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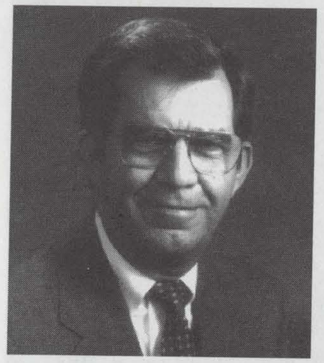
Madden's Message



Roger Madden
President

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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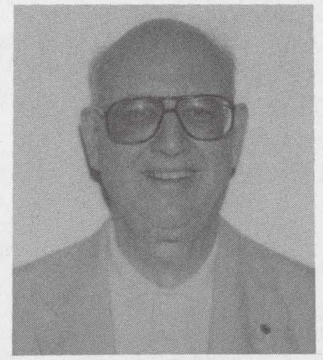
Editor's Corner



Robert W. McKnight

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	IEEE Society
139	Signal Processing
75	Broadcast Technology
157	Antennas and Propagation
73	Circuits and Systems
5	Nuclear and Plasma Sciences
690	Vehicular Technology Society
9	Reliability
26	Consumer Electronics
16	Instrumentation and Measurement
48	Aerospace and Electronics Systems
29	Information Theory
47	Industrial Electronics
99	Engineering Management
20	Electron Devices
112	Computer
33	Microwave Theory and Techniques
10	Engineering in Medicine and Biology
563	Communications
6	Ultrasonics, Ferroelectrics & Frequency Control
18	Components, Hybrids & Manufacturing Technology

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1 Oceanic Engineering
33 Control Systems
6 Education
1 Professional Communication
25 Electromagnetic Compatibility
7 Systems, Man and Cybernetics
3 Geoscience and Remote Sensing
2 Social Implications of Technology
54 Power Engineering
5 Dielectrics and Electrical Insulation
6 Magnetics
14 Industry Applications
8 Power Electronics
19 Lasers and Electro-Optics
24 Solid State Circuits
34 Interdisciplinary & New Activities

There you have the first place choices of VTS members. Actually quite a wide range of interests. I have no conclusions to draw. Just present this for your information. ✦

Chapter News

Gaspar Messina, *Chapter News Editor*

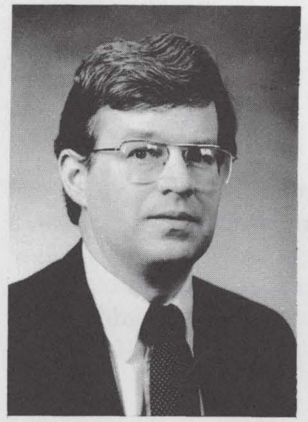
News from Philadelphia, Toronto and Washington

Philadelphia Section of VTS Land Transportation Division hosted the June 13, 1991 technical session. Belknap Freeman, PE, presented a paper on "Hardening of Control Centers—a Case for the Issues to be Considered." Attendance was 22.

The Toronto VTS in conjunction with Ryerson Department of Electrical Engineering and Applied Sciences hosted the March 21, 1991 meeting. Gene Dempsey, Chapter Chairman and President of Threshold Communications, presented a paper titled "Mobile Digital Communications — an Overview." Attendance totaled 53.

Washington Chapter Land Transportation Division of VTS in conjunction with American Society of Mechanical Engineers, held their September 10, 1991 meeting at which some 35 members and guests heard Joseph Vranich, Public and Government Affairs Vice President, High Speed Rail Association, discuss the legislative agenda for intercity rail. ✦

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 MMIC (Microwave Monolithic Integrated Circuit) 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.

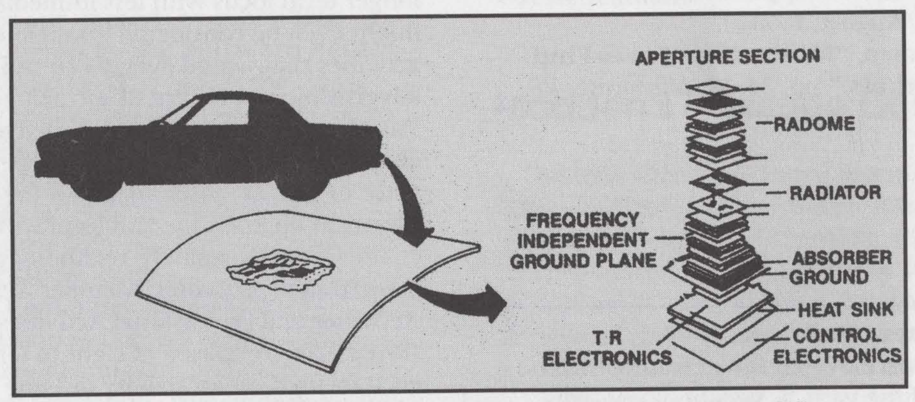
Automotive guidance and collision-avoidance systems would add thousands of dollars to the cost of a late 1990s car. But these systems will reduce the number of accidents, reduce wasted time of drivers searching aimlessly for their destinations, reduce delays during rush-hour traffic, and reduce gasoline consumption and air pollution [1]

According to Ref. [2], no fewer than 15 electronics companies are currently experimenting with

TABLE 1
EMERGING MICROWAVE APPLICATIONS IN AUTOMOBILES

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

Worldwide Automotive Microwave Applications — Ref. [1]



Concealed Conformal Planar Microwave Antenna Array [1] anticollision radars. In Europe: Standard Elektrik Lorenz AG (SEL) along with the U.S. firm, Epsilon Lambda, are working with Mercedes-Benz to develop a millimeter-wave based collision-avoidance radar for commercial vehicles. SEL projects that the radar system will cost no more than a high-end entertainment system; i.e., about $1K to $1.5K [2]. The SEL system tracks the vehicle in front of it, calculates the speed of the target vehicle relative to its own vehicle speed, and displays a safe or unsafe condition in red, yellow, or green indicators on the driver's dashboard.

In the U.S., General Motors is working with its subsidiary, Hughes Microwave Division; while Ford Motor is working with Millitech Corp [2]. Either the pulsed or the FM-CW system will be used to detect distances, speed, and acceleration of a target. If the target (it may or may not be a vehicle) is too close, a warning is given to the driver to take action. (Note. Automatic braking is considered to be too dangerous).

Motorola is proposing its Advanced Driving Information System (ADIS) that it expects will appear in 1994 vehicles [1]. Motorola estimates as many as 300,000 cars, or 10 percent of 1994 models priced over $20K will carry such equipment — this will add approximately $3000 to their list price. The ADIS system features destination guidance assisted by on-board computer, magnetic compass, and other sensors.

For microwave systems, automotive manufacturers are finding new ways to unobtrusively integrate the microwave antenna into the vehicle body structure. One approach, having great current interest, is the use of conformal (planar) antenna arrays sandwiched into the composite material of the vehicle body structure [1].

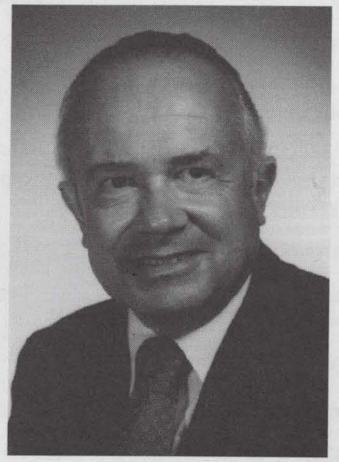
REFERENCES

1. H. Bierman, **"Personal Communications, and Motor Vehicle and Highway Automation Spark New Microwave Applications,"** pp. 26-40, *Microwave Journal*, August, 1991.

2. D. Schneiderman, **"Millimeter-Waves Find Commercial Markets,"** pp. 35-39, *Microwaves RF*, July, 1991. ✦

Alton & Southern Railroad, in 1941, located the yardmaster in an elevated tower from which he could see much of the yard. A system of two-way, voices-calling, talkback loudspeakers and paging loudspeakers were installed for communications either way between the yardmaster's tower and various locations within the yard.

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 profession 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 State 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 in support of 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 October 18, 1990. Member response to a Legislative Alert on this bill helped the process. A great deal of work on the part of the Career Maintenance and Development 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 interface 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/or 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, engaged in concerted lobbying activities in support of legislation to expand coverage, improve portability and increase savings for retirement. They translated their retirement income policy recommendations 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

Election 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 F. McClure
Stuart F. Meyer
Jesse E. Russell

Madden's Message Continued

The IEEE Standards Board recently formed an IVHS Coordinating Committee. Jesse Russell, our Standards Committee Chairman, is looking for 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, vehicular electronics or 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, had over 350 in attendance from countries all over the world.

Abstracts of the technical papers are presented herewith:

Advanced Train Control System (ATCS) Control Flow Development and Validation by Robert G. Ayers, Arinc 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 interactions 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 refinements have continued so that the project is continuing the validation of the "user protocol stack" in the STATEMATE CASE tool. This logic defines how ATCS applications access the ATCS communications subsystem, and is more amenable to conversion to the STATEMATE graphical representations.

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 enginemen, will not be inticed 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 useful information can be obtained through simple man-machine interface (MMI) procedures.

This paper provides human factoring methods to develop MMI and related displays for the locomotive onboard terminal. Onboard terminal equipment's applicability to the railroad industry is emphasized. The recommended human factors activities will promote safe, efficient and reliable train operation.

A Practical Survival Strategy for Taking Advantage of New Technology that can Provide Safer and More Profitable Train Operation by Gideon Ben-Yaacov, Automated Monitoring & Control International.

This paper covers most of the economic benefits that can be achieved by railroad companies when these companies use computer systems based on state-of-the-art technology — systems which use advanced data communication networks for the efficient exchange of data between all major areas of railroad operations. Advanced Train Control Systems (ATCS), Work Order Reporting Systems (WORS), Locomotive Health Monitoring Systems, Maintenance-of-way (MOW) Work Monitoring Systems, and other real-time computer systems are examples of such systems. Use of these systems results in safer and more profitable train operations.

A list of benefits derived when using these new computer system is provided together with brief explanations of the potential benefits.

Verification and Validation for Advanced Train Control Systems by Gideon Ben-Yaacov, Automated Monitoring & Control International.

Verification and validation (V&V) techniques are used in military, space, nuclear power and other industries to improve the quality of digital systems. V&V will ensure that quality advanced train control systems (ATCS) are implemented.

This paper describes V&V programs which can be used by railroads or system suppliers when developing V&V procedures, plans, tasks and activities for use during the implementation of ATCS.

ASTREE: A Global Command, Control and Communication System by Patrice H. Bernard, Societie Nationale des Chemins de Fer Francais (SNCF).

ASTREE is a research project on a global command, control and communications system for train operations and road management developed by the French National Railways (SNCF).

It is based on maintaining in a distributed data base an up-to-date, accurate, and comprehensive representation of route layout and train progress. Computer applications use the image of the actual situation gathered in the data base to make (or in some cases help human operators make) all decisions regarding route setting and train control. The results are transmitted back to wayside equipment and to locomotives, where they are displayed and enforced, if need be, by a vital brake application.

This paper will give a technical presentation of the system, with emphasis on positioning and transmission, and will also focus on route control and monitoring, train consist acquisition and integrity checking. It will also report on project status.

Microprocessored Diagnosis System for Heavy Haul Trains in Actual Operation by Joao Paulo do Amaral Braga, Nelyo Choucair de Oliveira, Marcos Baeta Miranda, and Willington Silva, Brazilian Federal Railways.

Operation with heavy haul trains on the Ferrovia do Aco (Steel Railway) began in March 1989. Although the original project was for a totally electrified railroad using 25 Kv, 60 Hz, the initial operation was with diesel electric locomotives.

Since this railroad has many tunnels, the longest one being 8.6 km long, diesel-electric locomotive performance inside tunnels and questions such as type of consist, headway and environmental conditions inside tunnels were intensively discussed.

Since the dynamic operation of a heavy haul train through long and difficult stretches is extremely complicated, and many random variable are involved, such an operation cannot be estimated in a simple mathematical simulation. So, the necessity of preliminary tests in actual operation became a reality before the beginning of traffic activities.

This paper describes some of the tests performed on this railroad and the development of one system to gather data from several points of the tunnels and another one to gather data from on board the locomotives. Both systems were computerized, coupled directly to sensors strategically located inside the locomotives and tunnels. The collecting of data both inside the tunnels and that concerned with the locomotive behavior was performed in real time, both systems being synchronized with the computer's built-in timer.

Automatic Train Protection on British Rail by K. W. Burrage, British Railways Board.

In the autumn of 1988, a decision was taken by British Rail to embark on a 3-year program to produce an automatic train protection system which could be available for implementation by early 1992. Given the 3-year timescale, it was not possible to embark on original technical development of a completely new system. Therefore, a program was embarked upon to produce a performance specification for the perceived needs of the BR network and at the same time to review the experience of other railway administrations with automatic train protection systems. Then, two pilot schemes were to be run to assess in practice, the performance of the proposed specification on BR lines, leading finally to the procurement of a system for national application.

The need for automatic train protection on British Rail is that during the 1980s the number of signals passed at danger has shown a significant increase, for example, 843 incidents in 1988 resulting in 87 derailments or collisions; and 963 incidents in 1989.

This phenomenon of signals passed at danger (SPAD's) has been thoroughly studied from human and technical viewpoints and the conclusion reached that human performance factors are the cause of 85% of all SPAD's and of the rising trend. This had led to the search for a technical solution to prevent driver error in approaching signals and obeying speed restrictions — and a solution that could be implemented fairly quickly, such as automatic train protection.

The existing driver supervision system on British Rail, AWS (Automatic Warning System) only alerts the driver to the presence of a warning or stop signal. It cannot differentiate between the two and has no speed supervision function. It was quickly concluded that his technology could not be adapted to fulfill the needs of ATP on BR.

A Prototype and Test Environment for ATCS Data Communications by Dorothy A. Colburn, ARINC Research.

ATCS is a distributed command, control and communications system which also provides an infrastructure usable for train control and for numerous ancillary applications. This paper describes the techniques being used to verify the logic which allows applications to access this infrastructure.

The communications protocols used to connect applications in different physical components are described in ATCS Specification 200, which represents the protocols as Finite State Machines using CCITT Recommendations Z.101 notation. These state machine representations are converted into a Statechartrepresentation in a Computer-Aided Software Engineering (CASE) tool. This tool simulates the protocol operations and generates an Ada prototype of the protocols.

The communications between applications within a physical ATCS component are not standardized. For our prototyping purposes, however, these communications have been modeled as a "Software Bus." The software bus allows applications to communicate with the prototype of the protocol stack, providing an integrated environment where the interactions of applications, the protocols, and the bus may all be examined and monitored.

The prototype code generated by the CASE tool is supplemented by Ada code developed to simulate events which would occur within the interactions of the communications protocol. The interdependency of the software bus, the CASE-generated Ada code, and the programmer-developed Ada code provides an environment for meaningful prototyping and testing of the access logic, as well as the communications protocols.

Instances of this prototype may be connected through a network emulator for use in further testing and prototyping of the ATCS communications architecture.

Essential Elements of System Integration by Agu R. Ets and Ken Koziol, Smartware Associates.

Systems integration is more than just cabling 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 many diverse parts 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 on 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. Furman, 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 ATCS communication system. Computer performance predictions and data from the installed system are evaluated to obtain insight into the capabilities of this type of mobile data network. The average traffic outbound for each 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 BCPs inbound capacity. The successful large scale implementation of a Spec 200 network on Union Pacific indicates that the ATCS specification provides the basis for a viable communication network.

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

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

1. The signaling system is designed so that safety of very high speed train is not dependent on correct observation of lineside 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 braking 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, whence 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) have 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 or 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 form the linkages between strategy 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 sole supplier, there is an obvious need for a standardized means of communicating among all devices.

This paper presents a proposed framework from which a candidate communication standard is then developed. 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. Hipfner 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 early 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-ctc territory.
- Development and installation of its own ctc office system with an eventual goal of a single generic office system.
- Demonstration 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 Hornung and Howard Rosen, ALK Associates; and John Szymkowiak and Dan Dion, Canadian National Railway.

The motive power management function can be significantly improved due to more timely and 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 addition, there must be established a mechanism for timely communication to field forces of the motive power managers' plans. To achieve this, a computerized motive power control system was designed and implemented at CN Rail. It consists of graphic displays of current train and locomotive location and status, alerts which highlight critical new information, functions for motive power planning, 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.

While ATCS is 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 Systems Group.

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/h. The system for high-speed lines comprise the following:

- Operation control centers for automatic train supervision.
- Decentralized interlockings 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 Dejan Jovanovic, Burlington Northern; and Patrick T. Harker, University of Pennsylvania.

This paper present a new methodological 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 the 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. Karbowski 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 intelligent display terminals.

Flat panel display screens are well suited for locomotive display terminals. Flat panel display screens are compact and have the potential of being able to sustain reliable operation in harsh environments such as those found onboard locomotives.

This paper 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. 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 packets switched a second,
- The time it takes for a packet to be switched,
- Availability of the communications service.

The paper will define data switching node to be either a Front End Processor (FEP), Cluster Controller (CC), or combined FEP/CC.

AUSTRAC: The Australian ATCS by Keith Lugsden and Ron Davison, International Railroad Systems.

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

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

Open computer system architectures are based on industry standard programmable microprocessors and programming languages. Such systems can offer a less costly alternative to special purpose (closed) embedded hardware and software for rail applications. Discussed herein is 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. Poltorak and John H. Bailey, 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. This allows ATCS to 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 locomotives, on-board work vehicles and in field devices. The use of these elements will have a significant impact on the manner in which dispatchers, enginemen and foremen conduct their daily operations. These elements also provide for numerous applications besides train control.

The Value of High Quality Service: How Should the ARES Equipped Railroad Operate by Michael E. Smith, Burlington Northern, and Randolph R. Resor, Zeta-Tech Associates.

Through investments in new technology railroads have the opportunity to lower costs and improve service simultaneously. Burlington Northern along with Rockwell International has developed its version of ATCS, known as Advanced Railroad Electronics System (ARES). In this paper two alternatives for using ARES on BN are presented:

- One which improves quality and reduces cost,
- One which only reduces cost.

Also the paper looks at different methods of looking at the value of higher quality. Finally, it summarizes the design and operational impacts of alternative ways of using ARES.

The UIC European Train Control System by W. R. Smith, ORE, Netherlands, and B. J. Sterner, Banverket, Sweden.

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 to and differences from the North American ATCS, and the reasons for these.

In Western and Central Europe the density and distribution of population with major centers of population only a few hundred miles apart, are favorable for intercity passenger transport by rail.

The Migration from Conventional Signaling to Next-Generation Train Control by Jeff Twombly, General Railway Signal.

There are several key issues regarding both the ease of migration and the overall total 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 in a piecemeal fashion, 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, the ability to address these migration issues will have 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 Ikuo Watanabe and Tetsuo Takashige, Railway Technical Research Institute.

A new Automatic Train Protection (ATP) system is presented utilizing the existing signaling systems effectively. This 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 as the distance up to the train going ahead, gradient, speed restriction on curves, switches and so forth are transmitted to each train. These data modulated by minimum shift keying (MSK) of 3 kHz band are also provided over the track circuit at a speed of 200 bits/sec. A train processor generates a brake pattern corresponding to its own braking performance and actuates the brake automatically if the actual train speed is above the calculated value.

As substantial information is given on a cab signal display, a train can run following a preceding one at an extremely short interval and energy-saving operation can be done. The function of Automatic Train Operation (ATO) can be added easily. A level crossing is controlled safely based on this train detection method.

This system is applicable to any heavy traffic density railway where various kinds of trains run; a high speed train, a low speed one, a freight train, and so forth. This system has much flexibility for its introduction and a train without cab signaling can be operated by using an existing wayside signal.

Integration of ACTS with MIS by M. Frank Wilson, Rockwell International.

Many Advanced Train Control System benefits can be realized through the integration of ATCS with the railroad's Management Information Systems (MIS). The integration of ATCS with MIS MUST COMBINE THE REQUIREMENTS OF ATCS systems for timely, efficient and safe control, and of MIS systems for security and change. Therefore, successful integration imposes requirements upon both ATCS and MIS.

This paper explores those requirements including the basic one that of implementing common communication protocols.

Pilot System of CARAT on the Sanyo Shkinkansen Line by Haruo Yamamoto, Hirotane Inage, and Yutaka Hasegawa, Railway Technical Research Institute.

In Japan, train operation density of a commuter line in a big city has to be higher and the inter-urban train speed has to be higher. It is not economical to improve them by adjustment of current practices.

A train control system called CARAT (Computer and Radio Aided Train control system) has been developed. This is a system equipped with a micro-computer, train position detection function and driving control function onboard in which position information and interval control information and so on are exchanged by radio between onboard units and ground units at central control.

For information regarding complete papers including a reprint of the entire set of papers presented at this technical conference contact Ms. Elain King, Rail Transport Specialist, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, DC 20418 U.S.A. Telephone 202-334-3206.

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 to provide for more efficient and safe transportation services.

Abstracts of papers are presented herewith:

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 classification yard and report their activities to 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 DTMF tones 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 analyzes the data, and if all safety conditions are met, performs the desired function such as moving the selected switch or retarder. The computer then generates a synthesized voice message which contains verbiage that confirms 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. J. Downing, Senior Telecommunications Engineer, ConRail.

ConRail has in rural areas made use of cellular radio to transmit controls and indications between control points in the field at switch and signal locations in centralized traffic control territory and the nearest railroad or communications common carrier trunk type facility. Often the control points on the railroad are in areas not near any major communications facility, 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. Luhm, 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 DM&IR SCADA features a HOST computer with a centralized data base where all pertinent 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-grade circuits with 300 bit per second modems, depending upon the transmission equipment available to the REMOTE location. The communication between the HOST and the SLAVE 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 de-activate crossing signal operation if a train stops in the approach to a crossing and when the train has passed over the crossing. Constant warning controls provide the same warning time to the motorist regardless of the speed of the train approaching the crossing.

Increasing the Visibility of Trains at Night at Passive Highway Grade Crossings by James G. Le Vere, Engineer Methods & Standards, Burlington Northern.

Burlington Northern Railroad is seeking to improve the safety of highway grade crossings through several innovative projects. BN has installed a solar powered crossing illumination system. The system uses the stored electricity in batteries to operate flood lamps which illuminate the crossing at night. It is activated by the headlight of an approaching train. This system was installed in November 1990 at a non-signaled crossing north of 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, at night, the 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. Storbeck, 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 City of Jonesboro, Arkansas and the BN installed a prototype traffic monitoring system. This system uses "state of the art" technology to capture video images of motorists driving around activated 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.

Today, 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 original specification 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 complex programming and testing procedures to provide a system that helps protect personnel and track equipment on the railway.

Overview of Dispatcher Consolidation Projects on 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 people 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 facility consolidations.

Skills for Today and Tomorrow Through Partnerships in Training by Richard Flower, Senior Instructor, Union Pacific Technical Training Center.

Union Pacific and Salt Lake Community College (in Salt Lake City, Utah) have developed an electronics program as well as a partnership in training. UP has provided support from its signal and communications departments staff and facilities, while Salt Lake Community College has provided delivery systems and training concepts to meet the needs of railway men.

"Smart Bolt" On-Board Hot Bearing Detection System by Robert C. Leedham, Manager Mechanical & Electronics Research & Development, Burlington Northern Railroad, and John Tabacchi, Project Manager, Carnegie Mellon Research Institute.

Current freight railway technology provides for automatic monitoring of defective, hot bearings through the use of wayside infrared detection devices. Standard practice is to place such wayside equipment at intervals of 10 to 30 miles along major lines. It has been shown that roller bearings can fail in very short distances, having passed a wayside detector at normal operating temperature, but go into catastrophic failure before reaching the next detector.

Advances in communication electronics and battery technologies as well as innovative packaging ideas lead to the development of a thermal sensor-bolt which provides for "real time" continuous monitoring of bearing temperatures. The thermal sensor replaces a standard bearing end cap screw at each end of an axle. The thermal sensor and transmitter contained in the body of the bolt, when activated, will transmit a distress signal alerting the train crew. The system consists of a battery, a thermo-mechanical sensor and actuator, a transmitter and receiver.

Carnegie Mellon Research Institute under sponsorship from Burlington Northern Railroad and General Railway Signal Co. has carried out an extensive joint development program, testing the system and various components in the laboratory, in a railroad yard, and at the Pueblo Test Center. Additional tests in railroad service will continue at ON as the SMART BOLT production models become available.

Metra Installs Microprocessor-Based On-Board Train Control System by Richard Vadnal, Assistant Department Head, Mechanical Department, Metropolitan Rail.

New locomotive and cab control cars being delivered to Metra, the commuter rail agency for Northeastern Illinois, will be equipped with a cab signal and train control system that is compatible with all of the various signal systems that had been installed by the predecessor railroads. This increases the availability of the locomotive and cab control cars for service on all 11 routes operated by the agency.

The GRS MicroCabmatic 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 346 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-Restoring 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 OS track circuit, the switch would automatically return for main track moves.

A Phase-Selective Signal Solution for Inductive Interference on Non-Electrified Railroads by Heinz Gilcher, Union Switch & Signal Inc., Joseph R. Kwasizur, Philadelphia Electric Co., and Irv Lipsitz, Consolidated Rail Corp.

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 Hz 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.

Advanced Train Control Systems, Project Status, by Howard G. Moody, Manager Train Control Technology, Association of American Railroads.

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 the C&S Division, 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, antenna and others.

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, consumer communications, indoor radio communications, power-line communications, 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 on 8½″ 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 TAX 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.

Telephone: +81-45-335-1451 Ext. 2813.
Telefax: +81-45-338-1157
E-mail: kohno@kohnolab.dnj.ynu.ac.jp
Schedule summary is due May 1, 1992
Notification of acceptance mailed July 31, 1992
Camera ready manuscript due Sept. 30, 1992.
For further information contact:

Prof. Masao Nakagawa, Chairman of Executive Committee ISSSTA '92, Department of Electrical Engineering, Keio University, 3-14-1, Hiyoshi, Kohoku-ku, Yokohama 223 JAPAN.
Telephone: +81-45-563-1141 Ext. 3329
Telefax: +81-45-563-2773
E-Mail: nakagawa@nkgw.elec.keio.ac.jp

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

Applications: navigation and route guidance; driver aids (vision enhancement and collision avoidance); travel information; advance traffic management; fleet and freight management; automation for toll collection; vehicle identification and monitoring; route planning and optimization; traffic simulation tools; demand management; public transport management & control; road safety; and environment monitoring & control.

Evaluation: Tests and demonstrations; economic estimates; social acceptability; field trials; human behavior; driver vigilance monitoring; driver response and acceptance; man/machine interface; and safety problems.

Institutional issues: Future development and policies; standardization; public/private ownership; national and international programs and technology sharing; organizational issues; systems architectures; product liability; and jurisdictional problems.

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 5SB, England.

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

Comprail '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 August 18-20, 1992 at the Old Colony Inn in Alexandria, Virginia.

The following major areas of interest are to be 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.

Management 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.

Manufacture and testing: Computer integrated manufacturing; robotics; measurement of track and rolling stock performance and stability; CAD/CAM and its use in railway 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.

Signaling and train control: Transmission based signaling for metros; automatic train control; recent advances in central control rooms; electromechanical interlocking and other automated systems; computer software for command and control; safety evaluation of computer based ATC/signaling systems; and modern signaling techniques.

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 Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO4 2AA, United Kingdom.
Telephone: (0703) 293223 Int. Tele: 44 703 293223
FAX (0703) 292853 Int. FAX 44 703 292853 ✦

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 Railroad. 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 toward the year 2,000 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 ares 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 2,000 96%+ of BN's ton miles will be on welded rail. New in-track electric 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 with conventional wood ties. By 2,000 BN plans to have approximately 15% of its heavy tonnage, high curvature lines on concrete ties.
- 33% improvement in rail life, due to cleaner steel, head hardening, wheel flange lubrication and rail grinding. Rail life of 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 the dynamic 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 bracing trucks. Reduces wheel wear and rolling resistance and also enhances truck stability, and raises the threshold speed at which truck hunting begins. Test results at Pueblo 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 fault detection and diagnostics (BN-Rockwell)
- AC traction with better adhesion and better reliability (BN-EMD)

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

BN's major thrust in alternate fuels is 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 inter-car gaps/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 projects 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 digital microwave and fiber optics for transmission of data and voice in the rail industry. For the most part see majority 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.

Henderson 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 portables, 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 99.99% accuracy. An industry standards has been approved. BN is equipping locomotives, fuel tenders and end-of-train devices with AEI tags. By the end of 1991 BN will have 46s 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 these detectors detect 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 1½ years. Five others will be installed at Mandan, ND; Guernsey, WY; Weston, MO; Big Lake, MN and Wayzata, MN.

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

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

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 Bold") uses a replacement for one of the bearing cap retainers that has been hollowed 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 carsets 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 locomotives and maintenance-of-way vehicles.
- Real-time position and speed information provided on all on-track vehicles (satellite derived in ARES system).

Automatic/computerized 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).
- Track authority sent via digital data link.

- Authorities displayed on CRT in locomotive cab in user friendly way to eliminate confusion and misinterpretation (and time).
- Computerized schedule planning to accommodate changing customer requirements and facilitate reaction to off-normal, emergency situations.
- Computerized maintenance planning to improve utilization of maintenance windows and minimize train delays.
- Real-time, accurate data provides the tools for better asset management and utilization providing locomotive tracking and power assignment, and work-order status/tracking-pick-up/set-out lists.
- Accurate position and speeds will allow reduced train spacing and yield more track capacity (density).
- Accurate train history automatically available through automatic record (no train sheets) and automatic crew time/payroll.

Displays reduce crew workload, avoid misinterpretation, confusion and enhance safety. Displays also help in familiarization with new territory and other aspects of crew training.

Real-time information on locomotive health and status on BN consists of on-board fault detection and diagnostics. Data is sent to maintenance/service facilities via digital data link. Advantages include helping locomotive engineer correct minor problems enroute, cut out/idle low efficiency power, and reduces on-line failures.

BN is in the process of deploying a locomotive analysis and reporting system on 100 locomotive (50 Gp 50's and 50 SD 40-2's). Data will be collected on 41 parameters including horsepower, fuel quantity, oil quantity, oil pressure, oil and water temperature, traction motor amps, etc. Each of these parameters will have nominal values stored in a computer and exceedences will be recorded and sent via a digital data link to computer terminals at BN maintenance facilities and to locomotive distribution people.

Safety

innovation and new technology can play a key role in improving the safety environment in the railroad industry, Henderson stated. As a means of reducing crossing accidents, BN is putting strobe lights on locomotives.

A joint project between BN and Video Masters and the City of Jonesboro, AR has resulted in the installation of a prototype traffic monitoring system in an effort to improve grade crossing safety. This system uses video cameras to record images of motorists driving around activated crossing gates. The video images including a license plate close-up are digitized and automatically sent to a playback unit in the Jonesboro Police Department. Video snap shots are printed into hard copy for evidence in ticketing violators. ✦

Problem statement made for ATCS

Costs of implementing the Advanced Train Control System on America's railroad has been discussed widely among railroad men, suppliers and others. Recently, the Transportation Research Board's Committee A2MO2-Electrification and Train Control Systems for Guided Ground Transportation Systems, developed a research problem statement on this subject. It is printed herewith:

NAME OF PROBLEM: Advanced Train Control System Implementation Costs.

THE PROBLEM: Only very general estimates have been developed by potential users as to costs to install, operate and maintain Advanced Train Control Systems. Also, no detailed cost analyses have surfaced covering the training of personnel using ATCS or those who maintain hardware or software used in ATCS.

ATCS can be implemented in a building-block approach with incremental investment. Thus ATCS should be evaluated specifically at each level of implementation. For example, ATCS has been developed with four basic levels:

Level 10—Centralized route and block interlocking logic in a computer-aided dispatch system.

Level 20—Automated transmission of movement authorities and other instructions via a data communications system; the data communications may also be used for manual reports of train location or other data.

Level 30—Automatic location reports and full train tracking within the dispatch system.

Level 40—Full field interlocking.

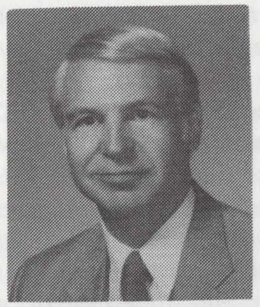
Thus there are four opportunities for an economic and feasibility evaluation of ATCS implementation.

OBJECTIVE: Identify and document specific costs covering purchase or lease of hardware or software, training of personnel who will operate and use ATCS, such as train dispatchers, train crews, maintenance of way personnel, signal and communications personnel as well as management who may well have to be reoriented into the real-time ATCS operations. Training of personnel who will maintain the ATCS hardware and software will be a cost study in itself.

CURRENT: Some individual railroads have made cost analyses but there is a need for an economic evaluation to be made of ATCS.

URGENCY: While specifications have been developed for ATCS components, and a few railroads have test installations covering portions of an ATCS system, the potential savings would indicate that more rapid implementation of ATCS by railroads would be of great economic benefit. ✦

Washington News



Eric Schimmel, Washington News Editor

Refarming Spectrum

The Federal Communications Commission has issued a Notice of Inquiry in 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 virgin spectrum is history, we must also learn to 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 (Notice)* 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 the regulatory 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 plan today to meet tomorrow's demand for more reliable and diverse communications services that will include normal mobile to base communications, mobile data, mobile 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 above 800 MHz permit and encourage the use of spectrum efficient technology and equipment. Users may also establish their own radio systems or purchase service from commercial providers. Channel exclusivity provides incentives for users to operate in the most efficient mode available. Users also have the flexibility to install highly efficient technologies, such as 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 provide users the same technical flexibility and licensing options available at 800 MHz and above. That is, we

want to assure that users have the flexibility to use the most advanced technology and equipment available and not be frustrated in their efforts to do so by an antiquated set of rules and regulations.

5. Thus, many of the concepts discussed below, technical flexibility, channel exclusivity, broadly defined radio services, and private carriers, would modify our regulations for the bands below 470 so they are more like the regulations for the bands above 800 MHz. We also consider the concept of instituting an alternative licensing fee designed to act as an incentive for spectrum efficiency. In addition, we consider band licensing, which would facilitate technologies such as spread spectrum that do not require exclusive channel assignments. Finally, we ask whether additional regulatory changes that would mandate spectrum efficiency in the absence of sufficient incentives are necessary.

6. The overall thrust of this *Notice* is to compile a full record that will allow us to develop policies and rules that include the best mix of approaches in each individual segment of the spectrum occupied by PLMR users. We hope, through this broad *Notice*, to obtain information that will allow us to resolve PLMR issues through a unified strategy rather than through the current method of handling various symptoms in many reactive, independent proceedings. We are also concerned that any such strategy minimize adverse impact on existing users. The proceeding initiated by this *Notice* is an important step toward resolving the significant problems currently facing PLMR users and providing a modern regulatory framework capable of meeting the future needs of the PLMR community.

III. BACKGROUND

7. There are three bands that are the primary focus of this *Notice*, low band (25-50 MHz, 638 channels), high band (150-174 MHz, 600 channels) and UHF band (450-470 MHz). The channels in low and high bands are generally interleaved. Thus not all channels are available at a given site. Simplex operation, in which one frequency is used for both sides of the conversation, is used on low and high band. In the UHF band, there are 302 primary channel pairs, 9 one-way paging, and 8 two-way simplex channels, spaced every 25 kHz. Channels are paired to allow use of repeater stations. In addition, there are 615 frequency offsets separated by 12.5 kHz from the regularly assigned channels in the UHF band, generally used in pairs, available for low power use on a secondary basis to the primary assignments in the UHF band.

8. There are about 1.5 million stations and 14 million transmitters licensed for private land mobile use, representing about 40 percent of the licenses issued by the Commission. The bands below 470 MHz represent about 75 percent of the PLMR licenses and about 81 percent of the transmitters. Growth in the PLMR services has been significant. Since 1968, the number of licensed PLMR stations has increased over 400 percent. In the past 5 years, the number of licensed PLMR transmitters has increased at a 10 percent annual rate. Licensees use these channels 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 470 MHz are essentially unchanged since 1968. The most significant of these rules involve specific channel allocations to specific PLMR services, specified modulation techniques, channel bandwidth limitations, modulation requirements, frequency tolerance, acceptable power levels, and shared use of channels. Many of these channels carry additional restrictions beyond our general technical standards. 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 shared with which other radio services, others specify power restrictions and type of allowable emissions. The most fundamental rule for 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.

A. Previous Internal Studies

10. In 1983, the Private Radio Bureau issued a report entitled "Future Private Land Mobile Telecommunications Requirements" (*Future PLM Requirements*) which projected spectrum requirements for the years 1990 and 2000. *Future PLM Requirements* projected significant spectrum shortages in at least twenty-one markets by the year 1990, with significantly larger shortages by the year 2000.

11. On August 1, 1985, the Private Radio Bureau issued a report on future public safety telecommunications requirements. That report projected a spectrum shortfall of between 12.5 megahertz and 44.6 megahertz in the 21 largest markets, assuming voluntary adoption of spectrum saving technologies. In response to this report and to a Congressional mandate to meet the communications needs of state and local public safety entities, we allocated six megahertz of spectrum and developed a public safety national plan that employs 55 regional public safety planning committees. This national plan also emphasizes the efficient use of available public safety spectrum.

B. Studies of the Current Situation

12. Reviews of our licensing records indicate that each channel allocated to the PLMR services has several hundred licensees operating several thousand transmitters. For frequencies below 470 MHz, a user in a major metropolitan area must expect to share his channel with one or more co-channel users located

nearby. The Appendix provides a review of PLMR use on the 150-174 MHz and 450-470 MHz bands in 49 major markets. For example, our database showed that as of October 1990, there were 516 channel pairs in the 450-470 MHz band in use within fifty miles of a central point in New York City. There were over 5000 licenses totaling 103.697 mobiles (201 per channel pair) and 46.767 pagers. Of these, 281 channel pairs were used by business licensees, with an average of 246 mobiles per channel pair, and 384 channel pairs were used by non-public safety entities, with an average of 221 mobiles per channel pair. Although mobiles per channel is an imperfect measure 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 radio service, with 110 mobiles being a reasonable upper limit for the Business Radio Service. Even if these data are not perfectly accurate, they illustrate clearly that the PLMR services in the New York metropolitan area are excessively crowded.

13. Reviews of other markets also find excessive crowding. A review of 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 channels. The average of 123 mobiles per channel 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 every 15 kHz. The overlap is made possible by geographically separating use of overlapping channels. Furthermore, given the Effective Radiated Power (ERP) used by many licensees, the fifty mile radius is less than the co-channel separation required between unrelated base stations to eliminate interference problems. Clearly, the 150-174 MHz band is extremely crowded in the Chicago metropolitan area.

14. We also studied the 450-470 MHz band within 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 thirteenth of the population of the New York Consolidated Metropolitan Statistical Area (CMSA). In *Future PLM requirements*, New Orleans was the last of the twenty-one markets for which we forecast a spectrum shortage. That report considered several possible scenarios, one of which is reasonably close to current conditions. That scenario predicted a slight surplus of channels for use in New Orleans in 1990. In fact, we found 1235 licensees on 414 channel pairs using 33.237 mobile radios (80 per channel) and 28.487 pagers. Thus, the UHF band in New Orleans is heavily used, but not saturated. Additional use of this band in New Orleans during the next few years is likely to cause the quality of communications on the existing systems to deteriorate. New York, with thirteen times the population of New Orleans, however, has only three times the number of mobiles. That fact indicates that the 450-470 band is more than saturated in New York, thus discouraging additional use of that band given current conditions.

15. In general, the evidence in the Appendix is consistent with spectrum congestion in 150-174 MHz and 450-470 MHz bands; mobiles per capita decline as population increases, indicating that congestion, rather than price or some other device, is acting as a rationing mechanism on these bands. Clearly, spectrum congestion has led many potential users either to use 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 851-866 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, Miami, New York, Philadelphia, San Francisco, Seattle, and Washington.

16. Although spectrum crowding is worst 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 Commission receive many complaints concerning new licensee, on shared spectrum from established licensees with PLMR systems outside the major metropolitan areas.

C. Trends

17. 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 stations reflects several factors including the growth of SMR systems, some consolidation due to licensing of systems as private carriers rather than community repeaters, and 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, over the last 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 channels, including those above 800 MHz, are already heavily loaded. In medium and smaller markets, the low cost of the equipment currently

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 current rules, those markets in which PLMR channels are currently crowded will 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 can 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 the form of improved spectrum efficiency, particularly by SMRs. 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 crowding on the older PLMR bands. There is need for more general adoption of 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 50 years. A variety of potentially spectrum efficient technologies, including narrowband technologies, trunking, efficient geographic reuse methods, digital multiple access technologies, 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 avoidable if enough PLMR users can be induced to adopt spectrum efficient techniques and technologies. We must, therefore, take action now to assure that PLMR needs continue to be satisfied in the future.

22. Accordingly, this *Notice* focuses on 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, spread spectrum, and digital techniques. These techniques could provide increased access to the older bands with minimal impact on current users. Our existing general policy requires shared use of these bands without any direct reward for spectrum efficiency. We must, therefore, also consider whether broader regulatory and policy changes might be required to 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 efficiency on the older PLMR bands: incentive programs such as exclusivity and fee-based incentives, and on alternative channel assignment policies including band licensing, private carriers, and consolidation of the PLMR service pools. We also seek comment on rule changes that would prohibit less efficient use of the spectrum. Finally, this *Notice* seeks solutions, technological and otherwise, 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. The fee-based spectrum incentive concept 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 spectrum efficiency. 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 that are more spectrum 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 or eliminating spectrum congestion in many markets.

25. Dynamic frequency reassignment on shared bands, packet radio, and spread spectrum 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 bursts that can be squeezed between transmissions of other users. Thus, this technology is ideal for shared spectrum. Spread spectrum uses extremely low power per unit bandwidth and can operate in a very noisy environment. 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 transmissions, might have a somewhat greater impact on existing users than use of packet radio or spread spectrum, but also have great potential for 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 transmit on any of the channels through specific base station facilities. The system automatically searches for and assigns a user an open channel assigned to that system. Trunked technology provides significantly more efficient use of the radio spectrum in terms of the number of users that can be supported. We have in the past required certain PLMR licensees 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 on a system increases, *i.e.*, the relative efficiency of trunked operations increases as the number of channels used by the system increases. Therefore, to the extent we permit trunking, we may wish to permit a licensee to trunk as many channels as practical.

27. Dynamic channel reassignment can also be done without central management. Mobile radios have been designed to monitor a series of channels automatically until an open channel is identified. That open channel is then used for that communications sequence. Other radios in the fleet identify incoming calls by continuously sequentially monitoring channels. This type of decentralized 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 dynamic channel reassignment is not trunking in the traditional sense, for the purposes of this Notice, the concepts are similar enough to be considered together.

28. The rules for operation on frequencies below 800 MHz are silent on trunked operations. This is not because we intended to prohibit trunking below 800 MHz. Rather, those rules were enacted before trunked mobile radio systems existed or were even contemplated for use on those frequencies.

29. 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 spectrum. Most commenters, however, expressed concerns about allowing trunking on the shared use bands. The Commission expressed similar concerns, stating that the "problem of allowing the use of trunked technology on frequencies that have no provisions 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 above 800 MHz. We are, therefore, starting the next stage in the process of examining the implementation of trunking in the PLMR services in this docket. This stage will also 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 sufficient 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 automatically based solely on activity by users of that system, this 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 operation. Traditional trunking is prohibited by policy below 800 MHz and requires exclusive channel assignments. The new decentralized type uses monitoring, is not prohibited, and does not require exclusive channel assignments. In considering issues regarding trunked operation, we request that commenters differentiate between these types of dynamic frequency assignment.

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 centralized trunking. For example, we asked if 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 must also be considered in the context of the existing shared use system and in the context of the band licensing proposal 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? Should we develop separate rules to govern the two types of trunking discussed above? Consider these questions for each of the following licensing schemes: shared channels under our 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 trunking on shared spectrum to assure efficient and effective operations (*e.g.*, should all users of a system be licensed 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 there be on other co-channel licensees? How spectrum efficient compared to conventional analog voice is this new type of trunking when all factors, including the impact on other licensees, are taken into account? How does the efficiency of traditional, centralized trunked operation compare to this type of trunked operations? Should this type of equipment be mandated for all users of some PLMR band?

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 permit trunked operations using frequencies from different pools? Should the same rules and policies that apply to trunking 800 MHz channels apply here, including frequency coordination, loading, and construction 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

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

34. 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 between voice transmissions without significant impact on those voice transmissions. 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 quality. We also believe 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. Data-voice hybrid 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 transmissions?

b. Are there significant problems in using packet radio on a channel shared with analog voice transmissions? If there are problems, are there rule changes 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 transmissions 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 very wide bandwidth. Spread spectrum systems offer two important advantages over conventional transmission schemes. First, the power density of the signal is reduced at any frequency within the transmitted bandwidth, thereby reducing 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 abilities to resist jamming (intentional interference), detection and interception. Spread spectrum is allowed 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 those 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 shared use frequencies. Before we can do so, there are several technical, operational and policy issues that must be addressed. For example, we need to address 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 with 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 accept that spread spectrum has little application for PLMR use. Spread spectrum systems may require many contiguous channels. This has implications regarding band licensing and intercategory sharing, as discussed below. Finally, we must consider what policies 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. Can spread spectrum be successfully used by 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 dedicate some band 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. One of the most significant advantages offered by digital is increased calling capacity through the use of various multiple access techniques. There are several other potential operational advantages to digital technology.

38. In 1988, we modified our regulations to permit the cellular industry to develop 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 explicitly 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 to facilitate 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 non-standard 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, should they be mandatory?

5. Narrowband

40. Narrowband is a relative term. By the standards of PLMR use prior 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 most PLMR applications below 896 MHz. Channel spacing is even narrower on several PLMR bands. In the 150-174 MHz band, PLMR channels are generally 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 generally spaced every 25 kHz. Between those 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. At 900 MHz, our rules restrict bandwidth to 13.6 kHz and channels are only spaced 12.5 apart. Alternatively, narrowband may refer to 5 kHz amplitude compandored 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 mandatory and voluntary 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 apply the bandwidth standards (13.6 kHz) for use of 896-901 MHz and 935-940 MHz to the older PLMR bands or develop a channelization scheme to convert the 150-170 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 will also soon be expanded as a result of our recent allocation of the 220-222 MHz band for narrowband land mobile radio use.

43. As recent rule makings indicate, we would prefer to permit, rather than to mandate, use of spectrum efficient narrowband technology. In

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 carriers where permitted, could seek the most 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 kHz band emission can concurrently transmit on any other part of that channel. During that narrowband transmission, only that user has access to residual portions of the overall 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 permit and 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 rule 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 technology may be incorporated into highway systems to interact with the vehicles using those roads. PLMR systems may eventually interact with new services such as personal 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 on 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 use of 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 on the older PLMR bands is that interference criteria are comparatively easy to develop and enforce. It is more difficult to develop interference criteria when differing 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 the crowded radio environment in this band. We have therefore reallocated the 220-222 MHz band to the PLMR service partly to afford spectrally efficient narrowband technology an opportunity to develop and gain acceptance in the marketplace.

50. As we discussed above in paragraph 5, many of the policies we consider in this *Notice*, including exclusivity, 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 spectrum allocation. In the older PLMR bands, however, adoption of these policies is complicated by the fact that these channels are assigned on a shared, non-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 exclusivity, 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 past. SMR and 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 granted to 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 incentives may be required. We consider below two possible incentives, one incorporating exclusivity and one fee-based.

a. Exclusivity

52. We have granted exclusive use of frequencies in the past to encourage specific spectrum efficient technologies such as trunking. Trunking as applied to PLMR use above 800 MHz was designed for exclusive use channels. Other spectrum efficient techniques, such as cellular radio and some digital multiple access techniques, are inefficient or impractical without exclusivity as presently implemented.

53. It has also been argued that licensees will be more concerned about spectrum efficiency if they have exclusive rights to use a channel in a given area. While a licensee with exclusive use of one or more channels may continue to be inefficient in the short run, in the long run, rational licensees will seek to maximize the value of "their" spectrum, much as they would seek to maximize the value of an asset such as land. We view the probable application during the 1990's of second generation digital cellular and SMR technology as affirmation of the validity of this theory. This maximization of value may involve selling part or all of one's rights, particularly if another party has a higher value use for that spectrum. Higher value can occur either through an alternative application or through better operational or financial management (perhaps due to economies of scale from consolidation of several smaller operations). The concept of exclusivity has gained such general acceptance that it has become viewed as an automatic feature of new allocations to the PLMR services.

i. Stop New Licensing

54. The policy of uncapped, shared use channels, can be phased out in favor of exclusive use channels in several ways. The simplest method would be to stop accepting applications, in some or all markets, for use of some or all of the shared bands. Additional use, either in the form of expansion by existing users or the addition of new users, would require concurrence of all co-channel users within a specified radius. In certain radio services, the number of existing licensees on a channel is very low, even in crowded markets such as New York. On any such channel, existing licensees would quickly be in a position to maximize the value of that channel. In other radio services, particularly the Business Radio Service, many licensees share each channel. On those channels, a licensee would have some difficulty implementing advanced technologies such as centralized trunking or digital TDMA. The fact that no additional users could be added without permission would, however, encourage coordination among existing licensees to implement advanced technology.

55. Applicants seeking licenses for new systems would be forced either to pay existing licensees for the right to share their channel or to use another band, perhaps above 800 MHz. Some existing licensees on other bands would probably respond by

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 constructive manner, implementing, or agreeing (for a fee or other considerations) to allow other existing or future licensees to implement spectrum efficient systems, some licensees may obstruct efficient, intensive use of their channels. The large number of channels involved should, however, provide sufficient channels in each market on which existing licensees would be willing to permit additional use, particularly through use of spectrum efficient equipment.

ii. 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, on an exclusive use 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 band newly made 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 access to clear spectrum. In addition to 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. Even if a band were to become available soon, 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, and 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 we could begin licensing again on the old band.

59. Another problem with this plan is that some existing licensees would be forced to replace equipment sooner than they wanted. 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 use on given frequencies in a specific geographic area. The exclusive use overlay licensee would have sole access to current and future residual communications capacity on those channels in that market. As a condition of obtaining an exclusive use overlay license, an applicant would be required to use highly spectrum efficient technology based on an efficiency standard that we would set above the level of currently available equipment. The existing licensees would continue to have the same access to their assigned spectrum. The exclusive overlay user, however, could contract to provide service to existing users on the new highly efficient system to eliminate potential interference. Alternatively, to gain fuller 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 induce development of equipment at least as efficient as the standard we set. Second, it would induce new and existing users, particularly in crowded markets, to adopt such 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 an exclusive overlay 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 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 allow a licensee to determine whether to implement another spectrum efficient technique or technology.

62. A concern with this plan is that spectrum efficient equipment has greater per 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 coordination, 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 that preference from encumbering the licensing process.

64. 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 over-concentration of channels in individual markets. There is also the issue of paperwork. For example, tens of thousands of licensees who previously were 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 accruing to them over the appropriate 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 justifies a particular number of channels. 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. We raise these issues and the problems associated with the three conversion plans because, we believe, short of out right spectrum efficiency requirements, exclusivity would be the most effective method of reducing spectrum crowding through increased spectrum efficiency.

Question 9:

a. Should 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, which band(s)?

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

c. For each plan, address the various major details such as timing, geographic area of exclusivity, and the specific rights of current licensees.

d. If some currently shared use channels are converted to exclusive use channels, should the potential for monopolization of channels in individual markets be a concern and, if so, what rules and regulations should we use to prevent such monopolization?

b. Fee-based Incentives

65. We could provide direct financial incentives to implement spectrum efficient equipment by charging licensing fees that vary according to factors such as bandwidth, area of operations, and spectrum efficiency. For example, the fee for a traditional 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 more communications 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 approximate the impact their existing equipment had 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 most forcefully where most needed.

67. This incentive would allow us to emphasize technical 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 save money through spectrum efficiency.

68. The biggest problems with such a fee program would be its implementation and its enforcement. For example, applicants would have an incentive to underreport ERP area of operation, bandwidth and other operational parameters. They might exaggerate efficiencies gained from trunking or from digital compression techniques, and exact measures would be nearly impossible to develop. An additional problem would be that public safety entities would be likely to he exempt, and thus would require separate treatment. In the long term, however, the cost of such a fee program, both to us and to new and exiling applicants, might be far out-weighed by the resultant improvements in spectrum efficiency.

69. An important factor with this policy is that our next step, if we decide to pursue a spectrum efficiency solution involving fees, would be to request Congress to amend 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, area of operation or other measures of spectrum use?

b. Currently PLMR licensees pay a $35 application filing fee. Licensing fees would have to be raised significantly to be a credible incentive for spectrum efficiency. If we were to use fees as an incentive for spectrum efficiency, what should be the basic fee (*i.e.*, for a single channel, single site, FM analog mobile radio system)? What discounts should be used for which factors (*e.g.*, what should the increment in fees be for 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 that we discussed above might not be 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 multisite, 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 channels in 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 spread spectrum 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 any channel within a specified set of channels. Band licensing can promote spectrum efficiency by allowing licensees to switch channels within a band at will. Greater efficiency results from licensees switching to the best, or least utilized, channels. The best channels can be identified by a person or computer based on actual on-air activity rather than by the search of a database of licenses. When channels are chosen 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 fact that signals can "skip" hundreds of miles under certain conditions, makes frequency coordination using a licensing database less effective. 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 ourselves 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 cases we handle each year. For example, band licensing makes more "air time" available in the form of quicker channel access. More important, a licensee with interference 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- or adjacent 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 (such as a chemical spill) would suffer impingement by other licensees. That problem already exists to some 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 during an emergency automatically override any other licensee. Such preemptive access exists in the United Kingdom between cellular providers and military users in the 900 MHz bands.

76. A more limited form of band licensing would entail licensing 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 repeaters using several channels and/or sites. 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 a plan is that paperwork, both for licensing and frequency coordination, would be reduced. That paperwork reduction would be particularly notable if we were to permit trunking on these 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 authorization of band licensing for that technique only. Spread spectrum requires access to many channels whose bandwidths may not be of standard size. It is unlikely that spread spectrum can exist and operate efficiently without a very 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 individual 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 eligibility and technical rules (an approach that would result in licensees using only those channels for which they are currently eligible)?

c. Should some PLMR services, such as public safety services, be exempted 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 station operations 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 technologies, and if so, which 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 user groups into the present 19 PLMR services. One of the radio services created at that time was the Business Radio Service, whose definition fits any business and many other organizations. A survey of the licensees for this category will reveal a very large number of small businesses plus almost every major institution in the country, from department stores to museums, from universities to factories, and from hospitals to hotels. That same survey will also reveal that the Business Radio Service is the most crowded of all PLMR services.

79. Channel utilization is not even across the 19 user groups. As a result, in 1981 we instituted rules to facilitate sharing among the various radio service categories below 470 MHz. In the 150-174 MHz and 450-470 MHz bands, if no satisfactory frequencies are available within an applicant's own radio service in the desired area of operation, an applicant may be assigned vacant channel(s) allocated to a different radio service.

80. The establishment of intercategory sharing rules was designed to ease the rigidity inherent in our past practice of typically allocating channels on a nationwide basis to the 19 narrowly defined radio services. In instituting those rules we considered and rejected excluding radio services from interservice sharing of frequencies on the basis of unique use of frequencies. We did, however, establish two categories of users for the purposes of intercategory sharing. The first category includes governmental eligibles in the Public Safety and Special Emergency Radio Services (SERS); the second category includes non-government eligibles in SERS and all other eligibles in the Industrial and Land Transportation Radio Services (except for the Radiolocation Service). Generally, within a category of users, the proposed rules permit frequencies allocated to one radio service to be used in another radio service in the same category. There remains significant disparity between usage levels in the categories in certain markets. Our study of the New York market did not reveal unacceptably different loading levels among the different categories, but it did find significant variation in licensing on channels allocated to different radio services within the same interservice sharing category. For example, some of the land transportation services had significantly greater geographic co-channel separation between licensees than other non-public safety radio services.

81. Starting with UHF-TV/Land Mobile Sharing in 1968, all subsequent allocations to private land mobile radio have resulted in channel assignments based upon broader user group categories such as Public Safety, Industrial/Land Transportation and Business, except in one case where technology was the sole criterion. Most recently, in the 220-222 MHz *Notice of Proposed Rule Making*, we proposed to divide the 200 available channels between the Federal Government, nationwide licenses, commercial licensees and non-commercial licensees, with no suballocation for Business, other Industrial, Land 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 group 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.

82. Several commenters 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 band, or 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 should be allocated primarily to other Industrial Radio Services was that broadly defined services (together with intercategory sharing) works well in the 800 MHz and 900 MHz bands. Those comments seeking narrowly defined PLMR pools are of interest here because they appear to argue against the concept of consolidation of the PLMR service pools. They also seem to argue against the trend of the past three decades in which those narrowly defined allocations that we considered justified have been met on a case-by-case basis using waiver procedures,

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 needs of each radio user group. 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 proceedings that might modify the services below 800 MHz. One *Notice of Proposed Rule Making* would expand the eligibility criteria for the Motion Picture Radio Service to include persons involved in producing 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 (EMRS).

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 Commission stated, "is likely 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 volume of EMS transmissions rather than from the use of the applicable frequencies by incompatible non-EMS licensees . . . Congestion resulting from EMS transmissions . . . will be alleviated only if the various eligible entities are committed . . . to the development of innovative and efficient technologies."

85. Besides the problems discussed above, particularly general inefficiencies in terms of usage patterns, the current allocation system on the shared bands inhibits spectrum efficiency by making certain spectrum efficient technologies more difficult to implement. Some digital multiple access techniques, including code division multiple access, may require a significant number of adjacent channels to operate efficiently. Because specific channel allocations for each of the 19 radio services are generally scattered within each of the older PLMR bands, rather than in contiguous blocks, significant interservice sharing, possibly using several channels in each of the two interservice categories, would be necessary to implement such techniques. In addition, several of the smaller radio services, such as the Relay Press Radio Service, have relatively few channels allocated for their use. This means that techniques such as trunking may only be practical with access to channels from other radio services. If interservice sharing were made easy enough, this might not be a problem. On the other hand, if we accept the need for interservice sharing to increase, then the existence of so many radio services may no longer be justified.

86. Any conversion from uncapped, shared use channels to exclusive use channels makes consolidation of the PLMR pools or increased interservice sharing more critical in that band. With exclusive use channels, an underallocation can exclude users from that band at the same time that other service allocations are relatively little used. In addition, various entities seeking access to channels might complain if the price paid for equivalent rights were to vary substantially within a given market because of channel allocations made on a nationwide basis many years ago.

87. We do not contemplate a complete elimination of the current policy of suballocations to PLMR services, but rather a reduction in the number of PLMR services, perhaps eventually developing a pool structure similar to the structure above 800 MHz. We would consider, for example, combining several of the industrial radio services. We could also combine several of the transportation radio services.

88. Certain radio services share many of their channels and could be consolidated without significant impact on the groups eligible for those channels. For example, the Interurban Passenger, Interurban Property, Urban Passenger and Urban Property Radio Services are already treated in our rules as a combined Motor Carrier Radio Service. The Motion Picture Radio Service shares each of its channels in the older PLMR bands with either the Special Industrial or Relay Press Radio Services. In addition, our rules can be modified to ensure that channels with necessary operational characteristics continue to be available to a given user group. For example, several channels allocated to the Business Radio Service are generally only assigned to entities engaged in furnishing commercial air transportation service or third parties engaged in providing communications to such entities.

Question 12:

a. Should interservice sharing on the older PLMR bands be expanded and, if so, how?

b. Should some of the 19 PLMR services be consolidated? If so, how should the new services be defined?

c. If services are consolidated, should technical and operational restrictions on individual channels be adjusted and, if so, how?

c. Private Carriers/Shared Use

89. We have previously explored the issue of a private carrier licensing option, in which commercial enterprises that are not eligible in a given radio service could be licensed to serve eligibles in that radio service. Many commenters at that time expressed strong opposition to the private carrier concept. They argued, for example, that allowing private entrepreneurs to operate systems on channels designated for a narrowly defined radio service would exacerbate the problems of congestion and interference. On the other hand, commenters supported our proposal to permit private carriers for paging operations. Several parties made convincing arguments that entrepreneurs can improve efficiencies on one-way paging frequencies significantly.

90. We generally believe that providing additional options will normally promote the interests of current and future licensees. In a shared use environment, entities interested in mobile radio service will only turn to a third party for service if that third party can provide more cost effective or higher quality service than they could provide on their own. If no third party is willing to provide the PLMR service they want at a price they are willing to pay, any entity may provide its own service.

91. Although we previously rejected expanding private carrier operations on two-way channels below 800 MHz, we did state that "private carriers might, at some future date, provide useful means for implementation of new technologies. Many spectrum efficient technologies, such as trunking, require operating and loading many channels or a large capital investment. As a result, only large licensees and groups of several licensees sharing equipment would find it cost effective to invest in these techniques. The private carrier option may be a practical method of making spectrum efficient communications services accessible to small licensees, much as SMRs made trunked 800 MHz service available to small businesses.

92. Private carriers have more incentive to enhance spectrum efficiency with a technology that permits the use of several hundred mobiles per channel than does an entity with only ten mobile radios. Once spectrum efficiency becomes an incentive to all licensees, the private carrier option will be justifiable to more PLMR entities. Licensees who care about spectrum efficiency, but who cannot justify their own spectrum efficient systems would opt for a private carrier that can provide such spectrum efficient service in a cost effective manner.

93. We can also consider the private carrier option in relation to the various proposals considered above. For example, we could permit private carriers only if they use spectrum efficient technology or techniques. We also could restrict private carriers to some limited number of specific channels if a band is converted from uncapped, shared use to exclusive use.

94. Finally, the private carrier concept is considered here because, to the extent that spectrum efficiency provides part of the solution to the spectrum crowding problem, it solves many of the specific problems that commenters perceived about the private carrier concept. For example, if a private carrier using advanced, spectrum efficient technology provides service on a ten channel system to scores of small and middle sized licensees using a total of several thousand mobiles, it frees many other channels to be used by other eligible PLMR users. Private carriers, by specifically promoting spectrum efficiency, should resolve many of the fears previously expressed about this concept. We would encourage PLMR entities to implement more spectrum efficient techniques/technologies on their own, or to buy service from others, like private carriers, who will implement such techniques/technologies.

Question 13:

a. In the long run, would private carriers improve or reduce spectrum efficiency on the shared bands? What other impact would private carriers have on specific PLMR services?

b. Should we allow noneligibles to serve eligibles in various PLMR services? If so, for which radio services and under what, if any, restrictions?

c. What restrictions should there be on private carriers and shared use with regard to each of the technologies and policies discussed above?

C. Restrictions on Spectrum Inefficient Technologies

95. While most of this *Notice* focuses on steps we can take to promote spectrum efficiency, we must also consider measures to require spectrum efficiency. Such restrictive regulation is reasonable in the absence of sufficient incentive for spectrum efficiency on the part of licensees. In fact, tightening our technical standards has long been one of our main tools to increase access to the spectrum.

1. Reduction of Permitted Power Levels

96. The area of coverage of a radio station is dependent on a variety of factors including output power, antenna height above average terrain, and the topography of the desired area of operations. Given typical terrain in the center of a major urban market, a 100 watt transmitter operating in the 450-470 MHz band, and an antenna 100 feet (30.4 meters) above average terrain, one would expect to receive reasonably clear transmissions as far as 25-30 miles (40-48 kilometers) away. In the 150-174 MHz band, the range is about 15 miles (24 kilometers) more. Below 50 MHz, the range is even greater. Radio systems that maximize area of coverage through use of a single highpower base station are not necessarily using the most spectrum efficient mobile radio system design.

97. Spectrum must be reused over time, frequency, and geography. Common carrier cellular mobile telephone service is a major example of a technological application designed to maximize spectrum reuse over geographic space. Cellular systems achieve coverage of a large area by dividing the area into several smaller areas (cells). Each cell uses a small number of the total available frequencies. Total power is kept low so that a given channel may be used several times within the system's coverage area (a metropolitan or rural area), although not in adjacent cells. Capacity can be increased by reducing cell size, thereby increasing

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 telephone (CT-2) and PCS both involve use of microcells. Fleet Call has proposed a multi-site system design for its SMR service. Development of PLMR cellular-like systems, particularly by large users, private carriers, and on systems shared by several users, would be one way to increase capacity on the older PLMR bands.

99. Geographic reuse in the PLMR services also may be accomplished 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 as if the associated mobiles were 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 channel sharing. A 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 increase 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 little geographic space 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 a process be applied to 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 radiolocation.

103. There will soon be several fully developed technologies that will be up to 10 times more 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 CCIR is examining various technical parameters for digital land mobile voice and data communication. We have recently established rules for a new 220-222 MHz service using narrowband technology. In the older bands, companies have begun advertising PLMR decentralized trunked systems 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 comparably efficient modes of operation. Based upon this, we allowed RAM Mobile Data, Inc. (formerly called American Mobile Data Communications, Inc.) to use an alternative technology that does not use all available 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 some specific technology, such as a trunked digital multiple access technique. The standard could be required for all new systems. Existing systems could be permitted to remain in operation for several years to allow licensees a reasonable period of usage from any equipment purchased before new standards are in place. The specific technology the standard would be based on must be able to co-exist with existing analog equipment. Alternative technologies would be permitted provided that such equipment a) can co-exist with existing equipment, b) can coexist with the type of equipment that the standard is based on, and c) is as, or more, spectrum efficient than the equipment the standard is based on. A licensee or manufacturer seeking to use or sell equipment using alternative technology would be required to demonstrate to our satisfaction that the spectrum efficiency standard is met, although we would be flexible about what is an acceptable alternative technology.

106. One shortcoming of establishing spectrum efficiency standards is that while they would provide immediate spectrum efficiency gains, they would not provide incentives to develop more spectrum efficient techniques in the future. Furthermore, new technologies developed 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:

a. Should 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

107. Unlicensed activity may 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 inaccurate. In addition, unauthorized users may disrupt critical public safety or other communications.

108. Antitheft technology exists that allows a base station to remotely switch mobile radios on or off. This same technology prevents 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. Automatic transmitter 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. ATIS mandated for all PLMR, would assist our operation Bureaus 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 radio services could 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 radios only to eligibles. Such a plan is more practical if public safety channels have a distinct frequency allocation.

110. We also see potential for the amount or 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 proposed fee-based spectrum incentives might increase the amount of unlicensed activity, particularly by disgruntled users of spectrum inefficient equipment. Exclusivity may make unlicensed use of a PLMR channel easier for licensed users to identify because the number of existing users may be more limited or unchanging. On the other hand, some advanced techniques such as spread spectrum are difficult for third parties to identify as unlicensed.

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? Would the effect on the level of unlicensed activity be sufficient cause 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?

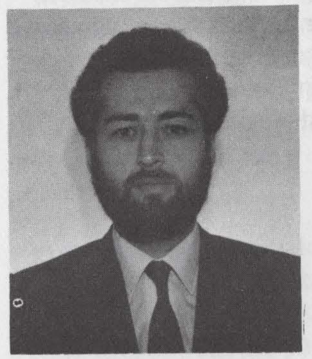
V. CONCLUSION

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

on each of the older bands. For example, we do not envision converting all shared PLMR channels to exclusive use. Rather we are developing a full record that will allow us to formulate a policy that includes the best mix of these approaches in each individual segment of the spectrum occupied by PLMR users.

112. This proceeding seeks to provide increased access to PLMR spectrum. In providing access to new and expanding users, we would also like to provide for higher quality communications (*e.g.*, less wait time to a channel and clearer communications) by both new and existing users. Among our considerations is a desire not to harm existing users and especially not to overburden new or existing public safety users. We invite all commenters to include in their comments their views as to the combination of the above concepts that would best promote spectrum efficiency, *i.e.*, provide increased access to the maximum number of licensees, without imposing an unacceptable burden on either new or existing users, and as to any other alternatives, not presented in this *Notice*, that would improve use of the older PLMR bands in the long and short runs. ✦

Communications Abstracts



J. R. Cruz,
Communications Editor

"Cross-Correlation Between 900 MHz Signals Received on Vertically Separated Antennas in Small-Cell Mobile Radio Systems," *IEE Proceedings-I*, M. T. Feeney and J. D. Parsons, Vol. 138, No. 2, 1991.

In order to establish the antenna separation necessary to receive sufficiently decorrelated samples of the signal 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 halfwave dipoles which were spaced in a vertical configuration. The received signals were coherently 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 8λ to 13λ at the base station and 1≈λ 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 arrival angle and hence low correlation can be achieved while maintaining omnidirectional coverage. At the mobile the small vertical antenna separation required suggests that an unobtrusive antenna arrangement is feasible.

"Mathematical Analysis of the Three-Ray Dispersive Fading Channel Model," Haim Goldman, *IEE Proceedings-I*, Vol. 138, No. 2, 1991.

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 rays' delays. Explicit formulas are presented for several pertinent single-variable probability density functions, covariances and joint probability density functions of the channel transfer function and of the channel power gain function.

"Alcatel Involvement in RACE," F. Casali, M. Dieudonne, J. Ernest, and P. Verbeck, *Electrical Communication*, Vol. 64, No. 2/3, 1990.

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

"Capacity of Cordless Telephone Systems with Discontinuous Transmission," H. Kashorda and E. V. Jones, *Electronics Letters*, Vol. 27, No. 10, 1991.

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

"Linc Transmitter," S. A. Hetzel, A. Bateman, and J. P. McGeehan, Electronics Letters, Vol. 27, No. 10, 1991.

An LINC 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.

"Measured Scattered Signals at 4 GHz Confirm Strong Specular Reflections off Buildings," A. R. Noerpel, M. J. Krain, and A. Ranade, *Electronics Letters*, Vol. 27, No. 10, 1991.

Measurements show the existence of large specular reflections from building surfaces of terrestrial microwave 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 boresight beam of the transmitter.

"Performance of Power Control Method for CDMA Radio Communications System," L. F. Chang and S. Ariyavisitakul, *Electronics Letters*, Vol. 27, No. 11, 1991.

Power control is used to solve the 'near-far' problem which arises in a spread spectrum system using direct sequence code-division multiple access (CDMA). A method to estimate 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 of Antenna Diversity and Decision Feedback Equalisers in Narrowband Digital Cellular Systems," Y.-J Liu and J. Ketchum, *Electronics Letters*, Vol. 27, No. 11, 1991.

Performance results are given for the combined use of a decision feedback equaliser with antenna diversity in time dispersive 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 ports.

"Effect of Errors on a Contention-Based TDMA Protocol," Lung-sing Liang and Jin-Fu Chang, *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 27, No. 3, 1991.

A hybrid contention-based time-division multiple access (TDMA) protocol was previously proposed for data transmissions. It provides satisfactory performance for an 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.

"Fade-Durations Derived from Land-Mobile-Satellite Measurements in Australia," Yoshihiro Hase, Wolfhard J. Vogel, and Julius Goldhirsh, *IEEE Transactions on Communications*, Vol. 39, No. 5, 1991.

Transmissions (CW) from the Japanese ETS-V geostationary satellite were measured at *L* band (1.5 GHz) in a vehicle driving on roads of South-Eastern Australia. The measurements were part of a program designed to characterize propagation effects due to road-side trees and terrain for mobile-satellite-service (MSS). It is shown that the cumulative distributions of fade and nonfade durations follow a lognormal and power law, respectively. At 1% probability, fades last 2-8 m, and nonfades 10-100 m, depending on the degree of shadowing. Phase fluctuations are generally small, allowing the channel characteristics to be estimated from levels only.

"A Space Diversity Channel Model for Multipath Propagation Measurements in New Zealand," Mansoor Shafi and Walter Smith, *IEEE Transactions on Communications*, Vol. 39, No. 5, 1991.

This paper describes the results of a 140 Mb/s 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 Rummler model has been fitted. It is shown that the model can also be fitted when 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.

"OFDM for Data Communication Over Mobile Radio FM Channels—Part I: Analysis and Experimental Results," Eduardo F. Casas and Cyril Leung, *IEEE Transactions on Communications*, Vol. 39, No. 5, 1991.

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 Cimini. 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.

"Statistical Channel Impulse Response Models for Factory and Open Plan Building Radio Communication System Design," Theodore S. Rappaport, Scott Y. Seidel, and Koichiro

Takamizawa, *IEEE Transactions on Communications*, Vol. 39, No. 5, 1991.

This paper presents statistical radio channel impulse response models for the analysis and design of wireless factory and open plan office communication systems. The models incorporate first- and second-order statistics to characterize the discrete impulse responses of indoor radio channels for both line-of-sight (LOS) and obstructed (OBS) topographies. The effects of large scale transmitter-receiver (T-R) separation distance, small scale receiver movement, and models for the correlation of multipath component amplitudes over one meter local areas are developed from 1.3 GHz measurements reported in [1]. SIRCIM, a computer simulator based upon the models presented in this paper, has recreated multipath power delay profiles and CW fading profiles that are highly representative of measured data. Large scale models for path loss are implicitly included in this work.

"New 16-QAM Trellis Codes for Fading Channels," J. Du and B. Vucetic, *Electronics Letters*, Vol. 27, No. 12, 1991.

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 TCM code design criteria based on effective code length (ECL) and product distance (PD) as well as Euclidean distance (ED) are used to construct new 16-QAM TCM schemes with ideal channel state information (CSI) on 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 codes.

"Frequency Response and Path Loss Measurements of Indoor Channel," G. Morrison and M. Fattouche, *Electronics Letters*, Vol. 27, No. 12, 1991.

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 described. An improved postprocessing procedure is also described. Test results obtained for indoor measurements in the 1-2 GHz band (2.3 ns resolution after windowing) and 945 MHz path loss measurements are presented as examples.

"Simple Method of Multipath Delay Difference Detection for π/4-Shift QPSK," S. Yoshida, G. L. Tan, H. Zhou, A. Hirai and T. Takeuchi, *Electronics Letters*, Vol. 27, No. 12, 1991.

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

"Performance of Phase-Invariant Trellis Coding for Differentially-Encoded Coherent M-PSK Signals on Rayleigh Fading Channels," L H. C. Lee and P. G. Farrell, *Electronics Letters*, Vol. 27, No. 12, 1991.

Rate-$(n-1)/n$ phase-invariant trellis coding with unquantised maximum-likelihood Viterbi decoding for differentially-encoded coherent M-ary ($M = 2^n$) PSK signals on Rayleigh fading channels is considered. The simulated bit error probability performance of the trellis-coded modulation is presented for four- and eight-state linear and nonlinear codes of constraint lengths 3 and 4, respectively, with coding gains of at least 2.5 db at a bit error rate of 10^{-3}

"New Low-Complexity Decision Feedback Equalisation Technique for Narrowband Digital Cellular Systems," Y. -J. Liu, *Electronics Letters*, Vol. 27 No. 13, 1991.

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 digital cellular systems over fast time-varying Rayleigh fading channels.

"Statistical Modelling and Computer Simulation of Indoor Radio Channel," R. Ganesh and K. Pahlavan, *IEE Proceedings-I*, Vol. 138, No. 3, 1991.

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 college offices. In the manufacturing floors, there is plenty of open space without any presence of walls, as a result of which most of the received power is concentrated in the initial paths. The college office areas have 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 spreads from the simulated profiles is compared with that obtained from the measured profiles.

"Bandwidth Efficient QAM Schemes for Rayleigh Fading Channels," W. T. Webb, L. Hanzo, and R. Steele, *IEE Proceedings-I*, Vol. 138, No. 3, 1991.

Techniques to improve the BER performance of 16-level QAM transmission over 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 over an order of magnitude, by introducing a circular constellation coupled with differential amplitude and phase encoding, compared with a square QAM constellation. When an oversampling and interpolation technique was combined with the circular constellation with differential encoding another order of magnitude 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 do. 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.

"The Effect of Capture on Performance of Multichannel Slotted ALOHA Systems," Wuyi Yue, *IEEE Transactions on Communications*, Vol. 39, No. 6, 1991.

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, then by using these probabilities, we calculate the throughputs, average packet delays for both IFT (immediate-first-transmission) and DFT (delayed-first-transmission) protocols and numerically compare the performances of the systems to and without capture. Numerical results show that when we consider a quantitative capture restriction u, in a multichannel system having fixed total bandwidth, depending on parameter u and channel number M, the improved system performance such as the average channel utilization and average packet delay can be obtained. We also can calculate coefficients of variation of the packet delay and the packet interdeparture time of this capture system by using the analysis of probabilities of successful transmission given in this paper and the analysis in [7].

"Error Floors in the Satellite and Land Mobile Channels," Israel Korn, *IEEE Transactions on Communications*, Vol. 39, No. 6, 1991.

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) of frequency shift keying (FSK) with either DPD, limiter discriminator integrator detection (LDID) or limiter discriminator detection (LDD) are suitable candidates. The probability of error in a digital communication scheme is a decreasing function of signal to noise ratio (SNR) and usually decreases to zero when SNR tends to infinity. This does not happen in the SMC and LMC due 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 present formulas for the error floor for DPSK-DPD, FSK-DPD, 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.

"Trellis-Coded Differentially Coherent (TCDC) MPSK with Carrier-Phase-Noise," Harry Leib and Subbarayan Pasupathy, *IEEE Transactions on Communications*, Vol. 39, No. 6, 1991.

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 coherently demodulated 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. The main advantage of differentially coherent trellis-coded MPSK is when a low probability of error is required over a channel which is dominated by carrier-phase-noise and bandwidth conservation is important.

"Trends in Cellular and Cordless Communication," David J. Goodman, *IEEE Communications Magazine*, Vol. 29, No. 6, 1991.

As products that allow people to use the 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 rapidly. To meet this demand, increase quality, and enlarge the range of applications, new second generation systems are emerging. The second generation will be characterized by digital speech transmission and enhanced capabilities of wireless terminals to exchange signaling and control information with the remainder of the network. Meanwhile, researchers and planners are devoting increasing attention to third generation technologies to meet the needs of the next century.

"Explicit Multiple Building Diffraction Attenuation Function for Mobile Radio Wave Propagation," S. R. Saunders and F. R. Bonar, *Electronics Letters*, Vol. 27, No. 14, 1991.

A new explicit solution to the problem of multiple edge diffraction over arbitrary numbers of equal height parallel half planes is presented. The solution applies to a source of any height and is straightforward to evaluate. The result is important in modelling radio propagation in built up areas.

"Simplified Evaluation of Outage Probability for Cellular Mobile Radio Systems," G. Immovilli and M. L. Merani, *Electronics Letters*, Vol. 27, No. 14, 1991.

The effects of cochannel interference in a mobile radio network are investigated, to highlight a method with which to analytically evaluate the corresponding outage probability in an extremely simplified manner. The general methodology presented can in particular be applied when Rayleigh fading, log-normal shadowing and path losses larger than those in free space are considered.

"Concatenated Coding and Interleaving for Half-Rate GSM Digital Mobile Radio System," L. H. C. Lee and P. G. Farrell, *Electronics Letters*, Vol. 27, No. 14, 1991.

A concatenated Fire and convolutional coding scheme with burst error-trapping and eight-level soft-decision Viterbi decoding for the half-rate GSM digital mobile radio system, operating at a gross coded speed of 11.4 kbit/s is proposed. The concatenated coding scheme was designed in conjunction with a 6.7 kbit/s speech coder which offers good speech quality and robustness against noise disturbance. The simulated bit error probability performance of the scheme is presented, and is compared with that of the full-rate GSM system.

"Path Loss Prediction in Multifloored Buildings at 914 MHz," S. Y. Seidel and T. S. Rappaport, *Electronics Letters*, Vol. 27, No. 15, 1991.

Quantitative models are presented that predict the effect of walls, office partitions, floors, and building layout on path loss at 914 MHz. Average floor attenuation factors (FAF), which describe the additional path loss (in dB) caused by floors between transmitter and receiver are found for up to four floors in a typical office building. Average FAFs are 12.9 dB and 16.2 dB for one floor between the transmission and receiver in two different office buildings. For same floor measurements, attenuation factors (AF) are found to be 1.4 dB for each cloth-covered office partition and 2.4 dB for each concrete wall between transmitter and receiver.

"Subband Speech Coding and Matched Convolutional Channel Coding for Mobile Radio Channels," Richard V. Cox, Joachim Hagenauer, Nambirajan Seshadri, and Carl-Erik W. Sundberg, *IEEE Transactions on Signal Processing*, Vol. 39, No. 8, 1991.

Due to increased radio spectral congestion, the trend in future cellular radio systems is toward digital transmission. The recent advances in spectrally efficient modulation techniques and high quality low bit rate speech coding have further aided this move. However, mobile radio channels are subject to signal fading and interference which causes significant transmission errors. The design of speech and channel coding for this application is therefore challenging. In this paper, the effects of digital transmission errors on a family of variable-rate embedded subband speech coders (SBC) have been analyzed in detail. It is shown that there is a difference in error sensitivity of four orders of magnitude between the most and the least sensitive bits of the speech coder. As a result, a family of rate-compatible punctured convolutional (RCPC) codes with flexible unequal error protection capabilities have been matched to the speech coder. These codes are optimally decoded with the Viterbi algorithm. On a Rayleigh fading channel with differential four phase shift keyed modulation, more than 5 dB gain in channel signal-to-noise ratio can be obtained by using 4 levels of unequal error protection over conventional designs that utilize only 2 levels. This gain is achieved over a large range of channel signal-to-noise ratios, at no extra bandwidth requirement and only a small complexity increase. Among the results, analysis and informal listening tests show that with a 4-level unequal error protection scheme, transmission of 12 kb/s speech is possible with very little degradation in quality over a 16 kb/s channel with an average bit error rate of 2.10-2 at a vehicle speed of 60 mph and with interleaving over two 16 ms speech frames. The SBC speech encoder/decoder and the RCPC channel coder/decoder have been implemented on a single AT&T DSP-32 floating point signal processor. The overall end-to-end delay is about 88 ms. ✦

In 1847, Professor Moses G. Farmer, a notable American scientist, succesfully operated an experimental locomotive, powered by a 48-cell Grove nitric-acid battery, that carried two passengers along an 18-in. gauge track at Dover, NH.

FRA and TRB explore safety of high-speed rail and maglev

Safety of passengers is a main concern in the operation of high-speed rail and magnetically levitated vehicle systems. These concerns were expressed by some 100 engineers, planners, research scientists and railroad operators attending the April 7-10, 1991 workshops in St. Louis, MO. The workshops were sponsored by the Transportation Research Board and particularly its Committee A2MO5-Guided Intercity Passenger Transportation, and the Federal Railroad Administration.

Maglev Guideway and Vehicles

Safety issues related to maglev guideway and vehicles consisted of seven topics and groups developed research statements concerning these topics.

As to guideway design and standards, it was brought out that intrusion into the guideway structure to cause misalignment should be considered. Also egress from the guideway in emergencies where trains cannot proceed should be taken into account when guideways are designed. Maintenance should be considered, especially the time required for it should be low compared to operating time. Probably, there should be monitoring of the guideway.

As for tunnels, some work has been done with aerodynamic modeling but more should be done. With high-speed rail trains, there is a wake of air pushed by the trains in tunnels. Some tunnels have side vents so trains pushing air causes it to leak out of the tunnel reducing pressure in the tunnel. This air problem must be considered if the tunnel is large enough for two tracks and will have the condition of trains passing in the tunnel.

Crashworthiness of vehicles for maglev systems is a key element because of the high speed, some say as high as 300 mph. Programs to test crashworthiness of vehicles are considered essential. Here, computer simulation may be of value. Some attendees said a maglev vehicle should be more like an airplane body. Safety standards should be developed.

Braking capabilities brought out many variations in the discussions to due the high speed of travel. A maximum allowable braking rate should be developed with three types of passenger carrying situations:

- Seated and belted passengers.
- Seated, non-belted passengers.
- Standing passengers.

Present maglev systems have a primary braking system with the linear motor, and a secondary braking system, the eddy current brake. Train separation and braking distances are also factors to be considered.

Performance standards for passenger seating need to be developed. Concerning vehicle interiors, luggage and on-board safety equipment need to be considered along with passengers. Emergency egress (exit) procedures must be developed, especially for maglev systems, which are elevated. If a maglev train stops between stations and passengers must leave the train, some safe means must be available to get people off the elevated structure and down to the ground. Note: In the discussion it was said that maglev will be elevated, although no present revenue systems are in service.

System Design Criteria and Operations

System design should plan for safe operation with a minimum of accidents. Also to be considered are the interactions between humans, the environment, machines and procedures. There are trade-offs between cost of safety and degrees of safety that should be considered.

In establishing methodology for system design, one must, as a minimum, consider the following elements:

- People
- Procedures
- Facilities and equipment
- Environment
- Hazard management

In accounting for track/train dynamics, track geometry safety limits have to be considered and developed. Interaction between guideway and vehicle is a vital safety and operational element.

Design guidelines are needed for rider comfort as well as for rider safety. Consideration should be given to "g" acceleration longitudinally as well as vertically. Noise vibration also affects ride quality.

When considering operational training, performance standards are vital to help create a profile of the person who will perform the function required. Human factors play an important part in this area of operations. Operational training must go through various phases to be successful:

- Classroom training
- Use of simulation
- On-the-job training
- Maintainability to do the job

Inspection and maintenance should consider new diagnostic techniques and concepts. Maintenance and testing cycles should be developed. Concerning maglev guideway, quality standards should be developed probably by structural engineers, who 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. ✦