainment items. Deadline for Charlie to coordinate your paper: 15 May. Complete typed versions will be due not later than 1 June so that printing can be accomplished before the Symposium.

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RTCA TO PUBLISH NEW AVIONICS TEST PROCEDURES

By the time this issue reaches our readers, the long-awaited document entitled "Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments" (RTCA Document DO-160) will probably be available. Prepared by RTCA Special Committee 123, this document describes qualification testing for avionics equipment for commercial aircraft. Of particular interest to G-EMC members are the portions covering EMI testing. Although the techniques generally replicate those of MIL-STD-462, it is interesting to note that a cable susceptibility test using a current probe to induce RF voltages is included. The price is $20.00* and copies may be obtained from: Radio Technical Commission for Aeronautics, Suite 655, 1717 H Street NW, Washington DC 20006.

G-EMC was well-represented on Special Committee 123. Among the members were: Elden Hughes, Lars Jorgensen, Charlie Seth, Len Thomas, Charles S.W. Anderson, William F. Johnson, and George Ufen.

* 50% discount if your organization is an RTCA member.

MAY G-EMC TRANSACTIONS

The following is a list of papers that will be included in the May 1975 issue of the G-EMC Transactions:

A Method of Detecting Significant Sources of Intermodulation Interference.... W.M.Chase, J.W.Rockway,G.C.Salisbury

Power Line Conducted Interference Measurement Differences Using U.S. and CISPR Line Impedance Stabilization Networks.... J.A. Malack

Ignition Noise Measurement in the VHF/UHF Bands....H.S. Oranc

Effects of Impulsive Noise on Phase-Locked Loop FM Demodulator...H.S. Oranc

Shielding Effectiveness of Braided Wire Shields .....E.F. Vance

Analysis of Airborne VHF Incidental Noise Over Metropolitan Areas - Part 2, Horizontal Dipole Antenna ....E.N. Skomal

Numerical Analysis of a Transmission Line EMP Simulator.....K.M. Soo Hoo

Interaction of Electromagnetic Transient Radiation with Biological Materials.... J.C. Lin

The Electromagnetic Field Very Near a Monopole....D.C. Chang, R.D. Halbgewachs, and C.W. Harrison, Jr.

Range-Doppler Resolution of Electromagnetic Walsh Waves in Radar.....H.F. Harmuth

On the Identification of Linear Dyadic Invariant Systems...S. Cohn-Sfectu and S.T. Nichols

Comments on: Sinusoids Versus Walsh Functions by N.M. Blachman...H.F. Harmuth

The editor of the Transactions, Richard B Schulz, may now be reached c/o ITT Research Institute, ECAC, North Severn, Annapolis, Md. 21402. He has announced the appointment of Robert B. Cowdell, Collins Radio Co., as the new Associate Editor for Equipment EMC Assurance and Prediction.

BOOK REVIEWS

BOOK REVIEW
by
Jim Hill

"An Electromagnetic Compatibility Program for the 1970s"
by
A.L. Hiebert and S. A. Scharff

A report prepared for the United States Air Force Project RAND, R-1114/1-PR, August 1974, THE RAND CORPORATION, Santa Monica, California 90406. Approved for public release, distribution unlimited.

This study of a proposed electromagnetic compatibility program for the 1970s described the technical processes and control programs that are necessary to achieve EMC. To assess intrasystem and inter-system compatibility problems, and suggest a program of action for the Air Force, this study examines frequency application requirements, specifications, weapons systems acquisition procedures, and Air Force and industry practices. It also analyzes radio spectrum usage and identifies shortcomings in our capabilities for handling both current spectrum utilization and future problems.

The report points out that the block allocation concept, and the idea that there is spectrum enough for all who really need it, continue to dominate policy. It advocates the shared usage concept as having great potential usefulness in spectrum engineering and management. An Intrasystem EMC Analysis Program for application to ground and aerospace systems acquisition, already approved for development and use by the Air Force, is described. The program will provide a computer analysis capability for vulnerability assessment, design of specifications, and control of undesired electromagnetic energy in communications/electronics/electronics systems.

The report also describes what it terms "a National Integrated Spectrum Engineering System (ISES)". This is a suggstion for improved management of the spectrum as a resource. The approach includes new national and regional analytical capabilities linked by a computer-communications network and with existing analytic resources, which will concentrate on shared useage and frequency assignments, regionally implemented. The ISES will provide engineering and analysis services at the national level and will be concerned with inter-regional and government/non-government uses in support of Federal spectrum management.

The Regional Centers will, through spectrum engineering and analysis, support assignments that lead to more efficient utilization, interservice frequency sharing, determination of spectrum requirements, and resolution of interference. Each Center will serve users in its region and provide region-to-region interaction.

Any shift in policy relative to spectrum usage will also necessitate additional and more sophisticated support at the DOD and FCC level. It is the firm conclusion of this study that the status quo view are no longer appropriate, and that changes must be made in the planning and support of technical and administrative processes. The report winds up with two appendices and a list of references. Appendix A contains supplemental data, including the SEMCAP program, transfer function derivations, model data requirements, and transfer function models. Appendix B discusses channel useage and contains an illustrative "test case", an FAA local control channel.

While this report was prepared for the Air Force, it proposes a program for implementation on a national and international level. Coming from such an auspicious source, it is a plan that will bear study and will generate comment from the EMC community.

REPRINTED BOOK REVIEWS IN THE PROCEEDINGS

At the last meeting of the Editorial Board of the PROCEEDINGS OF THE IEEE a decision was made to begin reprinting in the PROCEEDINGS selected book reviews published in the various TRANSACTIONS and Newsletters. At the time this decision was reached, the Board was searching for a way to provide a useful service for our readership that would be flexible in page count so as to achieve the proper "fill" for each issue. In the past, the proper fill in each issue has been achieved through the queue of letters published. However, the number of letters submitted to the PROCEEDINGS has decreased in recent years as more and more TRANSACTIONS have taken an active role in the publishing of correspondence.

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The actual book reviews selected for reprinting in PROCEEDINGS would be selected by the PROCEEDINGS Editor or Managing Editor (in either event, with the advise of the Editorial Board) on the basis of the degree of general interest for the average reader of the PROCEEDINGS in the particular reviews under consideration. Reviews selected on this basis would be published as space permits. Credit to the original source would be given explicitly in all cases, and in no event would our publication precede publication of the review in the TRANSACTIONS or Newsletter. Based on a count of reviews that appeared in 1973 and on estimates of space available in PROCEEDINGS, it appears that roughly half of the book reviews would be reprinted. For some TRANSACTIONS or Newsletters, whose subject matter might be inherently of more "general interest" than others, virtually all of the book reviews would be selected for reprinting.

HAROLD DINGER DIES

During his career, Harold Eugene Dinger was an expert on EMC and contributed greatly to the work of many scientific and professional organizations, including the American National Standards Institute, the International Consultative Committee on Radio, the International Radio Scientific Union, the International Special Committee on Radio Interference, the American Institute of Electrical Engineers, the Institute of Radio Engineers and the IEEE. Harold also devoted his efforts to the establishment of the Washington, D.C. Chapter of the IEEE Group on EMC and served as an officer of this Chapter. He also served as a member of the Administrative Committee of the Group.

Harold first became an Associate Member of the IRE in 1927. In 1943 he advanced to Member and Senior Member. In 1958 he was honored by the IRE by being elected as a Fellow, and in 1970 was further honored by being designated as Life Fellow.

Harold had many honors bestowed upon him by other organizations, including the Service Award from the American National Standards Institute, the Meritorious Civilian Service Award from the Navy Department and the Fellow Award from the American Association for the Advancement of Science.

MEETINGS & EVENTS

"IEEE SUPERMARKET" AT IEEE INTERCON '75

The IEEE announced the establishment of a "Supermarket" to permit the inspection and purchase of virtually all IEEE publications during IEEE INTERCON '75. Copies of all recently published, plus especially popular backfile items, will be in stock for purchase on a cash-and-carry or mail-delivery basis. These will include IEEE PRESS Clothbound and Paperbound books, Conference Records, Annual Indexes, IEEE Standards Publications, Manpower Reports, Abstract Journals, Self-Study Courses, Audio-Tape Cassettes, Membership Emblems, Membership Directory, Journal Special Issues, and other items. In addition to its extensive periodical publishing program, the IEEE produces over 400 Special Publications on technical and professional subjects each year. The "IEEE Supermarket" will be located in the Versailles Terrace on the second floor of the Hotel Americana, Seventh Avenue at 52nd Street, New York City. It will be open to IEEE members and non-members between 9 a.m. and 5 p.m. on April 7th through April 10th, 1975.

PROGRAM FOR EMC/EMI SESSION AT INTERNATIONAL CONFERENCE ON COMMUNICATIONS

(A) "Modern Techniques for Intersystem Interference Predication", by E. P. Drummet (Lockheed MSD)

(B) " Some Pages from the Casebook of an Interference Detective (with apologies to Mr. Sherlock Holmes)", by C. F. W. Anderson (Honeywell, Inc.)

(C) "The Noise Analysis and Filter Requirements in Digital Communication Systems", by Dr. G.C. Huang (Philco-Ford Corp.)

(D) "Definitions, Measurements and Parameters of Audio Program Loops Furnished by Telephone Utilities" by S.G. Doell and O.L. Byrne (Pacific Telephone Co.)

(E) "EMC Between Radio Links and Frequency-agile Radars" by E. Chiarucci and R. Esposito (Soc. Selenia, Italy)

(F) "Aspects of Channel Quality Monitoring Relating to the Detection and Measurement of Interference" by L.W. Pickering (SNR Inc.)

1975 INTERNATIONAL

MICROWAVE POWER SYMPOSIUM

The 10th Annual International Microwave Power Symposium to be held at the University of Waterloo in Waterloo, Ontario, Canada on May 27th through May 30, 1975 will draw worldwide participation. Scientists, engineers, businessmen and users of microwave energy from the U.S., Canada, Far East, Asia and East European countries will gather to present papers and hold discussions covering the latest technology in microwave heating, microwave power generation, medical and biological effects of microwave energy, microwave chemistry and microwaves in the food industry. Representatives from Russia, Hungary, Czechoslovakia and Poland have been invited as guest speakers so that attendees may have an opportunity to evaluate the progress of microwave development and the difference in emission standards of these countries as compared to the U.S. and Canada.

Special emphasis will be given in this year's Symposium to the large segment of users of microwave energy in the food industry. A one-day short course of a tutorial nature will equip such users who have little or no background knowledge in microwaves to better understand the nature of microwave heating and get a good grasp of the economics and potential use for this unique form of energy. The principles outlined in the Short Course relate not only to food, but also to numerous other applications in such areas as chemical, rubber, textile, agricultural, medical and general industrial processing with microwave energy.

Those interested in attending this Symposium can receive a program booklet by contacting the International Microwave Power Institute, P.O. Box 1556, Edmonton, Alberta, Canada.

IMPI is a technical society that was formed in 1966 to foster the exchange of ideas in the science of microwave energy. Over the years it has proven to be the catalyst that has helped science and industry adapt microwave energy to important applications in such fields as food, chemistry, rubber, forestry, medicine and printing, to name a few.

CONTACT: Bernard Krieger
Cober Electronics, Inc.
7 Gleason Avenue
Stamford, Conn. 06902

CALL FOR PAPERS - NTC '75

You are invited to attend and actively participate at NTC '75 to be held in NEW ORLEANS, DECEMBER 1 - 3, 1975. The conference theme is "COMMUNICATIONS - NUCLEUS OF A NATION" and provides the focal point of interest for the conference.

Original papers are invited on all aspects of Telecommunications; however, the following topics are suggested:

- COMMUNICATION SWITCHING
- SPACE COMMUNICATIONS
- COMMUNICATIONS THEORY
- SPECTRUM UTILIZATION
- WIRE TRANSMISSION SYSTEMS
- VEHICULAR COMMUNICATIONS
- RADIO COMMUNICATIONS
- COMMUNICATIONS SYSTEMS
- SATELLITE COMMUNICATIONS
- SIGNAL PROCESSING
- FIBER OPTIC COMMUNICATIONS
- GUIDED WAVE COMMUNICATIONS
- DATA AND COMPUTER COMMUNICATIONS
- DIGITAL VOICE, AND VIDEO TECHNOLOGY
- SOCIAL IMPLICATIONS OF TECHNOLOGY
- ENERGY AND ENVIRONMENTAL IMPACTS ON COMMUNICATIONS
- COMMUNICATIONS ROLE IN NATIONAL GROWTH
- INDUSTRIAL AND POWER SYSTEMS COMMUNICATIONS
- CONTROL SYSTEMS (DIG. OR ANALOG)

All authors of papers which are accepted should be prepared to make a twenty minute formal presentation at the conference. Prospective authors are requested to submit (5) copies, in English, of both the paper and a one-page summary to:

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NO LATER THAN MAY 1, 1975.

Authors of papers accepted for presentation at NTC '75 will receive author's kits at notification of acceptance.

The completed manuscript (five-page maximum length, camera-ready copy) must be submitted for publication by AUGUST 1, 1975.

U.S. NATIONAL MEETING OF

INTERNATIONAL UNION OF RADIO SCIENCE

ANNOUNCEMENT AND CALL FOR PAPERS

The 1975 Annual Meeting will be held October 20-23, 1975 at the University of Colorado, Boulder, Colorado in cooperation with various Societies of the IEEE and sponsored by the U.S. National Committee of URSI.

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Local hosts are the University of Colorado, the National Bureau of Standards, the Office of Telecommunications, and the National Oceanic and Atmospheric Administration.

SPECIAL TOPICS

In addition to the usual topics, submission in the following areas are especially welcome: Measurement Standards for Radio Noise (1,8); Biological Effects of Electromagnetic Fields (1,2,6); Wave Measurements to Sense Hidden Structures (1,2,6); Remote Sensing; Acoustics, Optical, Radio (2); Radar Meteorology (2); Radiometry (2); Turbulence (2); Space Telecommunications (2); Millimeter Waves and Beyond (2); Ionospheric Scintillations (3); ELF Propagation (3); Interference to Radio Astronomy (5,8); Ranging Accuracy for Future Planetary Orbiters (5,7); Communication Channels - Characterization, Measurement and Simulation (6); Communication via Optical Fibers (6); Integrated Optics (6); Communication Networks (6); Man-Made Noise (8); Effects of Noise on System Performance (8); Sub-Surface Telecommunications; New Developments in Devices for Telecommunications;

ABSTRACTS

Send original abstract and two copies, prepared in accordance with the instructions below to: Prof. James R. Wait, Chairman, USNC/URSI Technical Program, Room 242, RB 1, C.I.R.E.S., University of Colorado, Boulder, Colorado, 80302.

Deadline For Receipt of All Abstracts: July 14, 1975. Abstract will not be acknowledged but acceptances or rejections will be mailed by August 1, 1975.

For an advance program, write to: Mr. Richard Y. Dow, USNC/URSI Staff Officer, National Academy of Sciences, 2101 Constitution Avenue, Washington, DC 20418.

1976 INTERNATIONAL SYMPOSIUM ON EMC

13-15 July 1976

Washington, D.C.

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OCTOBER 7-9, 1975

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AN ELECTROMAGNETIC COMPATIBILITY

FIGURE OF MERIT (EMC-FOM)

A major new development in the field of EMC has been announced by the Group on Electromagnetic Compatibility. A scheme for determining the figure of merit for electronic systems has been developed. The EMC-FOM has potential long term ramifications to the development of communications-electronics equipments for the Department of Defense and other government agencies.

A detailed report on the FOM-EMC has been published in a special issue of the IEEE GEMC Transactions in February 1975.

The IEEE Group on Electromagnetic Compatibility and the Department of Defense Electromagnetic Compatibility Analysis Center (ECAC) jointly sponsored an ad hoc committee whose task was to devise a practical procedure for developing an EMC figure of Merit (FOM).

The procedure developed enables quantification of the EMC characteristics of transmitting and receiving equipment. Given the transmitter and receiver FOMs, methods are specified for calculating FOM measures for simple communications systems using this equipment.

This capability will provide system planners, design engineers and management with a tool for making objective, consistent decisions. It may also be used as a quantitative requirement in specifications and to help make uniform comparisons among competing technical proposals.

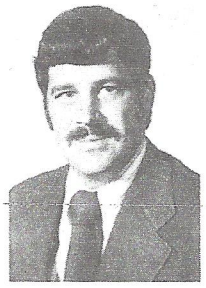
Additional information for feature articles and comments are available from:

Mr. Richard B. Schulz, IITRI
Department of Defense
Electromagnetic Compatibility
Analysis Center
North Severn
Annapolis, MD. 21402

NOTES FROM SEQUENCY UNION

by

G.R. Redinbo



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The following invited tutorial paper on piecewise-linear approximation of waveforms was written by Professor Clayton Paul, University of Kentucky.

Piecewise-Linear (PL) Basis Functions

A periodic function or signal, f(t), which is continuous for $0 \leq t \leq T$ with period T is classically approximated as a sum of sinusoids through the Fourier series as [1]

$$f(t) \cong \hat{f}(t)$$

$$\hat{f}(t) = a_o + \sum_{n=1}^{N} (a_n \cos n\omega t + b_n \sin n\omega t) \qquad (1)$$

where ω is the radian frequency of the signal, $\omega = \frac{2\pi}{T}$, and a_o, a_n, b_n are constants. The Fourier series representation of a signal, of course, greatly facilitates the steady state analysis of linear systems since if the steady state frequency response of the system is known, then the response to the approximation of f(t), $\hat{f}(t)$, can be found as the superposition of the responses to the various frequency components of $\hat{f}(t)$ as indicated in (1). In practice, only a finite number of terms, N, can be retained in the approximation and the coefficients are obtained from [1]

$$a_n = \frac{2}{T} \int_0^T f(t) \cos n\omega t \, dt$$

$$b_n = \frac{2}{T} \int_0^T f(t) \sin n\omega t \, dt \qquad (2)$$

The ability to determine the expansion coefficients for an arbitrary signal, f(t), via (2) is of course, a direct result of the fact that the "basis functions", cos nωt and sin nωt, are orthogonal [1]. These sinusoidal basis functions are special classes of more general orthogonal basis functions. In the general case, a periodic function, f(t), is represented as the sum of basis functions, $\phi_n(t)$, which are linearly independent over $0 \leq t \leq T$ as

$$f(t) \simeq \hat{f}(t)$$

$$\hat{f}(t) = \sum_{n=0}^{N} c_n \phi_n(t) \qquad (3)$$

The 1975 Sumposium on Theory and Applications of Walsh Functions at the Hatfield Polytechnic, Hatfield, Hertfordshire, England, will be held, July 1-3. For further information, contact P. D. Lines, Department of Electrical Engineering.

Preliminary plans are underway to organize a session on Walsh and nonsinusoidal functions at the 1976 International Symposium on Radio Spectrum Utilization, an EMC sponsored conference to be held in Washington, D.C., 13-15 July 1976. The theme of the symposium is directed toward the spectrum user's problems. Papers concerning Walsh and nonsinusoidal functions which fit this theme are solicited; e.g., interference problems in multiplex systems which use nonsinusoidal carriers, EMC measurement techniques employing Walsh and other types of functions, radiation of Walsh functions. Anyone interested in this session should contact G.R. Redinbo (address on inside of front cover). Summaries of submitted papers are due by July 15, 1975, while the final manuscript deadline is tentatively January, 1976.

****

Orthogonal basis functions possess the property that

$$\int_0^T \phi_i(t) \, \phi_j(t) \, dt = 0 \qquad (4)$$

for $i \neq j$. Orthonormal basis functions are orthogonal and further possess the property that

$$\frac{1}{T} \int_0^T \phi_i^2(t) \, dt = 1 \qquad (5)$$

Therefore, for orthonormal basis functions, the expansion coefficients in (3) may be easily obtained by multiplying both sides of (3) by $\phi_i(t)$ and integrating from 0 to T which yields [1]

$$c_n = \frac{1}{T} \int_0^T \phi_n(t) \, f(t) \, dt \qquad (6)$$

Thus, orthonormal basis functions are particularly attractive for approximating arbitrary signals as properly weighted sums of these basis functions since the expansion coefficients can be straightforwardly determined as in (6). This is one of the reasons for the importance of orthonormal basis functions such as the sinusoids used in a Fourier series. Another important advantage of orthogonal basis functions is the property of finality of coefficients [1]. This property ensures that each expansion coefficient, c_n, is determined independent of the choices of all the other expansion coefficients. In a practical situation one can only retain a finite number of terms in the approximation in (3). When increasing the number of terms in the expansion to provide a better approximation, one can compute these additional expansion coefficients without the necessity of recomputing the previous coefficients if the basis functions are orthogonal. Another important property of orthogonal basis functions is that the choice of expansion coefficients as in (6) minimizes the mean squared error between f(t) and the approximate function, $\hat{f}(t)$ [1]. The mean squared approximation error between the approximating series, $\hat{f}(t)$, and the actual function is defined as

$$I = \frac{1}{T} \int_0^T [\hat{f}(t) - f(t)]^2 \, dt \qquad (7)$$

For example, once the set of basis functions is chosen, then the choice of expansion coefficients in (6) is the optimum choice in the sense of minimizing the mean squared approximation error. Mean square approximation error, of course, is not the only possible criteria for evaluating the quality of the approximation. One may be more interested in minimizing the maximum pointwise error over $0 \leq t \leq T$ involved in the approximation.

There are, of course, orthonormal basis functions other than the sinusoidal functions. One such set of orthonormal basis functions is the set of Walsh functions, and the first 8 are shown in Fig. 1 and denoted as $\phi_i(t) = \text{Wal}(i,t)$ [2]. The index i corresponds to the number of sign changes within the interval, i.e., for $0<t<T$. These basis functions are piece-wise-constant and assume the values ± 1 over certain subintervals of $0<t<T$. Therefore the time-domain multiplication of $\phi_n(t)\, f(t)$ in the intergrand of (6) need not be explicity carried out and only the integration is required. For example, the expansion coefficients for a Walsh series are from (6) and Fig. 1.

$$c_0 = \frac{1}{T}\int_0^T f(t)\,dt$$

$$c_1 = \frac{1}{T}\int_0^{T/2} f(t)\,dt - \frac{1}{T}\int_{T/2}^{T} f(t)\,dt \qquad (8)$$

$$c_2 = \frac{1}{T}\int_0^{T/4} f(t)\,dt - \frac{1}{T}\int_{T/4}^{3T/4} f(t)\,dt + \frac{1}{T}\int_{3T/4}^{T} f(t)\,dt$$

$$\vdots \qquad\qquad \vdots$$

and the Walsh function expansion coefficients are simply linear combinations of constants which represent various averages of f(t) over certain subintervals of $0 \leq t \leq T$.

Since the Walsh functions are piecewise-constant (or stepwise-constant) functions they have received considerable attention in the decomposition of stepwise-constant functions such as occur in picture processing wherein the function to be expanded would represent the various levels of gray along the picture raster [2]. To expand continuous functions in a series of basis functions, continuous basis functions may have more merit in that convergence of $\hat{f}(t)$ to f(t) in (3) may be more rapidly achieved with fewer terms. The choice of the most efficient set of expansion or basis functions is not always clear cut. As a rather trivial example, it would certainly be more efficient to expand a single frequency sinusoid in a Fourier series rather than a Walsh series since only one term would be required with the Walsh series. Certainly there is a large class of continuous signals for which the choice is not so obvious.

Piecewise-linear approximation of nonlinear electrical network element characteristics have achieved much success as have piecewise-linear approximations in electromagnetic field theory problems. It is natural then to investigate piecewise-linear basis functions for use in expanding piecewise-linear approximations of functions.

A set of piecewise-linear basis functions (PL functions) has recently been proposed [3]. These basis functions are derived by integrating the Walsh functions and the first 9 PL functions are shown in Fig. 1 and denoted as $\phi_i(t) = \text{PL}(i,t)$. The PL basis functions are linearly independent over $0<t<T$ since they are derived from the Walsh functions (which are linearly independent over $0<t<T$) by integration and therefore they constitute a valid set of basis functions since no member of the set can be obtained as a finite combination of some of the other members of the set. The PL functions are normalized so that the peaks of the functions have values of ± 1. Notice that the Walsh functions in Fig. 1 have been grouped according to a group index, k. The Walsh functions are taken to be zero at t = 0 and t = T and each Walsh function within a group with index k has a maximum of $2^k - 1$ transitions over $0<t<T$. Each group consists of $2^{(k-1)}$ Walsh functions. The PL basis functions are explicitly defined as [3]

$$\text{PL}(i+1,\, t) = \frac{2^k}{T}\int_0^t \text{Wal}(i,\, \tau)\,d\tau \qquad (9)$$

$$0 \leq t \leq T$$

for i = 0, 1, 2, ..., and PL(0, t) = 1 for $0 \leq t \leq T$.

The PL functions are not orthogonal and therefore it would appear that one of the major advantages of orthogonal basis functions, the ability to straightforwardly determine the expansion coefficients via (6), is destroyed However, if one chooses the expansion coefficients so that the approximating series, f(t), exactly represents the signal at certain points in the interval, then the expansion coefficients can be determined in an almost trivial fashion. For example, if one chooses a k, k = 0, 1, 2, ..., and $2^k + 1$ points equally spaced over $0 \leq t \leq T$, then an approximation with a PL series expansion consisting of the first $2^k + 1$ PL functions will exactly match the original function at these $2^k + 1$ points (which include t = 0 and t = T) where k is the group index of the Walsh function group from which the PL functions are derived. If k is chosen to be 3, then 9 PL functions are required as indicated in Fig. 2. The expansion coefficients can be shown to be [3]

$$c_i = -\frac{1}{2^k}\int_0^T f(t)\,\text{Wal}'(i-1,\, t)\,dt \qquad (10)$$

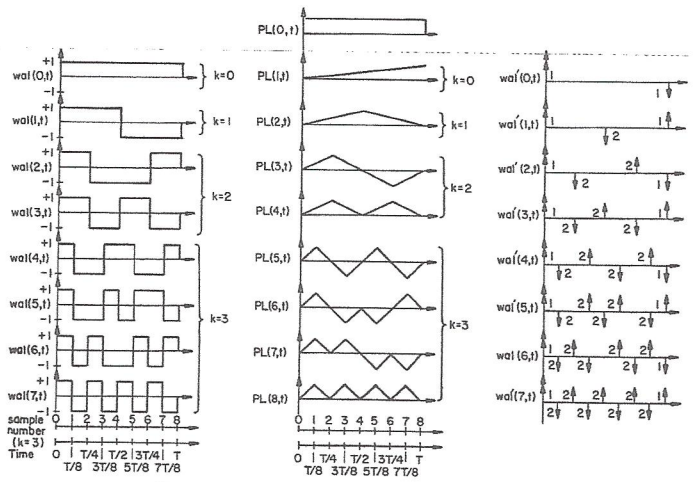

Fig. 1. Walsh Functions at Left, PL Functions Center, and Derivatives of Walsh Functions at Right

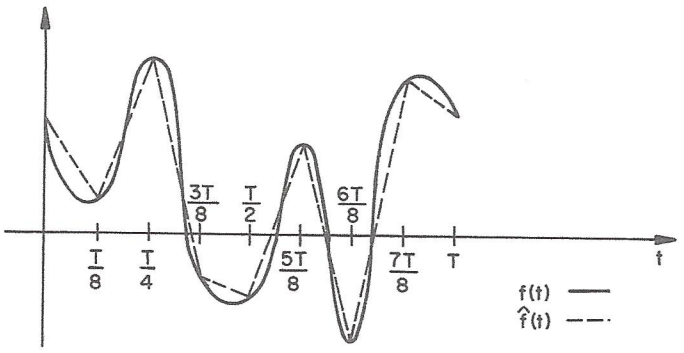

Fig. 2. Piecewise-linear approximation of f(t), k=3.

$i = 1, 2, \ldots$ and Wal′ indicates the derivative of the Walsh function from which the PL function associated with c_i is derived and $c_0 = f(0)$ where $f(0)$ denotes the value of $f(t)$ at $t = 0$. Since the derivatives of the Walsh functions are simply impulses with weight 2 except at $t = 0$ and $t = T$ where the weights of the impulses are 1, then (10) shows that the expansion coefficients in a PL series are simply linear combinations of samples of the function to be expanded. For example, for $k = 3$, we obtain from (10) and Fig. 1

$$
\begin{aligned}
c_0 &= f(0) \\
c_1 &= -[f(0) - f(T)] \\
c_2 &= -\tfrac{1}{2}[f(0) - 2f(T/2) + f(T)] \\
c_3 &= -\tfrac{1}{4}[f(0) - 2f(T/4) + 2f(3T/4) - f(T)] \\
c_4 &= -\tfrac{1}{4}[f(0) - 2f(T/4) + 2f(T/2) - 2f(3T/4) + f(T)] \\
c_5 &= -\tfrac{1}{8}[f(0) - 2f(T/8) + 2f(3T/8) - 2f(5T/8) \\
&\quad + 2f(7T/8) - f(T)] \qquad (11) \\
c_6 &= -\tfrac{1}{8}[f(0) - 2f(T/8) - 2f(3T/8) - 2f(T/2) \\
&\quad + 2f(5T/8) - 2f(7T/8) + f(T)] \\
c_7 &= -\tfrac{1}{8}[f(0) - 2f(T/8) + 2f(T/4) - 2f(3T/8) + 2f(5T/8) \\
&\quad - 2f(3T/4) + 2f(7T/8) - f(T)] \\
c_8 &= -\tfrac{1}{8}[f(0) - 2f(T/8) + 2f(T/4) - 2f(3T/8) + 2f(T/2) \\
&\quad - 2f(5T/8) + 2f(3T/4) - 2f(7T/8) + f(T)]
\end{aligned}
$$

Although these relations may appear complicated, it should be noted that all that is needed for determining the expansion coefficients are the values or samples of $f(t)$ at $t = 0$, $T/8$, $T/4$, $3T/8$, $T/2$, $5T/8$, $3T/4$, $7T/8$, T (for $k = 3$). The expansion coefficients are then simply linear combinations of these samples. In fact, the proper linear combinations associated with each coefficient, c_i, are explicitly determined by the derivative of the Walsh function from which the associated PL function was derived by integration and both the Walsh functions and their derivative can be generated recursively so that there is no need for a complicated formula for them [3]. One should compare this with the corresponding required calculation for orthonormal basis functions in (6). Note that in (6), in order to determine the expansion coefficients, one must multiply at each t, the basis function, $\phi_i(t)$, and $f(t)$ and integrate this product over $0 \le t \le T$. For practical signal expansions where $f(t)$ is not expressable in functional form, then the time domain multiplication and integration of the product of $\phi_i(t)$ and $f(t)$ over $0 \le t \le T$ must be evaluated approximately.

The advantages of the PL functions are that the expansion coefficients can be almost trivially determined as linear combinations of samples of the function to be expanded and the specific linear combinations are determined by the derivatives of the Walsh functions which can be recursively generated. Expansions in terms of PL functions also obey the property of finality of coefficients as is clear from (11). One can also select, a priori, the required number of PL functions to achieve a certain maximum pointwise approximation error. A further advantage of the PL functions is that the PL functions need not be generated when reconstructing a signal. Since the PL functions are generated by integrating the Walsh functions, then the reconstruction of a signal with PL functions can be easily achieved by multiplying the Walsh functions by the appropriate PL expansion coefficients and integrating the sum. Techniques of digital generation of the Walsh functions abound in the literature. It can also be shown that a PL function series approximation to $f(t)$ converges uniformly to $f(t)$ for increasing k and therefore the maximum pointwise approximation error decreases for increasing k and continuous $f(t)$.

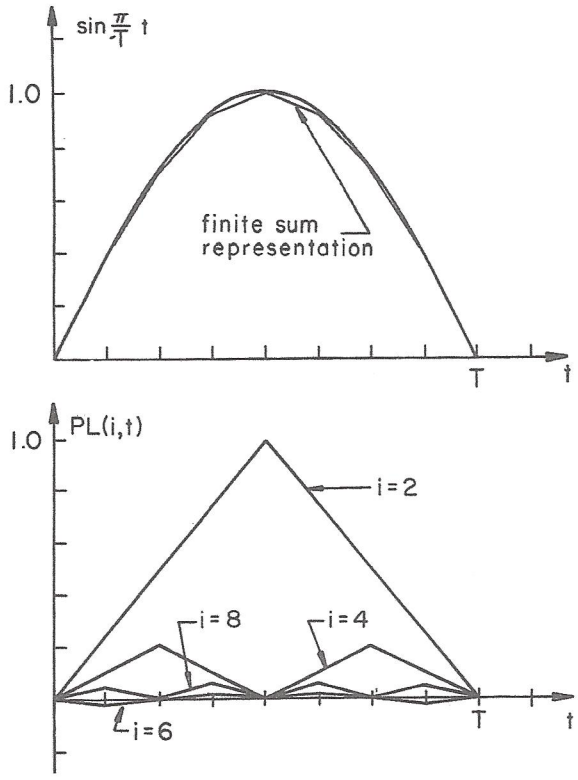

Figure 3. A finite sum representation of a half period sinusoid in terms of the basis set $\{PL(i,t)\}$.

The PL function expansion technique was implemented on an IBM 360/65 computer and central-processor-unit time for determining the expansion coefficients for $k = 8$, i.e., 257 PL functions, was only 9 seconds. As an example, consider the half period sinusoid shown in Fig. 3. Using only 9 PL functions ($k = 3$), we obtain a remarkable fit and the maximum pointwise error is small; less than 2 percent. In addition, since the function is even about $t = T/2$, then c_0, c_1, c_3, c_5 and c_7 are identically zero and this is easily determined with (11).

REFERENCES

[1] G. R. Cooper and C. D. McGillem, Methods of Signal and System Analysis. New York: Holt, Rinehart and Winston, 1967.

[2] H. F. Harmuth, Transformation of Information by Orthogonal Functions. New York: Springer-Verlag, 1972.

[3] C. R. Paul and R. W. Koch, "On piecewise-linear basis functions and piecewise-linear signal expansions", IEEE Trans. on Acoustics, Speech, and Signal Processing, Vol. ASSP-22, No. 4, pp. 263-268, August 1974.

INSTITUTIONAL LISTINGS

The IEEE Electromagnetic Compatibility Group is grateful for the assistance given by the firms listed below and invites application for Institutional Listings from other firms interested in the electromagnetic compatibility field.

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