Vehicular electronics has interest in microwave p. 4

High tech featured at two railroad meetings p. 8

BN official talks about high tech rr applications p. 18

Abstracts cover 30 technical communications papers p. 38

FCC wants spectrum usage information on frequencies of 470 MHz and below p. 21

Safety of high speed rail and magnetic levitation is topic of FRA/TRB meeting p. 43
Madden's Message

Several things are on my mind today. One is the hue and cry by U.S. Government agencies and some educators about the coming shortage in the U.S. of engineers and scientists. Yet another is the increasing number of newly graduated EE's who have not yet found engineering positions, or received reasonable job offers in engineering. Still another is the plight of experienced EE's who, through no fault of their own, find themselves unemployed, and their careers as engineers terminated, 10 to 20 years before retirement age. Their numbers are also increasing. Are those who say "shortage" and those who say "surplus" talking about the same commodity? Do EE's really have a "half-life" of about 10 years? Do their skills really lessen as they age? A conference on the subject will have occurred by the distribution of this newsletter, and I am sure that Frank Lord's column in February, 1992 will have something interesting to say about the subject. Please drop a line to Frank if you want to express an opinion on the topic. Frank also serves on the IEEE-USA Manpower Committee, and that committee has been interested in these apparent disparities for some time.

Corporations and governments alike are fascinated by the highway guidance, motorist assistance and locational capabilities of Intelligent Vehicle Highway Systems, or IVHS. Vehicular Technology Society is not far behind the curve on this one. This Society has been publishing papers on various aspects of these technologies for over twenty years, and has seen several of the technologies move from concept to reality to manufacturability. We are proud to be the initiators and sponsors of the Vehicular Navigation and Information Systems (VNIS) series of conferences, and we believe that the VNIS conferences will continue to be the IVHS international conference for some years to come.

Please plan to attend the VNIS 92 Conference, September 2-4, in Oslo, Norway.

(Please turn to page 7)

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Editor's Corner

Continuing the subject of technical interest profiles of VTS members here is the complete rundown of the first choices of members as reported to IEEE headquarters on members' dues renewals or new memberships.

Number |
--- |
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139 |
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Broadcast Technology |
157 |
Antennas and Propagation |
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Circuits and Systems |
5 |
Nuclear and Plasma Sciences |
693 |
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10 |
Engineering in Medicine and Biology |
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Vehicular Electronics

Bill Fleming, Vehicular Electronics Editor

Automotive Electronics Create Renewed Microwave Interest

Major automotive firms in the U.S., Europe, and Japan are creating microwave-based equipment for their 1994 models [1]. For example, Motorola estimates that 300,000 1994 vehicles will include electronic navigation equipment. Furthermore, the Federal Highway Administration is currently evaluating programs that could exceed $2 billion by the end of this decade, with microwave subsystems and systems as key ingredients.

Automotive microwave electronics applications are actively being pursued in Europe by Thomson CSF (T-CSF), Telefunken SystemTechnik (TST), and Siemens while Toyota, NEC, and Matsushita are heavily involved in Japan [1]. In the U.S., General Motors and its subsidiaries Delco Electronics and Hughes Microwave Division, along with Chrysler, are developing prototype systems.

Impetus for microwave development is due in part to technology gains stemming from government-supported MMC (Microwave Monolithic Integrated Circuits) programs which are making available high-volume, low-cost, microwave ICs. Applications, ranging from collision warning and avoidance to vehicle guidance and intelligent highways are now being developed. Table 1 lists these, and several more, automotive application areas; together with a partial listing of participating automotive and electronics companies.

Table 1: Emerging Microwave Applications in Automobiles

<table>
<thead>
<tr>
<th>Category</th>
<th>Typical Frequency Band</th>
<th>Partial List of Developers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near Obstacle Detection (rear)</td>
<td>X</td>
<td>Delco Electronics</td>
</tr>
<tr>
<td>Blind Spot Detection</td>
<td>Ka</td>
<td>Delco Electronics</td>
</tr>
<tr>
<td>Semi Automatic Headway Control</td>
<td>mm-wave</td>
<td>GM and Toyota</td>
</tr>
<tr>
<td>Airbag Arming</td>
<td>X</td>
<td>GM and Hughes</td>
</tr>
<tr>
<td>Collision Warning and Avoidance</td>
<td>mm-wave</td>
<td>GM and Hughes</td>
</tr>
<tr>
<td>Speed Sensing</td>
<td>Ka</td>
<td>Siemens</td>
</tr>
<tr>
<td>Adaptive Cruise Control</td>
<td>mm-wave</td>
<td>GM, Delco Electronics</td>
</tr>
<tr>
<td>Vehicle Identification</td>
<td>C and X</td>
<td>T-CSF and TST</td>
</tr>
<tr>
<td>Automotive Telecommunications</td>
<td>L</td>
<td>NEC, Matsushita, Telcos, HNS and Motorola</td>
</tr>
<tr>
<td>Navigation</td>
<td>Ku</td>
<td>HNS and ETAK</td>
</tr>
<tr>
<td>Position Tracking</td>
<td>Ku</td>
<td>DoD, HNS and ITT</td>
</tr>
<tr>
<td>Automotive Entertainment</td>
<td>C and S</td>
<td>Chrysler, GM and Japanese electronics giants</td>
</tr>
<tr>
<td>Traffic Management</td>
<td>X, Ka and mm-wave</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>Intelligent Highways</td>
<td>DC to light</td>
<td>Fiat, US DoT, Siemens and Daimler Benz</td>
</tr>
<tr>
<td>Auto Dealer Networks</td>
<td>C and Ku</td>
<td>GM and Chrysler</td>
</tr>
</tbody>
</table>

Worldwide Automotive Microwave Applications — Ref. [1]

Concealed Conformal Planar Microwave Antenna Array [1]

November 1991
Professional Activities

Frank E. Lord
Professional Activities Editor

Career Support

From time to time I have mentioned the Councils operating under IEEE-United States Activities (IEEE-USA) and described the things that they are doing to make Electrical Engineering (and all engineering to some extent) a more visible factor on the United States scene. The somewhat professor of electrical engineering has always been a significant contributor to the enhancement of life and culture of all peoples and it has been particularly so in the United States. However, this has not been adequately recognized, thus denying the profession and its practitioners their proper role in United States society. The Councils of IEEE-USA work to improve this situation. Some of their efforts are focused on present problems with goals of achieving direct effects. Other efforts have longer term focus with less immediate results; some might even be considered intangible. There are some activities that would even be considered institutional advertising, i.e., a form of soft sell public relations.

The overall goal of all these varied activities could be characterized as to establish a proper and recognized place in United States affairs for the profession of Electrical Engineering and its practitioners.

The Councils, namely Technology Policy, Government Activities, Member Activities, Career Activities and Professional Activities for Engineers (PACE) are composed of eight to ten committees each focused on an activity or issue where specific results can be achieved. The goals of some committees are near term while others are long range. Some committees have both types of goals. The same is true of the Councils. Some Councils, with their composite of committees, tend to be concerned with long range matters while others focus on more immediate matters. For instance, the development of positions on technology policy by the Technology Policy Council (TPC) to be ultimately advocated to the federal government by the Government Activities Council (GAC) may not produce results as quickly as the Employment Assistance effort of the Member Activities Council (MAC). Professional Activities Council for Engineers (PACE) engages in near term activities for the most part. PACE is the network that links all entities, such as Societies, Group Chapters, Regions and Sections, at all levels of the Institute to support identification of issues, achievement of consensus and coordination of efforts. PACE reaches out with information to all members including students.

We are all interested in specific achievements, so I read intently a group of recent reports from the committees of the Career Activities Council (CAC), this Council seems to have about a 50/50 division between short term and long term activities. A report from Richard Plummer, Chairman of the Anti-Discrimination Committee indicated that they are monitoring and exerting influence on five items of the current legislation. This committee’s effort last year ensured passage of the Older Workers Benefit Protection Act of 1990 which was signed into law on September 18, 1990. The Council’s response to a Legislative Alert on this bill helped the process. A great deal of work on the past of the Career Maintenance and Development Activity Committee culminated in the Seventh Biennial IEEE-USA Careers Conference held October 10th and 11th. The theme was “Change and Competitiveness and Careers”.

Over the past year the Ethics Committee had a proposed simplified IEEE Code of Ethics approved which was subsequently released in January. The committee then proceeded to interact with other professional organizations to strengthen cooperation in this area.

Meanwhile the Intellectual Property Committee was looking out for our interests by submitting amendments to Congress for the Software Rental Act of 1990. They also testified before the House Subcommittee on Technology and Competitiveness on behalf of the Technology Transfer Improvements Act of 1991 (H. R. 191).

Committee representatives also met with key legislators and their staff members to express views on other legislative items.

The Manpower Committee has submitted a statement for inclusion in the record of House Judiciary Committee hearings on proposed immigration reform legislation. This committee also expanded its contacts and working arrangements with foreign labor certifying officials at regional Department of Labor Offices. This effort is to assist in application of the law that is meant to protect opportunities for U.S. citizen workers.

The Pensions Committee, chaired by our own George McClure, emphasized their concern lobbying activities in support of legislation to expand coverage, improve portability and increase savings for retirement. They translated their retirement income policy communications into a proposed bill for introduction as H. R. 2390, the Pension Coverage and Portability Improvement Act, by Congressman Sam Gibbons (D-FL), the second ranking Democrat on the House Ways and Means Committee. They are also developing improved retirement savings vehicles for IEEE to offer us in the future.

Some may wonder about the title of this piece and how it relates to the content. It is simply that, like it or not, life in our modern society is more complex. While most of us would like to concentrate on our technology interests, our lives, both professional and family, are being impacted by factors that are beyond our individual control. Thus exerting influence that, hopefully, is beneficial to both society and ourselves through our Institute and IEEE-USA is indeed career support. Think of the professional environment that may be realized as the platform from which you may attain your individual achievements. The higher the platform the greater the opportunity.

Five governors are reelected

Elective results are in for the Vehicular Technology Society Board of Governors. The following governors have been reelected for 3-year terms beginning January 1, 1992:

Robert E. Fenton
Robert A. Mazzola
George M. Church
Stuart F. Meyer
Jesse E. Russell

Maanden’s Message Continued

The IEEE Standards Board recently formed an IVHS Coordinating Committee. Jesse Russell, our Standards Committee chairman, is looking for up to 10 volunteers to serve on the various subcommittees. Please contact Jesse at AT&T Bell Laboratories, Whippany Road, Whippany, New Jersey, 07981 if you would like to work on IVHS Standards.

Finally, the lifeblood of any organization like this is service to its members. Please let me know if we aren’t addressing the areas of mobile communications, telecommunications, transportation systems in which you have a particular interest. My phone number is 904-224-4451, FAX 904-224-3059.
Transportation Systems

Advanced train control meeting held in June

The first international symposium on advanced train control systems held June 17-19, 1991 in Denver, Colorado, drew 350 in attendance from countries all over the world.

Abstracts of the technical papers are presented here:

Advanced Train Control System (ATCS) Control Flow Development and Validation by Robert G. Ayers, Artec Research.
The advanced train control system project was initiated by the Railway Association of Canada and the Association of American Railroads in 1984. By 1986, a need to define the functions of the various ATCS application programs resulted in a set of control flows. At this time they were developed into a flowchart format and a process of iterative review and updating began. In 1989, the volume and complexity of the control flows required another look at how to handle them which resulted in computer-aided software engineering (CASE) technology. Revisions and issues strategies have continued so that the project is continuing the validation of the “user protocol stack.”

Verification and Validation for Advanced Train Control Systems by Gideon Ben-Yaacov, Automated Monitoring & Control International.
Verification and validation (VV&V) are used in military, space, nuclear power and other industries to improve the quality of digital systems. VV&V will ensure that quality advance train control systems (ATCS) are implemented.

Improvement of ATCS Operational Safety and Efficiency Through Human Factors Applications by Gideon Ben-Yaacov, Automated Monitoring & Control International.
Successful implementation of any advanced computer system depends on its usage. Users, in this case engineers, will not be inclined to use advanced train control systems because these system have sophisticated software structures and complex hardware configurations, rather they will use the systems only if necessary and be obtained through simple man-machine interface (MMI) procedures.

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Essential Elements of System Integration by Agn K. Rits and Ken Kozoli, Smartware Associates.

Systems integration is not just connecting black boxes together, turning them on as a unit, testing them and then installing them in the field. Systems integration is an engineering discipline that successfully integrates various components with independent operating characteristics into an entity which functions together as a system. Systems integration is the resolution of design disconnects that occur when many diverse components are brought together, often for the first time to solve a problem or achieve a goal. Each resolution requires engineering and management decisions, and each decision must consider the impact of the system as a whole. The impact of these design decisions on the components (downward) and on the system (upward) must be considered.

Performance and Capacity Analysis of an Operating ATCS Communications System by Edward L. Purcell, Automated Monitoring & Control International.

Automated Monitoring & Control has been working with the Union Pacific Railroad to implement a communication network based on ACTS Specification 200. This is the first large-scale implementation of the ACTS communications system. Computer performance and data from the installed system are evaluated to obtain insight into the capabilities of this type of mobile data network. The average traffic output for the Base Communications Package (BCP) in the installed system uses less than 5% of the estimated capacity of the BCP. The average inbound load for each BCP in the installed system is less than 12% of the BCPIs inbound capacity. The successful large-scale implementation of a Spec 200 network on Union Pacific indicates that the system's implementation provides the basis for a viable communication network.

Train Control on French Railroads by J. P. Charpentier, French National Railroads (SNCF).

SNCF's high-speed lines (2 now in service) have passenger trains operating up to 187 mph (300 km/h). In signaling for these speeds, SNCF has followed two principles:

1. The signaling system is designed so that safety of very high speed train is not dependent on correct observation of line-side signals.
2. Trains are to be manually operated with drivers controlling acceleration, deceleration, coasting and braking, but a speed monitoring system is used to check vehicle movement in relation to signals displayed in the cab and to intervene if necessary through sharp brake application.

The signaling system designed in relation to line throughput, vehicle characteristics and specific operating conditions consists of:

- A continuous data transmission system (18 data items)
- An intermittent data transmission system (14 data items) with track-to-train transmission
- SNCF also considers it necessary to have a continuous control system for detecting broken rails, whereas the choice of track-circuit based signaling technology.

Management and Information Systems; Components of a Successful ATCS by Patrick T. Harker and Jeffrey Ward, University of Pennsylvania.

Much of the focus in the development of and debates surrounding Advanced Train Control Systems (ATCS) has centered on the technical aspects of the various hardware and software components which comprise such a system. However, numerous failures of advanced technologies in the service sector point to the need for a careful consideration of the organizational and strategic needs of such a system prior to final design. This paper presents such a discussion by looking at how an ATCS can be used to support the overall strategy of the railroad. Having defined this relationship between ATCS and the railroad's strategy, the paper then presents a hierarchy of intelligent information systems components which are vital to the design and implementation within the ATCS context.

The Development of a Wayside Detector Open Communication Standard by Harold Harrison, Salient Systems.

There is an emerging trend in the railroad industry to consolidate more wayside detectors at fewer installations. By combining several detectors and auxiliary devices such as vehicle identification equipment (cameras and tag readers), considerable efficiencies are achievable which, in turn, benefit the growth towards ATCS integration. Given that the various devices are not generally available from a single vendor, there is an obvious need for a standardized means of communicating among all devices.

This paper presents a proposed framework from which a communication network standard may then develop. The primary goal of this effort is to separate information into relative groups by nature of their respective time criticality, the quantity of information passed, and the relative capacity of each device involved to handle its task.

ATCS at CP Rail: Steady and Measured by R. J. Hippler and F. A. Shea, CP Rail.

CP Rail's involvement in ATCS dates back to the initial concept stage conducted by the Canadian Railways in the 1980s. This paper is meant to expose CP Rail's internal development in ATCS to the present time and to outline what we see for the next couple of years.

CP Rail development has involved a number of items:

- Development and installation of a computer assisted dispatch system on all its non-cc track
- Development and installation of its own cc office system with an eventual goal of a single generic office system
- Development of ACTS concepts with "in track" installations

Progression from the developments to an ATCS-like system in a pilot production system.

Realizing Benefits from ATCS Using a Motive Power Information and Management Support System by Mark Horning and Howard Rosen, ALK Associates; and John Szyrnikowski and Dan Dion, Canadian National Railway.

The motive power management function can be significantly improved if the system can provide accurate information. With earlier and more reliable knowledge of train and locomotive performance and demands for power, motive power managers can improve their forward planning, leading to improved locomotive utilization and better on-time train performance.

Advanced Train Control Systems (ATCS) can be an important source of information for motive power management. With its train location, locomotive health and work order reporting systems, ATCS has the potential of increasing accuracy to near 100% and reducing to a matter of seconds the time lag between an event and when that event becomes known to motive power managers.

In order to exploit this more timely and accurate information, it must be organized and presented to the motive power managers in an efficient manner. In order to achieve this, a centralized motive power management system must be designed and implemented at CN Rail. It consists of geographic displays of current train and locomotive location and status, alerts which highlight critical new information, planning functions for motive power, and facilities for communicating plans to field forces. With the motive power system in place, and gathering its information from ATCS, managers know and can respond immediately to changes in train and locomotive demand and performance.

Whether or not a prerequisite for achieving benefits from an improved management control system, it is the authors' contention that an effective management control system for trains and locomotives is a prerequisite for achieving full benefits from ATCS.

Operation Control and Signaling System for High-Speed Lines by Klaus H. Hummer, Siemens AG Transportation System.

The equipment for signaling and operation control of new high-speed lines carrying Intercity Express passenger trains (ICE) are designed for train speeds in excess of 300 km/hr. The system for high-speed lines comprise the following:

- Operation control centers for automatic train supervision
- Determined interlocking for safeguarding routes
- Continuous automatic train control for protecting trains and for cab signaling
- On-board automatic speed control
- Audio-frequency track circuits with electromagnetic compatibility for track vacancy detection.

A Decision Support System for Train Dispatching: an Optimization-Based Methodology by Dan Yanovic, Burlington Northern; and Patrick T. Harker, University of Pennsylvania.

This paper presents a new methodology framework for the development and use of computer-aided train dispatching (CAD) systems. This paper presents through the use of examples the application of recently developed optimization algorithms for the dispatching problem. These examples highlight the need to focus on the adherence to schedules as the main objective of a CAD system and show that these new algorithms can be quite efficient in practice.

Also this paper presents decision-support tools aimed at improving capacity utilization through optimal CAD in real-time operations. The primary purpose of dispatching tools is to allow trains to arrive on-time rather than to minimize total train delays.

Advances in Flat Panel Display Technology and Applicability to ATCS Onboard Terminals by Chuck J. Karpowski and Gideon Ben-Yaacov, Automated Monitoring & Control International; and David Blass, Emerald Computers.

The introduction of ATCS to the railroad industry means that voice communications can now be supplemented and may be eventually replaced by data communications to locomotive crews via onboard display terminals. Flat panel display screens are well suited for locomotive display terminals. Flat panel displays are controlled WTechnology and Applicability to ATCS Onboard Terminals by Chuck J. Karpowski and Gideon Ben-Yaacov, Automated Monitoring & Control International; and David Blass, Emerald Computers.

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This presentation provides guidelines for the selection of ruggedized flat panel display screens for locomotive
ATCS applications. Technical features of flat panel displays are described and a comparison is made between different display technologies considered. A brief overview, as well as, the operational theory of the LCD, EL, TFT and Plasma Flat Panel display technologies is presented. This is followed by an item-by-item comparison of display screens for each physical and environmental characteristics. And finally, optimal display technology for ATCS is recommended.

ATCS Data Network Management by Bruce S. Kloster, Rockwell International.

One essential component of ATCS is the data communications network. Network management is the set of procedures that provides for the continuity of data network services that enables ATCS to reach its potential.

Network management provides network planning, overload protection and trouble shooting and repair. Each of these activities impose specific operational requirements upon the data network implementation.

The network management activities use a collection of automatic software processes augmented by some manual processes to achieve the desired service levels for network operation. Service level is the designated value of the service variables for the network. Examples of service variables are: The number of the packets, The time it takes for a packet to be switched, Availability of the communications service.

AUSTRA: The Australian ATCS by Keith Ludgen and Ron Davidson, International Railroad Systems.

This paper describes the design of AUSTRA, which is the Australian implementation of the North American Advanced Train Control System (ATCS) series of signaling specifications. AUSTRA is being installed on Australian National's Trans-Australian and Central Australian lines. In particular, this paper focuses on the differences between AUSTRA and ATCS, on some of the problems found with the ATCS specifications and on the unique features incorporated into AUSTRA.

Open Systems Architecture for Embedded Rail Applications by Richard G. Naedel, Pulse Electronics.

Open computer system architectures are based on industry standardized microprocessors and programming languages. Such systems can offer a less costly alternative to special purpose (closed) embedded hardware and software for rail applications. Discussion herein is focused on a solution for achieving cost-effectiveness in programmability and upgradability via an open hardware/software architecture which has been engineered for the severe railroad operating environment.

Railroad Operation Using the Advanced Train Control System by David A. Potorock and John R. Ranft, ARINC Research.

This paper will provide insight into railroad operation with the Advanced Train Control System (ATCS). Significant aspects of ATCS which will be addressed include the basic architecture and operation of ATCS as it is currently specified. Alternate applications of ATCS will also be explored.

The basic approach taken in the development of ATCS has been that railroad operations can be made safer and more efficient by applying modern command, control and communications technology. By using precise speed and location information the system is able to provide more timely and precise traffic information than traditional train control systems. The new ATCS system will benefit from "moving block" operation, where the separation necessary for safe operation is dynamically determined from traffic levels and capabilities of trains (e.g. braking distances and location updates). Smaller train separation is made possible with a resultant increase in line capacity.

Major design elements employed by ATCS are the data communications system and information processing nodes that reside at the central dispatch office, on-board processors associated with each train and in field devices. The use of these elements will have a significant impact on the manner in which dispatchers, engineers and foremen conduct their daily operations. These elements also provide for numerous applications besides train control.


Through efforts as the development of railroad signaling systems have the opportunity to lower costs and improve service simultaneously. Burlington Northern along with Rockwell International has developed its version of the Advanced Railroad Electronics System (ARES). This paper describes a new method of measuring the rail impedance shunted by train axles.

The railroad system integrates the traditional signaling system with the ARES, a micro-computer, train position detection system, and driving control function, all mounted on board a train. The data collected from this system is then passed to the ARES control computer, which in turn determines the optimal train speed.


This paper describes the background of the International Union of Railways (UIC) project to develop a European Train Control System (ETCS). As far as possible at this early stage, the paper describes the similarities and differences from the North American ATCS, and the desire to achieve these for these.

The migration from Conventional Signaling to Next-Generation Train Control by Jeff Tweedly, General Electric, the Pennsylvania Railroad.

There are several key issues regarding both the ease of migration and the overall cost/benefit of converting from conventional signaling to next-generation train control. These issues include compatibility with existing signal systems, movement of unequipped trains over controlled territory, ability to implement the system both line-by-line and at the same time, and the possibility of significant training costs for dispatchers, locomotive maintenance personnel and train crews.

There are two basic implementation scenarios which must be considered in this discussion: adding dark territory to existing ctc territory, and overlaying a next-generation train control system over existing ctc territory, both scenarios mandate that some sort of transition path be determined to allow a smooth, orderly change with no disruption in operation. Due to the tremendous investment in traditional signaling systems, it is unlikely that the introduction of ARES will have a significant impact on the acceptance and implementation of next-generation train control systems.

Advanced ATP System for Improving Train Traffic Density and Control Efficiency by Ikuhara Watanabe and Tetsuo Takashige, Railway Technical Research Institute.

A new Automatic Train Protection (ATP) system is presented utilizing the existing signaling systems efficiently. This new system can detect a train position continuously with accuracy of less than 30 meters by measuring the rail impedance shunted by train axles. Such information is then used in combination with the track data to determine the current position of the train. Control functions, such as track occupancy, are determined based on the track circuit data. This new ATP system can be applied to various types of signaling systems.

Railroads continue to pursue advancing technology

Papers presented at the 31st annual technical conference of the Communication & Signal Division, Association of American Railroads in Nashville, Tennessee August 26-28, 1991, provided evidence that the industry is continuing to apply advanced technology.
Control of Class Yard Signal Equipment Using DTMF Data Transmission Through the Use of a Hand Held Radio by B. L. Sykes, Chief Engineer, Communications & Signals, Norfolk Southern.
Norfolk Southern has developed a system whereby maintenance personnel can make field tests in a classified yard with respect to their activities in the central computer in the yard which responds with voice messages concerning the actions taken. The system consists of a hand held radio equipped with a DTMF pad which transmits to a base station located in the computer building. The audio output of the base station is connected to a radio interface module whose function is to convert the DTMF tones received by the base station into their respective ASCII representations. These ASCII characters are then passed to the control system computer which, when all safety conditions are met, performs the desired function such as moving the switch or retar rer. The computer then generates a synthesized voice message which contains verbalization of the action taken by the computer and passes the message through the radio interface module to the base station, which then transmits it to the hand held radio.

Cellular Solution for Traffic Control Reliability by O. G. S. Smith.
Telecommunications Engineer, ConRail.
ConRail has in rural areas made use of cellular radio to transmit controls and indications between control points. The signal is transmitted in the areas not near major communications facilities, such as microwave, fiber optics or cable system. This “last mile” solution is now bridged through the use of cellular radio.

Low Cost SCADA for the Smaller Railroad by Timothy R. Lohm, Supervisor Communications and Robert D. Olson, Radio Engineer, Duluth, Missabe & Iron Range.
The Duluth, Missabe & Iron Range Railway has developed and installed a Supervisory Control and Data Acquisition (SCADA) system to monitor and control systems and report alarms.
The DMIS/IR SCADA features a host computer with a centralized storage and real-time processing of input and personnel information on the attached devices is stored. It is located in the Communications Department headquarters for easy access to circuits and system monitoring during normal working hours. All important alarm conditions are transmitted to the SLAVE computer located in the dispatch center where 24-hour per day coverage is available.
There are 16 REMOTES in use with the additional capacity for a total of 64. The communications between the HOST and the REMOTES is a polled ASCII based scheme using RS232 digital circuits or 4-wire voice circuits. The communications rate of the REMOTE is a point-to-point dedicated 2-wire, 1200 bit per second circuit but could easily be changed to dial-up if the requirements changed.

Motion Sensor and Constant Warning Control System for Grade Crossing Warning Devices by J. M. Murphy, Signal Design Engineer, Union Pacific.
Motion sensors deactivate crossing signal operation if a train stops in the approach to a crossing and when the train has passed over the crossing. Constant warning signals which provide the same warning time to the motorist regardless of the speed of the train approaching the crossing.

Burlington Northern Railroad is seeking to improve the safety of highway grade crossings through several innovative projects. BN has installed a solar powered train detection illumination system which uses the stored electricity in batteries to operate flood lights which illuminate the crossing at night. It is activated by the headlight of an approaching train and signal is transmitted in November 1990 at a non-signaled crossing through Longmont, Colorado and has been operating successfully since that time.

In a joint research and development effort with 3M Company, BN is developing a passive warning sign. As an approaching train nears the crossing, a passive warning sign collects a portion of the light from the locomotive's headlight and redirects it outward toward the oncoming traffic providing a visual indication that a train is approaching.

Innovations in Engineering and Enforcement at Highway Grade Crossings by Gary W. Starbeck, Engineer System Applications, Burlington Northern.
Burlington Northern Railroad is seeking to improve the safety of highway grade crossings through several innovative demonstration projects. In 1990 the company hazard by the accident risk of a train crossing the intersection of a high-speed highway and a railroad.

The system uses "state of the art" technology to capture video images of motorists driving around grade crossing gates and is transmitted to the Jonesboro Police Department so they may issue a citation to the offending motorist.

A Procedure to Address Safety in the Design and Operation of Modern Train Control Systems by J. M. Patterson, Chief Engineer Signals & Communications, CP Rail.
The computerized office control system and, within it, the combination of previously separate dispatching and critical safety activities, is resulting in train control systems becoming increasingly complex to the point that system safety is being questioned.
CP Rail has developed a safety analysis procedure which allows CP Rail to measure the level of safety on any portion of any train control system. The railroad can then decide if the level should be improved. The procedure can be used on an existing system or can be used in the design of a new train control system.

The Development of Computer Based Track and Time Limits on the Santa Fe by Charles N. Wheeler, Director Signals System, and William D. Potts, Assistant Electronics Engineer, Santa Fe Railway.
The specific origin for Track and Time Limits stated:

"A bookkeeping procedure to account for the blocking of a CTC device (track sections, including OS sections) to provide safe conditions for on-track work equipment and personnel in a defined operating area and prevent the releasing of such a blocked device without the dispatcher first complying with the completion of a record that the defined operating area is clear for traffic movement.*"

From this definition, Santa Fe developed a compact programming and printed circuit board to provide a system that helps protect personnel and track equipment on the railway.

Overview of Dispatcher Consolidation Projects at Norfolk Southern by W. C. Johnson, Manager Signal & Electrical Engineering, Norfolk Southern.
At Norfolk Southern a train dispatching facility is a group of experienced people, the necessary equipment, and a building to form an organized body which, by its actions, makes arrangements for disposition of trains and equipment to affect a transportation service, along with the required maintenance forces to ensure that this process can continue.

Management and operating philosophies are described along with methods of making dispatching facilitations.

Skills for Today and Tomorrow Through Partnerships in Training by Richard Flower.
The GRS MicroCaptive train control system provides automatic train protection functions plus built-in self-test capabilities. In-service testing over all Metra divisions has been completed with satisfactory results. The microprocessor-based equipment because of its more compact size saves 146 seats in the 173 cab control cars being ordered, and will be delivered in the next 2-3 years. In 1991 30 new locomotives will be equipped with the new microprocessor based system.

Self-Reloading Remote Dual Controlled Switch for Cabooseless Train Operation by Terry E. Therrien, Manager Signal Design, Canadian National

The signal design group in conjunction with the Rules Department of CN developed a concept which would allow the head end crew to line a switch for their required route and then leave the area without any further switch manipulation. Once the last car on the train vacates the 05 track circuit, the switch would automatically return for main track moves.


In 1983, Consolidated Rail Corporation agreed to permit Philadelphia Electric Co. to build and operate a 230 kv transmission line on a 7-mile section of non-electrified railroad in suburban Philadelphia. Although this transmission line is designed for a maximum load of 1,418 MVA steady-state, it soon became apparent that 600 MVA was sufficient to interrupt service and damage ConRail's signal facilities. The solution was to provide a low resistance path to ground for the 60 cycle interference currents. In the new signal system, a 100 Hz ungrounded reference AC power supply is provided. Also, impedance bonds are used in which the center tap of every other pair of bonds is grounded and attached to the power line's structure ground. As a result, current loops are formed which allow the voltages across insulated joints and from rail to ground to remain low, similar to the electric propulsion applications.


Major advances in the AAR's ATCS program have been made during the past year in communications testing and system logic specifications. Work is also continuing on control flow specifications, which tells how a railroad would be operated using ATCS.

The papers abstracted above are contained in the 1991 Committee Reports and Technical Papers bulletin of this division of AAR. For information on how to obtain this bulletin or papers, contact W. L. Peters, Secretary, Communication & Signal Division, AAR, 50 F Street, NW, Washington, DC 20001. Telephone: 202-639-2216.

Meetings

Spread spectrum techniques meeting set for Japan

The IEEE second International Symposium on Spread Spectrum Techniques and Applications will be held November 29-December 2, 1992 at the Pacific Convention Plaza in Yokohama, Japan. This conference is sponsored by the IEEE Tokyo Section and the IEICE Spread Spectrum Technology Group. Topics of interests include theory, design, implementation and application aspects of the representative areas listed below but are not limited: Spread spectrum communication theory and techniques; Modulation and demodulation, acquisition and tracking, pseudo-noise sequence, interference cancellation; CDMA capacity, information security, error controlling, anti-jamming data; Spread spectrum for ranging and navigation; GPS, radar and others.

Spread spectrum device and circuit: SAW filter, frequency synthesizer and others.

Applications: Mobile communications, satellite communications, sensor communications, wireless communications, power-line communication, broadcasting, medical electronics, home factory and office automation.

Call for Papers

A limited number of original papers, not previously published and related to the above mentioned topics will be accepted for presentation. The paper must be written in English (the official conference language is English) and should not exceed 4 pages (about 2,000 words typed 10" by 11" white bond paper). The title of the paper, the name and affiliation of the author(s) and full return address with phone and TAC numbers must appear at name, abbreviated title paper. Authors are requested to send 5 copies to: Prof. Ryuji Kohno, Chairman of Program Committee of ISSSTA '92, Division of Electrical and Computer Engineering, Yokohama National University, 156 Tokiwadai, Hodogaya-ku, Yokohama 240, JAPAN.

Road Transport & IVHS to be discussed at June 1-5, 1992 meeting in Florence, Italy

The 25th International Symposium on Automotive Technology and Automation will road transport informatics and intelligent vehicle highway systems. Four basic areas of interest are:

Technologies: mobile data communication: vehicular control and automation; communication networks and media: vehicle location and positioning: in-vehicle equipment; on-board displays; system installation and maintenance: digital cartography; systems and integration: radio and data systems: machine interfaces: vehicle scheduling; driver information (to include variable message signs as well as in-vehicle displays): speed control; access control; and traffic sensors.


This 25th ISATA conference will be held in Florence, Italy on June 1-5, 1992, for more details, write ISATA Secretariat, 42 Lloyd Park Avenue, Croydon, Surrey CR0 5BB, England.

Phone: 081-681-3069; Telefax: 081-686-1490.

Compriai '92 set for USA near Washington, DC

The Third International Conference on computer aided design, manufacturing and operation in the railway and other advanced mass transit systems will be held Aug 18-20, 1992 at the Old Colony Inn in Alexandra, Virginia.

The following major areas of interest are topics discussed and presented in papers at the conference:

Planning: Planning and scheduling systems, forecasting studies including project evaluation and service integration, computer-based evaluation and life cycle costs of equipment and systems.

Manufacturing and information systems: Maintenance of track, alignment and bridge design; reliability and punctuality of train service; electronic data interchange (EDI); and open systems interconnection.

Design: Track, rolling stock, plants and systems: infrastructure and fixed installations; vehicle dynamics; prediction of track and locomotive performance and stability; software for safety systems: CAD for preparation of circuit diagrams and mechanical diagrams.

Manufacturing and testing: Computer integrated manufacturing: robotics: measurement of track and rolling stock performance and stability: CAD/CAM and design of track equipment and facility design.

Train operations: Computer aided traffic control: automatic vehicle detection, identification and reporting systems: railway distribution system and freight train marshalling: decision support systems: inspection and maintenance systems.


Computer simulation: Simulation applications in research and design: total electric railway network: system simulation: rail vehicle dynamics simulation: train and track performance.

Call for papers

Abstracts of no more than 300 words in English should be submitted to the Secretariat as soon as possible. Final papers are due April 15, 1992 with final acceptance of May 19, 1992. For information contact: Sue Owen, Conference Secretary, Weesox Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO30 2AR, United Kingdom. Telephone: (0703) 293222 Int. Tel: 44 703 293223 FAX (0703) 292853 Int. FAX 44 703 292853.

November 1991
Keeping pace with technological change is vital to railroads.

Change is one key word to describe what’s happening to the railroad industry according to Donald W. Henderson, Vice President Technology, Burlington Northern. "Change, he said, is driven by both internal and external forces, particularly change mandated by customer requirements and rising fuel costs.

Speaking to the IEEE/ASME Joint Railroad Conference in St. Louis, MO on May 23, 1991, Henderson expressed concern that the railroad industry is spending less for research and development than are other industries. "The entire railroad industry (AAR, railroads and suppliers) spend less than 0.1% of revenues on research and development. This compares to 5.3% for the electronics industry, 4.9% for chemicals, 3.6% for motor vehicles and 0.7% for steel. Over the past 5 years, BN has spent approximately 0.3%.”

Looking into the crystal ball, Henderson said that by the year 2000 Henderson said an important element will be cooperative efforts of railroads and suppliers to make technological changes that will keep railroads successful.

Specifically he mentioned BN-supplier projects as examples of what can be done to meet technological change.

In the track/roadway areas Henderson mentioned five areas of change and the impact of change:

- Continuing trend toward welded rail, especially on mainlines. Why? Rail life, reduced derailments, ride quality, maintenance costs. By 2000 96% of BN’s ton miles will be on welded rail. New-in-track electronic-arc welding equipment will replace existing thermite field welding systems, yielding higher productivity and superior quality.

- Concrete ties will find broader application on North American freight railroads. Why? Longer life, reduced maintenance costs, safety (fewer derailments), automated insertion and environmental considerations). On BN we have experienced an 84% reduction in the number of derailments on concrete ties as compared to the same territory on conventional wood ties. By 2000 BN plans to have approximately 15% of its heavy tonnage, high curvature lines on concrete ties.

- 3R improvement in rail life, due to cleaner steel, head hardening, wheel flange lubrication and rail grinding. Rail life of a 1.6 billion gross ton miles is feasible with a sound maintenance program.

- High speed rail flaw detection systems that will allow shorter detection cycles that will be essential to sound track maintenance efforts. High speed tangential turn-outs will see increased application in US freight operations. They bring increased operating speed, reduced wear and decreased maintenance with the obvious implications on customer service.

AAR’s Track Loading Vehicle was operated over 100 miles of BN mainline south of Pueblo, Colorado in which only loaded gauge measurements were being measured. At one location, a potential track buckle was identified and prevented. The TLV is designed to identify weak track conditions from the stand point of lateral track strength, that is, ties, ballast, rail and hold-down fasteners.

Equipment/Rolling Stock

Equipment life can be extended 20-30% through:

- More and better electronics
- Better preventative maintenance (too much run-to-failure now)
- Aggressive re-manufacturing
- Joint project of Can-Am Barber and BN using frame bonded trucks. Reduces wheel wear and rolling resistance and also enhances track stability, and raises the threshold speed at which track hunting begins. Test results at Alto showed reduction in rolling resistance of 20-50% (tangent curve). BN has equipped 400 bulkhead flats and have raised the 45 mph speed restriction on empties to 60 mph, maximum mainline speed.

Airplane avionics technology is coming into BN locomotives in several ways:

- Re-designed cabs (joint BN-EMD)
- On board computers for a variety of functions
- CRT displays (BN-EMD-Rockwell)
- Automatic vehicle detection and diagnostics (BN-Rockwell)
- AC traction with better adhesion and better reliability (BN-EMD)

Alternative fuel are a significant possibility, Henderson said, the major drivers being cost/availability and environmental considerations. Two primary near-term alternatives are natural gas and liquefied petroleum. He noted that coal fueled locomotive technology is a longer term initiative with significant technological problems to be resolved.

BN’s multi-fuel burning system as a joint refrigerated liquid natural gas project with Air Products & Chemicals, Inc., that will have a high-horsepower unit and fuel tender in a test mode in coal service by the end of 1991.

Henderson cited four reasons for natural gas:

1. Natural gas will allow BN to meet 1994 proposed EPA emission standards for the trucking industry (not possible with diesel). Standards are not yet promulgated for railroads.

2. Experience with fixed and vehicular natural gas power plants shows 50-100% improvement in engine component life and a 40% reduction in maintenance costs.

3. The price of natural gas on a BTU equivalent basis has historically been 20-40% less than diesel fuel. This could translate to annual savings of $100 million plus, even when the costs of fuel tenders, locomotive engine modification and natural gas handling are considered.

4. A conversion kit for a high horsepower, turbocharged locomotive has been developed and was successfully tested on gas. This development project also includes a tender car for refrigerated liquid methane and a fueling station. BN plans to test a dual fueled SD-40-2 in coal service in 1992.

Henderson said that 125-ton cars are feasible now and 150-ton cars are being tested. A trend is toward multiple cars with slackless drawbars.

Electromagnetic brake systems will be developed to give better train handling, better reliability, improved safety and reduced operating costs, Henderson predicted.

A joint BN-Airflow Sciences project is for improved aerodynamics to be integrated into rail car design including airfoil treatment on top and sides of cars, decrease internal gas leakage/spacing, and provide undercarriage (truck) treatment.

A joint BN-Timken project has resulted in a low resistant seal for roller bearings that reduces seal torque by 60%. This project into a 2% fuel savings per round trip in unit coal train operation. In 1990, 240 new aluminum, high capacity coal cars were equipped on BN.

Communications/Electronics/Data

Data requirements are growing at the rate of 15-20% per year at BN, which is driven by customer requirements and internal systems such as electronic data interchange (EDI). There will be increasing use of integration of microwave and fiber optics for transmission of data and voice in the rail industry. For the most part see major role of railroad communication being handled by land based systems because train operations are along right-of-way. Satellite communications a possibility, but dependent on costs, especially for remote locations.

Major thrust in interoperability with customers and other railroad and transportation providers will involve voice mail, EDI all working in a paperless environment.

A locomotive would like to see throw away equipment/modules for radios, $500 for a portable radio now, and $200 radios are in service tests. Henderson considers $150-$200 is throw away cost which could be worth it if no radio repair or maintenance would be required. He said BN has 18,000 radios consisting of portals, mobiles and in locomotives.

Concerning automatic equipment identification using RF technology, Henderson said 2,200 cars equipped for two year test period on BN provided 99.9% accuracy. Trackside standards has been approved BN is equiping locomotives, fuel tenders and end-of-train devices with AEI tags. By the end of 1991 BN will have 466 readers in service. Benefits cited for AEI include data accuracy, reliability and timeliness, and the potential to reduce costs.

Concerning acoustic bearing detectors, Henderson mentioned a joint BN-Servo project and said that the detectors determine which bearings in early stages of failure history. Acoustic bearing detectors allow a preventative maintenance policy to be implemented; catch bearings on empties early in failure process, and routes cars into a maintenance facility.

BN has had one acoustic detector in service for about 1 1/2 years. Five others will be installed at Mandsan, ND Grenz, WY, Weston, MO, Big Lake, MN and Wayzata, MN.

Of over 2,300 bearings removed in coal train sets, 85% were condemned. BN details due to failed bearings are down 25%.

BN plan is to install acoustic bearing detectors inbound to major maintenance facilities across systems.

A joint BN-Carnegie Mellon Research Institute-General Railway Signal project to develop a car mounted hot bearing detector (so called “Smart Bolt or Hot Bolt”) uses a replacement for one of the bearing cap retainers that has been hallowed out and equipped with a heat sensor, a battery and a transmitter. The hot temperature distress signal is instantaneously transmitted to the locomotive engineer so immediate action can be taken to stop the train. BN expects to equip 10 coal cars to evaluate production equipment in 1991.

Command and Control Systems

A joint BN-Rockwell project for advanced railroad electronics system (known as ARES) has several key elements.

- Real-time data link from command to locomotive.
- Real-time position and speed information provided on all on-track vehicles (satellite derived in ARES system).

Automation and remote dispatching will do several functions for BN, such as:

- Train meets and passes generated automatically in “optimum” way (all/most trains on schedule).
- Automatic authority conflict checking and enforcement (remote intervention will ensure that no train exceeds its authority).
Washington News

Reforming Spectrum

The Federal Communications Commission has issued a Notice of Inquiry (NOI) on the matter of spectrum efficiency in the Private Land Mobile Radio Bands in use prior to 1968. Recent debates over the economic value of radio spectrum and the proposals to allocate by auction have often compared spectrum to other finite natural resources such as land. Now, with the realization that vision has not always been correct, we may also better manage what we have. The FCC has taken the initiative to address this issue with a Notice of Inquiry. Questions posed by this proceeding are reproduced below. Should this copy not reach you in time to respond by the October 25 Comment due date, there is a strong possibility that it will have been extended.

Before the
Federal Communications Commission
Washington, D.C. 20554

PR Docket No. 91-170
In the Matter of
Spectrum Efficiency in the Private Land Mobile Radio Bands In Use Prior to 1968

NOTICE OF INQUIRY
Adopted: June 13, 1991; Released: July 2, 1991

Comment Date: October 25, 1991
Reply Comment Date: December 13, 1991

I. INTRODUCTION

1. We are commencing this Notice of Inquiry (NOI) to explore options to promote more effective and efficient use of the bands below 470 MHz by Private Land Mobile Radio (PLMR) licensees. The objective of this Notice is to solicit information to assist us in developing an overall strategy on how to use these existing spectrum allocations more efficiently to meet future private land mobile telecommunications requirements. This is an era of unparalleled advances in mobile radio technology. It is also an era of unparalleled demand for radio spectrum to meet an exciting array of new communications services. The need for spectrum efficiency is greater than ever. Fortunately, technological advances also provide more and better options for spectrum efficiency than ever. This Notice, therefore, is intended to examine the complex set of technical and policy issues on how this statutory environment governing the PLMR allocations below 470 MHz can be modified to permit, facilitate and promote more efficient use of this spectrum. This Notice may be just the first step of a broader information gathering process including panel discussions and committee reports, reviewing both specific and generalized issues.

II. EXECUTIVE SUMMARY

2. The immediate problem that this Notice seeks to address is frequency congestion. In many areas of the country the demand for spectrum for PLMR use is and will continue to be significantly greater than the supply. Spectrum crowding causes serious problems for private land mobile users. Safety related communications, for example, require clear, usable channels. Reliable mobile communications also improve industrial productivity.

3. We must also pay heed to the future's demand for more reliable and diverse communications services that will include normal mobile to base communications, mobile data, FAX, intelligent highways, mobile video, and many other telecommunications services. In the PLMR spectrum below 470 MHz, the current regulatory environment is not generally designed to promote technological innovation.

4. We are limiting this Inquiry to the PLMR bands below 470 MHz for several reasons. First, the technologies, radio equipment, and licensing schemes have been essentially in place and unchanged for many years. Second, the rules governing the spectrum above 800 MHz already contain incentives designed to foster the research and development of advanced, spectrum efficient techniques. For example, the rules governing spectrum allocations to the various analog or digital multiple access techniques, designed for either voice or data applications. Our goal for this proceeding is to develop a regulatory environment for the spectrum below 470 MHz that will enable users the same technical flexibility and licensing options available at 800 MHz and above. That is, we...
Growth in the PLMR services has been significant. Since 1968, the number of licensed PLMR stations has increased from 56,000 to 470,000. In the past 5 years, the number of licensed PLMR transmitters has increased at a 10 percent annual rate. Licensees use these transmitters for a variety of purposes, including transmission of voice and data, paging, and remote control.

9. The rules for operation on the PLMR bands below 450 MHz are specified in the 1968 FMPL regulation, which is the most significant of these rules. These rules include provisions for specific channel assignments for PLMR services, specified modulation techniques, channel bandwidth limitations, minimum operating frequencies, interference tolerances, acceptable power levels, and shared use of the bands. Many of these channels carry additional restrictions beyond those of the general technical regulations. There are, for example, 36 different limitations on channels available to the Forest Products Radio Service. Some of these restrictions spell out which channels are not acceptable for radio services, other power restrictions and types of allowable emissions. The most fundamental rule for the use of these bands pertains to the assignment of frequencies. Our rules state that these channels are shared and that additional licensees may be added at any time. As a result, the PLMR bands, particularly those below 470 MHz, have become extremely crowded in many areas of the country. The Appendix provides a review of PLMR use in the 450-470 MHz band in 49 major markets. For example, our database showed that as of October 1990, there were 516 channel pairs in the 430-470 MHz band in use within fifty-minute radius of a central point in New York City. The network was over 10,000 licensees consisting of 103,697 mobiles (201 per channel pair) and 46,767 pagers. Of these, 281 channel pairs were used by business licensees, within a two-mile radius of 248,789 mobiles and 384 channel pairs were used by public-safety licensees, with an average of 221 mobiles per channel pair. Although these numbers are imperfect measures of radio activity, using current equipment available for frequencies below 470 MHz for voice dispatch communications, a channel pair can typically be effectively used to dispatch between 50 mobile units and 150 mobile units, depending on the service, with 110 mobiles being a reasonable upper limit for the Business Radio Service. Even if these data are not accurate, they illustrate clearly that the PLMR services in the New York metropolitan area are excessively crowded. This report on the 150-174 MHz band in a fifty-mile radius of a central point in Chicago found 63,314 mobile radios and 58,968 pagers using 513 channel pairs. The average of 123 mobiles per channel pair understates the degree of crowding. The average number of mobiles per channel also ignores the fact that in the 150-174 MHz band, channels are 30 kHz wide but spaced only 25 kHz apart. These channels are used for public-safety communications, which, because of the frequency separation, is made possible by geographically separating use of overlapping channels. Furthermore, the effective Radiated Power (ERP) used by such mobiles, the fifty-mile radius is less than the co-channel separation required between unrelated base stations to eliminate interference problems. Citywide, the 150-154 MHz band is extremely crowded in the Chicago metropolitan area. The report on the 150-174 MHz band in a fifty-mile radius of a central point in New Orleans, Louisiana, the New Orleans Metropolitan Statistical Area (MSA) had a population of about 1.35 million people in 1990, about one-third of the population of the Houston, Texas MSA and less than one-tenth of the population of New Orleans. The New Orleans Consolidated Metropolitan Statistical Area (CMSA), in Future PLMR requirements, New Orleans was one of the last regions of the country to be touched by this process. We were faced with a spectrum shortage. That report showed several possible scenarios, one of which is reasonably close to current conditions. That report predicted a slight surplus of channels for use in New Orleans in 1990. In fact, we found 1235 licensees on 414 channel pairs using 33,277 mobile radios (80 per channel pair) and 487 pagers per channel pair. New Orleans is heavily used, but not saturated. Additional use of this band in New Orleans during the next years is likely to cause the quality of communications on the existing system to decline. With thirteen times the population of New Orleans, however, has only three times the number of mobiles. That fact indicates that the 450-470 MHz band is more than saturated. Furthermore, the next group of additional uses of that band given current conditions.

15. In general, the evidence in the Appendix is consistent with spectrum congestion in 150-174 MHz and the 450-470 MHz bands. Revisions can be made to accommodate additional use of that band given current conditions. The spectrum congestion has led many potential users to consider other PLMR bands or other radio services such as cellular radio, or to trim or abandon their communications expenditures. On the other hand, in the 470-512 MHz band, where there is some channel exclusivity, and in the 851-886 MHz band in markets where there is an available supply of channels, there is evidence that mobiles rise in proportion to population. The appendix also states that, depending upon the measure used for full channel capacity, either 70 or 100 mobiles per channel, between 12 and 28 markets are overloaded. Using the higher loading standard, the twelve overloaded markets are Boston, Chicago, Denver, Detroit, Houston, Los Angeles, New York, Philadelphia, San Francisco, Seattle, and Washington.

16. Although spectrum crowding is worse in major metropolitan areas, crowding also exists to varying degrees in many rural markets in some radio services. Both the frequency coordinating committees and the Commissioner receive many complaints concerning new licensees on shared spectrum from established licensees with PLMR systems outside the major metropolitan areas.

C. Tests

11. Analysis of licensing records show that annual growth of all licensed PLMR stations over the last 5, 10, 20, and 30 years has been 4.5 percent, 6.8 percent, 7.9 percent and 9.0 percent, respectively. Licensed transmitters have grown even more dramatically over the last six years, growing at a 9.5 percent annual rate. The higher growth rate of transmitters than of licensees is due to the effect of a group of factors including the growth of SMR systems. Some consolidation due to licensing of systems as private carriers rather than common carriers, and the general economic growth of existing licensees. While much of the growth occurred above 800 MHz, the bands below 470 MHz continue to experience growth, for example, in the past six years the total number of transmitters below 470 MHz has grown from about 7.5 million to 11.5 million.

18. In markets such as Los Angeles and New York, all PLMR channels, including those currently already heavily loaded. In medium and smaller markets, the low cost of the equipment currently

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used below 470 MHz will continue to attract additional PLMR use until crowding causes service quality to deteriorate significantly in those markets.

In general, under currently prevailing market conditions in which PLMR channels are currently crowded, we can continue to suffer from crowding, and spectrum congestion will become a significant problem in additional markets.

19. Given the growth pattern of the past six years, the number of total licensed PLMR transmitters would double in under eight years. Even a more conservative annual growth rate of 7 percent would double the number of licensed PLMR transmitters between 1990 and 2000 and double it again by 2010. A great deal of growth could occur above 800 MHz and at 220-222 MHz, both as a result of recent spectrum allocations and through employment of more spectrum efficient equipment. On those newer bands, we have incorporated many of the regulatory concepts discussed below, including technical flexibility, private carriers and exclusivity. As a result, we are seeing benefits in improvements of spectrum efficiency, particularly by SMR's. Given the magnitude of current PLMR use and future mobile radio demand, however, it is impossible for the newer PLMR bands to accommodate every additional PLMR transmitter, much less to relieve existing spectrum congestion on the older PLMR bands. There is need for more efficient use of sub-bands and for spectrum efficient techniques and technologies.

20. The technology used by most mobile radio systems on these bands, conventional analog frequency modulation (FM) technology, has been commercially available for over 40 years. A variety of potentially spectrum efficient technologies, including narrowband techniques, trunking, efficient geographic reuse methods, digital multiple access techniques, packet radio and spread spectrum techniques, are applicable to these bands.

D. The Objective of This Inquiry

21. The problems of increasing congestion and declining quality of service are clearly unavoidable if enough PLMR users can be induced to adopt more efficient spectrum efficient technology. We must, therefore, take action now to assure that PLMR needs continue to be satisfied in the future.

22. Accordingly, in two major areas. First, we seek comment on changes in our technical standards to permit and to promote advanced communications techniques such as trunking on shared channels, packet radio and spread spectrum, and digital techniques. These techniques could provide increased access to the older bands with minimal impact on current users. Our objective is to provide general policy guidance that would encourage and facilitate the use of spectrum efficient equipment on these older bands. Second, we seek comment on regulatory policies that could be used to promote more spectrum efficient use of PLMR bands: incentive programs such as exclusivity and fee-based incentives, and on alternative channel assignment policies including basic trunking, private carriers, and consolidation of the PLMR service pools. We also seek comment on rules that would prohibit less efficient use of the spectrum. Finally, this notice seeks solutions on any of the channels other than to the problem of unlicensed operation.

IV. ISSUES

23. We see three general ways to meet current and future PLMR requirements. First, the supply of spectrum available for PLMR use can be expanded. In doing so, the needs of PLMR users must be balanced against those of other radio users such as broadcasters, common carriers and the federal government. Second, economic incentives can be created to encourage the use of the radio spectrum in terms of the number of users that can be supported. We have in the past required certain PLMR licenses to trunk their channels because of the efficiencies obtained. The number of mobile radios per channel that can be accommodated at a given blocking rate Increases as the number of trunked channels decreases. The fee-based incentive discussed in paragraphs 65-69 below, differs from many other economic solutions because it does not try to deter license applicants, but instead seeks to influence their choice of technology. If successful, this concept would not raise the average fee paid by PLMR licensees. The third class of solutions, and the primary focus of this Notice, is to develop new technology. This may be accomplished through development of new technology, better application of existing technology, better administrative procedures, and better regulations.

A. Technical/Operational Issues

24. As little as fifteen years ago, the equipment used below 470 MHz was at least as spectrum efficient as equipment available for other mobile radio services. Since 1975, however, several technologies have been, or are being developed for commercial application. These new technologies are significantly more efficient than current conventional analog FM equipment. Use of some of these technologies in the lower bands could greatly increase the capacity of these bands, thereby reducing spectrum congestion in many markets.

25. Dynamic frequency reassignment on shared bands, packet radio, spread spectrum and techniques may make it possible to add additional users without disrupting current use. Trunking on shared bands involves scanning channels until an open channel is found. The system then assigns that channel for use. Such a dynamic reassignment technique provides significantly greater access to the spectrum for its users. Packet radio sends transmissions in short, burst-like packets that can be successful in avoiding transmissions of other users. Thus, this technology is ideal for shared spectrum. Spread spectrum uses extremely low power per unit bandwidth, and is well suited for use in very noisy environments. Because of these factors, spread spectrum is used for Part 15 applications and may be well suited as an addition to current use on the older PLMR bands. Other technologies, such as digital voice modulation and narrowband frequency hopping, might have a somewhat greater impact on existing users than use of packet radio or spread spectrum, but also have the advantage of increasing the overall capacity of the PLMR bands.

1. Trunking Below 512 MHz

26. A trunked system is a multi-channel system in which a user can establish a connection to the channel through specific base station facilities. The system automatically searches for and assigns a user an open channel assigned to that system. Trunked technology provides the most significant improvement of the radio spectrum in terms of the number of users that can be supported. We have in the past required certain PLMR licenses to trunk their channels because of the efficiencies obtained. The number of mobile radios per channel that can be accommodated at a given blocking rate increases as the number of trunked channels decreases. The fee-based incentive discussed in paragraphs 65-69 below, differs from many other economic solutions because it does not try to deter license applicants, but instead seeks to influence their choice of technology. If successful, this concept would not raise the average fee paid by PLMR licensees. The third class of solutions, and the primary focus of this Notice, is to develop new technology. This may be accomplished through development of new technology, better application of existing technology, better administrative procedures, and better regulations.

27. Dynamic channel reassignment can also be done through the use of mobile radio techniques that have been designed to monitor a series of channels automatically until an open channel is identified. That open channel is then used for that communication requirement. Other radio systems in the fleet identity incoming calls by continuously sequentially monitoring channels. This type of centralized dynamic channel reassignment does not require repeaters specifically designed for trunked operation. It also does not require the Commission to set aside channels specifically for this purpose. Although this decentralized approach may not be as efficient as trunking in the traditional sense, for the purposes of this Notice, the concepts are similar enough to be considered together.

28. In 1987, we considered whether trunking should be permitted in all bands including the shared use bands. Several commenters in that proceeding stated that trunking should be permitted in all portions of the private land mobile service. Most commenters, however, expressed concerns about allowing trunking on the shared use bands. The Commission expressed similar concerns, stating that the "use of trunking technology on frequencies that have no privacy for exclusivity is difficult and would take much time and effort to resolve." On June 14, 1990, we adopted a Report and Order that permitted trunking on additional channels in the 470-512 MHz band, and indicated that we would consider trunking in one other PLMR band, 470-512 MHz, in addition to those considered in the broader context of this Notice.

30. We believe that efficient technological progress has been made that many of the technical problems associated with trunking on shared use spectrum can be resolved. New equipment, discussed in paragraph 27 above, has been developed that uses mobile radio units to monitor until a clear channel can be identified and assigned. This new type of equipment may be used on shared spectrum. The critical difference between equipment designed to trunk on exclusive use channels and this new equipment is that rather than using centrally located equipment to assign channels to mobile users, the activity by users of that system, new equipment monitors for potential interference to co-channel users. This monitoring is an automated variation of the monitoring required of all users of shared spectrum.

31. Thus, we now consider two types of trunked operations. The first type is the prohibition by policy below 800 MHz and requires exclusive channel assignments. The new decentralized type uses monitoring, is not prohibited, and does not require exclusive assignments. In considering issues regarding trunked operation, we request that commenters differentiate between these types of dynamic frequency assignments.

32. Finally, when we initially considered trunking on the shared use bands, we raised several specific issues that must be resolved, particularly with regard to coordination and interference. For example, we asked whether there are adjacent channel problems in the 150-170 MHz band where we permit 5 kHz channels. We also asked about making exclusive assignments in the bands below 470 MHz for trunked operations. In paragraphs 52-64, below, we consider the concept of exclusivity in a broader context. In addition, trunking technology must be in the context of the existing shared use system and in the context of the band licensing policy discussed below.

Question 1:

a. Current rules do not specifically address trunking on the older frequencies below 470 MHz. Should we specifically allow trunking below 470 MHz?

b. Should we develop separate trunking rules to govern the two types of trunking discussed above? Consider these questions for each of the following licensing schemes: (1) current rules and policies, exclusive assignments, and band licensing (as discussed below in paragraphs 71-77).
b. Should any technical or operational rules be modified or added with respect to trunks on shared spectrum to assure efficient and effective operations (e.g., should all users be required to transmit on all channels on which their systems are trunked)?

c. If a licensee uses decentralized, monitored trunking equipment on several shared use channels, what impact, if any, would it have on other co-channel licensees? How would spectrum efficiency compared to conventional analog voice be this new type of trunking when all users, including the general access pool, are taken into account? How does the efficiency of the centralized, trunks shared on channel are compared to this type of trunked operations? Should any retransmission be mandated for all users of some PLMR bands?

d. Should we promote either type of trunking on the older PLMR bands, and, if so, how?

e. Should we permit traditional, centralized trunking in the 470-512 MHz band and, if so, should there be trunking in all pools, including the general access pool? Should we promote trunks shared on channels if some pools are used from different pools? Should the same rules and policies apply that apply to trunking 800 MHz channels apply here, including frequency coordination, loading, and interference requirements? Is the fact that a frequency pair may generally be reassigned at distances of 40 miles (64 kilometers) without regard to loading a serious problem, and, if so, what solutions are there?

2. Packet Radio

Packet transmissions are short data bursts, called packets, which are sent uninterrupted until received and acknowledged. It is a form of time division multiplexing that is already used in other communications radio services. It is high efficiency, resistance to loss of unoccupied single channels and can accommodate many users on a single channel while giving each user what appears to be a dedicated channel. In our proposed rules for the 220-222 MHz band we asked whether we should require its use or some similar digital technology format.

3. For the purposes of spectrum management, data packet radio systems are an attractive alternative to traditional analog voice dispatch systems. Besides being highly efficient, data packet radio can transmit voice communications without significant impact on those voice systems. Packet radio does not generally require paired channels for repeater operations and can, therefore, make productive use of unoccupied single channels in bands that are generally assigned, but not always used in pairs. Many packet radio systems can share a small number of channels, providing each licensee with superior quiet zones that given existing technology, several channels dedicated to packet radio could accommodate multiple simultaneous users operating a total of several hundred mobile units per channel.

Question 2: a. Packet radio as currently applied to PLMR is used for data transmission only, but systems, possibly in conjunction with voice synthesizers, can also be extremely efficient. Given considerations such as delay between initial transmission and final reception, can packet radio be used for real time digital voice transmissions? If so, should any technical or operational rules be eliminated, added, or modified to enable use of packet radio for voice or data/voice hybrid communications?

b. Are there significant problems in using packet radio on a channel shared with voice channels? If so, what should be the technical and operational standards for such transmissions? If there are problems, are there rules that would eliminate or reduce these problems?

c. Should we promote the use of packet radio on the older PLMR bands and if so, how?

d. Should we stop licensing analog voice systems on several channels in the older PLMR bands and permit only digital transceivers such as packet radio on those channels? If so, how many channels in each band and each radio service should be set aside for digital operations?

3. Spread Spectrum

35. Spread spectrum communications systems use special modulation techniques that spread the energy of the signal being transmitted over a wide bandwidth. Spread spectrum systems offer two important advantages over conventional transmission schemes. First, as the signal becomes more spread out, the probability of causing interference to other signals occupying the same spectrum. Second, such spread spectrum signals are able to tolerate strong interfering signal. Spread spectrum systems were originally developed in military applications due to their ability to resist jamming (intentional interference), detection and interception. Spread spectrum is also permitted in the Police and Amateur Radio Services. It is also permitted under Part 15 of our rules (governing low power, unlicensed radiators). We have recently amended these rules to facilitate greater flexibility in the design and use of low power, non-licensed spread spectrum systems.

36. We would consider allowing spread spectrum communications systems to operate on frequencies available under Part 90 of our rules, because it appears that spread spectrum is uniquely suited to share use frequencies. Before we can do so, there are several technical, operational and policy issues that must be addressed. First, we must deal with the issue of permissible power levels for various types of spread spectrum systems. There is the important question of whether spread spectrum can operate effectively when sharing spectrum open many high powered analog FM systems. If not, it may be best eventually to dedicate sufficient spectrum for PLMR systems using spread spectrum techniques or to access that spectrum on an opportunistic basis with little application for PLMR use. Spread spectrum systems may require many contiguous channels. This has implications including band licensing and interagency sharing, as discussed below. Finally, we must consider what policies we would successfully promote use of this technology in a PLMR environment.

Question 3: a. Should we permit use of spread spectrum on the older PLMR bands? If so, what should be the technical and operational standards for such transmissions?

b. Should spread spectrum be successfully used on PLMR on a secondary basis, i.e., without interference to existing users and accepting interference from all other users?

c. Should we promote usage of spread spectrum on the older PLMR bands and, if so, how?

d. Should we promote some bands for use by PLMR systems using spread spectrum techniques? If no other spectrum is available, should we convert some channels from the older PLMR bands to exclusive spread spectrum use?

4. Digital Voice Modulation

37. In radio services such as cellular and SMRs, increasing spectrum efficiency through use of digital voice modulation is a major area of research and development. Digital voice modulation offers several advantages of high efficiency, increased reliability, and increased channel capacity. The cellular industry has announced that they will deploy digital technology by approximately 1992. Digital technology will be used in several proposed 800 and 900 MHz SMR systems. We are also exploring the issue of digital standards for public safety communications systems.

38. In 1988, we modified our regulations to permit the cellular industry to digital or other advanced technologies. The cellular industry has announced that they will deploy digital technology by approximately 1992. Digital technology will be used in several proposed 800 and 900 MHz SMR systems. We are also exploring the issue of digital standards for public safety communications systems.

39. It does not appear, however, given our present regulations, that any major use of digital multiple access techniques by PLMR licensees will soon occur on the shared use bands. While we implicitly permit digital voice modulation, other rules may discourage the use of such technology. For example, we require that digital modulation be disabled during station identification. In addition, non-voice operations are restricted to frequencies subject to frequency coordination.

Question 4: a. What rules, if any, should we amend or delete relative to the use of digital modulation techniques?

b. Digital technology can sometimes be made more spectrum efficient by allowing wider bandwidths. Should we permit the use of digital techniques for bandwidths for digital modulation techniques in the older PLMR bands?

c. Should we promote use digital modulation techniques for voice communications on the older PLMR bands and, if so, how?

d. Should digital standards for PLMR communications systems be developed and, if so, they be mandatory?

5. Narrowband

40. Narrowband is a relative term. By the standards of 1954 to 1968, all current PLMR use is narrowband. For example, originally, land mobile radio operated with channels of 120 kHz bandwidth, as compared with the current 25 kHz bandwidths for PLMR applications below 896 MHz. Channel spacing is even narrower on several PLMR bands. In the 150-174 MHz band, PLMR channels are spaced every 15 kHz. Because the FM emission commonly used in this band occupies somewhat more than 15 kHz, a mileage separation is required between adjacent channel assignments to prevent interference. In the 450-470 MHz band, PLMR channels are spaced every 25 kHz. Between these channels are offset channels that must operate on a secondary basis.

41. Today, narrowband may refer to FM systems, such as those above 900 MHz, that occupy less than 20 kHz (e.g., channels from 900-910 MHz to 13.6 to 13.8 kHz and channels are only spaced 12.5 apart. Alternatively, narrowband may refer to 5 kHz amplitude companded single-sideband (ACSB), which is permitted in the 150-170 MHz and 220-222 MHz bands.

42. In the context of this Notice, we consider both mandatories and non-mandatorv use of narrowband. Mandatory use of narrowband would represent a return to our past practice of channel splitting to improve spectrum efficiency. Specifically, we might either reduce the bandwidths to 5 kHz for use of 896-901 MHz and 935-940 MHz to the older PLMR bands or develop a channelization scheme to convert the 195-200 MHz band for use primarily with 5 kHz channels using ACSB or other 5 kHz technology. Either method would significantly increase the number of assignable PLMR channels at a given location. A channelization plan based on 12.5 kHz channel spacing and 13.6 kHz or less bandwidth is appealing in that it draws on technology already used in the 900 MHz band in major urban areas. Use of ACSB would be expanded as the increased bandwidth is an option of our recent allocation of the 220-222 MHz band for narrowband land mobile radio use.

43. As recent rule making indicates, we would prefer to permit, rather than to mandate, use of spectrum efficient narrowband technology.
particular we could provide more liberal operational standards for use of multiple narrowband emissions within current and future channel assignments. Large PLMR users, including private users, where permitted, could develop efficient methods of using existing and future assignments. Frequency division multiple access (FDMA) techniques within channels might prove to be economically and technically viable under more liberal rules. One reason is that use of any portion of an assigned channel should ensure that no other user operating with a standard kts band can concurrently transmit on any other part of that channel. During that narrowband transmission, only that user has access to residual portions of the channel assignment he is using. This means that FDMA may prove to be a good way to gain greater access to open channels in the most crowded markets.

44. Flexible rules are also useful because of the direct relationship between acceptable bit transmission rates and bandwidth. Reducing channel bandwidth, therefore, may not increase spectrum efficiency if digital techniques are used. We would not want to mandate narrow channels that discourage or prohibit any other spectrum efficient technology.

Question 5:

a. Is FDMA on shared channels feasible? Should our rules be modified to facilitate multiple narrowband FM emission transmissions on a single channel assignment on some or all of the frequencies below 470 MHz? If so, what specific rules changes should be made?

b. Should we split channels again, i.e., reduce bandwidth below 20 kHz, on part or all of a band below 470 MHz, and if so, what should be the new bandwidth?

6. Other Technologies

45. We do not intend to limit consideration to those technologies discussed above. The mobile communications needs of PLMR users may change over the next few years, requiring different technical and operational rules and policies. For example, mobile technologies may be incorporated into highway systems to interact with the vehicles using those roads. PLMR systems may eventually interact with new services and communications systems (PCS). We do not want our rules to inhibit such applications.

Question 6:

Are there other technologies or operational techniques that could be used to add a significant number of new users to the older PLMR bands without disrupting other users, and, if so, what are they? What rule changes, if any, would be required to permit such technologies or operational techniques in the older PLMR bands? Should we promote such technologies or operational techniques and, if so, how?

7. Compatibility

46. One of the advantages of the stable and homogeneous technological environment that has prevailed in the lower PLMR bands during the past two decades is that a high degree of compatibility exists among different users. As new technologies are introduced, compatibility may be reduced or eliminated. This may have significant implications.

Consider, for example, the relationship between digital modulation techniques and enforcement of our permissible communications rules. Enforcement of those rules requires monitoring and proper interpretation of the signal. Such enforcement typically requires the efforts of other co-channel users. If such co-channel users have analog equipment or do not know the digital modulation code, it is unlikely that prohibited communications could be detected.

47. Another advantage of the homogeneous technological environment of older PLMR bands is that interference criteria are comparatively easy to develop and enforce. It is more difficult to develop interference criteria when different technologies share a band.

Question 7:

What problems might arise as various PLMR users employ different technologies that are spectrally compatible, but incompatible for communications between end users? How can these problems be solved?

8. Other Technical or Operational Standards

48. Technical or operational rules other than those discussed above may remain in place even though they are outdated, serve no useful purpose, or, on balance, reduce spectrum efficiency. We hope to identify and amend or eliminate such rules. We would also consider adding new technical or operational rules if they can improve spectrum efficiency without imposing high economic costs or other problems.

Question 8:

a. Are there technical or operational standards other than permissible power levels and the spectrum efficiency standard that we could modify, add or eliminate in order to promote spectrum efficiency? What would be the costs and benefits of such changes?

b. How should we authorize equipment under flexible technical standards?

B. Policy Issues

49. We consider below several policy alternatives to promote and facilitate spectrum efficient technologies. Simply permitting a new technology, particularly on shared spectrum, may not result in its widespread use. For example, we have permitted the use of unlicensed spread spectrum systems on certain bands under Part 15 of our rules since 1985, but few such devices have achieved marketplace success. As a result, we have recently revised Parts 2 and 15 of our Rules to facilitate greater flexibility in the design and use of unlicensed spread spectrum systems. Similarly, narrowband technology has been permitted for PLMR use on the 150-170 MHz band since 1985, but the technology has not developed rapidly likely due to lack of regulatory and economic incentive.

50. As we discussed above in paragraph 5, many of the policies we consider in this Notice, including exclusion of small numbers of broadly defined radio service pools, and private carriers, had been successfully adopted in the PLMR bands above 800 MHz and are likely to be seriously considered for any future licensing. This low level of PLMR bands, however, adoption of these policies is complicated by the fact that these channels are assigned on a shared, exclusive basis and occupied by thousands of licensees. We therefore also consider several policies, including fee-based incentives, band licensing, and adoption of a spectrum efficiency standard, that could be adopted without eliminating the long-standing policy of uncapped, shared use channels. Application of these concepts may, for example, provide incentives that are largely absent without exclusive use, or that impose justifiable spectrum efficient solutions to the crowding problem that probably would not be voluntarily adopted in a shared use environment.

1. Incentives for Spectrum Efficiency

51. Flexible standards together with incentives for spectrum efficiency have successfully promoted spectrum efficiency in the digital cellular and SMR technology. Many other licensees at 800 and 900 MHz and cellular radio operators are permitted to use non-standard bandwidths, subject to interference standards. In each of these examples, flexibility is as New York. On any such channel, existing licensees with exclusive use of specific channels in a particular geographic area. This is not the case in the older PLMR bands. The incentive for spectrum efficiency is not the same for licensees without exclusive use as for licensees with exclusive use of channels. On shared use channels, the advantage gained if one licensee is spectrum efficient is shared by all the channel's users. In some cases, such as use of lower ERP or slightly narrower bandwidth, none of the benefits of spectrum efficiency may accrue to the user of the spectrum efficient equipment. Therefore, if we wish technical flexibility in the older PLMR bands to have a significant positive effect, some incentive may be required. We could consider below two possible incentives, one incorporating exclusivity and one fee-based.

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implementing advanced, spectrum efficient technology so that they could increase channel capacity and, for a profit, accommodate additional users.

56. For the most part, the additional rights that would be granted to existing licensees are in the form of a veto power. While many existing users would use this right in a manner of implementing, or agreeing (for a fee or other considerations) to allow other existing or future licensees to implement spectrum efficient systems, some licensees may obtain additional, intensive use of their channels. The large number of channels involved should, however, provide sufficient channels in each market while their licenses would be willing to permit additional use, particularly through use of spectrum efficient equipment.

b. Empty a Bank

57. A second method of converting a currently uncapped, shared use band to exclusive use would be not only to stop licensing on some portion or all of that band, but also, after a certain date, to stop accepting license renewals by existing users of that band. Once the band is emptied, channels on that band can be made available for exclusive use in a basis, with technical and operational standards that would result in a high level of spectrum efficiency. This plan would work best if new users and displaced users could be licensed on a first-come, first-served basis. The only user available for PLMR use (although none are currently available). The rules for that new band would also allow for exclusive use channels and require spectrum efficiency, particularly for larger users. The advantage of this plan is that it would provide an ideal environment for advanced technologies by providing a high level of spectrum efficiency, and it would be easier for the technical advantages of clear spectrum, there are economic advantages with regard to low transactions costs for implementation of new technologies.

58. The most obvious problem with this plan is that it requires additional spectrum that is not currently available. This plan would also take a long time to implement fully. If an empty band were to become available sooner than the rule making process, including an allocation Notice, an allocation Report and Order, followed by a Notice to propose technical and operational rules for the new band, a Report and Order adopting those proposed rules, would be likely to take several years. Additional time would be required to empty the old band. It could be well into the twenty first century before new bands could begin licensing again on the old band.

59. Another problem with this plan is that some existing licensees would be willing to use the exclusive use channel without them. Unlike the previous plan, no one would be willing to compensate them in exchange for moving or updating their equipment. Given sufficient time and spectrum, however, the degree and scope of this problem would be minimal.

iii. Exclusive Use Overlay

60. The third plan, exclusive use overlay, would introduce exclusivity into currently shared bands by granting a new or existing licensee the exclusive right to add to the existing radio traffic in a frequency in a specific geographic area. The exclusive use overlay licensee would have sole access to current and future residual communications capacity on those channels. The key condition of obtaining an exclusive use overlay license, an applicant would be required to use highly spectrum efficient technology based on a technical standard that we would set. The level of currently available equipment. The existing licensees would continue to have the same access to their assigned spectrum. The exclusive use overlay user would, however, could contract to provide service to existing users on the new high efficiency system to eliminate potential interference. Alternatively, to gain full access to the spectrum the exclusive use overlay licensee could offer to compensate existing users for moving to a different portion of the spectrum.

61. This policy would promote spectrum efficiency in several ways. First it would reduce the requirement for equipment at least as efficient as the standard we set. Second, it would induce new and existing users, particularly in crowded markets, to develop and use new, improved technology. Finally, it would induce those licensees with this new exclusivity to encourage existing users to be spectrum efficient. We would not freeze shared use licensing except where the spectrum license is granted on specific channel(s) at a specific site. Most markets would, therefore, only be affected by the possibility of exclusivity to the extent that we set the level of investment in spectrum efficient equipment is beneficial. The exclusivity created by this plan would also promote long term spectrum efficiency because users with exclusivity should consider spectrum efficiency an important factor in maximizing the value of their spectrum. In addition, technical flexibility would be available to licensees to determine whether to implement another spectrum efficient technique or technology.

62. A concern with this plan is that spectrum efficient equipment has greater channel capacity and often must use several channels to be efficient. As a result, larger users would be likely to be the direct beneficiaries. Smaller users would have to pool together, through direct cooperation, shared equipment, or use of private carriers, to take advantage of the more spectrum efficient equipment.

63. An important issue associated with this plan is whether existing licensees should be granted a preference and, if so, how to prevent such preference from encumbering the licensing process. This plan also shares several major issues associated with all plans for exclusivity. For example, over what geographic area should exclusivity be granted? In particular, we would want to encourage geographic reuse of channels while continuing to meet the wide-area coverage needs of our licensees. While some consolidation of licenses would be beneficial, we would want to prevent overconcentration of exclusive use in individual markets. There is also the issue of paperwork. For example, tens of thousands of licensees who presently are not required to include the latitude and longitude of their base stations on their applications might be required to amend their licenses so that they could receive the licensing rights according to the correct geographic area. Rules must be developed regarding adjacent channel, narrowband operations in the 150-170 MHz band and regarding users of 12.5 kHz frequency offsets in the 450-470 MHz band. Finally, we might need rules to ensure short term utilization of channels. Related to this is the issue of how a licensee justified the use of channel licenses. If short term utilization of newly exclusive channels is inadequate, then spectrum shortages may worsen on other PLMR bands. Provisions would have to be developed regarding overlapping adjacent channels in the 150-170 MHz band. While these issues are all significant, experience should provide significant guidance to the commitments associated with the three conversion plans because, we believe, short of our right spectrum efficiency requirements, exclusivity would be the most effective method of achieving crowding through increased spectrum efficiency.

Question 9:

a. One of the older PLMR bands be converted from its present shared use condition into a band where channels may be used on an exclusive basis and, if so, how would we go about doing so?

b. If some currently uncapped, shared use channels should be converted to exclusive use channels, how should we go about doing so?

c. If we could do the various major details such as timing, geographic area of exclusivity, and the specific rights of current licensees, if any, what rules and regulations should we use to prevent such monopolization?

d. Fee-based Incentives

65. We could provide direct financial incentives to implement exclusive use equipment by charging licensing fees that vary according to factors such as bandwidth, area of operations, and spectrum efficiency. In addition, allowing new FM analog voice system could be significantly higher than for a more spectrum efficient system. Applicants for new and renewed licenses would pay a lower fee for a lower power base station.

66. A fee program of this nature would cause existing users to bear part of the burden imposed by their use of inefficient equipment. Licensees who preclude communications on their equipment could be required to pay more for that privilege. Licensees with inefficient equipment would weigh their cost for more spectrum efficient equipment against a fee that would apparently increase their cost. Their existing equipment had low on other users. As a result, inexpensive changes that would improve spectrum efficiency, that might not even be considered under the current regulatory environment, would be widely adopted to the benefit of all users. Basing the fee on area of operations would allow us to charge more in markets such as New York than in less populated areas. Spectrum efficiency would therefore be encouraged much more forcefully where most needed.

67. This incentive would allow us to emphasize technological flexibility rather than strict technical standards. For example, we could continue to permit high power levels knowing that applicants would take into consideration the impact of their systems on other users for different levels of power. Advanced spectrum efficient technologies could be permitted rather than required, because applicants could be required to develop the technology on their own.

68. The biggest problems with such a fee program would be its implementation and its enforcement. For example, applicants would have an incentive to understate the capacity or difficult aspects of a particular technology. The incentive to misrepresent would be greater for those technologies that would be most affected by the fee. As a result, the cost of such a fee program, both to us and to new and exiting applicants, might be far out-weighted by the resultant improvements in spectrum efficiency.

69. An important concern with this policy is that our next step, if we decide to pursue a spectrum efficiency solution involving fees, would be to require the Communications Act of 1934, as amended, to permit us to establish licensing fee rates that would promote spectrum efficiency in the PLMR services.

Question 10:

a. Should we seek permission from Congress to create a fee structure dependent on factors like spectrum efficiency, operation or other measures of spectrum use?

b. Currently PLMR licensees pay a $55 application filing fee with each base that would have to be raised, making it much higher. This fee would be significantly to be a credible incentive for spectrum efficiency. If we were to use fees as an incentive for November 1991

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spectrum efficiency, what should be the base fee
(i.e., for a single channel, single site, FM analog
mobile radio system)? What discounts should be
used for which factors (e.g., the increase in fees be
different ERPs, bandwidths,
etc.)? How should the base rate be adjusted for
different technologies/techniques such as digital
FDMA and spread spectrum?

2. Alternate Channel Assignment Policies

70. Without alternate channel assignment policies,
certain technologies and licensed channels might
be less practical for most PLMR users. For example,
while a spread spectrum system requires access to a
relatively large number of channels PLMR licensees
are typically authorized to operate on only a single
frequency. The current allocations to the various
PLMR services could inhibit a technology requiring
use of several adjacent channels. Several spectrum
efficient technologies, including trunking, some
digital multiple access techniques, and multistate,
cellular-like systems, have so much capacity and
have such a high fixed cost that they are completely
impractical for many traditional, smaller PLMR
licensees.

a. Band Licensing

71. The essence of band licensing is the
simplification of the process required for a licensee
to switch channels. Licensees are currently granted
licenses for individual frequencies within specific
areas of operation. Band licensing entails providing licenses for
large sets of channels. A form of band licensing has already been implemented for SMR end users. The
provisions for core use by entities in the Police Radio Service are also a form of band licensing.

72. Band licensing is closely tied to trunking, a technology that is more spectrum efficient than
traditional operations because, like trunking, band licensing would permit a user to switch to a channel within a specified set of channels. Band licensing can improve spectrum efficiency by
allowing licensees to switch channels within a band at will. Greater efficiency results from licenses switching to the best, or lowest cost, channels. The best channels can be identified by a person or
computer based on actual on-air activity rather than by the search of random channels. Licensees are assigned on a call-by-call basis, then
decentralized, monitored trunking as discussed in paragraph 27 occurs, with its inherent spectrum efficiency advantage.

73. Even without trunking, band licensing could improve spectrum efficiency by allowing dynamic
localized frequency coordination. For example, in the
25-50 MHz band, the fast packet radio "skip"
hundreds of miles under certain conditions, makes
frequency coordination using a licensing database
difficult to achieve. Allowing licensees to change channels,
based on actual conditions, would permit more

intensive use of that band. In addition, band licensing
could significantly reduce paperwork for licensees and
by simplifying the granting of licenses and
by eliminating most license modifications for
channel changes.

74. Band licensing should reduce the number of
PLMR to PLMR interference we handle each
year. For example, band licensing makes more "air
time" available in the form of quicker channel access.
More importantly, a logical way to reduce problems on
one channel could switch to another. In the simplest case, users with single channel radio
systems who experience long waiting times on their
current channels, or co-channel interference, may switch channels without
coordination or modification of their license.

75. A disadvantage of band licensing is that certain operations designed with significant excess capacity for
public safety-type emergencies (e.g., as a chemical spill)
would suffer impairment by other licensees. This problem could be resolved to a degree on
shared channels. A partial answer is that
exclusive, or at least capped shared use, channels are
more appropriate than uncapped, shared channels for
systems that are designed for use during major
emergencies. Another potential solution would
involve preemptive access. Equipment could be designed so that those users who require a
channel and are authorized to override any
other license. Such preemptive access exists in the
United Kingdom between cellular providers and
military users in the 410 MHz band.

76. A more limited form of band licensing would
entail mobilizing mobiles and certain non-repeater
base stations for use with particular systems, rather
than on each frequency, at each site. This plan is
similar to current licensing of SMR end users. Such
a plan would allow greater flexibility for operators of
repeater systems in several channels and/or system.
It is in the interest of such a repeater operator to equalize
the use of each channel. In effect, such repeater operators would act as quasi-frequency coordinators.
An associated benefit of such band licensing, paperwork, both for licensing and frequency
coordination, would be reduced. That paperwork
reduction would be particularly noticeable if we were to
permit trunking on the lower bands.

77. Another more limited form of band licensing
would facilitate or promote specific technologies like
trunking, packet radio, and spread spectrum.
Trunking would be directly facilitated because it
requires access to multiple channels. Packet radio can
be promoted, in combination with trunking or even
spread spectrum, by authorizing a channel with
that purpose only. Spread spectrum requires accesses to many channels whose bandwidths may not
be of standard size. It is unlikely that spread spectrum can exist and operate efficiently without a
liberal form of band licensing. As stated before, it is
possible that each of these technologies can operate
almost invisibly to other users.

Question 11:

a. Should we grant licenses to operate on bands
rather than channels?

b. How should bands be defined? Should a band,
for example, be defined as a set of channels that are
in the same general part of the spectrum and share
common availability and similar technical data (an approach that would result in licenses using only
those channels for which they are currently eligible)?
c. Should a channel such as public safety services,
even be excluded from band licensing?
d. Should we implement a limited form of band
licensing similar to that for SMR end users, in which
mobiles associated with regularly licensed base
stations would be licensed for use on those
systems, rather than on each frequency at each site?
e. Should we authorize band licensing for certain
specific services only, like Interactions of one(s)?

b. Consolidation of the PLMR Service
Pools/Increased Intercategory Sharing

78. Until 1958, we allocated spectrum to very
specific private radio user groups. In 1958, we
reorganized users into the present 19 PLMR services.
One of the radio services created at that time was
Business Land Mobile, the only one that includes
Business, in case one where technology was the
sole criterion. Most recently, in the 220-222 MHz
Notice of Proposed Rule Making, we proposed to
add to the 200 available channels between the Federal
Government, nationwide licenses, commercial
licensees and non-commercial licensees, with no
suballocation was the case of Industrial, Other
Industrial, Laboratory, Transportation, or Public Safety. We proposed this because we find it difficult to gauge which users most need the spectrum and how much spectrum should be allocated to each level of users. We preferred to
let market forces determine how much spectrum will be
used by various types of users. We did, however,
see benefit in permitting typical PLMR licensees to
satisfy their land mobile communications needs by
establishing their own systems; hence the proposed
non-commercial set aside.

79. Several licensees to that Notice indicated a
desire for service pools. Generally those commenters
desired either a Public Safety Pool, pools similar to
those in the 806-821 MHz and 851-866 MHz bands,
or a for a set aside of several channels for a specific use
such as law enforcement tracking operations. In
proposing pools, commenters also recommended
intercategory sharing between pools. A common
reason given as to why certain channels should be
allocated primarily for the Business Radio Service and
others shared with other Industrial Radio Services
was that broadly defined services (together with intercategory sharing) works well in the
800 MHz and 900 MHz bands. Those commenters seeking to reallocate the 200 MHz band of interest here because they appear to argue against the
case of consolidation of the PLMR service pools.
They also seem to argue against the trend of the
past three years of suggesting that license pools that
were consolidated on a case-by-case basis using waiver procedures.

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rather than through a rule making creating a new PLMR service. We established intercategory sharing because we recognized that we cannot perfectly gauge the relative value of user groups. It is for this reason that we did not propose or provide for specific radio service pools in the 220 MHz band.

83. There are two open procedures that might modify the services. The Notice of Proposed Rule Making would expand the eligibility criteria for the Motion Picture Radio Service to include persons involved in production, television programs and educational and business training films. Another Notice of Proposed Rule Making would create a new public safety radio service, the Emergency Medical Radio Service.

84. The EMRS proposal highlights the difficulties with narrow radio services. Clearly, we must meet the spectrum needs of emergency medical service (EMS) providers. That Notice of Proposed Rule Making provides relief to EMS providers through access to additional channels. Yet the creation of the proposed radio service, the Communications Act is unlikely to provide only modest relief from the problems identified in the IMSA/IAFC petition. To a large extent, we believe the crowding of EMS spectrum results from the very multiple channel assignments rather than from the use of the applicable frequencies by incompatible non-EMS licensees. Congestion resulting from EMS transmissions...
geographic reuse. Cellular systems employ trunking of a large number of channels, automatic switching or handoff between cells, and central interconnection with the public switched telephone network, together with frequency reuse.

98. The cellular concept will soon be more widely applied. Second generation cordless telephones (CT-2) and PCS both involve similar cells. Cell is has proposed a multi-site system design for its SMR service. Development of PLMR cellular-like systems, particularly by large telephone companies using their own geographic reuse, will enable sharing of several users, would be one way to increase capacity on the older PLMR bands.

99. Geographic reuse in the PLMR services also may be accommodated through simpler means such as reduced power. PLMR base stations are generally designed to transmit all messages to any geographic area in which associated mobile units are likely to be operating. Maximum power is always used if the associated mobile units are always at the maximum distance.

100. The current regulatory environment permits licensees to emphasize maximum system coverage rather than efficient geographic reuse of spectrum. Individual licensees generally have no incentive to maximize geographic reuse of spectrum because the common response to a low signal/noise ratio caused by a co-channel user operating at high power levels is for other co-channel users to turn down their power. That approach reduces geographic reuse of channels. One goal of this notice is to develop rules under which PLMR licensees would build radio systems that use spectrum over as much area as necessary. This would be consistent with the Communications Act of 1934, as amended, which specifically requires all radio stations to use the "minimum amount of power necessary to carry out the communication desired."

Question 14:

a. Should maximum power be reduced on some or all frequencies below 470 MHz? If so, on which frequencies should the power limit be lowered and what should the new power limits be?

b. If power limits are lowered, how should existing systems with power levels exceeding the new limits be treated?

c. Cellular radio systems reduce output power for each transmission to the minimum level required. This process is called "software determined power levels." Can such be applied to be used on some or all of the bands below 470 MHz? If equipment with software determined power levels does become available on a given PLMR band, should we require such a process for all new equipment sold for that band?

d. Research has shown that it is possible to use phased array techniques to track vehicles with narrow beams in order to improve geographic

frequency re-use, and to use steered nulls to cancel interference. This process replaces omnidirectional transmissions with effectively point-to-point transmissions, producing a dramatic increase in spectrum efficiency. Can such a process be applied to some or all of the PLMR bands below 470 MHz? Should we promote and facilitate use of phased array techniques and, if so, how?

2. Adoption of a Spectrum Efficiency Standard

101. Without reasonable incentives to promote efficient use of the older PLMR bands, technical flexibility may not in itself be effective in limiting and reducing spectrum crowding. Unless new technologies are widely adopted, voluntarily or involuntarily, most users of these bands must expect their communications system to continue to become less satisfactory at a time when more and better technological solutions to spectrum crowding exist than ever before.

102. Most PLMR systems use single channel (or channel pair) FM analog voice equipment. The major exception for dispatch service is at 800 and 900 MHz, where trunked analog voice equipment is common. To a much more limited extent, there is some PLMR use of ACSB in the 150-174 MHz band, and of digital techniques for data. Besides dispatch service, channels are also set aside for PLMR on the bands below 470 MHz for paging, remote control use and radio location.

103. There will soon be several fully developed technologies that will be up to to spectrum efficient than traditional equipment in the older PLMR bands. For example, waiver requests relating to digital 900 MHz systems and cellular-type digital trunked 800 MHz service have been filed with us. Several digital techniques are being tested for cellular service. In addition, the federal government is developing standards for future digital land mobile equipment operating on federal spectrum, and the CCR is examining various technical parameters for digital land mobile voice and data communication.

We have recently established a 220-222 MHz service using narrowband technology. In the older bands, companies have begun advertising PLMR decentralization systems that are used to be used in the 450-470 MHz band, claiming their equipment allows two to three times the number of mobile radios per channel.

104. In the past, we have adopted flexible spectrum efficiency standards. Our Rules permit 900 MHz Specialized Mobile Radio (SMR) channels to be used in both trunked and other comparatively efficient modes of operation. Based on current RD Mobile Data, Inc. (formerly called American Mobile Data Communications, Inc.) to use an alternative technology that provides a range of allocable channels at the primary site. Narrowband (5 kHz) emission standards for the 150-174 MHz and 220-222 bands, although designed to specifically permit efficient and effective ACSB operations, are also intended to permit any technology meeting those technical standards.

105. A spectrum efficiency standard could be set at a level to permit permitting a standard for all PLMR, would assist our operation Bureau in identifying and locating unlicensed users. 109. Some of the other concepts discussed in this Notice, such as band licensing and exclusivity, could result in some exchange or even complete reallocation of channels. If this is done, then public safety activities may be given a distinct block of channels. It may then become easier to protect these channels from interference due to unlicensed activity. For example, we could require that only radios designed strictly for public safety use be able to access that block of channels and restrict sales of such radio only to eligible. Such a plan is more practical if public safety channels have a distinct frequency allocation.

110. We also see potential for the amount of unlicensed activity to be affected by many of the concepts discussed above. Band licensing, for example, may reduce unlicensed activity by reducing the relative cost of operating a licensed PLMR system as opposed to operating an unlicensed PLMR system. The reduced cost of licensing a channel would provide immediate spectrum efficiency gains, they would not provide incentives to develop more spectrum efficient technologies. Unfortunately, there are few of these technologies in the future, probably for use on other bands or for applications other than PLMR, would force us to reevaluate our standards and continue to update our rules.

Question 15: How could we establish spectrum efficiency standards for new systems on all or part of these bands? Should such standards be limited to specific markets and, if so, which markets?

b. If standards are established, what should they be? When should they go into effect?

c. Should current licensees be required to convert to more spectrum efficient techniques, and if so when? How should licensees seeking to expand an existing system be treated?

D. Unlicensed Activity

unlicensed activity can be a significant problem. We seek comments on several options to correct this problem. Frequency coordination based upon a database is less efficient if the database is incomplete. In addition, unauthorized users may disrupt critical public safety or other communications.

108. Antithetical technology exists that allows a base station to remotely switch mobile radios on or off. These techniques prevent mobile radios from using unauthorized repeaters. It is possible that this technology, or some similar technology, could be employed to prevent unlicensed radios from working. A multistandard identification system (ATIS), a system that automatically transmits an identification, such as a call sign before each communication, also may be used to reduce unlicensed activity. A system standardized for all PLMR, would assist our operation Bureau in identifying and locating unlicensed users.

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Question 16:

a. Would implementation of any of the concepts discussed above result in major changes in the level of unlicensed activity on the older PLMR bands? What would the effect of the level of unlicensed activity be? Could the effect be sufficient to modify the implementation of such a concept and, if so, how?

b. What steps can we take to reduce unlicensed radio activity? Can increased penalties act as a serious deterrent? Can a technological solution to unlicensed activity be found?

c. Because licensing is primarily a spectrum management tool, will dynamic channel assignment technology eventually eliminate the need for licensing?

V. CONCLUSION

111. We have discussed a wide variety of techniques and strategies. Some of these concepts are complementary, while others are mutually exclusive. We do not intend to pursue each of these concepts.

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Communications Abstracts


In order to establish the antenna separation necessary to receive sufficiently decorrelated signals of the same frequency at both base and mobile stations, extensive field trials have been carried out in which a CW signal was transmitted over a distance of 1.3 km. The receiving station was equipped with two vertical half-wave dipoles which were spaced in a vertical configuration. The received signals were coherent demodulated by a two-branch phase-locked receiver which could measure both the complex and envelope cross-correlation. Results show that a cross-correlation less than 0.7 can be achieved using an antenna separation of 8A to 13A at the base station and 1 to 5A, at the mobile, for a 1.3 km cell radius. At 900 MHz such an antenna separation is easily obtained and, in both cases, the space required is small. The cross-correlation using vertically spaced antennas at the base station is independent of the incoming angle of arrival and hence the time delay can be achieved while maintaining omnidirectional coverage. At the mobile the small vertical antenna separation required suggests that an omnidirectional antenna arrangement is feasible.


The paper presents a rigorous mathematical analysis of the three-ray multipath dispersive fading channel model. The channel transfer function in this model consists of three terms representing a direct ray, a ray refracted from the atmosphere and a ray reflected from the ground. The channel transfer function, conditioned on the amplitude of the direct ray, is proven to be a complex Gaussian process whose probability distribution is independent of the statistical moments of the ray’s delays. Explicit formulas are presented for several pertinent single variable probability distributions, such as the autocorrelation and joint probability density functions of the channel transfer function and of the channel power gain function.


Considerable work is being undertaken within RACE to define suitable approaches to a future integrated broadband digital network. Alcatel is playing an active part in many of the projects, and in particular in R1022 and R1044.


The muting of transmitters during periods of silence is shown to increase the capacity of a microcell cordless telephone system. Both average and instantaneous channel interference models are considered and used to compute the grade of service of such a technique against that of a continuous transmission system.


A Linic transmitter exploiting modern DSP Techniques is described, together with a method for significantly reducing the bandwidth of the processing required. Practical results are presented which show the linearity of the transmitter to compare favourably with established linearising techniques such as Cartesian feedback.


Measurements show the existence of large specular reflections from building surfaces of terahertz radio signals. The measured specular reflection is 20 to 30 dB higher than the diffusely scattered energy and is caused by reflection from a building illuminated by a sidelobe 17 dB below the main lobe brightness of the transmitted signal.


Power control is used to solve the ‘near-far’ problem which arises in a spread spectrum system using direct sequence code-divide multiple access (CDMA). A method to evaluate the signal-to-interference ratio to be used for power control is proposed and the difference in the signal-to-interference ratio between the set power control threshold and the average value actually received at the antenna over a fading multipath channel is presented.


Performance results are given for the combined use of a decision feedback equaliser with antenna diversity in spread spectrum Rayleigh fading channels such as those typically encountered in narrowband digital cellular mobile systems. The results show that the use of dual antenna diversity provides significant gains over nondiversity receivers with decision feedback equalisers, and that this performance is robust in the presence of uncompensated paths and correlation between the diversity outputs.


A hybrid contention-based time-division multiple access (TDMA) protocol was previously proposed for data transmissions. It provides satisfactory performance for the error-free channel. Here the effect of channel errors on the performance of this protocol is studied. To remain operational the protocol has to be first modified. The modified protocol is then analyzed. Results derived include the average of frame length, the number of slots wasted, the number of residual packets, and delay. Numerical examples show that channel errors can sometimes be damaging but can be recovered by proper error control codes.


Measurements show the existence of large specular reflections from building surfaces of terahertz radio signals. The measured specular reflection is 20 to 30 dB higher than the diffusely scattered energy and is caused by reflection from a building illuminated by a sidelobe 17 dB below the main lobe brightness of the transmitted signal.


This paper describes the results of a 140 MHz 64 QAM digital microwave radio field trial to characterize a space diversity channel model with maximum power combining. Measurements were taken on a 60.8 km overwater route in New Zealand. To the spectral data collected from the field trial, a Rumniler model has been fitted. It is shown that the model can also be fitted with the effects of maximum power combining are considered. The pdf's of the nondiversity and diversity channel model parameters are estimated from the measured data.


This paper describes the performance of OFDM/FM modulation for digital communication over Rayleigh-fading mobile radio channels. The use of orthogonal frequency division multiplexing (OFDM) over mobile radio channels was proposed by Cinofini. OFDM transmits blocks of bits in parallel and reduces the bit error rate (BER) by averaging the effects of fading over the bits in the block. OFDM/FM is a modulation technique in which the OFDM baseband signal is used to modulate an FM transmitter. OFDM/FM can be implemented simply and inexpensively by retrofitting existing FM communication systems.


Growth in communications leads to increasing requirements for high data rate transmission that can be met by bandwidth efficient modulation schemes. In this Letter, the TMCA (effective code length) and product distance (PD) as well as Euclidean distance (ED) are used to construct new 16-QAM TCM schemes with ideal channel state information, and Rayleigh fading channels is evaluated by simulation. The results show that the proposed codes achieve significant improvements relative to the best known 16-QAM modulation.


An improved method of operation of an HP network analyser to perform measurements of the frequency response of the indoor RF propagation channel and the relative path loss envelope and phase of a CW signal is presented. The improved postprocessing procedure is also described. Test results obtained for indoor measurements in the 1-2 GHz band (2.3 to resolution after 935 MHz path loss measurements are presented as examples.)


A simple method for detection of multipath delay difference in a digital mobile communication channel employing 8/4-shift QPSK as the modulation scheme is proposed. The results show that this method is useful for in-service performance monitoring of such a communication channel.


Rate-(r-1)/n phase-invariant trellis coding with unquantised maximum-likelihood Viterbi decoding for rate-1 MPSK signals on Rayleigh fading channels is considered. The performance of the trellis-coded modulation is presented for four- and eight-state linear and non-linear constraints of code lengths 3 and 4, respectively, with coding gains of at least 2.5 dB at a bit error rate of 10^-5.


A novel, low-complexity decision feedback equalisation technique is presented, which is able to estimate the location of a deep fade within a time slot in a time-division multiple access (TDMA) system. Simulation results confirm the effectiveness of this technique in improving the performance of the proposed narrowband cellular fading channels over fast-time-varying Rayleigh fading channels.


Multipath profiles obtained from radio propagation measurements at 910 MHz are used to analyse the statistical characteristics of the indoor radio channel. The data base is divided into two classes: manufacturing floors and office floors. In the manufacturing floors, there is plenty of open space without any presence of walls, as a result of which most of the received signal power is concentrated in the initial paths. The office area offers a wider spread of power in delay, because of less open space and the frequent obstruction of the signal between the transmitter and the receiver by one or more walls. The statistical parameters required for computer simulation of multipath profiles in each environment are determined. The arrival of the paths is shown to fit a modified Poisson process and the amplitude of the paths follow a log-normal distribution. The mean and the standard deviation of the lognormal distribution are shown to decay exponentially with delay. To evaluate the performance of this simulation model, the distribution of the RMS delay of each multipath in the simulated profiles is compared with that obtained from the measured profiles.


Techniques to improve the BER performance of 16-QAM and 64-QAM on Rayleigh fading channels for PCN systems are presented. Simulations were carried out with a carrier frequency of 1.9 GHz data rate of 64 kbit/s and mobile speed of 30 mph. The residual BER was reduced by an order of magnitude, by introducing a circular constellation coupled with differential amplitude and phase encoding. The results were confirmed by spreading out the QAM constellation. When an oversampling and interpolation technique was combined with the circular constellation with differential encoding another order of magnitude of reduction in residual BER was obtained. By expanding the number of QAM levels to 64, and on using the two extra bits gained for block coding, the BER was reduced to 10^-6 for channel SNRs in excess of 35 dB. Decreasing the data throughput to 48 kbit/s using a 3/4 rate RS (60, 44, 12) code, 16-level QAM, interleaved over 40 ms, transmitted over a Rayleigh fading channel yielded a BER of 10^-6 for channel SNRs above 25 dB.


In this paper, we present an exact analysis to evaluate the effect of capture on multichannel slotted ALOHA protocol. We derive the probabilities of the successful transmission over these capture probabilities, we calculate the throughputs, average packet delays for both IFT (immediate transmission) and DFT (delayed-first-transmission) protocols and numerically compare the performances of the systems to and without capture. Numerical results show that the throughput is a qualitative function of the initial path, the number of channels, the number of nodes, and the time of the capture system by using the analysis of probabilities of successful transmission given in this paper and the analysis in [7].


In a satellite mobile channel (SMC) and land mobile channel (LMC) because of fading and nonlinear power amplifiers, constant envelope modulation and noncoherent detection methods may outperform other schemes. Differential phase shift keying (DPSK) with differential phase detection (DPD) and selector detectors over the same channel or SMC and LMC does not mainly to fading. An error floor is the residual error probability when SNR is infinity. That means that the error probability in the system is limited below by the error floor. In this paper, we consider the error floor for DPD-DPSK, FSK-DPSK, FSK-LDID, and FSK-LDD. We compute the error floor for M = 2, 4, 8 as a function of Doppler frequency, modulation index and ratio of powers in the specular and diffuse signal components.


This paper considers trellis-coded M-ary phase shift keying (MPSK) when used with differentially coherent demodulation over a carrier-phase-noise dominated channel. A tight upper-bound to the probability of error is introduced. This bound shows the presence of an irreducible probability of error. When compared to currently correlated trellis-coded MPSK, the irreducible probability of error of the differentially coherent scheme is much lower. However, this improved robustness to carrier-phase-noise is obtained at the expense of SNR coding gain. Numerical results for two Ungerboeck codes with differentially coherent MPSK demodulation show poor SNR coding gain. A modification of Ungerboeck codes which makes them more suitable for use with differentially coherent demodulation is shown to increase the SNR gain while maintaining good robustness to carrier-phase-noise.


As products that allow people to worldwide public telecommunications network in a natural, convenient manner, cellular telephones and residential cordless telephones enjoy widespread public approval. Both are relatively new, introduced in the 1980s in most places, and the demand for both is increasing. While this trend is expected to continue, the demand is expected to slow down, as increasing availability of cordless telephones in the second generation. The second generation will be characterized by digital speech.
in 1847, Professor Moses G. Farmer, a notable American scientist, successfully operated an experimental locomotive, powered by a 48-cell Grove nitric-acid battery, and carried two passengers along an 18-in. gauge track at Dover, N.H.
could also suggest maintenance and inspection cycles. Performance standards should be developed for inspection and maintenance including use of diagnostic concepts and methods.

New operating rules will be required for maglev and probably revised current rules for high-speed rail (150 mph or greater). A key element is to realize that obedience to operating rules is to operate safely.

Concerning emergency procedures, an important function is to identify emergency situations in maglev and high-speed rail and develop standards and guidelines to deal with them in a safe manner. Preventive procedures should be developed as well as reactive procedures.

Signal, Control and Power Supply

Concerns in this area are not only safety, but costs and benefits. It was pointed out that different types of operation are employed in maglev as compared to high-speed rail.

With high-speed rail it is likely to have an operator drive the train or at least be on board to take control in emergencies or in yard operations. As for maglev, the vehicles are driven by central control.

Present trains normally operate in fixed block situations that provide train separation. With high-speed rail and maglev, consideration is given to moving blocks because computer technology and digital communications, the mass of a train, its velocity, length, braking profile and location can be handled by an on-board or central computer.

Other factors to be considered include control system reliability, maintainability, safety and verification of both hardware and software. Route integrity and safety verification should also be considered.

Communications, in most cases, will be digital and will include wireless and ground networks. Communications will include extensive systems:

- Between vehicles and central control
- Between various wayside facilities
- Between vehicle operators and between them and central control.

Overall system architecture will have to be developed for high-speed rail and maglev.

Protocols, error correction, fault detection, diagnostic testing, inspection, maintenance, reliability and vitality are a few of the factors to be considered.

Where radio transmission is used between wayside and moving trains or vehicles, frequency spectrum management concerns must be addressed. At present, the US and Canadian Advanced Train Control System has been allocated six frequency pairs in the 900 MHz range by the Federal Communications Commission. Canada is expected to provide similar pairs for use by the Canadian railroads. Railroads in these two countries now use 450 MHz bands for end-of-train telemetry devices and remote control of helper locomotives. They use voice radio in the 160 MHz band. Maglev systems use 40 GHz for wayside to vehicle communications.

Concerning electrical power, with maglev power is delivered to the guideway whereas with high-speed rail, it is delivered to the vehicle. There is a need for electrical standards for compatibility with power and telecommunications industries. Safety standards and procedures must be applied to protect employees, the public and the equipment.

Concerning electro-magnetic interference, communications equipment and vehicle on-board computers may be affected. Also, there is a public perception of the impact of high voltage or power transmission facilities that should be studied and considered. Health effects are not proven, and as one expert at the workshop commented there is cause for concern but not alarm. Consideration may be given to shielding the passenger compartment on maglev vehicles.

High-Speed Rail Guideway and Vehicles

Concerning design and construction standards dealing with track centers, tunnels and security features, there is a need for performance-based standards and track geometry standards. For security, the costs and benefits of fencing may be compared to some type of surveillance. In the U.S. there may be a requirement for mixed traffic on the same tracks or on separate tracks on the same right-of-way.

As for track standards, a question to be answered is should there be condemning limits with speed limits stated? Present Federal Railroad Administration track standards will probably have to be revised.

As for rail-highway grade crossings, there would be none with maglev as it is presumed to operate on an elevated guideway. As for high-speed rail, consensus was that; for speeds over 150 mph, grade separations would be required so that highway and rail do not cross at grade. In some instances some rail-highway grade crossings would be closed and traffic routed to a separated crossing. In the workshop on this subject, it was suggested that criteria be developed to determine at what trains speeds should grade crossings be eliminated. Corridors for high-speed rail should be identified along with what crossings should be eliminated closures or grade separations.

Also, consideration should be given to integrating the Intelligent Vehicle Highway System (IVHS) into high-speed rail corridors.

Concerning vehicles, there is research needed to develop criteria for vehicle operation, compatibility of vehicles in high-speed rail territory. Guidelines or performance standards should be developed covering speed, environment, human factors and survivability.