will not be meeting. These needs include transmissions protected by the latest encryption technologies. For example, an imaged map indicating the location of a recent oil field find or an imminent drug bust.

C. An Allocation of 75 MHz For Private Users is Required.

81. Given the unique factors affecting private users, and as explained below, a spectrum allocation of 75 MHz for private emerging technology systems is extremely conservative and clearly warranted. This amount of spectrum is predicated on a detailed analysis of advanced land mobile communications services (e.g. facsimile, snapshot and slow scan and full motion video, voice dispatch, telephone interconnect, transaction processing, and decision processing/remote file access) including the: 1) raw information content associated with each service, 2) the expected advances in compression/source coding, 3) channel coding and 4) spectral efficient wireless delivery technologies.[38/] The results of this analysis, as shown in Table 1 of Appendix C, provide an estimate of the bandwidth requirements for each of these new services. A forecast of the request rate and penetration was made for each of these new services. Transaction processing is common to many currently operating private systems. The data stream is quite short in duration. Applications include caller identification, user status and order entry.

[38/] See Appendix C.

82. In contrast, decision processing/remote file access includes significantly larger data transactions and usually involves the combining and/or manipulation of the information by the end user. An example of such an application might be a bridge inspector who would combine the information obtained at a remote flood location with information drawn from a database to provide an analysis of the damage that a rapidly rising water table may have on the bridge.

83. Based on the above information and the estimates in Tables 4 and 5 of Appendix C, 75 MHz of spectrum would be required to support advanced services systems that would include both new and emerging information services, and traditional voice and data dispatch. It is important to note that this forecast assumes that only 25% of the total private land mobile users will have migrated to these new emerging technology systems. The penetration of individual services other than voice dispatch would be less and it is assumed that slow scan and full motion video would be limited during this decade.

84. The actual usage and penetration of these services will obviously be different than these estimates, but it appears that an allocation of at least 75 MHz will be required if a reasonable number of private users are to avail themselves of these advanced services and provide the public with the resultant benefits of

improved response time, productivity, safety, and emergency attention.

VIII. CONCLUSION

85. The demand for private land mobile communications capacity continues to grow in response to an increasing number of private radio users as well as the continuously evolving requirement for innovative information services. There is clear evidence that the historical growth trends for the private radio services will continue. In the past, the Commission and the private land mobile industry have worked together to meet this demand through timely spectrum allocations and the introduction of new spectrum efficient technologies. It is imperative that this mutual response by the Commission and the industry continue in the future if U.S. industry, businesses and public safety entities are to meet the emerging challenges of the future.

86. The spectrum refarming effort now underway at the Commission should, over time, introduce greater efficiencies in spectrum utilization. However, the resulting efficiencies will only permit the industry to keep pace with the continuing growth in traditional voice and dispatch services. Improvements in semiconductor technology will continue to stimulate new requirements, increasing the demand for advanced wireless information services.

87. The private land mobile industry and radio users are poised to invest in the future system architecture that will support advanced information services. A discrete allocation of 75 megahertz of spectrum for private dedicated emerging technology systems is imperative if the manifold benefits of advanced information services are to be made available to domestic public safety and public service entities.

88. To accommodate the critical future need for these advanced information services, the Commission must take immediate action to allocate sufficient spectrum for private user emerging technology systems. Accordingly, the Coalition of Private Users of Emerging Multimedia Technologies urges the Commission to designate 75 megahertz of spectrum to accommodate such systems. Only through such an allocation will the public safety, public service and private sectors be able to effectively compete in the prevailing world economy of the twenty-first century.

WHEREFORE, THE PREMISES CONSIDERED, the Coalition of Private Users of Emerging Multimedia Technologies submits this Petition for Rule Making and urges the Federal Communications Commission to place the Petition on Public Notice at its earliest convenience and proceed to issue a Notice of Proposed Rule Making aimed at allocation of spectrum in the manner requested.

Respectfully submitted,

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ATTACHMENTS:

Exhibits I, II, and III
Appendix A
Appendix B
Appendix C
Appendix D

EXHIBIT I

FLEET WIDE AREA SPECTRUM
(Major Urban Area)

Licensees	Total		Private	
Band - MHz	Chnls	MHz	Chnls	MHz
25-50	632	12.5	-	-
150-174	553	8.5	553	8.5
450-470	324	16.2	324	16.2
470-512	216	10.8	216	10.8
806-821	600	30.0	250	12.5
821-824	230	6.0	230	6.0
896-901	399	10.0	160	4.0
	2954	94.0	1733	58.0

EXHIBIT II

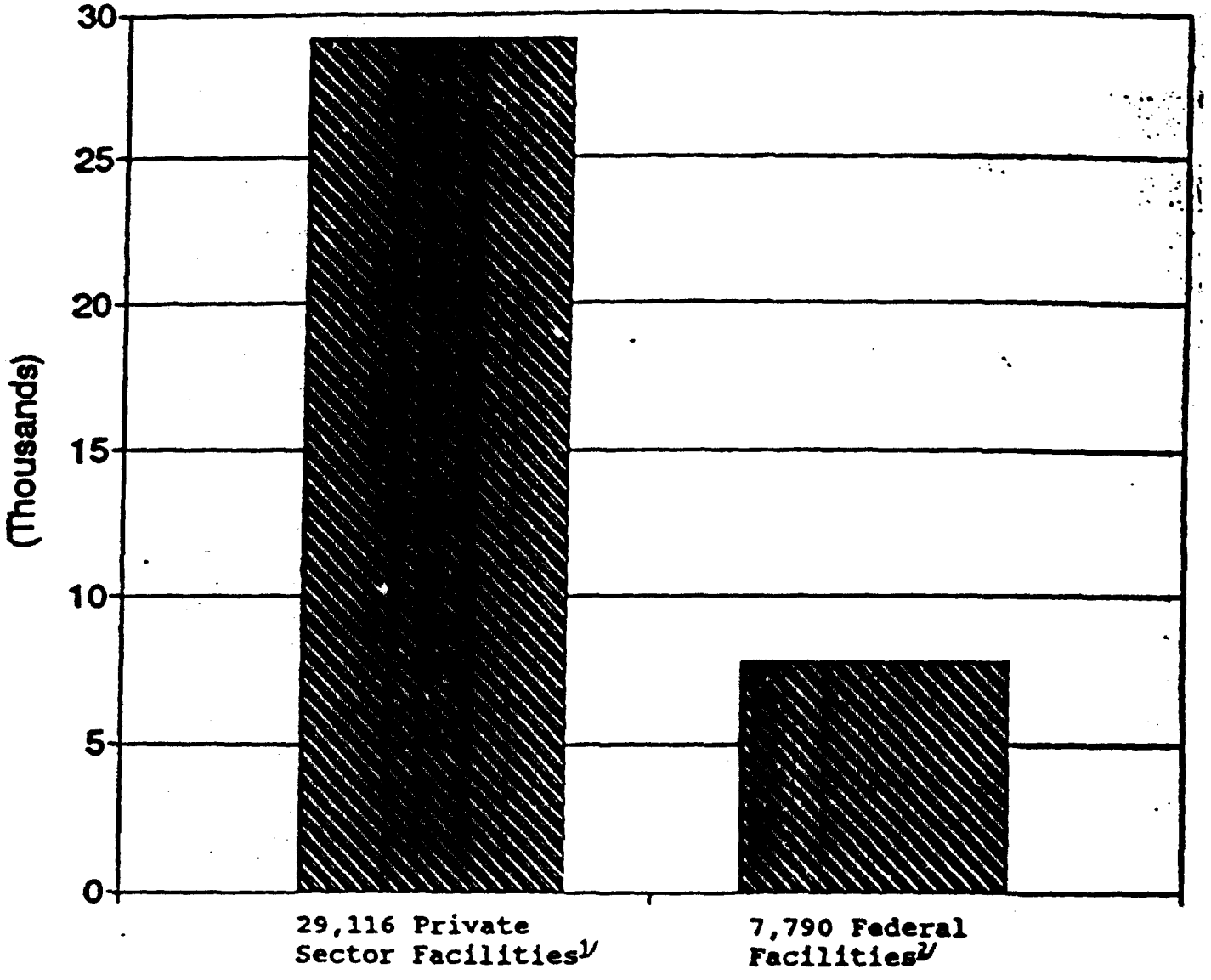
PRIVATE LAND MOBILE RADIO

TRANSMITTER/CHANNEL FORECAST
(Major Urban Area)

	1992	2000
Private Transmitters	645,000	1,028,000
Channels		
150-174	553	553
450-470	324	486
470-512	216	518
806-821	250	803
821-824	230	276
900 MHz	160	280
	1733	2976
Mobiles/Channel	372	345

EXHIBIT III

NUMBER OF FACILITIES IN COMMERCIAL 2 GHZ BAND VERSUS NUMBER OF FACILITIES IN FEDERAL 2 GHZ BAND



1/ /FCC OET Study TS/92-1, Table 3 at page 19.

2/ NTIA Report TR 92-285 at page 2-1 (5,539 facilities at 1710-1850 MHz, and 2,170 facilities at 2200-2290 MHz).

APPENDIX A

ABSTRACT:
The improvement in semiconductor technology has been and will continue to be the driving force behind improvements in land mobile radio. Its impact on computer and other communications needs expands the demand, and thus the spectrum requirements. Conversely, the improvements in information compression and channel efficiency that are possible because of semiconductor technology improvements offer a means of offsetting some, though not all, of the spectrum demand. System architecture trends and associated spectrum management policies must be responsive to these developments to provide the services required by the radio user.

INTRODUCTION:
This Appendix is an update of the material presented in a paper at the 1990 IEEE International Symposium on Electromagnetic Compatibility[1]. The thesis remains today as it was then, semiconductor technology brings with it additional ways of addressing spectrum requirements, but also creates additional demand for new features that require more innovative spectrum management policies such as the designation of emerging technologies bands and the allocation of that spectrum in a timely manner.

The fundamental technology thrust in the 1990's will be, as it has been in the recent past, that of semiconductor technology. This technology is increasing approximately an order of magnitude in capability every five years. The impact that this has had on computer and communications needs and capabilities has created the demand for increased spectrum. The increase in semiconductor capability will permit the partial offset of the spectrum demand by improved information compression techniques as well as increasing the capability of communication channels.

Communication system architecture and the associated spectrum management policies are also affected by semiconductor technology. It is the purpose of this Appendix to examine the impact of semiconductor technology on the communications system requirements of the future, and on the resultant requirement for the allocation of additional spectrum.

SEMICONDUCTOR TECHNOLOGY TRENDS:
The advancement of semiconductor technology has been the key contributor to the progress of other electronic technologies, particularly communications technology. The improvements in semiconductor processing and materials have resulted in roughly an order of magnitude advance every five years. This trend is demonstrated in the histories of memory devices, microprocessors, and computer systems.

In the area of semiconductor memory, tremendous advances have been achieved. Figure A-1 presents the chip density of Dynamic Random Access Memory (DRAM) in bits versus the year of original market introduction [2-4]. The clear trend indicated here shows that chip densities have increased by a factor of ten every four years. Although Figure A-1 addresses only DRAM devices, similar trends with almost identical slopes are observed for other types of memory devices [3].

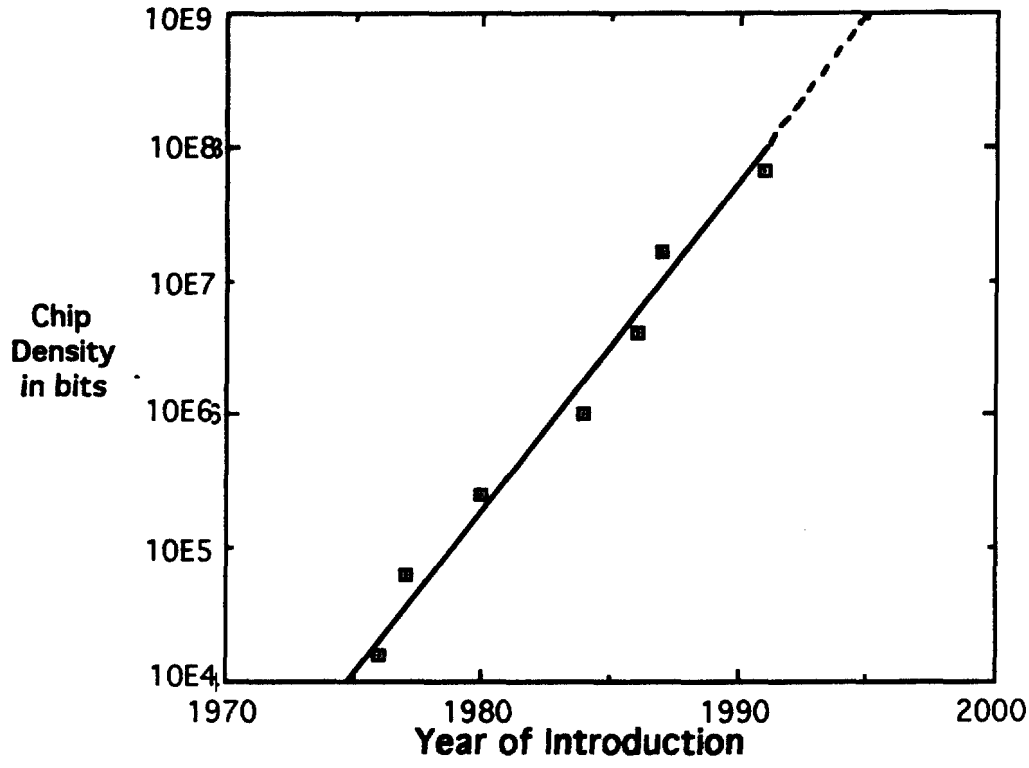


Figure A-1: DRAM Density Trend

Rapid advancement is also observed in the progress of microprocessor technology over the last two decades, and the projection to the year 2000 appears to be realizable [5,6]. The increase in number of transistors per chip is demonstrated in Figure A-2. In this chart, each data point represents a new microprocessor plotted at its year of introduction, and it can be seen that the technology accomplishes an order of magnitude improvement about every 6 years.

It is recognized that there are limits to this continued growth in memory and microprocessor density which are imposed by the physics of semiconductors. However, those limits will not be reached until well into the next century. Therefore, it is prudent to plan for continued memory growth for the next decade.

The result of these component level improvements has been that computer systems have advanced along similar trend lines. It has been observed that the performance of computer systems has advanced at approximately 35% per year [7]. Thus an order of magnitude improvement is seen every seven years. In the case of computer systems, this is equivalent to a step of one platform tier. For example, the trend would predict that the current performance of a minicomputer will be available in a workstation platform after seven years.

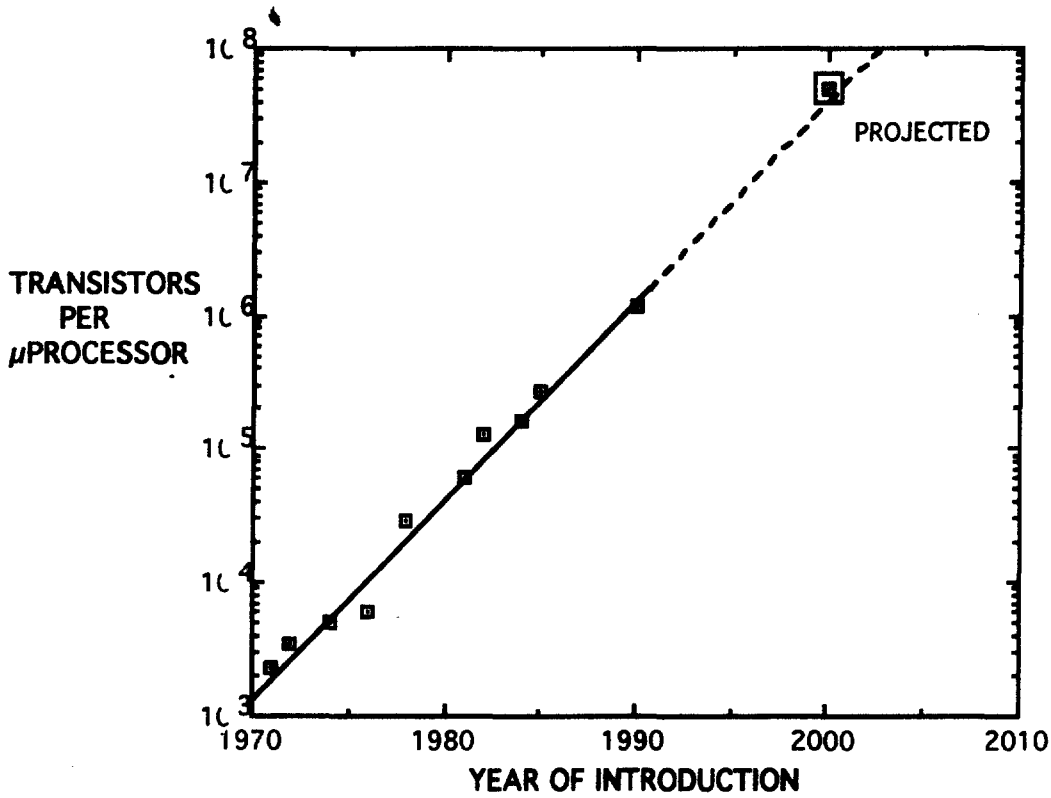


Figure A-2: Microprosessor Density Trend

LAND MOBILE RADIO CAPACITY DEMAND TREND

A representative spectrum demand growth curve for major metropolitan areas is shown in Figure A-3. The driving force creating this demand, and the consequent spectrum shortages, is the increasing use of land mobile radio for purposes of both safety and efficiency. The area of safety includes police, fire, emergency medical services, and public utilities among others. The impact on the economic efficiency of almost every kind of business has made land mobile radio a universal and standard operating tool.

It is important to note that not only is the demand for channel capacity increasing with time but it is doing so at an increasing rate. The growth curve shown in Figure A-3 is consistent with both industry and Federal Communications

Commission projections [8]. Since these projections have often been found to be conservative, the concern over spectrum shortages is legitimate. It is intended that the technology trends discussed in this paper will contribute some perspective to the long range planning effort that is required to deal with the spectrum problem.

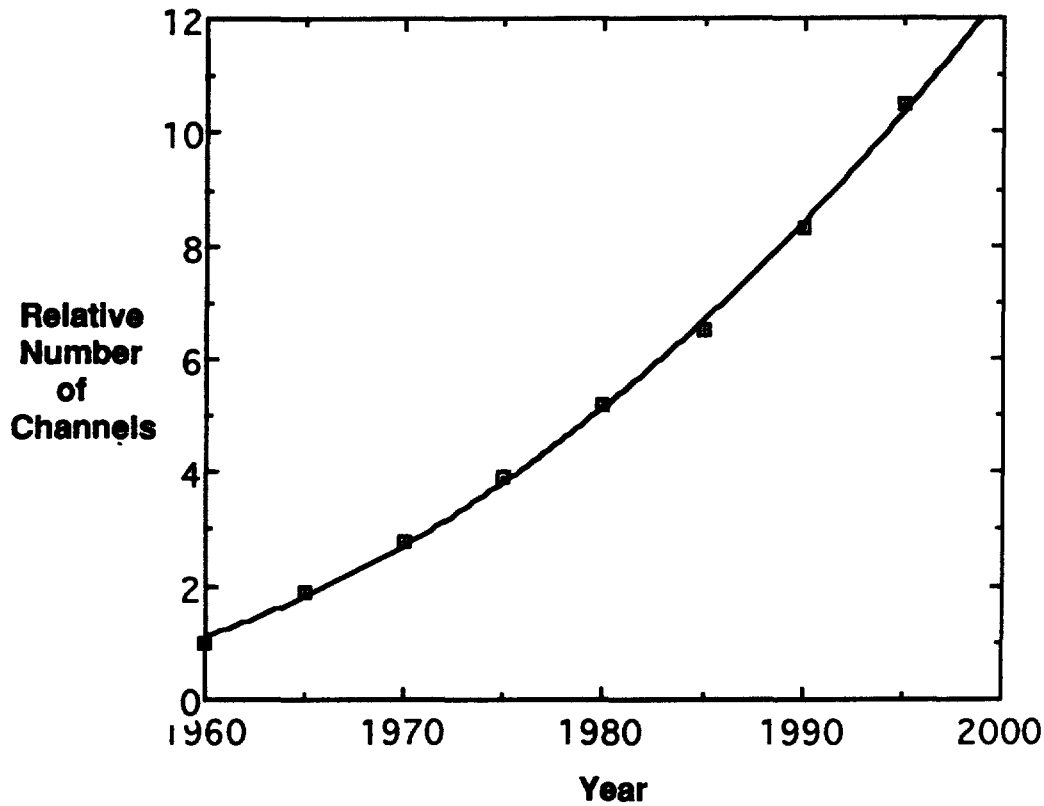


Figure A-3: Spectrum Demand Trend

It is important to note that the demand curve does not reflect the effects of new services, which will further add to the capacity demand. Some of these new services are discussed in Appendix C of this document; others will be discussed herein.

IMPACT ON COMMUNICATIONS SYSTEM REQUIREMENTS

It is generally recognized that the world is experiencing an information age, an explosion of information technologies and services. Service consumers are expecting faster access to more information every day. Communications systems are being affected as data traffic continues to increase [9]. The continuing development of portable computers, made possible by the advance of semiconductor technology, will serve to further increase the demand for information communications. Another trend being driven by semiconductor technology advancement is the evolution of personal communications. Increased

demand for wireless personal communications will dramatically increase the traffic load of mobile communications systems.

INFORMATION ACCESS

While the amount of data traffic today is small compared to voice communication, it is increasing rapidly. Past data applications have included computer inquiry, messaging, status reporting, and automatic vehicle location systems. These applications are characterized by data traffic, which is considerably more concise and efficient than voice traffic. These systems also benefit from a relatively less stringent latency requirement than voice communication. In situations where data traffic has been introduced as a substitute for voice communications, the capacity demand has been reduced. However, due to the increased efficiency of this form of communication, it has experienced rapid growth. Thus the overall per message capacity demand has continued to increase. Moreover, the expectations for data communications are expected to increase dramatically in the future, in part due to the advances of semiconductor technology.

Advances in semiconductors have resulted in an explosion of information services. This has occurred through the development of low-cost yet powerful computers, high density data storage systems, and high bandwidth computer networks. It has become commonplace for information system users to have access to very large amounts of data in a very short time. These same users will expect similar performance in a wireless network environment [10,11]. This will place a severe traffic burden on wireless communications systems where the harshness of the environment makes provision of similar information services extremely difficult. As a result, the impact of increased use of traditional wireless data applications and the introduction of information services will be to dramatically increase the demand for communications capacity.

PORTABLE COMPUTING

Small, easily portable computers have resulted from the improvements in semiconductor technology. However, the proliferation of computer networks described in the previous section has created a rich set of computer applications designed to access and use data stored outside the confines of the desktop or portable computer. In order to use these applications with the portable computer, the network access must also become portable. The obvious solution to this requirement is the wireless data communication system. A current example of this technology is the portable data terminal system developed by Motorola [12]; other examples exist. The result will be a significant increase in data traffic demands to service portable computing applications.

PERSONAL COMMUNICATIONS

Many experts are predicting the increased use of personal communications, a trend evident in the popularity of portable cellular telephones [13-15]. True personal communications will require extremely small and lightweight devices. Semiconductor technology advances can be expected to produce Integrated

Circuits capable of implementing complex radio features while reducing power requirements to the point that a small, lightweight unit is practical. Units will be developed for telephone interconnect on SMR systems as well as the more publicized cellular systems described above. In many cases, these portable communication devices will serve as substitutes for vehicle based units, and thus not affect traffic demand. But, certainly, additional traffic will be generated by new users who are attracted to the convenience afforded by the personal communications units. As a result, capacity demands will be further increased by this technology advancement.

IMPACT ON COMMUNICATIONS SYSTEM SOLUTIONS

Using today's systems, the additional traffic demands described above could only be met by increases in the available spectrum. Alternately, the demands could at least in part be offset by utilizing semiconductor advances to make more efficient use of the limited spectrum resources. The impact on land mobile spectrum efficiency is evident in four primary facets of communication system design; first, by a consideration of the amount of information to be transmitted; second, by the channel modulation scheme used to encode this information; third, by the amount of spectrum assigned to each communication channel, and fourth, by system architecture and organization. Each of these impact areas is discussed in more detail below.

INFORMATION COMPRESSION

Information compression allows reduction in the amount of information which must be transmitted on the communications channel. Typically, this is done by removing redundant information, thereby reducing the overall information bandwidth. An example of this, digital speech encoding, has received significant attention recently. In the past, various digital speech coders have been marketed mainly for security applications.

Figure A-4 shows the trends in digital voice compression technology. The top line represents the speech bit rate reduction experience for high or "toll" quality speech as used over telephone networks. The lower line shows estimated rates necessary for "communications" quality coders. These coders produce slightly degraded but demonstrably useful speech for land mobile applications such as dispatch.

In many cases, these speech encoding systems have actually increased the occupied bandwidth due to relatively unsophisticated coding schemes, while noticeably degrading the audio quality. More recently, advanced digital signal processors, made practical by improved Integrated Circuit technology, have contributed to the development of improved speech coding algorithms. For example, the processing proposed for US digital cellular (8.0 kbps VSELP shown in Figure A-4) provides near toll quality audio with an information bandwidth comparable to analog speech [11,16,17].

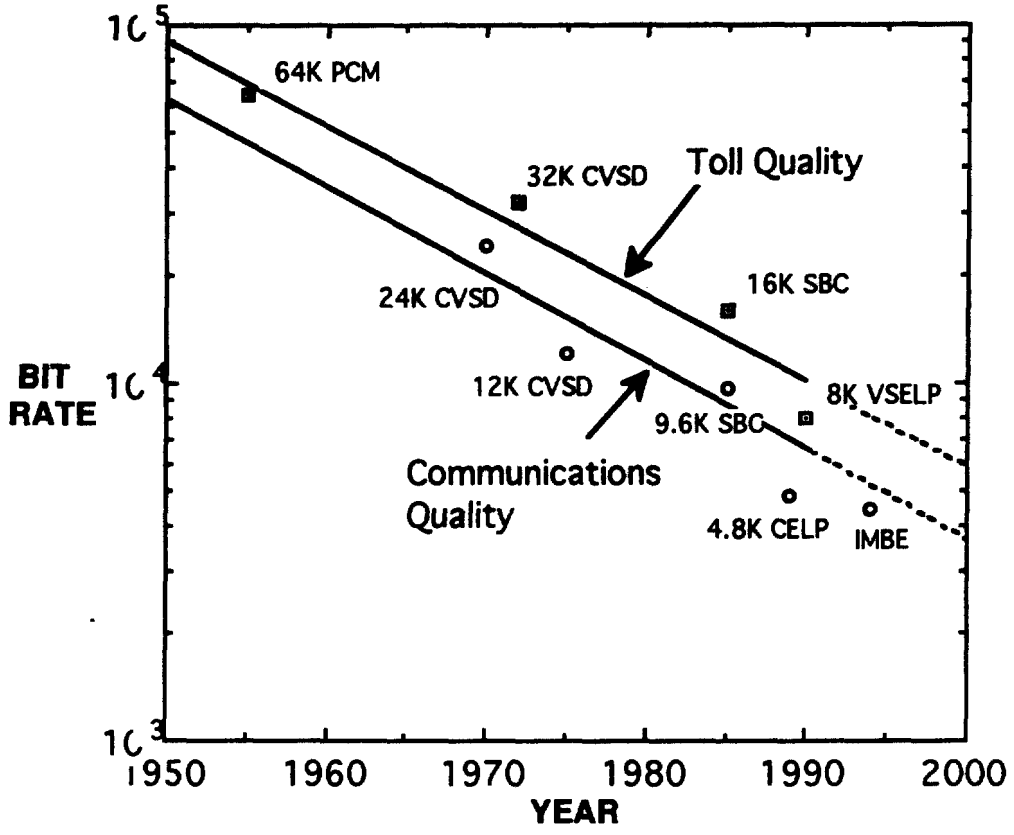


Figure A-4: Speech Coding Trends

Looking to the future, we can expect that increasingly powerful digital signal processing Integrated Circuits will facilitate the introduction of more powerful and effective methods for reducing the amount of information that must be transmitted on the communication channel. Speech and image (facsimile) communications are two areas that should benefit greatly by these techniques. Of course, the mobile radio channel is subject to severe signal degradation due to shadowing and multi-path fading. This makes the recovery and regeneration of the source information from the compressed information more difficult due to the lack of redundancy. Thus, only with complex fading mitigation techniques such as error correction coding (which further increases the required bandwidth) and diversity can the compressed information be used effectively. Here again the digital signal processor Integrated Circuits will allow the implementation of the complex recovery techniques needed to realize usable communications in the mobile radio environment.

SPECTRUM EFFICIENT MODULATION

Another method of achieving improved spectrum efficiency is to increase the amount of information that the communication channel can support. It is

important to note that a communication unit moving through a urban environment encounters severe multi-path fading. As a result, there are serious limitations of the data rates achievable compared to those in stationary point-to-point communications.

Figure A-5 shows the modulation efficiency of some representative digital systems that have been marketed or proposed for land mobile communications. Constant envelope systems have approached 1 bit/sec/Hz, considered to be the limit for those systems. However, this advancement has been achieved largely through the use of more complex multi-level, partial response, and channel coding techniques, made possible by the improved performance of digital signal processing hardware.

Recent research has indicated that systems employing linear modulation schemes can dramatically exceed the 1 bit/Hz limit [18-20]. We project that in the late 1990's, the efficiency will exceed 3.5 b/Hz. Implementation of these schemes will require even more digital signal processing to maintain their narrow bandwidths at these high data rates. Thus the realization of high efficiency modulations will need to draw upon the improvements in the Digital Signal Processing Integrated Circuits in order to successfully communicate in the mobile radio environment.

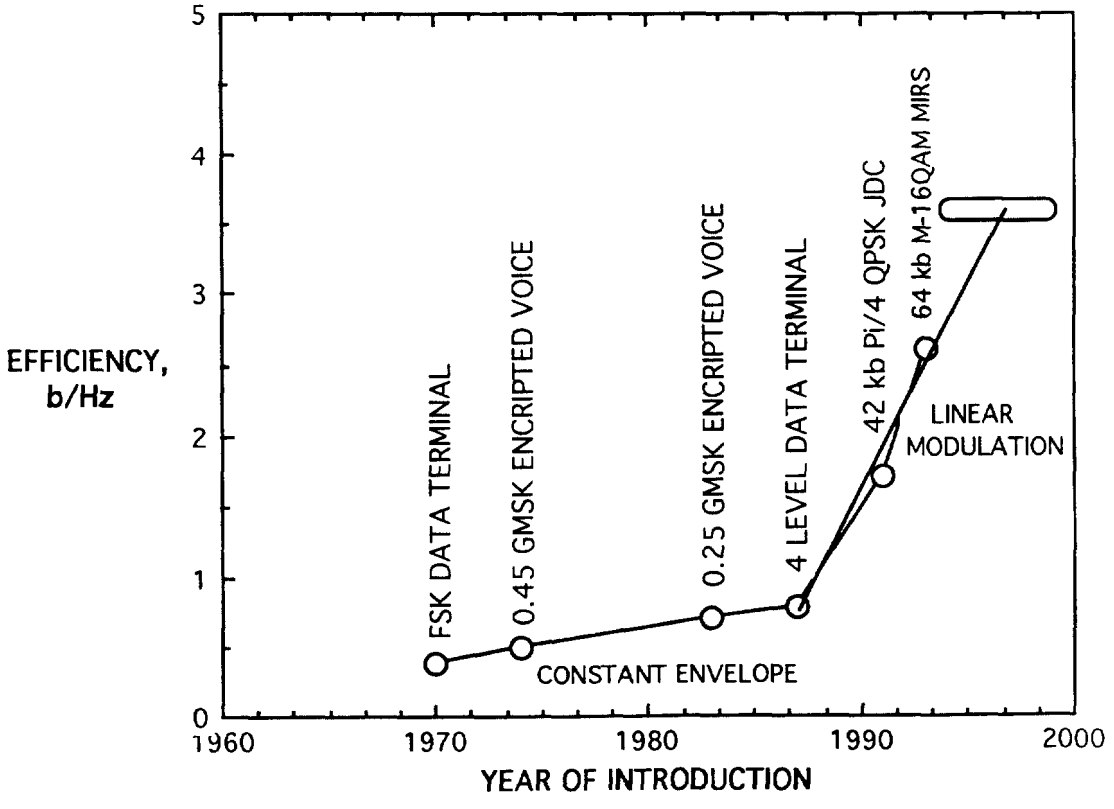


Figure A-5: Modulation Efficiency of 25 kHz Systems

CHANNEL SPACING

Clearly, spectrum efficiency is improved if more communication channels can be placed within a given band of spectrum. In the past, the ability to decrease the channel size has been limited by both the transmission bandwidth and frequency stability concerns. As described previously, we expect the application of advanced semiconductor technology to reduce the transmission bandwidth. Frequency stability in land mobile radio has also benefited from improvements in semiconductors.

Figure A-6 shows the trend of requirements on land mobile frequency stability. The trends for both base stations and mobiles are shown. Note that the two trends track together until the mid-60's. Thereafter, the base station trend has continued toward tighter tolerances at a steeper slope than that of mobile radio trend line. In both cases, semiconductor technology has contributed to the stability improvements of the last two decades to meet those requirements via two primary developments. These were the practical implementation of frequency synthesizers and the integration of temperature compensated oscillator devices.

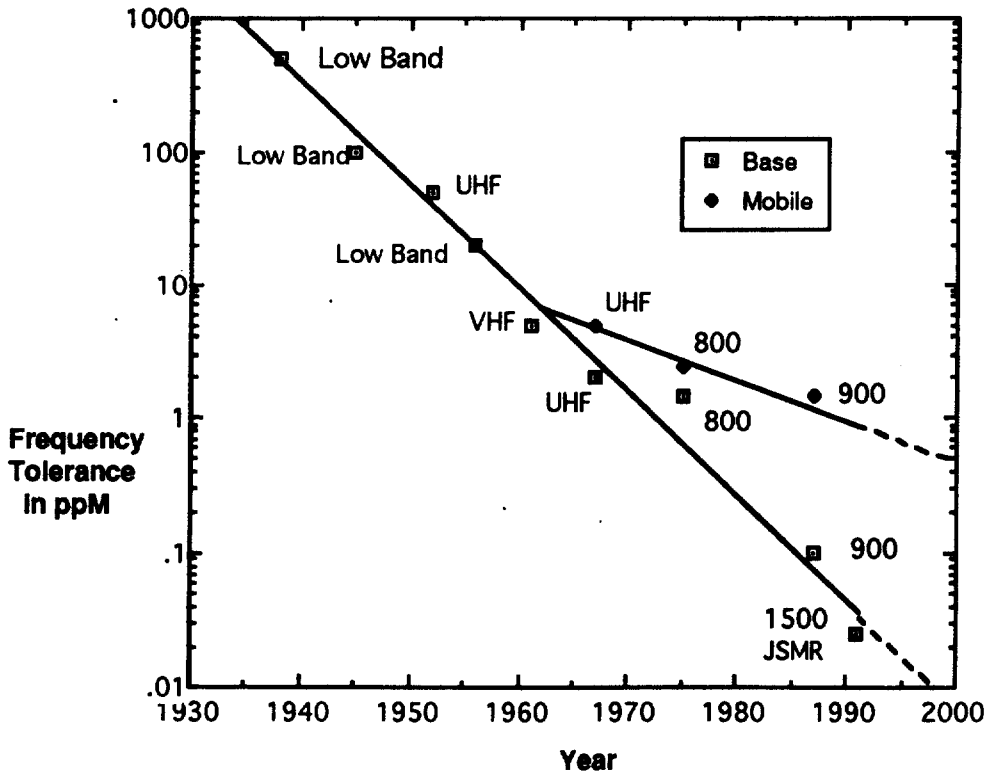


Figure A-6: Land Mobile Frequency Stability Trend

Advances in semiconductors allowed the development of integrated temperature compensation circuits which could be packaged with the crystal device. These compensation circuits dramatically reduce the variation in output frequency over the wide range of temperatures experienced by land mobile radio equipment. This reduced variation directly improves the frequency stability of the associated radio equipment.

The evolution to synthesized radio equipment was made practical by the integration of many complex functions into integrated circuits. These include loop filters, phase detectors, and frequency dividers among others. The contribution of synthesizers to frequency stability was the standardization of the frequency source from which all other signals were synthesized. This standardization allowed effort to be focused on a small set of oscillator devices with the result of improved frequency tolerance. This improved tolerance is then provided for all outputs from the synthesizer.

It should be noted that improvements in frequency stability can be used to enhance spectrum efficiency even if channel spacing is not reduced. This is because the prescribed channel spacing must allow spectral guard bands around each transmission due in part to frequency variations. Improved stability allows the specification of smaller guard bands; thus even when channel spacing is kept constant, the information content of the transmitted signal can be increased. This is important because reductions in channel spacing are limited by adjacent channel splatter considerations.

SYSTEM ARCHITECTURE AND ORGANIZATION

Finally, semiconductor technology improvements will contribute to the introduction of more complex and spectrally efficient communication system architecture's. This subject involves the system's physical configuration and capability and how the available channels are allocated and utilized. Similar to the developments in cellular systems, other land mobile radio architectures can be expected to evolve toward more geographic frequency reuse as a means of achieving increased spectrum efficiency. The trend towards more geographically distributed systems will also be driven by the increased interest in personal communications discussed earlier. However, the particular requirements of users must be considered when engineering these systems.

There exist significant economic barriers associated with geographically distributed infrastructures which can deal effectively with the great diversity of systems, functions, and features utilized in land mobile radio. The economies of scale dictate that these systems be quite large and support a very large user population to be viable. Such is the case for cellular telephony systems. Further, the management of these large distributed systems requires sophisticated system controller apparatus. While there are many contributors to the cost of these systems, advances in semiconductor technology can be expected to result in more powerful and cost-effective switch and controller systems, allowing these complex communication system architecture's to be implemented. Thus, it is anticipated that reuse systems will become practical for a more diverse range of land mobile applications before 1995.

Even so, the dispatch (one-to-many) requirement found in land mobile radio systems will dictate that only a portion of the communication load will be handled by frequency reuse systems.

SPECTRUM EFFICIENCY AND SPECTRUM MANAGEMENT

The general direction of communication worldwide toward digital formats is very clear. The rapid growth and evolution of Integrated Services Digital Network (ISDN) standards in the telephone network and elsewhere is indicative of this. It is also apparent that land mobile radio will follow this trend.

A key question is when will the future trends in information compression, modulation efficiency, and system architecture impact on spectrum efficiency. We have used the technology trends discussed previously to develop the spectrum efficiency trend chart shown in Figure A-7. This chart is a plot of the users per kHz over a wide area coverage system that we anticipate will be necessary to meet voice and data dispatch demands to the year 2000.

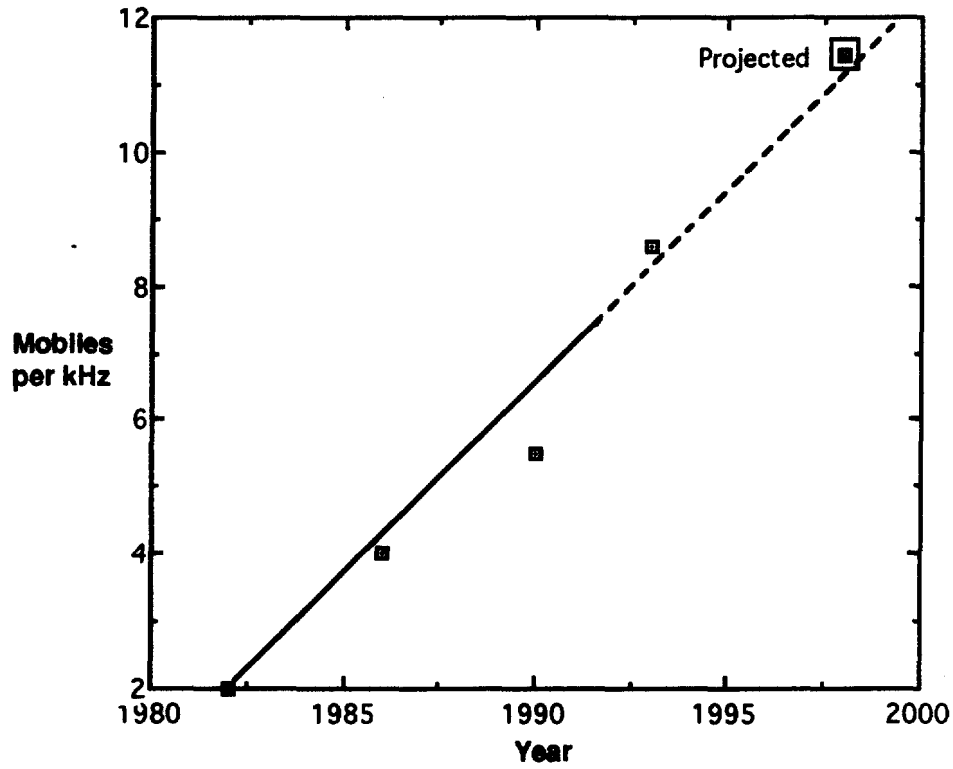


Figure A-7: Trend of Mobiles per kHz

Since the use of users per kHz is perhaps an unfamiliar measure of spectrum efficiency, an explanation is warranted. The starting point of 2 users per kHz shown for 1982 is based on a loading standard of 100 users per channel for trunked systems employing 25 kHz, duplex paired channels. The various dates for improvement to over 10 users per kHz are shown in the figure. Note that this corresponds to an improvement in "equivalent channel spacing" to less than 5 kHz by the year 2000. This "equivalent channel spacing" is not an actual spacing, and can be achieved, for instance, with 25 kHz channels and 6 to 1 TDMA. In order to achieve this projected increase in spectrum efficiency, it will

be necessary to accelerate the trends in information compression and modulation efficiency beyond those discussed above.

In addition to improvements in land mobile radio technology, spectrum management policies are needed that recognize the increasing demand for information by an increasingly mobile society. While technology can help in providing for these requirements as illustrated previously, policies which encourage a variety of creative ways in which technology can be applied to that spectrum is also of crucial importance.

CONCLUSION

The advances in semiconductor technology have contributed significantly to both the increase in demand for communications capacity and to the technology needed to provide that capacity. However, it is expected that the increase in demand will continue to overtake the additional capacity offered by technological improvements.

For these advanced technologies to be applied, it is necessary that the spectrum is known and the allocation uncertainties be resolved. **It is important that the regulatory environment be supportive by the allocation of additional spectrum to encourage the development of these advances** so the benefit of increased working efficiency can be passed on to the users of mobile radio.

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APPENDIX B

ABSTRACT

Since its birth in the 1930's, the use of land mobile radio has steadily increased. The increases in demand have been historically met by improvements in system technology to make efficient use of the existing spectrum, and by additional spectrum allocations. These system improvements and spectrum allocations have so far been able to accommodate the demand for today's voice-based land mobile services. The impending introduction of more advanced land mobile telecommunication services is expected to create an even larger demand than has ever been forecast for voice applications. It is expected that the demand created by these emerging information technologies will outstrip the capability of system technology improvements to provide capacity. Spectrum management policies must be responsive to these emerging technologies in order for land mobile radio to provide advanced services to its users.

INTRODUCTION

In recent years, the popularity of land mobile radio has increased dramatically. The resulting demand has placed severe strains on the limited amount of land mobile radio spectrum. Historically, this demand has been met either through more efficient use of the existing spectrum, or by additional spectrum allocations.

As described in Appendix A, the major enabling technology for more efficient spectrum use has been semiconductor technology. Advances in this field have enabled trunking, narrower channel bandwidths, efficient low bit rate voice coding, and the implementation of highly efficient digital modulation techniques. While these have served to increase the efficiency with which current spectrum is used, other semiconductor-enabled technologies, such as low bit rate source compression technology, have made possible the introduction of more data intensive advanced services, like file transfer, facsimile, imaging and video. The emergence of these advanced services will push user demand higher than forecasts based on voice services alone have predicted. The net effect of semiconductor advances will be to increase user demand faster than the technology itself can provide capacity for, given the current spectrum allocations. As a result, spectrum management policies must be responsive to these emerging technologies in order to make them available to the land mobile user.

This Appendix begins with a survey of current land mobile spectrum allocations. The past, present and future capacity of this spectrum will then be contrasted with the expected demand, based upon results presented in Appendices A and C. This will be accomplished by first summarizing how the demand for land mobile radio use has been successfully met in the past through technology improvements and additional spectrum allocations. It will then be shown that future demand, when both existing voice and emerging advanced services are

considered, will outstrip the capability of technology to provide capacity. Thus, new emerging technology allocations are necessary for land mobile radio.

CURRENT LAND MOBILE RADIO SPECTRUM ALLOCATIONS

The current spectrum allocations for private land mobile radio are summarized in Table 1, which describes the seven bands on which land mobile radio is authorized to operate. Systems in the 24-50, 150-174, and 450-512 MHz bands operate using base-to-mobile, mobile-to-mobile or mobile relay options (conventional systems), while trunking is utilized in the 800 and 900 MHz bands to improve spectral efficiency and system management. The 821-824/866-869 MHz band is exclusively dedicated to public safety use, while channels in other bands may be assigned to business, industrial, land transportation, public safety, or SMR users. In all bands, the spectrum is partitioned into channels of varying sizes. In the 450-470 MHz band, low power channels may be assigned on frequencies offset by 12.5 kHz from the primary channels.

Band	Technology	Equipment BW	Channel Spacing	Channels
24-50 MHz	Conventional Systems	25 kHz	20 kHz	632
150-174 MHz	"	25 kHz	15 kHz	553
450-470 MHz	"	25 kHz	25 kHz w/Low Pwr Offsets	324 310 Offset
470-512 MHz*	"	25 kHz	25 kHz	216
806-821 MHz/ 851-866 MHz	Conventional & Trunking	25 kHz	25 kHz	600
821-824 MHz/ 866-869 MHz	Conventional & Trunking	25 MHz	12.5 kHz	230
896-901 MHz/ 935-940 MHz	Conventional & Trunking	12.5 MHz	12.5 kHz	399

* Major 11 metropolitan areas only.

Table 1 - Land Mobile Band Profile

LAND MOBILE RADIO SPECTRUM CAPACITY VS. DEMAND: PAST AND PRESENT

Not only is the spectrum demand for land mobile radio increasing, but it is increasing at an accelerating rate. Figure 1, repeated here from Appendix A, shows a representative spectrum demand curve for a major metropolitan area [1]. As noted in Appendix A, this demand curve is consistent with both industry