Summary of Policy Support Division Activities

Volume II

April 7, 1972

M

Mobile Communications

November 24, 1971	Meeting with Thornell, Cooke, Hatfield, Lowe, Polishuk. Stated desire for in-depth analysis of proposals and comments due in Spring in response to FCC Docket 18262. Would like demand study for mobile service as a function of cost, technology, and social factors, and data concerning Government use of mobile. Deferred formal requests until December 13 meeting with Mr. Whitehead. (M1)
December 19	Hatfield notified Mr. Whitehead in agreement on action in the mobile area. Hatfield assisted in OTP interviews for potential contractor to study Docket filings. (M2)
December 22	Hatfield and Millie obtaining background information in anticipation of OTP activities. (M3)
December 28	Background paper on "Economic Benefits of Mobile Radio Systems" was prepared. (M4)
January 3, 1972	Meeting with Thornell and Polishuk to proceed on mobile program development. (M5)
January 25	Meeting with Thornell, Cooke, Polishuk, Black, and Salaman to discuss OTP's expectations in mobile area. (M6)
January 27	Attended Motorola briefing on mobile communications at OTP. (M7)
February 9	Meeting with Cooke and Hatfield concerning SRI mobile data, and revised project descriptions. (M8)
February 10	Revised program summary for mobile communications submitted to Cooke. (M9)
February 23	Work on mobile area with ITS initiated. (M10)
February 24	Work statement on mobile area received from Thornell. Obtained mobile simulation program from Motorola. (M11)

February 28	Statement of assistance in determining mobile system coverage submitted to ITS. (M12)
February 29	Meeting with ITS personnel to further define mobile tasks. (M13)
March 1-3	Attended IEEE Microwave Mobile Radio Symposium. (M14)
March 7	Meeting with Mandanis, Lane, and Hatfield on SAI Mobile Contract. (M15)
March 14, 15	Participated in AT&T briefing at OTP on their Docket 18262 filing. (M16)
March 23	Request submitted to Wil Dean to release frequency data regarding mobile study. (M17)
March 24	Interim Report on mobile program progress in Tasks I, II, and III submitted to Cooke. (M18)
March 31	Mobile cost data requested form Motorola. (M19)

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
Washington, D.C. 20230

M1

Date: November 30, 1971

To: R. K. Salaman

From: D. N. Hatfield

Subject: Meeting on 24 November 1971 with Messrs Thornell and Cookeof OTP and Messrs Lowe and Polishuk of OT-Washington

The subject meeting was held in Jack Thornell's office at 2:00 pm and lasted about one hour. The purpose of the meeting was to discuss the Mobile Communications program area and the support PSD could provide.

They started out by talking about the importance of the Mobile area in general and, in particular, about several decisions that will be made in the near future that will have significant impact on Mobile Communications over the next decade or more. The specific example they referred to is FCC Docket 18262 to which the carriers are to respond to by December 13 of this year. They stated that they are interested in an in-depth analysis of the proposal(s) and comments which are due next spring. The analysis would consider such things as economic efficiency, spectrum efficiency, and effects on industry structure. Along this line they noted their scheduled trip to Whippany, N.J., on December 12 to hear the Bell System presentation.

In terms of specific types of aid, they noted a possible need for specialists in Communications, Computers, Network Simulation, Marketing, Economics, Systems Engineering/OR, and Government Regulation. If we cannot supply these types of specialists in the proper time frame, they would like for us to get contract studies done. The program management functions would be shared.

They noted that this should be considered somewhat exploratory until after their program review with Mr. Whitehead on December 13.

In addition to the in-depth analysis of the responses to Docket 18262, they mentioned two specific studies in this area. One would involve a study of the demand for mobile service as a function of cost (i. e., what would be the demand for mobile radio if the cost could be reduced to the equivalent of home service), technology, and social (e. g., increasing crime) factors. The second is a data gathering project to determine government use of mobile systems.

I believe we have the capability to offer help on all three problems and I so stated. I recommend that we should prepare work statements for early submission.

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M2

Date: December 21, 1971

Reply to Attn of: PSD/DNH

Subject: Mobile Communications

To: R. K. Salaman, Chief
Boulder Section, PSD

As you know, our full participation in the Mobile Communication area has been kept on the "back burner" waiting for the OTP program to get better defined. Last week Jack Thornell and Art Cooke met with Mr. Whitehead regarding the Mobile Area. They indicated informally to me that they had been given the go-ahead. Their immediate concern is FCC Dockets 18261 and 18262 dealing with the reallocation of spectrum near 900 MHZ to common carrier and private land mobile use. Filings under Docket 18262 were due today (December 20).

Because of the limited time OTP will have to look at the policy issues presented by the filings and since we are not yet fully staffed, Thornell and Cooke are looking for possible contractor support. So in the last few days they have been conducting interviews with prospective contractors. I sat in on five of these interviews while I was in Washington. As they explained it, the need for contractor effort would depend upon the amount of additional material that must be gathered and analyzed--ie., in addition to the filings. They indicated to the prospective contractors that OT was represented at the meetings because the contract might be let by us and that we might be concerned with the day-to-day monitoring of it. In response to my direct questions, Art said that the OT role would be more precisely defined after the filing deadline. Thus our role is still not clear. I would like to study the filings in some detail so that we can contribute to the task of defining issues.

One of the basic issues that I am interested in is the economic and social value of mobile communications. I am interested in determining the increase in efficiency that results from the use of mobile radio by a taxicab company, for example. To get a start in that direction, I contacted several groups concerned with Land Mobile Radio.

I talked with Val Williams of the National Association of Business and Educational Radio (NABER), John Sodolsky of Electronics Industry

Association (EIA), and Len Kolsky of Motorola, regarding this topic. They generally indicated that there have been no really good, complete studies. They have plenty of "I couldn't do without mobile radio" testimonials but not much in the way of real economic analyses. They have agreed to send me various papers which relate to this area.

Dale N. Hatfield

Dale N. Hatfield

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M3

Date: December 22, 1971

Reply to Attn of: BPSD/DNH

Subject: Mobile Communications Tasks

To: Paul Polishuk

Attached is a brief description of the work that might be started immediately to support our analysis of the filings and issues presented by FCC Docket 18262. It should be useful to us in later discussions with OTP when other tasks are developed and it would also save considerable time in getting a contractor "up to speed" if OTP wants to go that route. Time is fairly critical because of the FCC imposed deadlines.

Dale N. Hatfield

cc: LABerry
RKSalaman

Attachment

Mobile Communication

Preliminary Tasks to Support Analysis of the Issues in FCC Docket 18262

Jack Thornell and Art Cooke are concerned with developing an OTP position on Docket 18262. Filings were due on December 20 and comments are to be filed by June. In order to insure a timely response to the forthcoming request for assistance from OTP, certain steps should be undertaken immediately. These include:

1. Getting copies of all pertinent FCC material leading up to the December 20 deadline--in particular, the Notice of Inquiry and Notice of Proposed Rulemaking.

2. Getting copies of the December 20 filings by AT&T, Motorola, etc. This would involve getting a list at FCC of those who have filed and then calling them. Dick Gabel can probably be of assistance in determining the most efficient way of going about this.

3. Preparing short summaries of each filing including their position on the major issues. Without knowing the number and size of the filings, it is not possible to indicate how much effort will be required. As a minimum the filings should be indexed.

Art Cooke indicated that he would like to have a meeting in late January to discuss possible outside contract effort and our role. By accomplishing the above tasks and holding an in-house OT meeting to discuss (1) the issues and (2) required analyses, we should be in a good position to contribute to the later meeting.

Draft
12-29-71 DNH

M4

PLAN OUTLINE

Economic Benefits of Mobile Radio Systems

1. BACKGROUND

The demand for mobile radio services is growing at a rapid pace and this growth has put substantial pressure on the spectrum resources allocated to it. Solutions--either in increasing the allocations or in using the existing allocations more intensively--are expensive and the effects are complex. In the Land Mobile Radio (LMR) area for example, proposed solutions of the former type may hurt broadcasting interests and the general public through a decrease in the number of available TV channels. The latter solution may involve more costly equipment and regulation, the expense of which must be borne by the general public through increased taxes, increased costs of goods and services, or decreased level of service.

One difficulty in resolving this complex resource allocation problem is the lack of definitive data on the economic and social benefits of the competing services. The overall purpose of this study is increase the quality of data available for considering the economic benefit of one type of LMR service. The techniques developed in the study should be useful in analyzing other types of services as well. Previous studies in this particular area, while useful in indicating the possible magnitude of the benefits, are questionable because they rely largely on unsubstantiated, general claims of increased efficiency. In some instances they were conducted or funded by groups with a vested interest in the results.

2. SPECIFIC OBJECTIVES

The specific objectives of this study are to:

(1) develop a methodology for providing more precise estimates of the economic benefits from the use of mobile communications system, and

(2) use the methodology developed in (a) to analyze several representative systems in the Business Radio Service.

3. APPROACH

Using Operations Research/Systems Engineering methods, a model of a fleet of vehicles in an industrial setting will be developed. The model would predict the productivity of the fleet in terms such as tons of goods delivered per day (package delivery service), ratio of revenue miles to total miles (taxicab service), or number of service calls per day (TV — repair service), for example. A typical existing model is described in a paper entitled "Cargo Vehicle Productivity" by Robert McQuie. Inputs to such a model would be such factors as average speed, loading and unloading time, MTBF (mean time between failures), MTTR (mean time to repair), probability of having proper repair part in the inventory carried on the vehicle (e.g., TV repair), average distance between stops, etc. Certain of these factors are affected by the presence and performance of a mobile radio system. It should be apparent how such a system will increase productivity. The dispatcher can rapidly send the nearest unit to a location thereby decreasing the average distance between stops. A mobile unit can immediately notify the dispatcher of a mechanical breakdown, minimizing the time required to return a vehicle to service. This may be especially important if the item carried is perishable (e.g., mixed cement). A TV repairman in the field may request advice from a more experienced man in the shop, decreasing the average duration of a service call. The model will be designed to predict the increase in productivity from basic parameters such as type of business and area covered.

Following development of the model, data will be gathered for it by observing a number of typical fleet operators. Similar businesses with and without radio systems will be analyzed or, if all businesses of a certain type use radio in an area, the operation will be analyzed in sufficient detail so that good estimates can be provided for changes in the parameters if mobile radio had not been used. The data will be used to verify the model and provide precise information on the actual increase in productivity for the typical businesses observed.

Finally the economic benefits to typical users will be computed using labor rates, mileage costs, etc. If the model can be made sufficiently general, gross estimates of the total economic benefit of the Business Radio Service will be made using available statistics.

4. STUDY BENEFITS

The techniques developed and the data gathered in this study will be of direct use to analysts in the spectrum policy area. It should increase both the quality and quantity of the information they have available. It will be of immediate benefit in studying the issues in FCC Docket 18262 dealing with spectrum reallocation near 900 MHz. It will be of direct use in estimating latent and future demand for business radio systems and it should serve as a starting point for the analysis of other services which are more complex because they involve public safety. It will provide data for evaluating the non-economic benefits of mobile radio such as decreasing the number of commercial vehicles on streets and highways.

A side benefit is that it would provide less sophisticated business users with a relatively simple method of determining the increase in productivity and return on investment they might expect from LMR systems.

5. TASKS

The following tasks are proposed to accomplish the study. A preliminary estimate of the man-months of effort required for each task is shown in parentheses.

1. Review and summarize the results of previous studies directly related to the economics of mobile communication. (1 mm)
2. Review and summarize previous methods and models for business fleet management. (1 mm)
3. Interview several typical LMR users for preliminary data to be used in model development. (1 mm)
4. Develop a model relating productivity to basic parameters such as type of business, area covered, number of mobile units, radio performance (dead spots, channel delay times). (4 mm)
5. Collect detailed data from typical users. (3 mm).
6. Test, evaluate, and revise model using data collected in 5. (2 mm)
7. Exercise model to show ranges of savings possible for different businesses and compare the results with previous estimates.
8. Prepare final report including complete documentation of model. (1 mm)

The estimated total effort based on the above is 14 mm at a total cost of $50K.

6. SCHEDULE

By paralleling certain of the tasks outlined in 5, the study could be completed in 6 months.

M5

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
Washington, D.C. 20230

Date January 13, 1972

To: Roger Salaman

From Paul Polishuk

Subject Meeting I Had Today with Jack Thornell on the Mobile Area and Technology

With regards to the mobile area--he discussed it with Tom Whitehead and he has approved the program and Jack would like to get together with us to discuss our role, at the beginning of next week.

In the technology area, Jack showed me a letter he had written to Tom. The attached sheet contains the six topics discussed. The only question was on Item 2, which they felt was too broad. Jack's feeling was that since they had not given approval, they had not given disapproval, so we would use the other five items as a basis of a technology program.

P.S. Talked to Thornell's office today (1/14) and have set up appointment for Thursday (1/20) at 1:30 p.m.

OT FORM 10
(1-71)

OFFICE OF TELECOMMUNICATIONS

M6

January 25, 1972

PSD/RKS

Toward establishment of mobile communication program

Dale N. Hatfield

Paul Polishuk, Sharon Black, and Roger Salaman met with Jack Thornell and Art Cooke on January 20 to discuss joint OTP/PSD activity in the mobile area. Jack Thornell stressed three points. 1. Primary interest is on supply and demand relation in the market, generally unrestricted by spectrum shortage. 2. Demand study is being performed by a contract with System Application Incorporated (a 6-month contract). 3. The supply study and economic analysis is to be performed by OTP and PSD. The contract with SAI is to be completed by mid-June. OTP wishes to present comments to the FCC by late March and therefore would like to have information for this purpose early in March. It was stressed that the program should not be geared entirely to the FCC Docket 18262; however, this did present some time constraints.

Concerning the SAI contract, they apparently had done some market surveys for GE in 1968. This work for OTP is to be an update of that work adding the current proposals in the telephone area. OTP realizes that at best this demand study will provide only guesstimates.

The rest of the program, supply and economic analysis, on which we are to place our emphasis, is to develop a system model for recommending policies in the mobile area. Several tasks were suggested. There needs to be an analysis of the systems proposed and implied in FCC Docket 18262 both from a technical and economic standpoint. It was suggested that the economic analysis might be performed by grouping similar proposed mobile concepts and performing an analysis for the group rather than for any specific system. Another analysis might be of the current imbedded cost of existing frequency compatibility. A third might be an analysis of institutional alternatives. How can the services be provided and what are these services? What are associated costs? In order to answer these questions it was suggested that data needs to be obtained on the cost of current systems, the cost of equipment, and so on, for the proposed systems.

OTP is in the process of establishing an interagency working group to integrate the requirements within the Executive Branch. For example,

SURNAME	DATE	SURNAME	DATE

FILE COPY

the Department of Transportation has five programs concerning mobile communications, the requirements for which have apparently not been provided to the FCC.

It was agreed that the supply and economic study cannot be devoid of the demand size. It was proposed that OTP and PSD mutually agree upon the market size to be addressed. This could be done in conjunction with the information from SAI. Growth demand beyond the urban environment should be considered. For example, on and off highways across the country. Questions were raised as to whether it was appropriate to have one supplier provide service in high demand areas and someone else where there is sparce population.

Specific questions raised included: What is the market penetration versus cost? In pursuing the ICS system, will the system be overdesigned? What would be the lowest cost to the user by 1985? Can there be a system which would cost on the order of $6.00 per month to the user? Based on the proposed markets, what is the cost to the user and what are the system alternatives? With the available cost data how should the equipment be depreciated, how should the system and service distribution be depreciated? Is it possible to triple the use of the available spectrum? If AT&T obtains the total 75 MHz what services will and can be provided in terms of dispatch, telephone service, and others? What are the institutional alternatives? Should current wire line carriers, radio common carriers, private services be utilized? Is there need for other common carriers? How is it possible to make the market grow? Is it necessary to grow? Is it necessary to have a national mobile system cross country? What are the possibilities for deregulation? How does system cost depend on technology? And what are the technological trends? Are there any real economies of scale?

Art Cooke will provide the primary contact in the mobile communications area with OTP. It was suggested that a further discussion of the mobile program be held at OTP during the first part of the week of January 24. A meeting has been tentatively scheduled for Tuesday, January 25.

Roger K. Salaman

cc: Carlos Rozo

U.S. DEPARTME[NT] OF COMMERCE
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Boulder, Colorado 80302

M7

Date: January 28, 1972

Reply to Attn of: PSD/DNH

Subject: Trip to Washington, D. C. January 25-27, 1972

To: Roger K. Salaman

These are my abbreviated notes from the subject trip:

1. Discussed the Ross TEC report with Lasher and Nelson at OTP. Evaluated comments of Kelleher.

2. Called Sam Fordyce at NASA regarding their report on DOMSAT Orbit/Spectrum Utilization for FCC. He appeared hostile but agreed to send copies to WRH and us.

3. Discussed the mobile area with Hal Millie and got his notes on previous meeting you attended. I will start detailed project planning steps and technical summaries.

4. Prepared material for use in Contract Procurement on Mobile Economic Benefit Study and discussed it with Mr. Bull of DOC Procurement Group.

5. Attended Motorola briefing at OTP with Millie and Polishuk. I was very impressed with the discussion led by George Mansur.

Dale N. Hatfield

U.S. DEPARTMI ' OF COMMERCE
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Boulder, Colorado 80302

M8

Date: February 9, 1972

Reply to Attn of: PSD/DNH

Subject: Trip Report

To: R. K. Salaman

1) I submitted DOMSAT Orbit/Spectrum paper on Monday and began review of complete OTP, OR, Ross TEC, and SRI paper.

2) Wrote two project descriptions for WRH.

3) Received copy of letter from Jack Kelleher to SAL regarding DOMSAT paper.

4. Talked with Art Cooke and he said he had paved the way for me to contact SRI about their computer simulation model and mobile communications data base. I agreed to submitting revised project/task descriptions by Wednesday or Thursday.

5. Had lunch with WRH and discussed his visit next week. Also discussed my future role in mobile versus help to him. He said he would discuss it at OT-OTP Tuesday meeting.

Dale N. Hatfield

Draft - DNH
Revised 2-10-72

PROGRAM PLANNING SUMMARY
MOBILE COMMUNICATIONS

This summary represents an initial effort to define a program which will provide analytical support in the area of mobile communications. It is based upon (1) discussions held with OTP on November 24, 1971, January 20, January 28, and February 2, 1972, and (2) a preliminary review of the submissions under FCC Docket 18282. Eight basic tasks (projects) have been identified. These are:

I. Technical Summaries of Filings
II. Mobile Communications Demand
III. Mobile Communications Supply
IV. Engineering and Related Economic Benefits
V. Technological Alternatives and Implications
VI. Inter-Agency LMR Working Group Support
VII. Evaluation of Rechannelization Alternatives
VIII. Basic Policy Implications

The time frame constraints have been set by the desire to submit preliminary comments to the FCC in March and by the FCC's deadline for comments in June. The above tasks should be regarded as both a response to the specific issues raised by Docket 18262 as well as a response to longer range questions relating to mobile communications. In the sections which follow each of the above tasks (except II) is described in more detail and preliminary budget, manpower, and schedule estimates are provided. Task II is not described because it will be done through a contract with SAI.

TASK I

Comparative Technical Summaries of Filings

1. Objective: To compile an LMR Program data base of pertinent FCC Docket information and filing summaries and other technical/economic concept information as a foundation for analysis work to be accomplished under Tasks III, IV, and V.

2. Requirements: The filings under Docket 18262 are sufficiently voluminous that summaries are required to aid study team personnel in efficiently assimilating the material contained therein.

3. Work Statement: Each of the current filings under Docket 18262 will be summarized. In addition, previous filings and relevant technical papers which provide additional detail on the filings will be collected and cataloged. Subsequent filings, trade journal articles, technical papers, and other pertinent materials will also be collected and summarized as required. The filings will be compared and contrasted in order to highlight the features and limitations of each.

4. Interfaces: This task will supply information to all other projects on a continuing basis.

5. Milestones: This project is currently under way. Copies of the current filings have been obtained and are currently being summarized. The remaining milestones are--

Summaries Completed	1 March 1972
Information Base Documented (Catalog)	15 June 1972

6. Manpower:

Engineer/OR Analyst	3 man-months
Support	1 man-month

7. Budget: $12K

TASK III

Mobile Communications Supply

1. Objective: To determine, through supply analysis, the application (capacity) of various proposed technologies and alternative industry structures to meet all LMR service needs as a function of: cost, spectral efficiency, and performance.

2. Requirements: There are many types of services to be provided under the general heading of mobile communications and there are many different technical configurations and industry structures that can provide such services. Many of these alternatives are addressed in the filings and others (possibly more innovative) are possible. Sound policy decisions require the analysis of these alternatives in terms of cost, performance, and spectrum efficiency. The complexity of these alternatives precludes the use of ordinary analytical methods and requires the adaptation/development of a suitable simulation model.

3. Work Statement: Since this is a fairly large study, the work statement has been divided into a number of subelements:

   (a) Identify and describe a number of representative alternative systems based on a study of the filings and discussions with OTP, OT, and industry personnel.

   (b) Develop or adapt a computer simulation model for evaluating the types of systems identified in (a) either individually or in combination. This model will predict the system performance (e.g., probability of blockage, average delay, maximum number of channels required, etc.) as a function of the number of mobile units, the geographic distribution of base stations and mobile units, and message statistics. It will provide data on the number and length of wireline facilities, the number of transmitter/receiver combinations, and other information necessary to develop cost information.

(c) Gather cost information on existing systems and systems proposed in the filings. This information will be developed as a function of frequency range, number of channels, power output, number of landlines, etc., so that it can be readily included in the model. Maintenance, administrative, and other operating costs will also be obtained. The cost information supplied in the filings will be analyzed in detail. All cost data will be organized for publication as a separate part of the report. This will include breakouts of current base station and in-car equipment costs as well as the sunk costs in current systems.

(d) Evaluate the alternatives outlined in (a) using the model developed in (b) and the cost data from (c). This will include studies of (1) the current system, (2) systems proposed in the filings, and (3) other innovative systems or combinations. A primary output of this task will be curves showing costs versus number of users for the alternative systems. These curves will show the lowest cost technology (configuration) for different levels of demand. They will also indicate economies of scale.

4. Interfaces: This project will receive inputs from Tasks I and II. Task I will provide general background information and Task II will provide information on innovative services and the range of demands that must be considered. This project will provide information to Task VIII which is concerned with broader economic issues. For example it will provide information on the economies of scale associated with the various alternatives. Furthermore it will provide insight into the reliability and sensitivity of the conclusions presented in the filings.

5. Milestones:

(a) Alternative Systems/Configurations Identified and Model Requirements Determined — 1 March 1972

(b) Computer Simulation Model Available* — 15 April 1972

(c) Evaluation of Alternative Configurations Completed and Interim Results — 15 May 1972

(d) Report Issued — 1 July 1972

6. Manpower:

Engineer/OR Analyst	6 man-months
Programmer	6 man-months
Support	3 man-months

7. Budget:

Labor	$35K
Computer	2K
Other	3K
	$40K

*This estimate is based on the assumption that existing model or models can be acquired from the applicants or other sources. Preliminary steps to acquire the Motorola model have already been taken because of the critical time constraints.

TASK IV

Economic and Social Benefits

1. Objective: To determine economic (and other) benefits to LMR users under various institutional structures resulting from several system application concepts.

2. Requirement: A major problem in rationally allocating the spectrum resource is the lack of definitive data on the economic and social benefits of competing services. This particular project is required to increase the quality of data available for estimating the economic benefit of one type of LMR service but the techniques developed should be useful in analyzing other types of services as well. Previous studies in this particular area, while useful in indicating the possible magnitude of the benefits, are questionable because they rely largely on unsubstantiated, general claims of increased efficiency. In some instances they were conducted or funded by groups with a vested interest in the results. The methodology and representative data collected will be used as one factor in (1) evaluating the economic benefit of LMR use of the radio spectrum, (2) estimating the sensitivity of these benefits to the performance of the radio system, and (3) analyzing latent and future demand for commercial and governmental LMR systems.

3. Work Statement: This study has been divided into the following elements:

(a) Review and summarize previous studies directly related to the economics of mobile radio and fleet management.

(b) Develop a model of the productivity of a fleet of units in a commercial/governmental setting (dispatch service). It will predict the productivity in such terms as tons of goods delivered per day (package delivery service), ratio of revenue miles to total miles (taxicab service), number of service calls per day (appliance repair service), or number of prospects visited per day (insurance salesman). Inputs to such a model might include the type of business, area covered, number of mobile units, average vehicle speed, duration of stops, etc. Most importantly the inputs would include the performance of the LMR system, e.g., dead spots, channel delay time and message statistics. The model will then be extended to include more innovative uses of LMR.

(c) Collect detailed data from typical LMR users and test, evaluate, and revise the model developed in (b). Exercise the model to show ranges of savings possible and compare with previous estimates. Estimate demand at various cost levels by determining possible savings.

(d) Prepare a final report describing the model and the analytical results.

4. Milestones:

RFPs Distributed	1 March 1972
Proposals Received	1 April 1972
Contract Awarded	1 May 1972
Preliminary Report	15 June 1972
Model Completed	15 August 1972
Analysis Completed	1 October 1972
Final Report	1 November 1972

5. Interfaces: This project will provide data for the demand analysis (Task II) and Task V. On a longer term basis it will provide data for consideration in any further spectrum reallocation plans.

6. Manpower:

Engineer/OR Analyst	12 man-months
Programmer	3 man-months

7. Budget: $60K.

TASK V

Technological Alternatives and Implications

1. Objective: To determine the technical feasibility of advanced system applications and to estimate the probability of their timely, economic development and implementation.

2. Requirements: OTP has indicated concern that the decisions in Docket 18262 may preclude the development of more advanced system concepts in the future. For example, they were concerned whether adequate attention had been paid to digital-voice systems using time-division multiple-access techniques. Such techniques would alleviate problems associated with using a single amplifier or antenna to handle many signals at a base site. The significance of allocating 75 MHz of spectrum for the development of a high-capacity system with a large capital investment requires assurance that (1) all current technological alternatives have been adequately investigated and (2) the decisions will not unduly restrict future options.

3. Work Statement: The subelements of this task are:

   (a) Identify advanced technological alternatives based on inputs from Task II, material inthe filings, technical papers, and discussions with OTP, industry, and government personnel.

   (b) Evaluate the alternatives identified in (a) in terms of (i) their performance advantages and disadvantages (in particular whether the system would be "transparent" to users), (ii) the current state-of-the-art, (iii) reason for rejection by current applicants if applicable, (iv) problems of future implementation if current proposals are accepted, (v) costs, (vi) changes in the future state-of-the-art that may affect any of the foregoing, and (vii) their overall probability of implementation.

   (c) Prepare a report describing the results and containing recommendations.

4. Interfaces: This project will receive data from Tasks I and II and it will make use of Task III to evaluate the more promising alternatives.

5. <u>Milestones</u>:

Advanced Alternatives Identified and Described	15 March 1972
Evaluation Completed	15 May 1972
Final Report Issued	15 June 1972

6. <u>Manpower</u>:

Engineer	6 man-months
Support	2 man-months

7. <u>Budget</u>: $25K.

TASK VI

Inter-Agency LMR Working Group Support

1. Objective: The objective of this task is to assist OTP in the leadership of the Inter-Agency LMR Working Group, consisting of representatives from OTP, FCC, HUD, HEW, DOT and LEAA.

2. Requirement: Decisions made by the FCC under Docket 18262 may have an impact on the successful implementation of programs of the various participating agencies. For example, Automatic Vehicle Monitoring systems may have spectrum requirements that must be met by assignments in the frequency bands that are the subject of the FCC Docket. Another example is the systems to telemeter medical information from ambulances to the emergency room of the hospital. The Inter-Agency Working Group will submit comments to the FCC on the impact of these requirements. OT will supply the secretarial and technical staff support required by the Working Group.

3. Work Statement: This task will include (1) preparation of agendas and minutes, (2) collection of reports dealing with proposed systems, (3) technical analysis and synthesis of requirements under the direction of the Working Group, and (4) other activities as required.

4. Milestones: Milestones will be determined by the meeting and report schedule adopted by the Working Group. A preliminary schedule is as follows:

First Meeting	18 Feb 1972
Second Meeting	1 Mar 1972
Third Meeting	5 April 1972
Draft Report	3 May 1972
Final Report	1 June 1972

5. Interfaces: This project is essentially complete in itself. Portions of the results will be directed toward Task VIII.

6. Manpower:

Professional	2 1/2 man-months
Support	1 man-month

7. Budget: $12K

TASK VII

Evaluation of Rechannelization Alternatives for Increased Spectral Efficiency

1. Objective: To identify and recommend alternative proposals for the rechannelization of public user groups in existing LMR bands, toward optimizing spectral and operational efficiency, as a function of: staggered peak busy periods, holding time, waiting time, and other pertinent technical and economic parameters.

2. Requirements: There have been some arguments made that the shortage of frequencies for Land Mobile Radio could be relieved by better frequency management techniques using essentially the existing technology. These arguments have been based on actual measurements and the observation that some channels were overloaded at times when other channels were only lightly loaded. In another geographic area the reverse might be true. A complete evaluation of the issues under Docket 18262 and a full understanding of the LMR problems in general requires an evaluation of techniques to rechannelize user groups in a more efficient fashion.

3. Work Statement: This project will include the following elements:

1. Identify and gather data on LMR channel usage that have been collected in previous studies.

2. Categorize by type of business the public users of LMR and collect data on their usage by time-of-day, average holding times, sensitivity to waiting time, etc.

3. Develop estimates of increased spectral efficiency possible through rechannelizing by exercising the model developed in Task III using the data from elements 1 and 2 above.

4. Milestones:

1.	Previous studies identified and available data gathered	15 April 1972
2.	Sample data gathered	15 May 1972
3.	Preliminary results available	15 June 1972
4.	Decision to increase data sample	1 July 1972

5.	Data base expanded	1 Oct 1972
6.	Analysis Completed	1 Nov 1972
7.	Final Report	15 Dec 1972

5. Manpower:

Engineer/OR Analyst	9 man-months
Support	6 man-months

6. Budget: $60K

TASK VIII

Basic Policy Implications

1. Objective: There are two objectives under this task: first, to identify basic policy issues which emerge from earlier tasks (I through VII); second, to obtain and document preliminary and final conclusions, recommendations, and results of analyses, derived during the course of the overall study effort.

2. Requirements: It is likely that additional policy issues will surface during the course of the other investigations. Furthermore, certain non-quantifiable issues which are not inherently considered in analytical studies of performance (quality of service), economic efficiency, and spectrum efficiency, must not be overlooked. The purpose of this task is to identify these issues. It is also necessary to collect in a single document the principal results, conclusion, and recommendations of the several other studies in this program area.

3. Work Statement:

(a) Basic policy issues which were identified in previous meetings will be reviewed and any further issues identified in the other tasks will be added as they are available.

(b) Preliminary results of the other tasks will be documented for use in initial comments to the FCC.

(c) Regular progress reports and a final report will be prepared.

4. Interfaces: This task will receive data from all other studies in the program area. It will provide information to the other projects as the policy issue definitions are refined.

5. Milestones:

Program Progress Reports	(Monthly)
Compilation of Policy Issues Completed	1 Mar 1972
Preliminary Results Summarized	15 Mar 1972
Report Issued	15 June 1972

6. Manpower

Economist	5 man-months
Engineer	2 man-months

7. Budget: $25K

MILESTONE CHART AND MANPOWER-BUDGET SUMMARY

Task/Milestone	1 Feb	1 Mar	1 Apr	1 May	1 June	1 July	1 Aug	1 Sept	1 Oct
I. Technical Summaries									
Summaries Completed		Δ							
Data Base Documented					Δ				
II. Demand									

III. Supply									
Alt. Systems and Model Req. Identified		Δ							
Computer Simulation Model Available			Δ						
Eval. of Alt. Systems Completed				Δ					
Report Issued						Δ			
IV. Economic and Social Benefits									
Contract Awarded				Δ					
Preliminary Report					Δ				
Model Completed							Δ		
Analysis Completed									Δ
Report Issued									Δ
V. Basic Policy Issues									
Issues Compiled		Δ							
Preliminary Report		Δ							
Analysis Completed				Δ					
Final Report Issued					Δ				
VI Technological Alternatives									
Alternatives Identified		Δ							
Evaluation Completed				Δ					
Report Issued					Δ				

Manpower & Budget

Professional Support Budget

II. Demand

III. Supply

Alt. Systems and Model Req. Identified Δ

Computer Simulation Model Available Δ

Eval. of Alt. Systems Completed Δ

Report Issued Δ

IV. Economic and Social Benefits

Contract Awarded Δ

Preliminary Report Δ

Model Completed Δ

Analysis Completed Δ

Report Issued Δ

V. Basic Policy Issues

Issues Compiled Δ

Preliminary Report Δ

Analysis Completed Δ

Final Report Issued Δ

VI Technological Alternatives

Alternatives Identified Δ

Evaluation Completed Δ

Report Issued Δ

Manpower & Budget

	Professional	Support	Budget
Task I	3 mm	1 mm	$12K
Task II			
Task III	6	3	40K
Task IV	12	3	60K
Task V	5	2	25K
Task VI	6	2	25K
Totals	32 mm	11 mm	$162K

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M10

Date: February 23, 1972

Reply to Attn of: PSD/DNH

Subject: Mobile Communications Program Area

To: George Haydon
Acting Associate Director, ITS

As you know I have been working with Jean Adams and Don Lucas to better define ITS support for PSD in the subject program area.

One thing that needs immediate attention and which is a logical extension of work done by Hoke Willis is to gather information on the tariffs and costs for existing Mobile Telephone Service (MTS) as provided by both the wireline and radio common carriers. This information was explicitly requested by OTP and is useful for several reasons: (1) it provides a "benchmark" for comparison with the new proposals in Docket 18262, and (2) these systems using existing VHF and UHF allocations may be used even after the 900 MHz band systems are operational and thus a complete analysis must include them. Wes Harding has already started some work in this area and I would urge that he and Hoke get together regarding base station equipment and operator costs, etc. Wes has information on mobile unit costs and Mountain Bell tariffs for MTS. A possible source of cost information for the non-wireline common carriers is the filing by the National Association of Radiotelephone Systems (NARS). They or their contractor (Kelly Scientific Corporation) could also be contacted directly. As soon as this is completed a full scale cost study of the new proposals will be needed.

A second area which will need attention almost immediately is in computer model development. I have arranged to stop at Motorola in Chicago to get a briefing and copy of their model. I will also get the model developed by Systems Applications Inc. if I can. This model will determine equipment requirements for a given level of performance for different system/industry configurations. I have received a memo from Pete McManamon regarding a mathematical model that may be useful. I am a little doubtful about its complete applicability because of (1) the mix of regular telephone and dispatch messages with different calling rates and holding times on the same channels, (2) the necessity to simulate geographic dispersion, and (3) the importance of simulating "handoffs" in cellular systems. I haven't had a chance to discuss this with Pete but I will as soon as I know the requirements and capabilities of the computer models.

Both of the above would fall under Task III of the OT/PSD Mobile Program Planning document which you have received.

A third relatively minor task is to become familiar with the Bell System Electronic Switching Systems (ESSs). Such a system will be an important technical and cost item in the Bell system. A good reference is "No. 2 ESS", Bell System Technical Journal, 48, No. 8, October 1969. I would like someone in ITS with good hardware and software experience to become acquainted with this switching computer, perhaps by arranging for a briefing at the Denver Bell Lab/Western Electric facility that is building some of the gear. Cost and performance comparisons with other suitable equipment would be useful.

Dale N. Hatfield/db

Dale N. Hatfield
Policy Support Division

cc: D. D. Crombie
J. E. Adams
W. B. Harding
D. L. Lucas
P. M. McManamon
H. Willis
R. K. Salaman
H. Millie (Washington PSD)

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M11

Date: February 28, 1972

Reply to Attn of: PSD/DNH

Subject: Trip Report, Washington, D. C. and Chicago, Illinois Feb. 21-25, 1972

To: R. K. Salaman

1. You are aware of the results of the OT meetings during the week so I won't repeat them here.

2. In a meeting with Art Cooke on Thursday, Paul Polishuk, Hal Millie, and I informally received the revised work statements on the Mobile Program. The remaining tasks and dollar amounts are as follows:

Task	Title	Amount	Responsibility
I.	Research and Data Base Preparation	$12K	PSD/ITS
II.	Mobile Communications Supply	40K	ITS
III.	Technological Alternatives and Implications	25K	ITS
IV.	Inter-Agency LMR Working Group Support	12K	PSD
V.	Basic Policy Implications	25K	PSD

OTP will formally send the work statements this week.

3. The meetings at Motorola on Friday were extremely useful. They gave me (1) a line-by-line explanation of their program, (2) a listing, (3) a paper tape copy, (4) sample runs, and (5) on-line instruction. I met with Jim Mikulski (Section Manager, Systems Research Lab of the Communications Division) and his programmer, Jim Engel. A copy of their transmittal letter is attached.

Dale N. Hatfield

Dale N. Hatfield

MOTOROLA INC. Communications Division

February 25, 1972

Mr. Dale Hatfield
U.S. Dept. of Commerce
Office of Telecommunications
Policy Support Division
Boulder, Colorado 80301

Dear Mr. Hatfield,

This letter accompanies the listing and paper tape copy of the "CCC Grid Simulation Program -- Dynamic Model". This program has been developed by Motorola, Inc., Communications Division, and has been described in our filing with the FCC relative to Docket No. 18262. It is considered to be proprietary to Motorola and is given to you, as a representative of the U.S. Department of Commerce, Office of Telecommunications, for the sole use of the Department. We ask that it not be disclosed to any other parties without our written permission.

The program and its operation have been explained to you. We make no representations as to the applicability for the particular usage you envision, that being your responsibility to determine. Similarly, we make no statement concerning the validity of the results in applications differing from those for which the program was specifically designed.

Sincerely,

James Mikulski

James Mikulski
Section Manager
Systems Research Lab

Accepted by Dale Hatfield
Mr. Dale Hatfield

cc: George Aichele
Mr. Jack M. [illegible]
Office of Telecommunications
Policy
Executive Office of the President
Washington, D.C.

M11

February 2[illegible], 1972

Mr. Robert Lowe
Office of Telecommunications
Department of Commerce
Washington, D.C. 20230

Dear Bob,

The attached Task Work Statements represent the results of discussions between the staff of PSD and OTP in defining the required work program to be accomplished by PSD in the Land Mobile Radio area. These tasks have been reviewed and approved by George Mansur and this letter represents your authority to proceed with the task as defined.

Art Cooke is designated as the Project Officer for the LMR activity and he and Geof Chesbrough will coordinate all the OTP activities under my direction. I look forward to working with PSD and to a successful completion of these tasks.

Sincerely,

/S/

Jack M. Thornell
Program Manager

Attach.

cc: Dr. Mansur
Mr. Polishuk
Mr. Hatfield
Mr. Cooke

PROGRAM PLANNING SUMMARY
MOBILE COMMUNICATIONS

This summary represents an initial effort to define a program which will provide analytical support in the area of mobile communications. It is based upon (1) discussions held with OTP on November 24, 1971, January 20, January 28, and February 2, 1972, and (2) a preliminary review of the submissions under FCC Docket 18262. Five basic tasks (projects) have been identified. These are:

I. Research and Data Base Preparation

II. Mobile Communications Supply

III. Technological Alternatives and Implications

IV. Inter-Agency LMR Working Group Support

V. Basic Policy Implications

The time frame constraints have been set by the desire to submit preliminary comments to the FCC in March and by the FCC's deadline for comments in June. The above tasks should be regarded as both a response to the specific issues raised by Docket 18262, as well as a response to longer range questions relating to mobile communications. In the sections which follow each of the above tasks is described in more detail and preliminary budget, manpower, and schedule estimates are provided. All tasks except Task I require interim feedback in late March.

TASK I

Research & Data Base Preparation

1. Objective: To compile an LMR Program data base of pertinent FCC Docket information and filing summaries and other technical/economic concept information as a foundation for analysis work to be accomplished under Tasks II and III.

2. Requirements: The filings under Docket 18262 are sufficiently voluminous that summaries are required to aid study team personnel in efficiently assimilating the material contained therein.

3. Work Statement: Each of the current filings under Docket 18262 will be summarized. In addition, previous filings and relevant technical papers which provide additional detail on the filings will be collected and cataloged. Subsequent filings, trade journal articles, technical papers, and other pertinent materials will also be collected and summarized as required. The filings will be compared and contrasted in order to highlight the features and limitations of each. An important task to be performed as a part of the data base preparation is to identify the 27 Major LMR market areas, and those institutional organizations presently requiring spectrum

within each of these areas, i.e., wireline companies, RCC's and private business users. Also, there should be a similar compilation which shows major highways and rural areas and those using spectrum in these areas.

4. Interfaces: This task will supply information to all other projects on a continuing basis.

5. Milestones: This project is currently under way. Copies of the current filings have been obtained and are currently being summarized. The remaining milestones are--

Summaries Completed	1 March 1972
Information Base Documented (Catalog)	15 June 1972

6. Manpower:

Engineer/OR Analyst	3 man-months
Support	1 man-month

7. Budget: $12K

TASK II

Mobile Communications Supply

1. Objective: To determine, through supply analysis, the application (capacity) of various proposed technologies and alternative industry structures to meet all LMR service needs as a function of: cost, spectral efficiency, and performance.

2. Requirements: There are many types of services to be provided under the general heading of mobile communications and there are many different technical configurations and industry structures that can provide such services. Many of these alternatives are addressed in the filings and others (possibly more innovative) are possible. Sound policy decisions require the analysis of these alternatives in terms of cost, performance, and spectrum efficiency. The complexity of these alternatives precludes the use of ordinary analytical methods and requires the adaptation/development of a suitable simulation model.

3. Work Statement: Since this is a fairly large study, the work statement has been divided into a number of sub-elements:

(a) Identify and describe a number of representative alternative systems based on a study of the filings, the SAI study work, and discussions with OTP, OT, and industry personnel.

(b) Develop or adapt a computer simulation model for evaluating the types of systems identified in (a) either individually or in combination. This model will predict the system performance (e.g., probability of blockage, average delay, spectrum required) as a function of market size, the geographic distribution of base stations and mobile units, and message statistics. It will provide data on the number and length of wireline facilities, the number of transmitter/receiver combinations, and other information necessary to develop cost information.

(c) Gather cost information on existing systems and systems proposed in the filings. This information will be developed as a function of frequency range, number of channels, power output, number of landlines, etc., so that it can be readily included in the model. Maintenance, administrative, and other operating costs will also be obtained. The cost information supplied in the filings will be analyzed in detail. All cost data will be organized for publication as a separate part of the report. This will include breakouts of current base station and in-car equipment costs, as well as the sunk costs in current systems.

(d) Evaluate the alternatives outlined in (a) using the model developed in (b) and the cost data from (c). This will include studies of (1) the current system, (2) systems proposed in the filings, and (3) other innovative systems or combinations. A primary output of this task will be curves showing costs versus number of users for the alternative systems. These curves will show the lowest cost technology (configuration) for different levels of demand. They will also indicate economies of scale.

4. Interfaces: This project will receive inputs from Tasks I and SAI. Task I will provide general background information and SAI will provide information on innovative services and the range of demands that must be considered. This project will provide information to Task V which is concerned with broader economic issues. For example, it will provide information on the economies of scale associated with the various alternatives. Furthermore, it will provide insight into the reliability and sensitivity of the conclusions presented in the filings.

5. Milestones:

(a) Alternative Systems/Configurations Identified and Model Requirements Determined — 1 March 1972

(b) Computer Simulation Model Available* — 15 April 1972

(c) Evaluation of Alternative Configurations Completed and Interim Results — 15 May 1972

(d) Report Issued — 1 July 1972

6. Manpower:

Engineer/OR Analyst	6 man-months
Programmer	6 man-months
Support	3 man-months

7. Budget:

Labor	$35K
Computer	2K
Other	3K
	$40K

*This estimate is based on the assumption that existing model or models can be acquired from the applicants or other sources. Preliminary steps to acquire the Motorola model have already been taken because of the critical time constraints.

TASK III

Technological Alternatives and Implications

1. Objective: To determine the technical feasibility of advanced system applications and to estimate the probability of their timely, economic development and implementation.

2. Requirements: There is a concern that the decisions in Docket 18262 may preclude the development of more advanced system concepts in the future. For example, has adequate attention been paid to digital-voice systems using time-division multiple-access techniques? Such techniques would alleviate problems associated with using a single amplifier or antenna to handle many signals at a base site. The significance of allocating 75 MHz of spectrum for the development of a high-capacity system with a large capital investment requires assurance that (1) all current technological alternatives have been adequately investigated, (2) the decisions will not unduly restrict future options, and (3) that the future systems will not be functionally inflexible.

3. Work Statement: The sub-elements of this task are:

(a) Identify advanced technological alternatives based on inputs from SAI material in the filings, technical papers, and discussions with OTP, industry, and governmen personnel.

(b) Evaluate the alternatives identified in (a) in terms of (i) their performance advantages and disadvantages (in particular whether the system would be "transparent" to users), (ii) the current state-of-the-art, (iii) reason for rejection by current applicants if applicable, (iv) problems of future implementation if current proposals are accepted, i.e., EMC, (v) costs, (vi) changes in the future state-of-the-art that may affect any of the foregoing, and (vii) their overall probability of implementation.

(c) Prepare a report describing the results and containing recommendations.

4. <u>Interfaces</u>: This project will receive data from Tasks I and the SAI study and it will make use of Task II to evaluate the more promising alternatives.

5. <u>Milestones</u>:

Advanced Alternatives Identified and Described	15 March 1972
Evaluation Completed	15 May 1972
Final Report Issued	15 June 1972

6. <u>Manpower</u>:

Engineer	6 man-months
Support	2 man-months

7. <u>Budget</u>: $25K.

TASK IV

Inter-Agency LMR Working Group Support

1. Objective: The objective of this task is to assist OTP in the leadership of the Inter-Agency LMR Working Group, consisting of representatives from OTP, FCC, HUD, HEW, DOT and LEAA.

2. Requirement: Decisions made by the FCC under Docket 18262 may have an impact on the successful implementation of programs of the various participating agencies. For example, Automatic Vehicle Monitoring systems may have spectrum requirements that must be met by assignments in the frequency bands that are the subject of the FCC Docket. Another example is the systems to telemeter medical information from ambulances to the emergency room of the hospital. The Inter-Agency Working Group will submit comments to the FCC on the impact of these requirements. OT will supply the secretarial and technical staff support required by the Working Group.

3. Work Statement: This task will include (1) preparation of agendas and minutes, (2) collection of reports dealing with proposed systems, (3) technical analysis and synthesis of requirements under the direction of the Working Group, and (4) other activities as required.

4. <u>Milestones</u>: Milestones will be determined by the meeting and report schedule adopted by the Working Group. A preliminary schedule is as follows:

First Meeting	18 Feb 1972
Second Meeting	7 Mar 1972
Third Meeting	5 Apr 1972
Draft Report	3 May 1972
Final Report	1 Jun 1972

5. <u>Interfaces</u>: This project is essentially complete in itself. Portions of the results will be directed toward Task V.

6. <u>Manpower</u>:

Professional	2½ man-months
Support	1 man-month

7. <u>Budget</u>: $12K

TASK V

Basic Policy Implications

1. Objective: There are two objectives under this task: first, to identify basic policy issues which emerge from earlier tasks (I through IV); second, to obtain and document preliminary and final conclusions, recommendations, and results of analyses, derived during the course of the overall study effort.

2. Requirements: It is likely that additional policy issues will surface during the course of the other investigations. Furthermore, certain non-quantifiable issues which are not inherently considered in analytical studies of performance (quality of service), economic efficiency, and spectrum efficiency, must not be overlooked. The purpose of this task is to identify these issues. It is also necessary to collect in a single document the principal results, conclusion, and recommendations of the several other studies in this program area.

3. Work Statement:

(a) Basic policy issues which were identified in previous meetings will be reviewed and any further issues identified in the other tasks will be added as they are available.

(b) Preliminary results of the other tasks will be documented for use in initial comments to the FCC.

(c) Regular progress reports and a final report will be prepared.

4. Interfaces: This task will receive data from all other studies in the program area. It will provide information to the other projects as the policy issue definitions are refined.

5. Milestones:

Program Progress Reports	(Monthly)
Compilation of Policy Issues Completed	1 Mar 1972
Preliminary Results Summarized	15 Mar 1972
Report Issued	15 Jun 1972

6. Manpower:

Economist	5 man-months
Engineer	2 man-months

7. Budget: $25K

DNH 2-23-72

MC2

Draft Work Statement

Mobile Telephone System Coverage

The Office of Telecommunications Policy (OTP) has noted that it does not have information on the present coverage of Mobile Telephone Systems in the U.S. This is another piece of information that is needed to serve as a benchmark for the analysis of new systems proposed for 900 MHz. Such coverage is now provided by the wireline common carriers (WCCs) and radio common carriers (RCCs). Both provide for the interconnection of mobile units with the nationwide telephone network.

OTP has specifically requested this task. The objective is to provide a series of maps (overlays) showing the existing coverage of WCC and RCC Mobile Telephone Systems. In many areas both RCCs and WCCs provide coverage so the overlays will be needed to show multiple coverage. Emphasis should be placed on the coverage in the top 27 markets although information on nationwide coverage is also desired. There are some maps already available from the RCC industry group (NARS) but OTP seemed to feel that they were inaccurate in terms of actual coverage.

The task will be divided into two phases. The purpose of Phase I will be to study the availability and form of existing data. From this preliminary study, an estimate of the effort required to actually prepare the coverage maps in Phase II will be made. A decision on whether to continue with Phase II will be made at the end of Phase I. A short memo will be required at the end of Phase I and a short report describing the maps will be required at the conclusion of Phase II.

It is estimated that Phase I will require about 1/2 man-month of effort.

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M13

Date: March 1, 1972

Reply to Attn of: PSD/DNH

Subject: Meeting with ITS regarding Mobile Program Area

To: R. K Salaman

On Tuesday, February 29, I held a meeting with ITS personnel who will be working on the Mobile Program. The purpose of the meeting was to (1) introduce the project team to each other, (2) familiarize them with the overall problem, and (3) make preliminary assignments of people to tasks.

We arrived at the following tentative assignments:

Scotty Hart	Current MTS coverage, subscribers, industry structure (Task I)
Wes Harding	Current MTS and Dispatch costs, prices, and technology (Task I) and costs of 900 MHz Mobile and Base-station equipment
Jean Adams Judy Stephenson	Computer Model (Task II)
Gene Ax	Technological Alternatives (Task III)

I still need help in analyzing processor and landline requirements and costs for cellular systems. I have contacted George Sugar in NBS regarding the processor analysis and have scheduled a meeting for 8:30 AM Friday to discuss it further. I also have the name of a consultant here in Boulder that has expertise in this area. I am still looking for help on landline costs.

Dale N. Hatfield

Dale N. Hatfield

MICROWAVE MOBILE RADIO SYMPOSIUM

Department of Commerce Laboratories

Boulder, Colorado 80302

March 1 - 3, 1972

Sponsored by the IEEE Vehicular Technology Group, the IEEE Communications Society, the Denver Section of the IEEE, and the Institute for Telecommunication Sciences of the Department of Commerce.

General Information: Technical sessions will be held at the Radio Building, Department of Commerce Laboratories, Boulder, Colorado. Registration will be held in the lobby of the Radio Building. Registration cost for the Symposium is $6.00; checks should be made out to the Denver Section of the IEEE. Tickets for the dinner meeting (spouses are cordially invited) at the Greenbriar Inn will be available at the registration desk; the cost is $5.50 per person.

This brochure includes a list of the technical sessions and titles of the papers to be presented. Additionally, paper abstracts or outlines, if available, are given. A formal Symposium Record will not be published, but the speakers are invited to present their material for publication in the technical journals of the sponsoring Groups.

PROGRAM FOR MICROWAVE MOBILE RADIO SYMPOSIUM

SESSION I - PROPAGATION - Wednesday, March 1, 1972, 8:30 - 12:00 AM

Chairman: A. J. Rustako, Jr., BTL, Holmdel, N.J.

Introductory Remarks by Officials of Sponsoring Groups

1. 910 MHz URBAN MOBILE RADIO PROPAGATION: MULTIPATH TIME DELAY MEASUREMENTS IN NEW YORK CITY.
   D. C. Cox, Bell Telephone Labs., Holmdel, N.J.

2. MOBILE RADIO PROPAGATION STATISTICS AT 900 MHz IN NEW YORK CITY.
   J. Shefer, G.S. Kaplan, and S.N. Honicknan*, RCA Laboratories, Princeton, N.J. (*now at Mitre Corp., McLean, Va.).

3. MULTIPATH AND MOBILE ANTENNA GAIN.
   N.H. Shepherd, G. E., Lynchburg, Va.

4. THE DETERMINATION OF SERVICE AREA FOR UHF-UHF LAND MOBILE AND BROADCAST OPERATION OVER IRREGULAR TERRAIN.
   A.P. Barsis, Inst. for Telecommunication Sciences, Boulder, Colorado.

5. THE ELEVATION ANGLE OF MOBILE RADIO SIGNAL ARRIVAL.
   W.C.Y. Lee, Bell Telephone Labs., Holmdel, N.J.

6. RESULTS OF SUBURBAN BASE STATION SPATIAL DIVERSITY MEASUREMENTS IN THE UHF BAND.
   S.B. Rhee and G.I. Zysman, Bell Telephone Laboratories, Whippany, N.J.

SESSION II - SYSTEM ORGANIZATION - Wednesday, March 1, 1972
1:30 - 5:00 PM

Chairman: D. O. Reudink, BTL, Holmdel

1. A SIMULATION STUDY OF SOME DYNAMIC CHANNEL ASSIGNMENT ALGORITHMS IN A HIGH CAPACITY MOBILE TELEPHONE SYSTEM.
   L. G. Anderson, Bell Telephone Labs, Columbus, Ohio.

2. PERFORMANCE OF DYNAMIC CHANNEL ASSIGNMENT IN SIMULATED HIGH CAPACITY MOBILE RADIO SYSTEMS.
   D. C. Cox and D. O. Reudink, Bell Telephone Labs, Holmdel, N. J.

3. NEW MOBILE COMMUNICATION SYSTEMS USING REPEATERS AT THE SAME FREQUENCY. (AN ALTERNATIVE TO SMALL CELL COVERAGE)
   Henry Magnuski, Consultant, Glenview, Ill.

4. MOBILE TELEPHONE COMMUNICATIONS AT MILLIMETER WAVELENGTHS.
   C. L. Ruthroff, Bell Telephone Labs, Holmdel, N. J.

5. THE EFFECTS OF LOCATION CAPABILITY ON DYNAMIC CELL SYSTEMS.
   J. J. Mikulski, Motorola, Schaumburg, Ill.

6. RADIO SIGNAL COVERAGE AND THE ESTIMATION OF BASIC SCALE PARAMETERS IN CELLULAR MOBILE RADIO SYSTEMS.
   L. J. McDonald, Bell Telephone Labs, Holmdel, N. J.

Dinner Meeting, Greenbriar Inn, Foothills Highway (U. S. 36) N of Boulder at intersection with Left Hand Canyon Road.

Wednesday, March 1, 1972 - Informal Get-together at 6:00 p.m.
Dinner at 7:00 p.m.

TELECOMMUNICATIONS AT THE FEDERAL LEVEL: SOME PROBLEMS AND FUTURE PROSPECTS.
T. F. Rogers, Vice President, Urban Affairs, Mitre Corporation

SESSION III - PROPAGATION - Thursday, March 2, 1972, 8:30 - 12:00 AM

Chairman: A. P. Barsis, OT/ITS, Boulder, Colorado

1. COHERENCE BANDWIDTH IN MOBILE RADIO.
   M. J. Gans, Bell Telephone Labs, Holmdel, N. J.

2. STATISTICS OF X-BAND PROPAGATION IN AN URBAN ENVIRONMENT.
   G. S. Kaplan, J. Shefer, and S.N Honicknan*, RCA Laboratories, Princeton, N. J. (*now at Mitre Corp., McLean, Va.)

3. MOBILE PROPAGATION EXPERIMENTS AT MILLIMETER WAVE FREQUENCIES.
   L. U. Kibler, Bell Telephone Labs., Holmdel, N. J.

4. COMMUNICATION CHANNEL CHARACTERIZATION AND MEASUREMENT.
   H. Salwen and P. A. Bello, Signatron Inc., Lexington, Mass.

5. THE DURATION OF LONG-TERM MOBILE RADIO SIGNAL FADING CAUSED BY SHADOW EFFECT.
   W.C.Y. Lee and Y.S. Yeh, Bell Telephone Labs, Holmdel, N. J.

6. WHEN ARE HIGHLY CORRELATED RAYLEIGH SIGNALS CORRELATED ENOUGH?
   L. Schiff, RCA Laboratories, Princeton, N. J.

SESSION IV - NOISE AND INTERFERENCE - Thursday, March 2, 1972
1:30 - 5:00 PM

Chairman: J. Tary - NBS, Boulder, Colorado

1. WIDEBAND MEASUREMENT OF MAN-MADE NOISE.
   R. Buck, Transportation Systems Center, DoT, Cambridge, Mass.; R. Esposito, Raytheon Research Division, Waltham, Mass.; P. Yoh, Transportation Systems Center, DoT, Cambridge, Mass.

Session IV
Continued

2. STATISTICAL-PHYSICAL MODELS OF MAN-MADE RADIO SIGNALS AND INTERFERENCE.
D. Middleton, Physicist and Applied Mathematician, New York, N.Y.

3. UPPER UHF AND L-BAND METROPOLITAN INCIDENTAL MAN-MADE RADIO NOISE.
E. N. Skomal, Aerospace Corp., San Bernardino California.

4. BASEBAND PERFORMANCE OF A PILOT-DIVERSITY SYSTEM IN THE PRESENCE OF RAYLEIGH-FADING SIGNALS AND CO-CHANNEL INTERFERENCE.
R. E. Langseth, Bell Telephone Labs, Holmdel, N.J.

5. SUBJECTIVE VOICE-CIRCUIT QUALITY MEASUREMENTS IN THE PRESENCE OF MULTIPATH FADING.
V. H. MacDonald, Bell Telephone Labs, Holmdel, N.J.

6. THE AMPLITUDE AND TIME STATISTICS OF ENVIRONMENTAL MAN-MADE NOISE AT 821 MHz.
H. L. Hanig, Bell Telephone Labs, Whippany, N.J.

<u>SESSION V</u> - <u>RADIO SYSTEMS AND TECHNIQUES</u> - Friday, March 3, 1972
8:30 - 12:30 AM

Chairman: Harold Staras, RCA Laboratories, Princeton, N.J.

1. A MOBILE RADIO, SINGLE FREQUENCY "TWO-WAY" DIVERSITY SYSTEMS USING ADAPTIVE RETRANSMISSION FROM THE BASE.
H. H. Hoffman, Bell Telephone Labs, Holmdel, N.J.; J. S. Bitler, Bell Telephone Labs, Merrimack Valley, Mass.; C. O. Stevens, Bell Telephone Labs, Holmdel, N.J.

2. ON THE USE OF PHASE-LOCKED LOOP DEMODULATORS IN THE PRESENCE OF RAYLEIGH FADING.
R. E. Langseth, Bell Telphone Labs, Holmdel, N.J.

3. A UHF MOBILE TELEPHONE SYSTEM USING DIGITAL MODULATION, PRELIMINARY STUDY.
   J. S. Bitler, Bell Telephone Labs, Merrimack Valley, Mass.; C. O. Stevens, Bell Telephone Labs, Holmdel, N.J.

4. A 900 MHz MULTIPLE ACCESS $F_1 F_1$ REPEATER MOBILE COMMUNICATION SYSTEM.
   P. F. Sielman, AIL, Deer Park, L.I., N.Y.

5. A NUMERICAL METHOD FOR THE SYNTHESIS OF CIRCULAR ARRAY ANTENNA PATTERNS WITH APPLICATIONS TO MOBILE RADIO SYSTEMS.
   Thomas H. Zachos, Bell Telephone Labs, Holmdel, N.J.

6. MULTIPLEXING PROBLEMS IN CENTRAL TALKOUT TRANSMITTERS.
   C. N. Lynk, Motorola, Schaumburg, Ill.

7. ANTENNA SITE MANAGEMENT, VOLLMER PEAK PROJECT, A PROGRESS REPORT.
   J. R. Hall, Microwave Associates, Sunnyvale, Calif.; J. Watson, Watson Communications, Inc., Lafayette, Calif.

MICROWAVE MOBILE RADIO SYMPOSIUM

SESSION I

I-1 910 MHZ URBAN MOBILE RADIO PROPAGATION: MULTIPATH TIME DELAY MEASUREMENTS IN NEW YORK CITY. D. C. Cox, Bell Telephone Labs., Holmdel, N. J.

SUMMARY: Amplitude and time delays associated with multipath propagation have been measured between a base station antenna on top of a 400-foot building in New York City and a vehicle moving along streets up to two miles away. The vehicle usually was shadowed from the transmitting antenna by intervening buildings. The measuring system, which was described at the 1971 USNC/URSI spring meeting, measures the 910 MHz complex bandpass impulse response (amplitude and phase of the multipath propagation) with a resolution of 0.1μsec in time delay. Individual power delay profiles illustrate that frequently more than 10 paths with significant amplitudes (less than 6 dB below the strongest path) exist. A multitude of weaker paths also are evident. Often the multipath structure is significant at excess delays as large as 10 μsec. The strongest paths are frequently a microsecond or more delayed from the shortest path observed. Local statistics for vehicle travel distances of about 100 feet, such as average power delay profiles and distributions of signal amplitude at fixed delays, are presented. RF doppler spectra associated with some particular delays (cross sections of delay-doppler scattering functions) are illustrated.

II-2 MOBILE RADIO PROPAGATION STATISTICS AT 900 MHz IN NEW YORK CITY. J. Shefer, G. S. Kaplan, and S. N. Honicknan*, RCA Laboratories, Princeton, N. J. (*Now at Mitre Corp., McLean, Va.)

SUMMARY: With mounting frequency spectrum congestion in urban areas, efforts are under way to utilize the newly allocated frequencies in the high UHF band at maximum efficiency. This paper describes a series of propagation experiments in New York City

in which a number of parameters pertinent to mobile radio communications were investigated. While these propagation tests were conducted in such a way as to find answers to problems arising in a conventional mobile radio system at 900 MHz, they were also aimed at providing system design data for a novel approach to mobile radio communications in which a given frequency is concurrently used in a number of sub-zones of an urban complex[1]. Specifically, tests had to provide data for the determination of so called speech-to-noise ratios not only in the presence of thermal and man-made random noise but also in the presence of a large number of interfering transmissions.

In the tests, a CW wave at 892 MHz and 16 watts power was omnidirectionally radiated from an 8 dB gain antenna. The vehicle-mounted receiver used a 5 dB gain omnidirectional antenna and had a sensitivity of -110 dBm in a 25 kHz bandwidth, accommodating a maximum path loss of 165 dB and a dynamic range of 80 dB. Signal amplitudes were stored on FM magnetic tape, then converted to digital format for analysis, with an overall effective frequency response of DC to 2 kHz and a 256 level resolution. The basic computer analysis output was an amplitude probability distribution of the received signal, acquired either while standing or moving in a prescribed zone for one or two minutes duration. These zones were laid out such that expected free-space propagation variations within a zone were less than 1 dB. The levels at which signals were exceeded 1%, 10%, 50%, 90% and 99% of time are presented in the form of contours, showing path loss as a function of distance for zones strung out at intervals on a radial line originating at the transmitter.

Data are presented for two transmitter antenna heights. One height is a more or less conventional rooftop location (135 ft) where the aim is for maximum coverage. The other height is only 30 ft which may be a more suitable height for small-zone coverage and maximum blocking of out-of-zone interference.

Signal statistics were obtained for three directions originating at a downtown Manhattan transmitter site. The directions chosen were north, into uptown Manhattan and the Bronx, south, including downtown Manhattan and parts of Brooklyn, and east into Queens. Good signals were measured out to ranges of 8 to 10 miles.

1. H. Staras and L. Schiff, "Spectrum conservation in the land mobile radio services", IEEE Spectrum, July 1971, pp. 28-36.

Samples of amplitude probability distributions, both for moving and standing vehicles, will be shown, as will also the amplitude statistical data as a function of distance in the different directions. Some implications for mobile radio systems in the 900 MHz band will be discussed.

I-3 MULTIPATH AND MOBILE ANTENNA GAIN, N. H. Shepherd, General Electric, Lynchburg, Virginia

SUMMARY: Multipath signal waves between the base transmitter and mobile receiver causes a disturbance in the audio output which is somewhat similar to impulse noise. The rate of disturbance increases directly with both the operating frequency and speed of the mobile. As its rate increases, each individual disturbance decreases in length, thus partially compensating from change in interference. Recordings will be presented at various speeds and frequencies of 450 and 900 MHz to allow subjective comparison of the effects of frequency and speed.

Mobile gain antennas have been used under various multipath conditions. Statistical comparisons will be made between $\lambda/4$ dipole and mobile gain antenna at 900 MHz for various multipath conditions such as, line-of-sight, diffraction path, and shadow path. Comparisons will be based on signal level distributions of 500 ft runs.

I-4 DETERMINATION OF SERVICE AREA FOR VHF/UHF LAND MOBILE AND BROADCAST OPERATIONS OVER IRREGULAR TERRAIN. A. P. Barsis, Office of Telecommunications, Institute for Telecommunication Sciences, Boulder, Colorado.

ABSTRACT: In this paper we define service area of VHF/UHF land mobile and broadcast stations and demonstrate graphical and computer methods to determine and present such areas as a function of known equipment parameters and of a propagation model derived largely from an extensive measurement program over irregular terrain.

I-5 THE ELEVATION ANGLE OF MOBILE RADIO SIGNAL ARRIVAL, W. C. Y. Lee, Bell Telephone Laboratories, Holmdel, New Jersey.

ABSTRACT: The elevation angle of arrival of mobile radio signals in two polarizations, vertical and horizontal, has been investigated while the mobile unit is moving on the streets in an urban area. We have used two high gain antennas mounted on the roof of a mobile unit:

a colinear (3-element) half wave in-phase antenna with a gain 4 dB above a whip antenna for receiving a vertically polarized wave, and a 5-element cloverleaf antenna with a gain 3 dB above a loop antenna for receiving a horizontally polarized wave. As we compared the signals received from these two antennas with those from two standard ones, the average field strengths received from the two high gain antennas were higher for most streets. This observation indicates that the signal arrival is concentrated in elevation angles near the horizontal for both polarizations. We may also predict that the signal arrival is concentrated along the horizontal in a metropolitan area by adapting the waveguide concept to the streets. Hence we suggest that a 4 dB high gain vertical polarization antenna may be used to replace the whip antenna in a diversity combining system in order to gain signal strength in addition to the advantage of the diversity scheme. We also suggest that a high gain horizontally polarized antenna with simple structure could be designed especially for use with polarization diversity.

I-6 RESULTS OF SUBURBAN BASE STATION SPATIAL DIVERSITY MEASUREMENTS IN THE UHF BAND. S. B. Rhee and G. I. Zysmann, Bell Telephone Laboratories, Whippany, New Jersey

ABSTRACT: Base station spatial diversity measurements in the UHF band were performed in the Whippany, New Jersey area using directional antennas. Antenna pairs were separated by 3.4, 6.6, and 10 wavelengths. The cross correlation coefficients between the signals received by two antennas were computed as a function of antenna height, antenna separation, and signal polarization. Both vertical and horizontal antenna spacings were employed in the measurements. The antenna azimuthal beam widths were typically 100 degrees at the half-power points.

The cross-correlation coefficients were obtained by measurements in seven different probing areas. The following table indicates variations obtained in these sites.

Antenna Height	Polarization	Antenna Spacing	Correlation Coefficients	
			Range	Mean
100 ft	Vertical	10 λ	0.285 - 0.835	0.525
		6.6 λ	0.445 - 0.890	0.674
		3.4 λ	0.760 - 0.910	0.828

The variations occur as a function of vehicle location and the particular terrain features between the mobile transmitter and the base station receiver. We feel that most of the diversity advantage may be realized with an antenna spacing of approximately seven wavelengths in a suburban environment.

SESSION II

II-1 A SIMULATION STUDY OF SOME DYNAMIC CHANNEL ASSIGNMENT ALGORITHMS IN A HIGH CAPACITY MOBILE TELEPHONE SYSTEM

L. G. Anderson, Bell Telephone Labs., Columbus, Ohio

SUMMARY: High Capacity Mobile Telephone System (HCMTS) is the name given to a system that has been proposed by BTL to meet the increased demand for mobile telephone service. A large number of radio channels are provided for such a system. Efficient use of the radio spectrum required for these channels is attained by providing multiple base stations and limiting coverage of each base station to a relatively small area termed a radio coverage cell. Radio channels are assigned to cells which are sufficiently separated so that co-channel interference is reduced to acceptable levels. Assignment may be on either a permanent basis, fixed channel assignment, or the assignment can be made only for the duration of the call. The latter method has been called dynamic channel assignment.

This paper reports an investigation to determine the increase in traffic capacity provided by dynamic channel assignment as compared to fixed channel assignment. Of the many dynamic channel assignment procedures one could choose, this work has been limited to those which use a fixed channel assignment as only a nominal or first choice channel assignment. When none of these nominal channels are available for use in a cell, an attempt is made to borrow a channel which is nominally assigned to some other cell.

A system layout containing 21 cells arranged in a hexagonal array was used in the study. It was assumed that traffic was highly concentrated in the center cells of the system. For study purposes it was assumed that traffic grows proportionally in each cell. A channel reuse criterion of six cell radii was assumed. That is, a radio channel can be simultaneously used by several base stations if they are separated by at least six cell radii. Assuming the base station is located at the cell center, the cell radius is the maximum distance from a base station that a mobile is permitted to use that base station. With fixed channel assignment, reuse criterion of six cell radii in a hexagonal array of cells implies a requirement of twelve sets of radio channels to completely cover the array. If all cells had the same amount of traffic, assigning channels to the twelve channel sets and then to cells would be a trivial

matter. However, when there is substantial cell-to-cell variation in offered traffic, some traffic capacity may be gained by assigning channels to cells at distances greater than the minimum required. This technique has been called fixed borrowing. Prior to evaluating dynamic channel assignment, the maximum capacity attainable with fixed borrowing must be found. A procedure for doing this has been developed which utilizes the concept of mutual interference sets of cells. A side result of this effort is an upper bound on the increased traffic capacity obtainable from dynamic channel assignment.

A more complex question is the effect handoffs have on probability of blocking and how much the traffic in each cell is modified. As before a transit time distribution is computed. This enables one to study the problem by computer simulation. Simulation of a system of 21 hexagonal cells has been performed. In addition to simulation efforts, an analytical model has been formulated based on the well known Erlang B formula for blocking probability. This results in a system of N simultaneous nonlinear equations where N is the number of cells. An efficient iterative procedure for solving these equations has been developed and tested. Solutions are compared to the simulation results above, showing good agreement.

The main effect of handoffs is to cause a reduction of cell-to-cell variation in the amount of offered traffic. These effects are of sufficient magnitude to cause substantial changes in the probability of blocking in each cell. By adjusting the amount of equipment provided each cell the probability of blocking can be made uniform. It is probably desirable to reduce the probability of blocking for handed off calls below that for new calls. No methods for doing this have been investigated, but the analytical model developed should provide a tool for investigating the effectiveness of at least some of the possible approaches for doing this.

II-2 PERFORMANCE OF DYNAMIC CHANNEL ASSIGNMENT IN SIMULATED HIGH CAPACITY MOBILE RADIO SYSTEMS.

D. C. Cox and D. O. Reudink, Bell Telephone Laboratories
Holmdel, N.J.

SUMMARY: High capacity mobile radio systems with large numbers of radio channels are being studied as a way to relieve the overcrowded conditions existing in mobile radio communications today.

In order to make efficient use of frequency spectrum, radio coverage of these proposed systems would be limited to small zones and channels would be reused several times within a particular urban area.[1] Computer control of such a system certainly would be necessary. Bounds on the behavior of simplified systems have been obtained previously[2] but the problem of determining the performance of these complex systems by rigorous analytical methods does not appear tractable. This paper presents a comparison of some performance characteristics of dynamic channel assignment and fixed channel assignment mobile radio systems obtained by simulation on a high-speed digital computer.[3] In the dynamic assignment system a channel is assigned to a requesting vehicle and its covering base station by methods which consider the channels in use at that instant at that base station and at base stations within some region surrounding the vehicle. Once a channel is assigned it will generally stay with the vehicle for the duration of the call which may involve the assignment of other base stations to that channel as needed to cover the vehicle. In the fixed assignment system only certain specified channels are available at each base station. The assignment of a channel to a mobile within the coverage area of a base station must be made from the specific channel set allocated to that base station.

The simulation program is broken into two parts. The first generates the demand on the mobile radio system. The second part operates on that demand with a given channel assignment strategy. In the first part, requests for service are initiated as a Poisson process in time. The locations of the mobiles initiating calls are distributed uniformly in space. These calls which are eventually assigned a channel by the second part of the program are moved about with random velocities for random lengths of time. The model at this stage assumes the following: (1) the existence of a reuse distance beyond which co-channel interference may be neglected, (2) that only one base station is required to provide adequate coverage to the vehicle and that this base station is known, and (3) that all channels can be generated and received at all base stations and by all vehicles. The assignment strategy chosen for this simulation attempts to pack channel assignments as close together as possible, but it never allows a channel to be used at base stations less than a reuse interval apart. If, during operation, a mobile crosses a coverage area boundary and causes co-channel interference, a search is made for a new channel. In the simulation, if no channel is available the call is terminated.

Computer simulations were run for a one-dimensional system with uniform base station spacing and for a two-dimensional system with base stations positioned uniformly on a rectangular grid. The parameters for the two systems are listed in Table 1.

Compared to fixed channel assignment systems with 10 channels allotted per base station, the dynamic channel assignment systems perform better (more traffic carried per channel) when operating at blocking rates below about 10 percent. Table 2 shows some relative comparisons for the three systems.

At low blocking, dynamic channel assignment systems are able to supply additional channels to meet the peaking demands of the Poisson call initiation process. At high blocking, the fixed channel assignment system forces channel reuse to be optimum and thus carries more traffic.

Table 1

Parameter	System: One Dimension	System: Two Dimension
Number of Base Stations	24	27×27
Base Station Coverage Area	2 mi.	2 mi.×2 mi.
Channel Reuse Interval	8.mi.	8 mi.
Total Number of Channels	40	160
Average Number of Channels Per Base Station	10	10
Vehicle Velocities	Truncated Gaussian Distribution Maximum Velocity = 60 mph σ = 30 mph	Truncated Gaussian Distribution Maximum Velocity = 60 mph σ = 30 mph
Call Duration	Gaussian and Exponential Mean = 103.5 sec	Exponential Mean = 103.5 sec

Table 2

Blocking of New Call Attempts (%)	Traffic Carried (Average Calls On Per Base Station) Fixed Channel Assignment Systems	Dynamic Channel Assignment Systems One Dimension	Dynamic Channel Assignment Systems Two Dimension
1	4.4	6.3	6.25
3	5.4	6.75	6.5
10	6.75	7.34	6.70
30	8.3	8.0	7.1

References

1. H. J. Schulte, Jr. and W. A. Cornell, "Multi-Area Mobile Telephone System," IRE Transactions on Vehicular Communications, Vol. 9, 1960, pp. 49-53.

2. L. Schiff, "Traffic Capacity of Three Types of Common-User Mobile Radio Communication Systems," IEEE Transactions on Communication Technology, Vol. COM 18, No. 1, February 1970, pp. 12-21.

3. D. C. Cox and D. O. Reudink, "Dynamic Channel Assignment in High Capacity Mobile Communications Systems," Bell System Technical Journal, July-August, 1971.

II-3 NEW MOBILE COMMUNICATION SYSTEMS USING REPEATERS AT THE SAME FREQUENCY. (AN ALTERNATIVE TO SMALL CELL COVERAGE)

Henry Magnuski, Consultant, Glenview, Ill.

SUMMARY: In mobile communications omnidirectional antennas are used and prohibitive RF power is required to extend the communication range, especially at microwave frequencies. Systems using chains of small, on-frequency repeaters will permit unlimited range extension with low power transmitters. The problem of interference between adjacent repeaters is solved by arranging the transmission and reception periods to be less than half of the time, so that the mobile vehicle never receives the two signals simultaneously. The main advantages of such systems are: low transmitter power, good spectrum utilization and uniformly good voice communication regardless of distance, since digital modulation is used.

II-4 MOBILE TELEPHONE COMMUNICATIONS AT MILLIMETER WAVELENGTHS.

C.L. Ruthroff, Bell Telephone Labs, Holmdel, N.J.

ABSTRACT: There are approximately 100 million cars and trucks in the United States without telephones. While important services exist and are planned at frequencies below 1000 megahertz, the use of these frequencies for general telephone service is severely restricted by one or both of the following fundamental limitations.

(i) There is not enough bandwidth available at these frequencies for the large number of circuits necessary to provide mobile telephone service to the general public.

(ii) Transmission between the base station and the mobile unit is via a scattered signal which fades deeply and rapidly and makes it very difficult, if not impossible, to achieve commercial grade telephone service most of the time.

The first limitation does not exist at millimeter wavelengths; above 30 GHz sufficient bandwidth is available for a widespread mobile telephone system. With respect to the second limitation, high quality transmission can be achieved with a combination of narrow-beamwidth antennas and line-of-sight transmission.

The purpose of this talk is to describe a model of a mobile telephone system with a potential capability of connecting all cars and trucks in the country to the existing telephone network. This potential mobile network is the same order of size as the present fixed telephone network. To obtain this enormous capability, multiplexing of the circuits in the mobile-base station link is required and will be described. Acquisition, tracking, and hand-off during a call in progress are also described.

As already suggested the system would operate at a frequency above 30 GHz. The effects of rain attenuation and atmospheric absorption loss will be discussed and examples of the expected signal-to-noise ratios will be presented.

The viability of the system model depends very strongly upon the hardware realization. Solid state device technology and the techniques of manufacturing integrated circuitry at millimeter wavelengths have reached the point where it is now possible and reasonable to realize the apparatus required to do the job. Circuits for performing the required functions at millimeter wavelengths will be described.

II-5 THE EFFECTS OF LOCATION CAPABILITY ON DYNAMIC CELL SYSTEMS.

James J. Mikulski, Motorola, Inc., Schaumburg, Ill.

SUMMARY: A simulation program has been described[1] which allows the study of traffic capabilities for communications systems providing an area coverage by means of an organized cell structure. It has the ability to reassign channels dynamically based on call location and a given D/R ratio, or based on a fixed buffer area criterion. The effects of these two criteria, reflecting the requirements on a vehicle location system, as they affect the traffic handling capabilities of a typical cell system, have been studied and will be discussed.

[1]James Mikulski, "A Central Coverage Cell System - An Approach for Multi Service High Capacity Radio Systems," IEEE-VTG Conference, December 1971.

II-6 RADIO SIGNAL COVERAGE AND THE ESTIMATION OF BASIC SCALE PARAMETERS IN CELLULAR MOBILE RADIO SYSTEMS.

L. J. McDonald, Bell Telephone Labs, Holmdel, N. J.

SUMMARY: The mobile radio systems considered here are based on the reuse of radio frequency channels in small geographical areas called cells. To obtain complete coverage, the cells need only cover the entire service area, but to achieve maximum frequency reuse capacity the cells must be packed together closely.

Two basic scale parameters are needed to specify a given system: (1) the maximum radius, R, of a cell and (2) the minimum distance, D, between the centers of cells of radius R using the same radio frequency (i.e., "co-channel cells"). The estimation of these two scale parameters is essential to the economic analysis of different system plans. However, the two parameters each depend on three independent but fundamental factors; (1) the transmission service objective, (2) the listener response and (3) the radio signal coverage. The first factor simply specifies the quality of service to be offered to the user. The second factor represents the subjective evaluation, by a random sample of listeners, of voice-circuit quality for different radio frequency signal-to-noise ratios (SNR) and signal-to-interference ratios (SIR). Finally, the radio signal coverage describes the distributions of SNR and SIR associated with different values of the scale parameters in each system plan. In other words, the two parameters, R and D, can be expressed in terms of the service objective once the listener response and radio signal coverage factors are known.

The purpose of this paper is to describe our results for the radio signal coverage factor. Recent experimental work by V. H. MacDonald at Bell Laboratories (BTL) describes the listener response to voice-circuit quality in the presence of Rayleigh fading. We also use his results together with our results to obtain estimates for the two basic scale parameters.

The electromagnetic propagation model used in our description of radio signal coverage is based on the work of Okumura, et al. Preliminary results from recent experimental measurements at BTL confirm much of Okumura's work. Our propagation model is constructed around Okumura's observation that the mean of the Rayleigh distributed local signal strength is a log-normal random variable. Parameters for this log-normal distribution are taken from BTL data and include variations with distance. The effect of Rayleigh fading is already included in MacDonald's work on listener response, leaving only the log-normal variation of the local mean to be considered in this paper.

Radio signal coverage is expressed in terms of probability distribution functions for SNR and SIR random variables. Such distribution functions are calculated directly from the electromagnetic propagation model, for a given system plan. The results for two system plans are presented here. In one plan (Plan A), one base station transceiver is located at the center of each cell. The second plan (Plan B) has three base stations for every cell. They are located at alternative corners of the cell and provide selective signaling. However, each base station serves three cells, so that both plans use the same number of base stations. The distribution functions for Plan B are shown to yield significantly better signal coverage when compared with Plan A.

Estimates of the two basic scale parameters, R and D, are presented in terms of service-quality phase diagrams for the two system plans. These diagrams relate the fraction of users who consider a given SNR or SIR to achieve a given quality of service (for a specific mobile radio system), to the fraction of time they experience that quality of service. This assumes the user is equally likely to be at any point in the cell. Finally, the value of R is shown to be larger, and the value of D shown to be lower, for Plan B than for Plan A when the same quality of service is provided.

SESSION III

III-1 COHERENCE BANDWIDTH IN MOBILE RADIO. M. J. Gans, Bell Telephone Labs, Holmdel, N. J.

ABSTRACT: Due to scattering of the radio frequency waves from obstacles located mainly in the vicinity of the mobile station, the propagation of microwave frequencies between a mobile station and a base station consists of paths of various lengths; i. e., time delays. The various scattered paths often as not contribute as much or more to the signal strength than does the direct wave between mobile and base stations. The spread in time delays ranges from 1/4 microsecond at 860 MHz in suburban areas to 5 microseconds at 450 MHz in urban areas. The spread in time delays determines what might be termed a coherence bandwidth. Signals separated in frequency by more than the coherence bandwidth are not correlated in the statistical properties of their propagation through the random scattering medium between land and mobile stations. Thus, the coherence bandwidth is the largest frequency separation between pilot and signal which allows the pilot to correct antenna phasing for coherent reception or retransmission of the signal with an array. Also transmission of signals whose bandwidths exceed the coherence bandwidth results in signal distortion.

Measurements, in New Providence, New Jersey, of the phase between elements of a receiving array on the mobile unit were made simultaneously at two frequencies near 836 MHz. Frequency separations of 50 kHz, 100 kHz, 200 kHz, 500 kHz, and 1 MHz were used. Plots of the measured probability distribution of phase error (phase shift between two antenna elements at one frequency minus phase shift at the other frequency) are presented for each separation frequency, at various locations for wide and close antenna spacing. By assuming an exponential shape for the probability distribution of time delays, the measured rms phase errors are related to coherence bandwidth (≈ 150 kHz), spread in time delays (≈ 1/2 microsecond), amplitude correlation, and loss in diversity gain due to decorrelation between pilot and signal.

III-2 STATISTICS OF X-BAND PROPAGATION IN AN URBAN ENVIRONMENT.

G. S. Kaplan and J. Shefer, RCA Laboratories, Princeton, New Jersey

SUMMARY: Recent developments in solid state technology indicate that potentially inexpensive and reliable power sources and microwave integrated circuitry at X-band are becoming available. Spectrum congestion at the lower frequencies and the availability of a new technology for utilizing the 10 GHz and higher frequencies indicate that these frequencies will be of increasing importance. Effective use of the higher frequencies depends on the knowledge of signal propagation in the operating environment. Although there has been some previous experimental effort at X-band in urban areas, there are gaps in our knowledge of propagation effects at these frequencies especially for low transmitting antenna heights. The series of experiments, which is the subject of this paper, was conducted within various areas of New York City at a frequency of 10.6 GHz. The transmitter locations (nine in all) were chosen so as to give as varied a sample of urban environment as possible, and also, exhibit a unique and well defined feature for each. Tests were run in the downtown Wall Street area encompassing tall buildings and wide streets, hilly areas, areas with and without trees, commercial and residential areas. The urban environment is not completely random as to shape of reflecting objects, their orientation and movement. There is a preponderance of flat vertical planes of reflections stacked in characteristic patterns along street lines, together with a (usually) continuous horizontal plane - the roadway. These reflections could conceivably behave differently for different polarization of the incident signal. Therefore the experiment was designed to allow vertical, horizontal and circular polarizations at both the receiver and transmitter so that polarization effects could be studied. Four antennas were used, one at a time, to measure the field at the receiver. These were an omnidirectional vertically polarized monopole on a ground plane and three open waveguide (3 dB gain) antennas for each of the polarizations.

At each of the transmitter sites, a transmitting antenna was placed at about 25 feet above street level. Three basic types of experiments (or runs) were performed:

1) A "straight run" with the receiver moving at 10-15 mph away from the transmitter and mostly within line of sight. These runs were normally terminated whenever the signal dipped consistently below noise level (about -105 dBm) or where the street turned out of line of sight.

2) A "standing run" with the receiver stationary at a location.

3) A "corner run" with the receiver out of line of sight of the transmitter.

Due to the multiplicity of both moving and stationary reflectors, as well as vehicle motion itself, the electromagnetic environment within which a vehicle receives an rf signal is perhaps best characterized as random. Accordingly the received signal is itself random and therefore the most appropriate descriptions are statistical in nature. The cumulative probability distribution of the X-band path loss was computed as a basic measure of propagation conditions. (Path loss is defined as the loss between the input to the transmitting antenna and the output of the receiving antenna mounted on the mobile vehicle.) The experimentally determined cumulative probability distributions of path loss are presented for a variety of test conditions and environments. These measured distributions tend to (although not always) follow either a Rayleigh or Ricean distribution. Substantial variations in received signal were measured even for a stationary receiver within line of sight of the transmitter.

III-3 MOBILE PROPAGATION EXPERIMENTS AT MILLIMETER WAVE FREQUENCIES. L. U. Kibler, Bell Telephone Laboratories, Holmdel, New Jersey

ABSTRACT: Millimeter wave frequencies hold the promise of providing the bandwidth necessary to accommodate present and foreseeable mobile communication services. The development of a millimeter wave mobile system requires a study of the propagation at these frequencies in the mobile environment. This mobile environment consists of both city streets bounded by tall buildings and the relatively open spaces of the suburban and rural areas.

The mobile system envisioned provides for fixed concentrators (transmit-receive units placed about 25 feet above the road) spaced about one mile apart along the streets or roads of the

various areas. A mobile unit moving between concentrators transmits or receives a direct signal and signals scattered by fixed and moving objects in this radio path. Experiments were conducted to measure two properties of this received signal; the doppler frequency shift of scattered signals relative to the direct signal, and the fading statistics of the signals.

The results of these experiments showed that the difference in doppler shift between the direct and scattered signals ranged from approximately 170 Hz to a few hertz. The largest frequency difference occurred for vehicles crossing the radio path at about 45 mph. Vehicles traveling at speeds less than 45 mph along the radio path or at small angles to it (less than 20^{o}) produced doppler shifts which ranged from 40 Hz to a few hertz.

In a rural area, signal fades seldom exceeded 3 dB. On rare occasions, the presence of a large truck or bus would cause a 10 dB signal fade. In the urban areas with both transmitter and receiver fixed, fades exceeding 10 dB occurred 5% of the time, while with a moving transmitter and a fixed receiver, fades exceeding 10 dB occurred 20% of the time. In this first urban case above, the signal fell below the measuring limit of -52 dBm 2% of the time, while in the second case, this limit was exceeded 7% of the time. Fades exceeding the measuring limit represent a fading depth of at least 15 dB.

This fading of the signal below the measuring limit was documented in each case as being due to a large truck or bus near the transmitter or receiver directly blocking the signal.

III-4 COMMUNICATION CHANNEL CHARACTERIZATION AND MEASUREMENT. H. W. Salwen and P. A. Bello, Signatron Inc., Lexington, Massachusetts.

SUMMARY: SIGNATRON is currently carrying out a number of contractual efforts in the area of communication channel characterization and measurement. One of these efforts requires the measurement and characterization of the land mobile channel in the urban environment in the frequency range from 100 MHz to 1 GHz. A channel playback apparatus will be constructed which simulates the channel propagation characteristics. It will be controlled from data collected in a field test program. A similar effort is being carried out for characterization, measurement, and simulation of the VHF tactical channel.

III-5 THE DURATION OF LONG-TERM MOBILE RADIO SIGNAL FADING CAUSED BY SHADOW EFFECT.

W. C. Y. Lee and Y. S. Yeh, Bell Telephone Labs, Holmdel, New Jersey.

ABSTRACT: The received signal strength in mobile radio can be characterized by rapid Rayleigh fadings with a slowly varying mean signal strength. The first and the second order statistics of the Rayleigh fading encountered in mobile radio had been adequately reported in the literature. This knowledge had been proved to be extremely helpful in system design considerations.

The slow or the long-term variation of the mean signal strength are generally attributed to the shadowing effect caused by building structures and had been reported by numerous investigators that the first order statistics of the mean value obey a log normal distribution with a standard deviation depending on the general propagation environment. In this paper we attempt to explore the possibility of obtaining some understanding of the second order statistics of the long-term fading. The interesting parameters here would be the level crossing rate and the density of the duration of fades. This information would be very helpful in the system concept of the high capacity mobile radio systems.

The experiments were performed at 860 MHz. A setup for receiving the fading signal at the mobile radio unit in two suburban areas which were within 3 miles from the UHF transmitter was done. The data, then, were passed through a low-pass filter with proper time constant to eliminate the fast Rayleigh fading so that a good estimate of the mean signal strength could be obtained. We first observed that the long-term fading was stationary as long as the general structure of the area where we took data remained the same.

A theoretical investigation indicated that the average duration of fades and the rate of level crossing can be expressed in terms of several simple parameters and the functional form of the level crossing rate resembles that of a Gaussian distribution. Experimental results were processed and indicated quite close agreements to the theoretical predictions.

III-6. WHEN ARE HIGHLY CORRELATED RAYLEIGH SIGNALS CORRELATED ENOUGH? L. Schiff, RCA Laboratories, Princeton, New Jersey

SUMMARY: When a fixed pilot signal is sent along with the modulated carrier to a mobile radio, and the frequency of the pilot and carrier are close, the two signals received are Rayleigh distributed and highly correlated. This correlation can be exploited in a number of ways. As an aid to understanding and invention one usually thinks of the limiting case in which the correlation is perfect. But how dependent is the system, derived this way, on the high correlation and how does performance degrade as the correlation coefficient is reduced from unity? We show, with the aid of two specific examples, that this critically depends on the type of system considered. Both examples are considered with the context of the mathematical model of Clarke[1].

The first example is the use of the pilot signal and multiple antennas to obtain maximal ratio combining. As described by Jakes[2], the explanation for the working of this system depends on perfect correlation between pilot and carrier at each antenna and independence between signals at different antennas. Lee[3] has considered the case of lack of independence between signals at different antennas as well. We consider the other side of the coin, i.e., independence between signals at different antennas but a pilot that is not perfectly correlated with the signal. We show that even when the correlation coefficient is not high considerable improvement is obtained and a coefficient of .9 gives essentially all the gain to be obtained. This example, then, illustrates a situation in which when the correlation is reduced, from the ideal value of unity, the results are still substantially the same. The next example illustrates quite the contrary.

Consider the case in which two signals (carriers) may arrive at the mobile radio and interfere with one another - the undesired signal having the smaller average value. Assume further that each carrier is accompanied by a pilot and that the receiver can distinguish the pilot of the desired from the pilot of the undesired (for example, if the pilot from one station is at the upper end of the modulation band and the pilot from the other station is at the lower end). Now in the limiting case of perfect correlation, the ratio of the desired pilot to the undesired pilot is exactly the same as the ratio of the desired to the undesired signal. If the ratio of the two pilots is greater than 0 dB, then the signal to interference ratio is greater than 0 dB and vice versa if the pilot ratio is less than 0. This can form the basis of a switch diversity scheme in which, when the ratio of the pilots falls below 0 dB, you switch to a diverse path (i. e., different receiving antenna or different transmitting antenna if feedback to the transmitter is used). But how well does this function when the correlation is not perfect? We show that the system works quite poorly and, in fact, extraordinarily high correlation coefficients are needed to extract any performance gain from this type of system.

The two examples taken together indicate that there is no simple answer to the question raised in the title.

1. R. H. Clarke, "A Statistical Theory of Mobile Radio Reception", BSTJ, Vol. 47, July 1968, 957-1000.

2. W. C. Jakes, Jr., "A comparison of specific space diversity techniques for reduction of fast fading in UHF mobile radio", IEEE Trans. Veh. Tech., Vol. VT-20, November 1971, 81-93.

3. W. C. Y. Lee, "A study of the antenna array configuration of an M-Branch diversity combining mobile radio receivers", IEEE Trans. Veh. Tech., Vol. VT-20, November 1971, 93-104.

SESSION IV

IV-1 WIDEBAND MEASUREMENTS OF MAN-MADE NOISE.

R. Buck, Transportation Systems Center, DoT, Cambridge, Mass.
R. Esposito, Raytheon Research Division, Waltham, Mass.
P. Yoh, Transportation Systems Center, DoT, Cambridge, Mass.

ABSTRACT: This talk will describe in detail an experimental program in progress at the Transportation System Center, DoT, Cambridge, Mass. for the wideband measurement, recording and analysis of man-made noise in the frequency bands of interest to land mobile communication, namely 150, 450, and 900 MHz. The conceptual design of the experiment and the necessary hardware will be discussed together with the data processing philosophy and some preliminary measurements.

IV-2 STATISTICAL-PHYSICAL MODELS OF MAN-MADE RADIO SIGNALS AND INTERFERENCE.

David Middleton, Physicist and Applied Mathematician, 127 E. 91 St., New York, N. Y. 10028

SUMMARY: Man-made electromagnetic signals and interference (or noise) have become a problem of great concern in the telecommunications community,[1] particularly in the face of finite available bandwidth resources. Such signals and noise are also, and will become more so, a major limiting factor on the successful functioning of communication systems, not only in urban environments but over large regions as well. Effective analysis of system performance and design requirements demands tractable models of these noise and signal mechanisms, so that the standard methods of Statistical Communication Theory (SCT) can then be employed for the desired system evaluations. Our models are necessarily statistical, on the one hand, since the processes they describe are inherently random in time and space. On the other hand, since these processes are generated in the real world, for an adequate description we must also include the appropriate physics of the propagation and reception.[2]

Accordingly, we shall construct first-order probability distributions for some typical classes of man-made interference: (1) "unintelligent" noise, produced by the radio emissions from, say, mobile land vehicles (e.g., automobiles, trucks, buses, etc.)[1] and (2) "intelligent" noise, which may appear in a communication link because of unwanted spectral overlap with, and physical proximity to, other communication links. The general models are the same, but the specific characteristics of the interfering signals, e.g., their

waveforms, frequencies, durations, source distributions and movement, geometries (location, beam patterns, etc.) are usually quite different. (Desired) signals and their statistical properties are constructed in precisely similar fashion.

Technically, what has made a quantitative treatment very difficult in the past is the fundamentally nongaussian character of these classes of noise and signals. However, with new techniques and recently developed models[3] this difficulty can be overcome. There appears to be little detailed earlier analytical work regarding man-made noise (and signals) of this type. Important exceptions, however, devoted primarily to atmospheric models are given by Furutsu and Ishida,[4] the critical study of Hall,[5] and more recently, the investigation of Giordano,[6] who establishes, among other results the justification of the quasi-phenomenological distribution derived by Hall.[5] The new results presented here are obtained by taking advantage of the above, and especially, the current studies on ocean reverberation models.[3] Thus, we show that useable statistical-physical models of man-made noise environments, including desired, or "intelligent" signals, can be constructed. These can be related also, when the circumstances permit, to simpler, equivalent analytical forms of the Hall type[1] (the so-called equivalent statistical model (ESM)).

The critical features of our analytical probability models are that (1) they incorporate the governing geometry and kinematics relating sources and receivers, including beam patterns, relative motion (doppler), propagation distributions; (2) they include signal structure, e.g., waveforms, duration, level, as determined and modified by the physics of the channels through which they propagate; (3) they allow for classes and mixtures of different emissions, as well as combinations of source-geometries, e.g., volume distributions (ground-air; air-air, ground-satellite, etc.). and/or essentially surface distributions (mobile land transport: ground-ground).

The basic statistical model (BSM) we choose is fundamentally Poissonian, in that the locations in space of signal sources (and receivers) are Poisson distributed. Because of the finite velocity of propagation, this necessarily produces in a typical receiver ultimately a Poisson time process, $X(t)$, consisting of the various desired and undesired emissions. The received process "density" is proportional to the actual physical density of sources in space.

Our approach is first to construct the characteristic function of the (received) poisson process and then, with the essential help of the physical model, seek a form of this characteristic function which yields tractable results upon Fourier transformation. The precise form of the characteristic function depends in each case on the detailed nature of the model, and is different, for example, for vehicular noise and signals vis-à-vis ocean reverberation processes, or atmospheric noise. A key result of our approach is that it yields manageable, explicit analytic expressions for the first-order probability density $W_1(X,t)$ and distribution $D_1(X,t)$ of the instantaneous amplitudes of the received interference. Tractable second-order results have also been found. These expressions involve convergent sums of weighted (first-order) gaussian densities with increasing variances, where the weights depend on (i) the "Impulse Index" - the effective number of sources active at a given time (t) in the overall source domain, and (ii) the fourth- (and higher-) order moments of the basic Poisson process. Characteristic of "impulsive" noise, there is a non-zero probability of zero amplitudes $(X = 0)$, representing finite periods of time during which there is no waveform present. As the Impulsive Index gets larger, however, these tend to disappear, and as expected, the densities, etc. become asymptotically gaussian. In the second order cases, a similar development is obtained, where now one has weighted second-order gauss densities, including the correlation function of the received process. The corresponding distributions are directly available upon integration. The structure and significance of the various moments depend on the physical model chosen. Their details are a direct consequence of the propagation model and the Poisson character of the statistical mechanism. Additive mixtures of gauss and Poisson interference are handles in the same fashion and yield the same form of results, except that now, as expected, there is zero probability of zero amplitude: there are no "gaps" in time for $X(t)$.

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[2] Middleton, D., Multidimensional Detection and Extraction of Signals in Random Media, Proc. I. E. E. E., Vol. 58, No. 5, May, 1970, pp. 696-706.

[3] Middleton, D., "Statistics of Low Density Ocean Reverberation," research in progress, Contract N0014-70-C-0198, Office of Naval Research.

[4]Furutsu, K., and T. Ishida, "On the Theory of Amplitude Distribution of Impulsive Random Noise," J. Appl. Phys., 32, No. 7, July, 1961, pp. 1206-1221.

[5]Hall, H.M., "A New Model for 'Impulsive' Phenomena: Application to Atmospheric-Noise Communication Channels," Stanford Electronics Laboratories (SEL), Report SEL-66-052, August, 1966, Stanford University, Stanford, California.

[6]Giordano, A.A., "Modelling of Atmospheric Noise," Doctoral Dissertation, Dept. of Electrical Eng., Univ. of Pennsylvania, 1970.

IV-3 UPPER UHF AND L-BAND METROPOLITAN INCIDENTAL MAN-MADE RADIO NOISE.

E. N. Skomal, Aerospace Corp., San Bernardino, California

SUMMARY: Metropolitan area incidental man-made radio noise measurements in the upper part of the UHF and in the lower microwave band have recently revealed a frequency variation of mean noise power significantly different from that demonstrated in the HF, VHF and lower UHF bands.

The frequency decrement for urban area, surface, incidental radio noise power typically - 10 to - 25 dB per decade change in frequency at and below 600 MHz undergoes a marked increase to values in excess of - 50 dB per decade above 800 MHz. This occurrence is attributable, at least in part, to a roll-off in the automotive ignition noise spectral density.

IV-4 BASEBAND PERFORMANCE OF A PILOT-DIVERSITY SYSTEM IN THE PRESENCE OF RAYLEIGH-FADING SIGNALS AND CO-CHANNEL INTERFERENCE.

R. E. Langseth, Bell Telephone Labs., Holmdel, N.J.

SUMMARY: Since the amount of RF spectrum available for microwave mobile telephony is limited, a given frequency channel must be reused several times in a given geographical area resulting in co-channel interference limits on the geographical frequency reuse interval. The baseband performance of a given radio system is further deteriorated by rapid Rayleigh fading caused by multipath propagation effects at microwave frequencies. One method of

combating such fading is to use some form of diversity reception. This paper presents some results on the performance of a particular diversity system in the presence of Rayleigh fading signals and interference. This system requires the transmission of a separate pilot-carrier, which is used to co-phase the outputs of the several antennas used in the space-diversity receiver. By using laboratory-generated fading carriers, several measurements of baseband SNRs were made for various RF carrier-to-noise and signal-to-interference ratios, and for various bandwidth expansion ratios. These results demonstrate the advantages of this diversity system in maintaining a useable baseband signal in both noise-limited and interference-limited regimes. For example, the use of diversity can result in a reduction of over 10 dB in the required average RF signal-to-interference ratio for a 20 dB baseband SNR when the RF CNR is 24 dB. Alternatively, with a signal-to-interference ratio of 15 dB and a CNR of 24 dB, the use of diversity can reduce the RF bandwidth requirement by an order of magnitude for a 20 dB baseband SNR. Some tape recordings will be played to demonstrate some of these effects.

IV-5 SUBJECTIVE VOICE-CIRCUIT QUALITY MEASUREMENTS IN THE PRESENCE OF MULTIPATH FADING.

V. H. MacDonald, Bell Telephone Labs., Holmdel, N. J.

SUMMARY: Two key parameters of the proposed High-Capacity Mobile Telephone Systems are the maximum call radius and the minimum separation between cells using the same frequencies. The cell radius is limited by the necessity of providing an acceptable signal-to-noise ratio on the voice channels at all points in the cell. Similarly, a minimum is imposed on the ratio of the co-channel cell separation to the cell radius by the need to maintain an acceptable signal-to-interference ratio on voice channels.

Prior to the experiment described in this paper, there seemed to be no definitive guidelines as to what RF signal-to-noise or signal-to-interference ratio is required to produce satisfactory voice channels in the presence of rapid, severe fading. Consequently, a subjective listening experiment was undertaken, in which 20 listeners rated the voice-circuit quality of a series of 36 different fading radio-channel conditions. These conditions included various values of local-mean RF $\overline{S}/N$ or $\overline{S}/\overline{I}$, 6 or 12 kHz peak deviation, and one or two branches of receiver diversity. (The term "local mean" designates the mean of a Rayleigh-distributed amplitude, observable over an area on the order of hundreds of square yards.) A pilot-tone diversity system was used, and the fading rate was set to correspond to a vehicle speed of 70 m.p.h.

The results are presented in the form of the percentage of listeners who rated each condition as good or better. For a fixed peak deviation and a fixed number of receiver diversity branches, one can determine the local-mean RF $\overline{S}/\overline{N}$ or $\overline{S}/\overline{I}$ required to obtain any desired percentage of good-or-better ratings from the customers. For example, in order for 75 percent of the customers to consider a voice channel to be good or better, the RF $\overline{S}/\overline{N}$ and $\overline{S}/\overline{I}$ must have the values indicated below:

Branches of Diversity	Peak Dev. (kHz)	$\overline{S}/\overline{N}$ (dB)	$\overline{S}/\overline{I}$ (dB)
2	12	16	19
2	6	22	21
1	12	22	21
1	6	30	24

From the results of the experiment, one can extract the effect of receiver diversity and increased peak deviation on customer reaction. It was found that two branches of diversity allow a reduction of about 3 dB in signal power and about 6 dB in $\overline{S}/\overline{I}$ without any loss of customer satisfaction. Similarly, doubling the peak deviation from 6 kHz to 12 kHz was observed to permit roughly a 3 dB reduction in signal power and a 6 dB reduction in $\overline{S}/\overline{I}$.

Although the number of listeners and the number of different values of $\overline{S}/\overline{N}$ and $\overline{S}/\overline{I}$ investigated were relatively small, it is unlikely that a more detailed experiment would substantially alter the results. A different diversity system or a different receiver would presumably shift the results by at most a few dB. We therefore assert that the results of this experiment can be regarded as reliable guidelines for determining necessary levels of $\overline{S}/\overline{N}$ and $\overline{S}/\overline{I}$.

It is outside the emphasis of this paper to discuss the many possible approaches to determining the maximum cell radius and minimum co-channel transmitter separation, but all the approaches require the use of the type of subjective customer reaction obtained in the listening experiment.

IV-6 THE AMPLITUDE AND TIME STATISTICS OF ENVIRONMENTAL MAN-MADE NOISE AT 821 MHz.

H. L. Hanig, Bell Telephone Labs, Whippany, N.J.

ABSTRACT: The amplitude and time statistics of environmental man-made noise have been examined at 821 MHz for various vehicular traffic conditions in an urban environment. Measurements were made in the spring of 1971 in Philadelphia, Pa. using a mobile receiver having 10 kHz IF bandwidth, 5 dB noise figure, and 80 dB dynamic range.

This data has been analyzed to yield the amplitude distribution of man-made noise, the mean noise power and its standard deviation, and the average noise pulse width and its associated standard deviation as functions of received power. The results indicate variations in the mean noise power and sigma from 9 dB above KTB with a sigma of 5 dB for heavy traffic, to 4 dB above KTB with a sigma of 3 dB for light traffic conditions. The time statistics indicate a maximum average noise pulse width for heavy vehicular traffic of 170 microseconds with a sigma of 120 microseconds, these numbers decreasing as the traffic intensity decreases.

SESSION V

V-1 A MOBILE RADIO, SINGLE FREQUENCY "TWO-WAY" DIVERSITY SYSTEM USING ADAPTIVE RETRANSMISSION FROM THE BASE.

H. H. Hoffman, Bell Telephone Labs, Holmdel, N.J.;
J.S. Bitler, Bell Telephone Labs, Merrimack Valley, Mass.;
C. O. Stevens, Bell Telephone Labs, Holmdel, N.J.

SUMMARY: This paper describes an adaptive retransmission system capable of providing a UHF (1 GHz) mobile radio channel with "two-way diversity" through the use of time division. The system is unique in that all signal processing associated with the diversity combining is done at the base station. The mobile transceiver is, therefore, desirably simple. A two branch prototype of the system, without modulation, was field tested to determine its adaptive retransmission performance.

The performance of a high capacity mobile radio system operating at a frequency near 1 GHz is severely affected by the multipath propagation medium through which the transmitted signal must pass. As a vehicle moves about in this medium the amplitude and phase of the received signal vary randomly. The effect is usually observed as deep fading in the received signal envelope. It has been shown that this multipath fading can be decreased considerably by the use of a space diversity receiver. The system described here offers duplex operation with a reduction of fading at both the mobile and base station receivers that is comparable to that previously obtained with mobile diversity receivers. An experimental program was set up to test the principles and assumptions involved in the system design.

In typical operation, the mobile station transmits a pulse of FM signal at a carrier frequency, f_m. Due to multipath effects, the signals arriving at each base station antenna contain additional random phase modulation. Within each base station branch, this random phase modulation is removed and the signals brought to a common phase in a cophasing network. The outputs of the cophasers are combined and fed into a receiver to extract the audio information. Each cophase has an additional output which contains the conjugate of the random phase introduced by the medium. The conjugate phase is impressed on the transmitter along with the base station audio for return transmission to the mobile station at a carrier frequency f_b. The signal from each base station antenna then add in phase at the mobile station receiver where the signals are demodulated. The system is adaptive in that changes in the environment, i.e., changes in the random phase modulation, are cancelled out for both the mobile and base stations.

Adaptive retransmission on widely separated frequencies, as in the original STAR concept, is not possible because of the very highly dispersive medium that one must deal with at UHF and microwave frequencies in populated areas. The phase coherence bandwidth in urban areas is approximately 150 kHz. An extremely high receiver Q, greater than 6000, would be required to transmit and receive simultaneously within the phase coherence bandwidth. It was, therefore, necessary to transmit and receive on exactly the same frequency, but at different times.

Sampling rate is determined by consideration of the phase distortion in the transmission medium and the need to satisfy the sampling theorem in reconstructing the signal at the receiver. Operating range limitations are dictated by propagation delay and choice of pulse duty cycle.

For prototype tests in the field, the transmitter generated 10 W pulses of 15 μsec duration, every 100 μsec, at 836 MHz. Receivers operating at levels as low as -110 dBm, used logarithmic amplifier outputs to drive tape recorders. Unmodulated pulses were used and envelope fading statistics were recorded at both mobile and base stations. The base station used a 60 foot antenna tower and the mobile unit was driven at constant speeds through several areas located up to 2-1/2 miles away. Some tests of envelope fading were made while switching from one to two channel operation.

The results of these tests indicate that the statistics of the fading envelope at both the base and mobile stations closely agree with those predicted by theory for an equal gain combiner with correlation between the branches. The reduction in both number and depth of fades, as indicated by cumulative distribution curves proves the effectiveness of this two-way diversity system.

V-2 ON THE USE OF PHASE-LOCKED LOOP DEMODULATORS IN THE PRESENCE OF RAYLEIGH FADING.

R. E. Langseth, Bell Telephone Labs, Holmdel, N. J.

SUMMARY: In addition to the use of diversity to improve the baseband SNR in the presence of Rayleigh-fading signals, it would appear that threshold-extension demodulators could also provide some improvement. Indeed by properly adjusting the loop bandwidth of a PLL to be just sufficient to pass the baseband modulation, baseband SNR improvements of 5-10 dB have been obtained in the threshold region, resulting in a like saving in the required RF CNR. Effects of loop damping and of limiting prior to the PLL will be demonstrated. It appears that in contrast to the nonfading case, limiting does not have a detrimental effect here, and may actually be helpful.

V-3 A UHF MOBILE TELEPHONE SYSTEM USING DIGITAL MODULATION, PRELIMINARY STUDY.

J. S. Bitler, Bell Telephone Labs, Merrimack Valley, Mass.;
C. O. Stevens, Bell Telephone Labs, Holmdel, N.J.

SUMMARY: With the increasing interest within the Bell System in digital transmission and high capacity mobile telephone going toward higher frequencies, digital modulation for mobile telephone has been considered by Rustako.[1] Rustako showed that a very simple and effective diversity receiver could be constructed if on-off keying was used in place of FSK or PSK. Exponential modulation could be used, but only at the expense of more bandwidth and a more complicated diversity receiver.

It is the purpose of this paper to describe an experimental system which was designed to test the use of digital modulation for mobile telephone. The system was field tested in suburban areas near Holmdel, New Jersey and in an urban environment in New York City. In this preliminary report, only a qualitative discussion of the test results is available.

The digital code is supplied by an adaptive delta coder described by Bosworth and Candy.[2] The decoder generates, at each sample time, weighted step sizes which depend upon the sequence of the last five bits received. With a clock rate of 50 kHz, or about 16 times the highest audio baseband frequency, a maximum audio RMS signal-to-noise ratio of approximately 30 dB is achieved.

A clock rate of 50 kHz implies a digital baseband bandwidth of at least 25 kHz. However due to the multipath nature of the medium, a full raised cosine roll-off was used, increasing the bandwidth to 50 kHz.

The recovery circuit employs a comparator which compares the digital baseband signal with a variable threshold. The variable threshold, derived from the digital baseband signal, has the capability of following the short term fading. The comparator output is fed into a modified phase lock loop (PLL). The PLL is modified to increase its flywheel action during strings of "one" or zero.

The base station consists of a coder and transmitter. Input to the coder was a tape of a male voice reading a technical paper. The transmitter was capable of providing up to two watts of power at 836 MHz.

The mobile station consists of a four branch diversity receiver and a decoder. Overall receiver noise figure is about 6 dB. The receiver could be configured to employ one, two, three or four branch diversity.

The system was tested both in the laboratory, using a fading simulator, and in the field. Field tests were conducted in both suburban and urban areas.

The laboratory tests consist of counting the average idle channel click rate in the audio baseband as a function of input power and diversity order. The simulator fading rate was equivalent to a speed of 60 MPH. Threshold was determined subjectively. The single branch system was considered unusable. The two branch system is poor with an average signal-to-noise ratio of 19 dB. However, the three and four branch systems performed quite well with thresholds of 14 at 12.5 dB respectively.

The suburban tests were made near Holmdel, New Jersey with the base station on Crawford Hill. The mobile station was in a van which was driven at normal driving speeds. Field strength measurements were monitored simultaneously with the received audio signal. Threshold was determined subjectively and the field strength noted. System thresholds determined in this fashion were very nearly the same as those determined from the laboratory tests.

The urban tests were made in the southeastern section of Manhattan in the financial sector. The base station was located on top of AT&T Headquarters at 195 Broadway. In general the aduio quality was very good for the three and four branch receiver. However isolated case of degradation was noted when the signal level was well above threshold.

We believe that this system demonstrated that digital modulation for UHF mobile telephone is possible.

[1] Rustako, A. J., Jr., Private Communication.

[2] Bosworth, R.H. and Candy, J.C., "A companded One-Bit Coder for Television Transmission," BSTJ Vol. 48, No. 5, May - June, 1969.

V-4 A 900 MHz MULTIPLE ACCESS F_1F_1 REPEATER MOBILE COMMUNICATION SYSTEM

P. F. Sielman, AIL, A Division of Cutler Hammer, Deer Park, L.I., N.Y.

SUMMARY: AIL has devised a system of two-way highway communications which utilizes low power, provides digital and emergency voice communications and depends on a Location Division Multiple Access scheme that is very conservative of spectrum in the 900 MHz band. AIL has implemented such a system using F_1F_1 Repeaters with 4/10 mile spacing on the Sagtikos Parkway in New York. Under DoT sponsorship AIL has been condudting propagation experiments and operational tests of such a system as reported at the VTG Conference in Detroit on December 8th.

Of particular interest are the results of propagation tests conducted between the roadside repeater source and the vehicle antenna. Data has been collected which relates propagation losses to distance (100-4000 ft), mobile antenna height and repeater antenna height. Initial tests indicate significant losses above free space loss, and these are being correlated with geometry and avialable reference material. The effect of transceiver design on propagation and the resultant ERP requirements for roadside-to-vehicle and vehicle-to-roadside communications will be presented.

V-5 A NUMERICAL METHOD FOR THE SYNTHESIS OF CIRCULAR ARRAY ANTENNA PATTERNS WITH APPLICATIONS TO MOBILE RADIO SYSTEMS:

Thomas H. Zachos, Bell Telephone Labs, Holmdel, N.J.

SUMMARY: This paper presents a new method that uses optimization theory to synthesize arbitrarily shaped power patterns of circular array antennas. Although the method can be utilized in a variety of applications, it has been specifically devised to synthesize many of the antenna beam shapes in azimuth that may be required in a proposed High Capacity Mobile Telephone System.[1]

The pattern synthesis is carried out numerically by a computer program, herein called MRA (Mobile Radio Antenna). This program implements both the conventional radiation characteristics of a circular array antenna[2] and certain successive approximation techniques[3] which find minima of functions of many variables. In addition to using these results from antenna and optimization theories, MRA also employs a set of data which guides the searching process that is inherent to optimization theory. Because of the fixed nature of this set, the program input is merely the shape of a desired pattern. The MRA algorithm accepts this simple input information and then determines electrical excitations which, when impressed on the antenna elements, produce a radiation pattern that closely approximates the desired pattern.

The synthesis method is illustrated by several examples that are given for an array which has 7 elements and a 0.4-wavelength radius. Subsequently, the program is employed to shape antenna beams for the purpose of improving radio coverage in mobile radio systems.

In two previously proposed small-cell[4] coverage plans[1,5] it is desirable uniformly to illuminate, at a given radius, the interior of each cell (or cell sector). The uniform illumination assures that every mobile transceiver within the required coverage area will receive a certain minimum signal strength, and also reduces "spillover" into nearby cells which may be using the same channels.

The conventional way to illuminate a coverage area is to transmit from an antenna having an omnidirectional (or sector-shaped) power pattern. However, this approach generally provides very nonuniform signal strength within the cell, especially if the terrain is not smooth.

In order for the mean signal strength to be more nearly uniform within the cell, R.E. Fisher has proposed that the antenna free-space pattern be shaped so as to beam more power to those cell regions that are shadowed by obstructions and less power to the open areas. Classical methods of providing this beam shaping usually involve "cut and try" procedures with consequent great expenditure of time and effort.

It is the purpose of this paper to show how this beam shaping might be implemented by the automated, systematic technique which is presently summarized.

The beam-shaping procedure would begin by transmitting a continuous carrier from an omnidirectional antenna and measuring the resulting illumination in the coverage area of interest. The measured data, in conjunction with an assumed radio propagation law, would then be used to determine a free-space pattern that the antenna must generate if the cell interior, at some particular radius, is to receive approximately uniform illumination in all applicable directions. The pattern of signal strength versus azimuth would finally be programmed into MRA, which would determine the phased array radiator current magnitudes and phases that generate the required free-space pattern.

[1] R. H. Frenkiel, "A high-capacity mobile radio-telephone system model using a coordinated small-zone approach," IEEE Trans. Vehicular Technology, vol. VT-19, pp. 173-177, May 1970.

[2] See, for example, S. Ramo and J. R. Whinnery, Fields and Waves in Modern Radio. New York: John Wiley, 1953, ch. 12.

[3] The steepest descent and least square techniques are used, which are described in standard textbooks on optimization theory. See, for example, D. J. Wilde and C. S. Beightler, Foundations of Optimization. New Jersey: Prentice-Hall, Inc., 1967, ch. 7. These two optimization techniques are combined and implemented in a BTL program (Suprox), originally written by J. A. Moraller and subsequently modified by R.F. Jessup and J. A. Kelly, Jr.

[4] H. J. Schule, Jr., and W. A. Cornell, "Multi-area mobile telephone system," IRE Trans. Vehicular Communications, vol. VC-9, pp. 49-53, May 1960.

[5] P. T. Porter, "Supervision and control features of a small-zone radiotelephone system," IEEE Trans. Vehicular Technology, vol. VT-20, pp. 75-79, August 1971.

V-6 MULTIPLEXING PROBLEMS IN CENTRAL TALKOUT TRANSMITTERS.

C. N. Lynk, Motorola, Inc., Schaumburg, Ill.

SUMMARY: This informal paper will concentrate on the problems of combining transmitters on a single antenna. The two main topics of discussion will be the use of FDM/FM (SSB) multiplex modulation,

and the low power combining of a multiplicity of narrowband FM transmitter into a common power amplifier. A brief discussion of the applicable theory of a FDM/FM (SSB) will be presented followed by both laboratory and field results of an experimental system. A brief summary of a theoretical model and the resulting analysis of a common amplifier system along with its effects on adjacent channel interference will conclude the paper.

V-7 ANTENNA SITE MANAGEMENT, VOLLMER PEAK PROJECT, A PROGRESS REPORT.

J. R. Hall, Microwave Associates, Sunnyvale, Calif.; J. Watson, Watson Communications, Inc., Lafayette, Calif.

ABSTRACT: This paper presents a report on a long range antenna site management program which is a joint undertaking between a communication equipment manufacturer and a company which owns and operates many two-way radio antenna sites in the San Francisco Bay area.

It is a well known fact that in addition to channel congestion in major metropolitan areas the antenna site itself is a major contributor to spectrum pollution. In many areas good antenna sites are at a premium and are therefore usually crowded with as many antennas as is physically possible to put on the site. Many transmitters operating with closely spaced antennas will create many intermodulation products which can decrease or destroy communications on other channels.

The approach to be discussed in this paper is one in which the antenna site is analyzed from two view points. The first view is to clean up the interference from the site so that existing communications are relatively clean. Secondly to maximize the number of communication channels on the site.

To accomplish these objectives we approached the Vollmer Peak site from two angles. First a technical analysis as to the condition of intermod and interference and an estimate of what could be done considering the conditions. Secondly a business analysis to determine equipment costs, computer costs, labor costs, etc., as opposed to advantages gained and increased site revenue.

Since this project is still underway this paper is intended as a progress report and will detail findings to date including computer programming and data on intermod reduction. In addition future plans will be discussed which include microwave linking several sites together for improved VHF-UHF radio coverage; site frequency lists which, from computer analysis, indicate the best channels available on existing antenna sites for frequency use planning; and other possibilities for better antenna site management.

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M15

Date: March 9, 1972

Reply to Attn of: PSD/DNH

Subject: Trip report, Systems Applications Inc. (SAI), Los Angeles, March 7, 1972

To: Roger K. Salaman

Some weeks ago Art Cooke suggested that I meet with SAI for the purpose of coordinating our efforts in the Land Mobile Radio (LMR) area. On March 7 I had a day-long meeting with George Mandanis and Richard Lane. Mr. Mandanis is the Chairman of SAI and project leader. Dr. Lane is their communications and modelling expert.

I was very impressed with the capability and work exhibited by SAI. The computer model that they have developed is considerably more sophisticated than the Motorola model that we are using. On the basis of this evaluation, I see the role of PSD-ITS in a slightly different light. I would suggest that we de-emphasize our own modelling effort and concentrate on monitoring the SAI effort. In doing so, we can use an extended version of the Motorola model. By limiting ourselves to confirming the spectral efficiency results of their analysis, we can put more emphasis on cost models (economic efficiency) and technological alternatives. SAI says that they will have the supply/spectral efficiency analysis largely completed by the end of this month. They supplied me with descriptions of each alternative system they were considering and they briefed me on their techniques for evaluating spectral efficiency.

The following are brief descriptions of subject areas we discussed:

<u>Cost Data.</u> SAI provided me with an outline of cost items to be considered in evaluating the costs of alternative systems. They were unable to provide some of the actual cost data since it was developed under a contract with and is considered proprietary to the sponsor. They also described a model to combine these costs to give costs per user per month. I have given this material to Wes Harding of ITS to aid him in his cost collection effort. They (and I) are particularly interested in synthesizer cost as a function of number of channels.

Innovative Uses and Technology. One of the principal uncertainties in forecasting LMR demand is the impact of innovative uses in such areas as law enforcement, emergency health services, fire prevention, mass transit, highway safety, municipally owned utilities, and environmental monitoring. The LMR Inter-Agency Working Group chaired by OTP will be a help in this, but it was agreed that all project personnel should be alert to such uses so that they can be included in the demand model. Likewise it was suggested that project personnel aid in identifying any promising new system alternatives.

Price Elasticity. Another critical factor in LMR analysis is estimating demand and especially estimating demand as a function of price. SAI discussed the possibility of our aiding in a survey in this area. I pointed out the limitations on Federal Agencies in sending out questionnaires. I discussed the possibility of OT doing the analysis of a survey conducted by them. We would need to check (1) the "legality" of this approach and (2) the work statement in their contract since we do not want to do what they are contractually required to provide.

Electromagnetic Compatibility Analysis (EMC). SAI's modelling is based on certain assumptions regarding required Signal-to-Interference Ratios (SIR). Since these assumptions significantly affect spectral efficiency, it would be well for us to review them in some detail. I will ask Gene Ax of ITS to do so as part of his review of the EMC aspects of the filings.

Commerce Support

Mr. Mandanis suggested two areas where DOC might have some relevant information. One is in identifying alternative suppliers of LMR equipment, particularly foreign suppliers. Because of labor cost differentials these suppliers might have a significant price advantage that should be taken into account. Foreign suppliers could not supply the service (I presume) but they could supply major pieces of equipment just as they are now doing with PBXs. Regardless of the desirability of this arrangement these suppliers could significantly affect demand (because of price elasticity) and industry structure. Another possibility is the DOD/DOC concern of shifting the large defense and aerospace contractors into civilian markets. Questions to be answered include: (1) Are these companies aware of the opportunities in supplying LMR services and equipment?, (2) Is there any funding to subsidize their entry?, (3) Would such a subsidy be in the public interest? I feel we have a role in these questions both from an OTP support role and our DOC mission.

FCC Regional Frequency Management Centers

If certain of the system and industry structure alternatives actually evolve, they will have an impact on the FCC Regional Frequency Management concept. Likewise their evolution will affect the LMR industry pattern. Mr. Mandanis pointed out the necessity for discussions with the FCC in this area. Is anyone in ITS closely following the development of these regional center concepts?

Automatic Vehicle Locating/Monitoring (AVL) Systems. Cellular systems require information on the location of the mobiles. DOT and others are interested in AVL systems for other applications in mass transit and law enforcement. If AVL is done separately for LMR systems, it will impact on the spectrum efficiency of the cellular concept. These lead to such questions as: (1) What is the spectral efficiency of AVL systems? (2) Is it in the public interest to have separate AVL systems for LMR, mass transit, etc? (3) If not, should it be done by a single franchised firm? (4) Should Bell provide it to all as a separate part of the LMR system since they would undoubtedly be the major user?

Mobile System Compatibility. This centers around the question of standards for LMR mobile units so that (perhaps) they could be used in both private and common carrier systems depending upon the immediate requirements of the user. It also concerns the requirements for nationwide compatibility. For various industry configurations, what should be the government's role in developing and enforcing these standards? What standards are required?

Monitoring (Channel Statistics) The models that SAI and others have developed and used assume certain theoretical statistics for calling rates, message durations, etc. Certain of these are pretty well substantiated while others are open to more doubt. For example, on a busy single channel system two mobiles may be waiting for the end of another transmission so that they can initiate a transmission. They may do this simultaneously such that one interferes with the other and extra transmissions (repeats) become necessary. Also, if the channel is very busy, two or more mobiles may initiate a transmission simultaneously by pure chance. Thus the amount of information transferred may increase at a decreasing rate with total channel utilization due to repeats. This must be considered when comparing multi-channel trunked and cellular systems with single channel systems.

Another alternative would be automatic control of the single channel system so that "doubling" would be prevented and additional mobiles could be handled at high gross utilization rates. On the other hand, it is pretty well established that holding times decrease with increasing utilization on single channel systems because the operators sense the crowding and shorten their transmissions. SAI suggested the possibility of us gathering some of this type of data since it is outside the scope of their contract.

I plan to discuss these items with Messrs Cooke and Thornell next week. I would appreciate your comments.

Dale N. Hatfield
Policy Support Division

cc: Art Cooke, OTP
Hal Millie, OT/WPSD
Jean Adams
Gene Ax
Wes Harding
Scotty Hart

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M16

Date: March 16, 1972

Reply to Attn of: PSD/DNH

Subject: Trip Report, Washington, D.C.
March 13-15, 1972

To: Roger Salaman

1. On Tuesday morning I attended the AT&T briefing on their Docket 18262 filing (proposal). On Tuesday afternoon I met with Jack Thornell and Art Cooke regarding the project status and my trip to SAI. Later in the afternoon I attended the meeting with Walt Hinchman, Les Berry, Tom Mustin, and Lockett Wood. I also discussed the Pacific Communications study with Walt and Tom. I have started a project file with the material they gave me. On Tuesday evening I met with SAI to discuss strategy for the Wednesday meeting with AT&T.

2. On Wednesday I attended the meeting with AT&T in which we asked questions about their system. The meeting seemed to go very well from both sides. We got additional information on the demand and cost factors which had been concerning us. Another meeting will be scheduled later. I used the remainder of the day to talk with Dick Gabel about Docket 18262.

Dale N. Hatfield

Dale N. Hatfield

Questions Regarding the AT&T HCMTS

1. Fleet calls in the Automatic Dispatch Service would normally require that the dispatcher wait until there is an available channel in each cell where he has a mobile unit. Even though the average wait is only 2-3 seconds, his transmission could be delayed considerably more, as governed by the "worst" cell. Is servicing fleet calls on a priority basis really an adequate solution? Wouldn't a dispatcher quickly learn this and make unnecessary fleet calls even when he really needs to communicate with just a single mobile? In the simulation in Section 4 of the Technical Report, what percentage of calls are fleet calls?
2. How is the presence or absence of freeways considered in the formula for density of offered traffic on page 1-10?
3. Is there documentation that supports the minimum cell size (one mile radius)? What "advances in data processing" (page 2-3) are necessary to decrease this further?
4. On page 2-35 reference is made to continuing studies of the optimum value of frequency deviation. Does the 12 kHz value still seem optimum?
5. In several places reference is made to intermodulation effects when the mobile unit is very near a base station. A system for automatically reducing the transmitter power to decrease overloading is mentioned. How severe is this problem? To what extent will it affect spectral efficiency?
6. On page 5-2 it is stated that "the combined coverage areas will contain about 63% of the United States population," What percentage of the geographic area of the contiguous U.S. will this represent?

7. In the reference example on page 4-5, the cost of shared equipment for the ADS user is 37% less than that for MTS. What specific items account for this difference? The MTS user generates more than seven times as much traffic as the ADS user. Could the shared costs be broken down by the base station, landline facility, and processor categories for the reference example?

8. Is there additional information available on the study leading to the development of the Vehicular Density model for the Philadelphia area?

March 23, 1972

Will Dean

Jack Thornell

Request for Assistance to PSD

The Policy Support Division of OT is attempting to determine the extent of mobile radio telephone service in the U.S. One approach to this is to plot the coverage of FCC licensed base stations of the Radio Common Carriers and Wireline Common Carriers. The FCC has offered to provide them with computer tapes containing the assignments.

However, considering that the Frequency Management area already has these data on tape which can be easily plotted using the OEP 1108 computer, I would appreciate your permission to have your group in OT provide support to PSD. The feasibility of the approach has already been discussed with Jean Adams in Boulder and George Garber in Washington.

We are concerned only with assignments in the LMR area and it does not involve classified data.

cc: Dale Hatfield
Art Cooke
Harold Millie

U.S. DEPARTMENT OF COMMERCE
Office of Telecommunications
INSTITUTE FOR TELECOMMUNICATION SCIENCES
Boulder, Colorado 80302

M18

Date: March 24, 1972

Reply to Attn of: PSD/DNH

Subject: Interim Report - OT/PSD LMR Study Effort

To: Art Cooke, OTP

We are currently working on all five tasks assigned to us in the February 24, 1972, letter from Jack Thornell. The purpose of this memorandum is to report on our preliminary efforts in each task. Because of the interim nature of these results, they are presented very informally.

Task I Research and Data Base Preparation

1. Hal Millie (Washington PSD) has completed summaries of the filings under FCC Docket 18262 and he will separately transmit copies of these to you.

2. Burgette Hart (Boulder OT/ITS), under the direction of Hal Millie, has started to compile coverage information for current LMR systems (WCC, RCC and Private). Initially she has been concerned with developing geographic coverage maps for the WCCs. Attachment 1 is an informal log of contacts she has made. It also contains other data on Continental Telephone, United Utilities, and GTE. We have also initiated an effort to get coverage data from the FCC assignment tapes.

Task II Mobile Communications Supply

1. Wes Harding (Boulder OT/ITS) has collected cost information on conventional private LMR systems operating at 150 and 450 MHz. He has also gathered tariff information on LMR services offered by common carriers. He is currently working on providing similar cost data for 900 MHz systems. A brief description of the data he has collected so far is contained in Attachment 2.

2. A preliminary analysis of LMR Spectrum Requirements and Implications" was undertaken for the Tulsa, Oklahoma, area. Tulsa was chosen because of its moderate size and because it was referred to in the AT&T filing. A report on the initial findings is contained in Attachment 3.

3. A LMR computer simulation program was obtained from Dr. James Mikusky of Motorola. Jean Adams and his group at ITS has converted it for running on the Boulder Laboratories' XDS-940 timesharing computer system. It is now available for remote access from your office and, within the next few days, it will be made available to you through the Telecommunications Services Center. A sample printout obtained on the Boulder computer is contained in Attachment 4.

4. Dr. James Crary (Boulder OT/ITS), assisted by Carlos Rozo (Boulder PSD), is undertaking a very limited study of vehicle densities in major metropolitan areas since these distributions have a significant impact on system design and spectrum requirements, especially for cellular systems.

Task III Technological Alternatives

1. Gene Ax (Boulder OT/ITS) has been given primary responsibility for this task. A short paper summarizing the major technological alternatives and implications considered in the filings is contained in Attachment 5.

Task IV Inter-Agency LMR Working Group Support

1. Hal Millie has been providing this support and I am sure you are aware of the status.

A major part of our effort so far has been concerned with establishing the projects and getting people "up to speed" on the problems. The pace should pick up significantly from here on. Please let me know your questions and comments.

Dale N. Hatfield
Policy Support Division

Enclosures (5)

cc: Hal Millie (with enclosures)
J. E. Adams (with enclosures)
G. G. Ax
B. Hart
H. Crary
RKS/mobile file
D. D. Crombie

INFORMAL LOG OF CONTACTS MADE AND MATERIALS REVIEWED

TO: D. N. Hatfield
FROM: B. A. Hart
PERIOD: March 1-17, 1972

1. John Tary thought the "Electronic Market Data Book" might have some mobile radio and telephone data. Called

Electronic Industries, Association
2001 Eye St., NW
Washington, D. C. 20006
202 659-2200

to see if 1971 yearbook was available. It was, but cost $15, so located one here in the Boulder Laboratories (Ben Gray). No common carrier data on radio or telephone.

2. Five data books on land mobile radio assignments (private, not common carrier) had just arrived in the library. Wondered if some were available on common carriers, so called

Arcata Communication Information
561 National Press Building
Washington, D. C. 20004
202 783-2482.

They referred me to office currently handling mobile communication data

Action Radio Information Systems, Inc.
Silver Springs, Maryland
(Mr. Ed Gordon)
301 587-0558.

Mr. Gordon said they have not compiled (nor, to the best of his knowledge, do they intend to compile) data on either land mobile telephone service or land mobile common carriers. However, he said they had had several previous requests for these.

3. Called

Statistical Information
Common Carrier Bureau
Washington, D. C.
202 632-7084

on March 15 to ask for their latest copy of "Statistics of Communications Common Carriers" (current through Dec. 31, 1969). Enclosed are data from the 1968 book, which may be useful for comparison purposes.

4. Borrowed "Exchange Service Telephone Rates," published by the National Association of Regulatory Utility Commissioners from Ben Gray. It gives figures on total telephones, as of June, 1970, in cities of 50,000 or more (1960 census) or the state capital plus the largest city if, like Wyoming, no city population is greater than 50,000. Listings are per state from 21 Bell companies and 10 independent telephone companies and range in number from 2 (for 16 states) to over 50 in California.

5. Noted the statistics from the annual report of USITA,
United States Independent Telephone Association
433 Pennsylvania Building
Washington, D. C. 20004
(Exec. Vice-president, Admiral William C. Mott).

Hal Millie has asked them for individual (11 in number) state maps of independent telephone company coverage. The annual report indicated that [illegible] reporting companies (representing 92% of the telephones in service of the total 1894 independent companies) show 18,045,000 telephones (representing about 13 million subscribers).

6. Telephones in use, by states and separated into two categories, owned by Bell companies or owned by all others (also listed per 100 population) are given on page 484 in "Statistical Abstract of the United States 1971". I have a copy from the U.S. Government Printing Office Bookstore in Denver.

7. Maps of U.S.A. area coverage by General Telephone System and United Telephone System (enclosed) were copied from "Moody's Public Utility Manual 1971". Phoned (212 267-6000, FTS 212 460-0100) Robert W. Burke's office to find out if any more maps were available. Was told these two systems (each involving 20 to 30 individual companies) were the only telephone companies who had included maps with their financial status reports. Sent xerox copies (March 16) to Hal Millie.

8. I reviewed the 1971 monthly copies of the Public Affairs Information Bulletin and recent copies of Public Utilities Fortnightly and the Bell Journal of Management and Science. Items which might be of interest were:

a. The October 8, 1970 issue of the Fortnightly was devoted to the independent telephone industry, but the papers were more general than specific, and had very little statistical data.
b. H. R. 12150 (Feb. 23-25, 1970, 91st Congress, 2nd session, serial number 91-81) by subcommittee on communications and power is concerned with role of interstate and intrastate common carriers.
c. One article mentioned that Bell system has recently doubled circuit capacity of major microwave systems (6000 to approximately 12,000) and circuit mile costs have dropped by about $20 in last 10 years.
d. Xeroxed an article "A generalization of the logistic curves and long-range forecasts (1966-1991) of residence telephones"; the statistical approach might suggest ways to project future usage of mobile telephones.

9. Found out that Mr. Reinking (phone 266-7507) is the Bell mobile telephone representative in Denver--suspect he would have data on all Colorado land mobile common carriers; however, these data can also be obtained from listings at the Colorado PUC (1845 Sherman) as a consistency check on the machine listings (which Jean Adams will extract from the FCC tapes), if Jean feels this might be worthwhile.

10. Checked Telephony's Directory of the Telephone Industry at the CU Business Library. The latest copy they had was 1967. Gives fairly complete listings of telephone subscribers with both Bell and independent companies. Called

Telephony Publishing Corporation
608 S. Dearborn Street
Chicago, Illinois 60605
312 922-2435.

Was told the 1971 Directory (data current through April, 1971) is available for [illegible] if you are connected with the telephone industry) from

Miss Vivian Rydan
Telephony Publishing Corporation
53 W. Jackson Blvd.
Chicago, Illinois 60604.

Asked Shirley Alldredge from our library to contact the Denver Bell Telephone Library to see if a copy could be borrowed, but they didn't have the directory. I sent a check to Telephony on March 17. asking for a receipt so I could turn it in with a purchase requisition to Art Stewart. (If he orders, the check has to clear Rockville, etc., resulting in a delay of approximately six weeks.) Mrs. Alldredge has ordered a 1972 copy (which will arrive in June or July) for the library reference shelves.

I think this directory has the information needed to plot company franchise coverage for all states in the U.S. The exchanges are given by town and city, but small towns of less than 500 population seem to be included; so this should outline the areas fairly well.

11. Have been checking semi-monthly 1971 and 1972 NTIS Government Reports Announcements for reports which might provide information on, or maps of, the U.S. telephone company coverages. The fields I am reviewing are

5B Documentation and Information Technology
5C Economics
5K Sociology
17B Communication.

This search will continue. So far no reports have been found which would be helpful to me on the telephone wire-line coverage maps, but a number have been found on related items, such as new technology in the mobile radio and radio-telephone mobile units. I will xerox some of these and give them to Gene Ax, in case he's interested.

12. Have corresponded with William J. Hamm, Special International Assistant to GT and E in the past year; so called him at

General Telephone and Electronics International Incorporated
Suite 900-1120 Connecticut Avenue, N.W.
Washington, D. C. 20036
202 293-2800

to ask him who might have information on the telephone subscriber coverage of GT and E. He said he knew they had franchised areas in about 35 states and gave me the Commercial Service Director's name as someone who might know of coverage maps. So I called

Mr. Donald G. Prigrone
212 551-1567

in New York City. He was out of town, but Mr. Hamm had called his office, and his secretary had contacted Mr. Hames (extension 1491), who had located a [illegible]'x3' map which they will copy and send to me this week.

CONTINENTAL TELEPHONE CORPORATION

Data on Manufacturing, Supply,
Directory and Service Affiliates

Prepared at Request of
Joint NARUC-FCC Subcommittee

For the year, 1970
June 1971

Note: The following pages (beginning with this one) give company listings and maps for some of the major telephone corporations. The information is always preceded by a page, listing the source.

CONTINENTAL TELEPHONE CORPORATION

HEADQUARTERS
St. Louis, Missouri

NORTHEAST DIVISION
Syracuse, New York

Maine
- MAINE STATE TELEPHONE
- MAINE TELEPHONE
- NASH TELEPHONE
- UNION TELEPHONE

Michigan
- MICHIGAMA TELEPHONE
- MICHIGAMA WESTERN TELEPHONE

New Hampshire
- NEW HAMPSHIRE TELEPHONE
- TUFTONBORO TELEPHONE

New Jersey
- [illegible]RS UNION TELEPHONE

New York
- [illegible] & UNADILLA TELEPHONE
- IROQUOIS TELEPHONE
- SOUTHERN COUNTIES TELEPHONE
- WESTERN COUNTIES TELEPHONE

Pennsylvania
- BIG EDDY TELEPHONE
- CENTRAL PENNSYLVANIA TELEPHONE
- CHAPMAN LAKE TELEPHONE
- KEYSTONE STATE TELEPHONE
- WAYOMING TELEPHONE
- QUAKER STATE TELEPHONE
- STEUBEN TELEPHONE

Vermont
- VERMONT STATE TELEPHONE
- VERMONT TELEPHONE

Canada
- BEAUCEVILLE RURAL TELEPHONE
- CENTRAL COMMUNITY TELEPHONE
- CONTINENTAL TELEPHONE, LTD.—QUEBEC
- [illegible]

SOUTHEAST DIVISION
Amherst, Virginia

Alabama
- ALABAMA TELEPHONE

Florida
- FLORIDA STATE TELEPHONE

Georgia
- GEORGIA STATE TELEPHONE

Indiana
- EUREKA TELEPHONE
- HOOSIER STATE TELEPHONE

Kentucky
- KENTUCKY TELEPHONE

North Carolina
- WESTCO TELEPHONE
- WESTERN CAROLINA TELEPHONE

South Carolina
- ELLOREE TELEPHONE
- HOME TELEPHONE OF SIMPSONVILLE

Tennessee
- TENNESSEE TELEPHONE

Virginia
- CONTINENTAL TELEPHONE OF VIRGINIA
- FIRST COLONY TELEPHONE

West Virginia
- W. VIRGINIA TELEPHONE

UPPER MIDWEST DIVISION
St. Paul, Minnesota

Colorado
- HAXTUN TELEPHONE

Iowa
- BELLAMY TELEPHONE
- FOWLER TELEPHONE
- HAWKEYE STATE TELEPHONE
- IOWA TELEPHONE
- TWIN CEDARS TELEPHONE

Minnesota
- GOPHER STATE TELEPHONE
- LAKE STATE TELEPHONE
- LITTLE CROW TELEPHONE
- MINNESOTA TELEPHONE

Nebraska
- CORNHUSKER STATE TELEPHONE
- DESHLER TELEPHONE

North Dakota
- NORTH DAKOTA TELEPHONE

South Dakota
- BISON STATE TELEPHONE

Wisconsin
- BADGER TELEPHONE
- FREDERIC TELEPHONE
- LAKELAND TELEPHONE
- OSCEOLA TELEPHONE
- POPLAR TELEPHONE
- SOLON SPRINGS TELEPHONE

Wyoming
- MONA SHORT LINE TELEPHONE

[illegible] DIVISION
Wentzville, Missouri

Illinois
- DeKALB-OGLE TELEPHONE
- ILLINI STATE TELEPHONE
- ILLINOIS TELEPHONE

Kansas
- AMERICAN COMMUNICATIONS
- KANSAS TELEPHONE

Missouri
- DREXEL TELEPHONE
- MISSOURI CENTRAL TELEPHONE
- MISSOURI STATE TELEPHONE
- MISSOURI TELEPHONE

[illegible]WEST DIVISION
Dallas, Texas

Arkansas
- [illegible]OOD TELEPHONE
- [illegible]ARKANSAS TELEPHONE

Louisiana
- CENTRAL LOUISIANA TELEPHONE

Oklahoma
- OKLAHOMA STATE TELEPHONE

Texas
- MERKEL TELEPHONE
- NASSAU BAY TELEPHONE
- TELEPHONES, INC.
- TEXAS TELEPHONE
- WEST TEXAS TELEPHONE

WESTERN DIVISION
Bakersfield, California

Alaska
- [illegible] TELEPHONE
- JUNEAU & DOUGLAS TELEPHONE

Arizona
- GOLDEN WEST TELEPHONE
- WESTERN STATES TELEPHONE

California
- CONTINENTAL TELEPHONE OF CALIFORNIA
- GOLDEN WEST TELEPHONE

Idaho
- IDAHO TELEPHONE

Montana
- TREASURE STATE TELEPHONE

Nevada
- CONTINENTAL TELEPHONE OF NEVADA

New Mexico
- WESTERN STATE TELEPHONE

[illegible]
- [illegible]

[illegible]

[illegible]
- [illegible]S TELEPHONE
- [illegible] TELEPHONE
- JAMAICA TELEPHONE
- TRINIDAD & TABAGO TELEPHONE

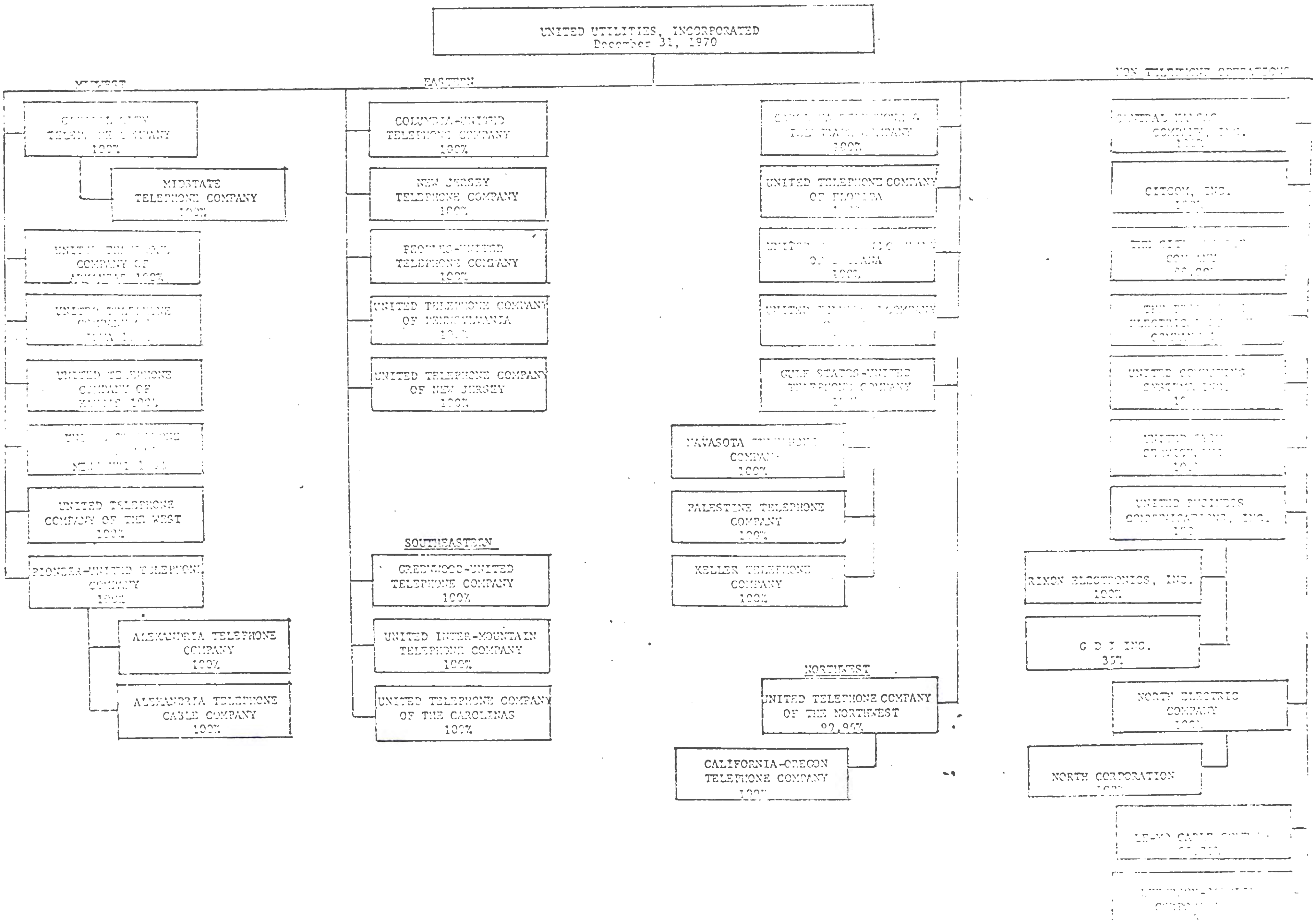
Bahamas
- ANDROS TRANSMISSION & TELEPHONE
- GRAND BAHAMA TELEPHONE

* UNITED UTILITIES, INCORPORATED

DATA ON MANUFACTURING, SUPPLY AND SERVICE AFFILIATES

FOR THE YEAR 1970

* In early 1972 this name was changed to
UNITED TELECOMMUNICATIONS, INCORPORATED



UNITED UTILITIES, INCORPORATED
December 31, 1970
EASTERN
COLUMBIA-UNITED TELEPHONE COMPANY
100%
NEW JERSEY TELEPHONE COMPANY
100%
TELEPHONE COMPANY
100%
UNITED TELEPHONE COMPANY OF PENNSYLVANIA
UNITED TELEPHONE COMPANY OF NEW JERSEY
100%
MIDSTATE TELEPHONE COMPANY
100%
COMPANY OF
UNITED TELEPHONE COMPANY OF THE WEST
100%
ALEXANDRIA TELEPHONE COMPANY
100%
ALEXANDRIA TELEPHONE CABLE COMPANY
100%
SOUTHEASTERN
TELEPHONE COMPANY
100%
UNITED INTER-MOUNTAIN TELEPHONE COMPANY
100%
UNITED TELEPHONE COMPANY OF THE CAROLINAS
100%
UNITED TELEPHONE COMPANY
COMPANY
100%
PALESTINE TELEPHONE COMPANY
100%
KELLER TELEPHONE COMPANY
100%
NORTHWEST
UNITED TELEPHONE COMPANY OF THE NORTHWEST
CALIFORNIA-OREGON TELEPHONE COMPANY
CITCOM, INC.
RINON ELECTRONICS, INC.
100%
G D I INC.
35%
NORTH ELECTRIC COMPANY
NORTH CORPORATION

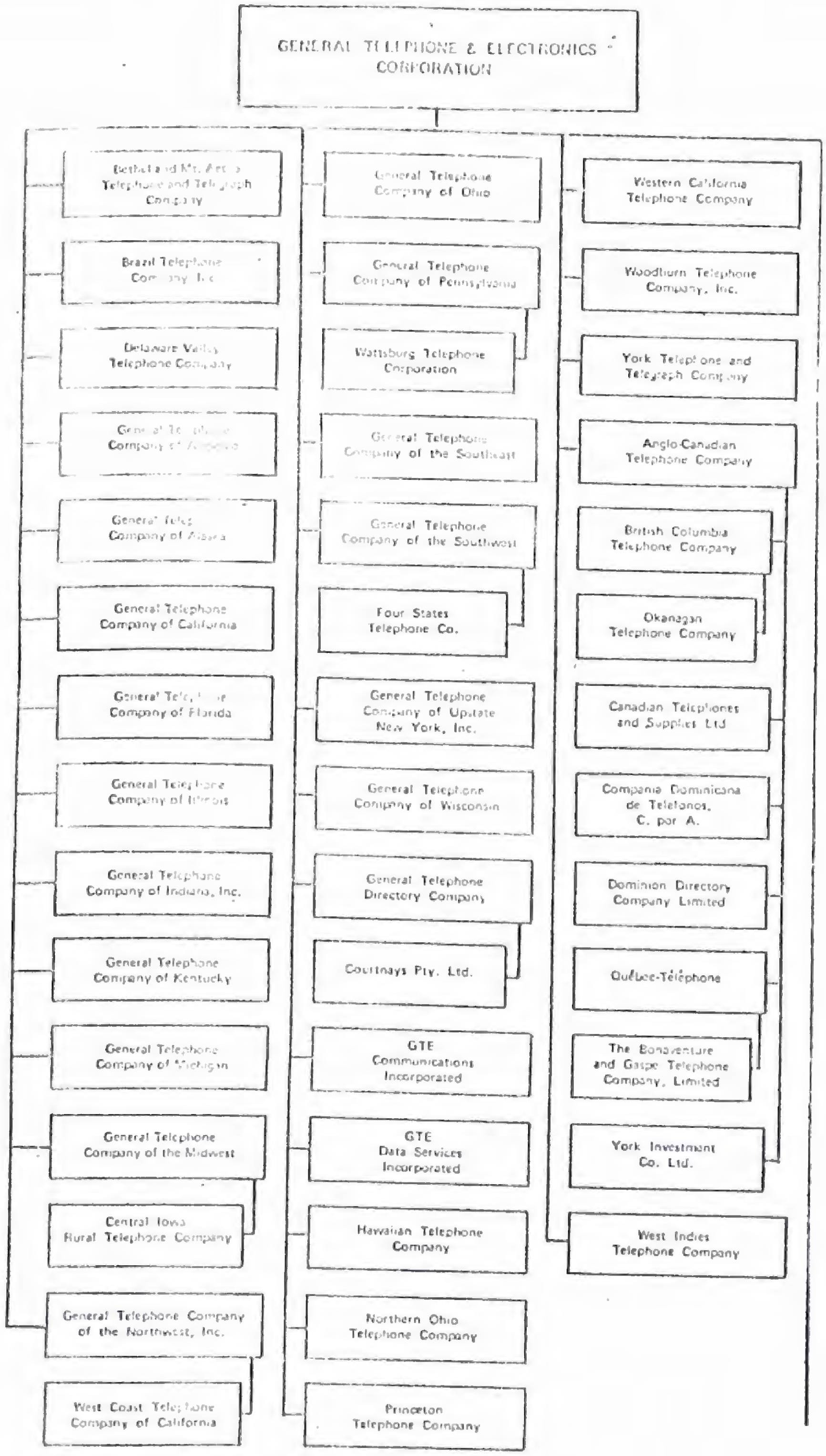
GENERAL TELEPHONE & ELECTRONICS CORPORATION

DATA ON MANUFACTURING, SUPPLY, DIRECTORY AND SERVICE

AFFILIATES

FOR THE YEAR 1970

JUNE, 1971



GENERAL TELEPHONE & ELECTRONICS CORPORATION
Telephone and Telegraph Company
Brazil Telephone
Delaware Valley Telephone Company
General Telephone Company of California
Company of Florida
General Telephone Company of Indiana, Inc.
General Telephone Company of Kentucky
General Telephone
General Telephone Company of the Midwest
Central Iowa Rural Telephone Company
General Telephone Company of the Northwest, Inc.
West Coast Telephone Company of California
General Telephone Company of Ohio
General Telephone Company of Pennsylvania
Wattsburg Telephone Corporation
General Telephone Company of the Southeast
General Telephone Company of the Southwest
Four States Telephone Co.
General Telephone Company of Upstate New York, Inc.
General Telephone Company of Wisconsin
General Telephone Directory Company
Courtnays Pty. Ltd.
GTE Communications Incorporated
GTE Data Services Incorporated
Hawaiian Telephone Company
Northern Ohio Telephone Company
Princeton Telephone Company
Western California Telephone Company
Woodburn Telephone Company, Inc.
York Telephone and Telegraph Company
Anglo-Canadian Telephone Company
British Columbia Telephone Company
Okanagan Telephone Company
Canadian Telephones and Supplies Ltd.
Compania Dominicana de Telefonos, C. por A.
Dominion Directory Company Limited
Québec-Téléphone
The Bonaventure and Gaspe Telephone Company, Limited
York Investment Co. Ltd.
West Indies Telephone Company

1971

MOODY'S

PUBLIC UTILITY MANUAL

MOODY'S INVESTORS SERVICE, INC.
99 CHURCH STREET, NEW YORK, N. Y. 10007 (212) 267-8800

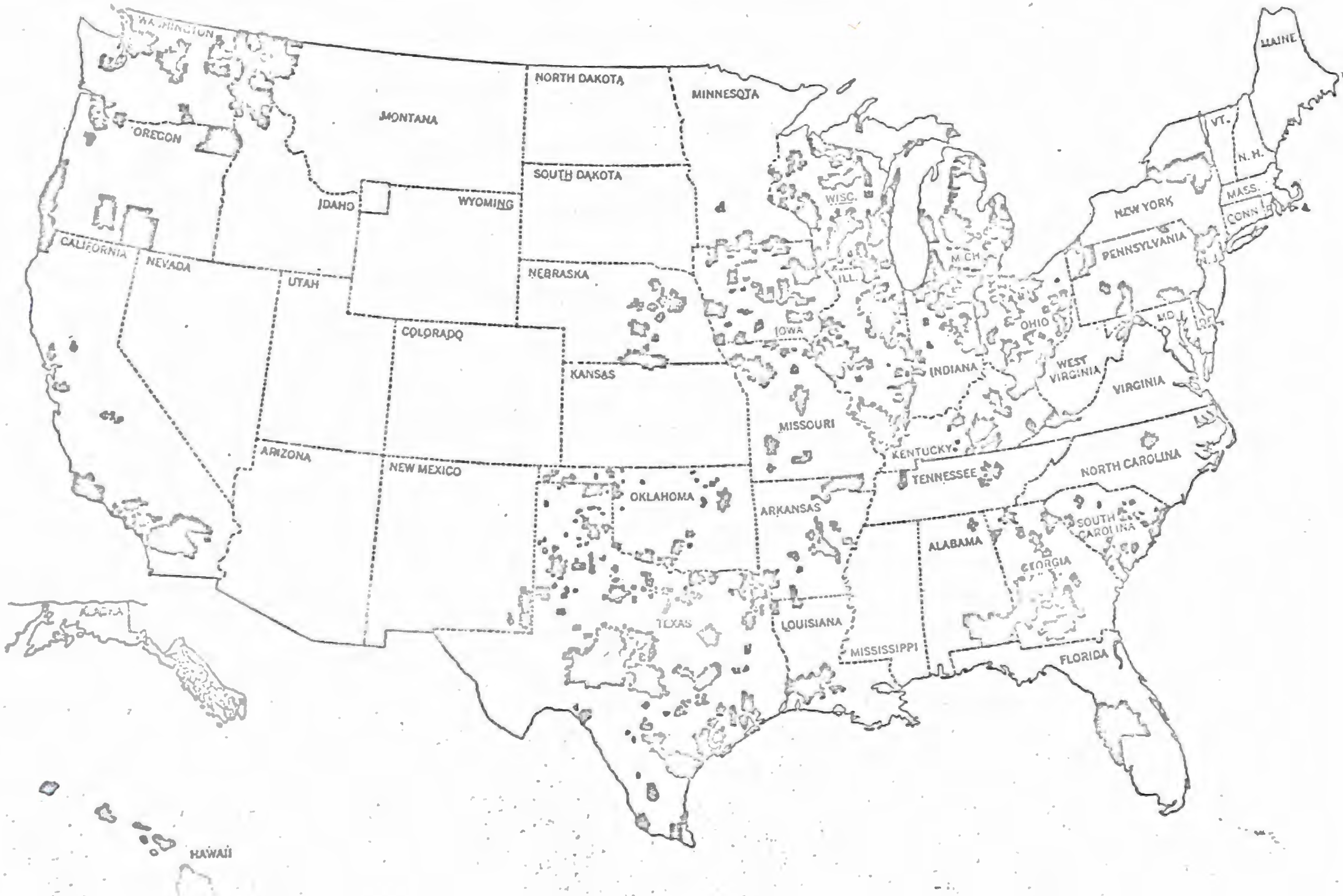
PHILADELPHIA Suburban Station Bldg.
BOSTON 75 Federal St.
CHICAGO 135 S. LaSalle St.
LOS ANGELES 611 W. 6th St.
SAN FRANCISCO 235 Montgomery St.
WASHINGTON Colorado Bldg.

LONDON: Moodies Services, Ltd.
Moodies House, 6, 7 & 8 Bonhill St., London E.C. 2


United Telephone Company of the Northwest
California-Oregon Telephone Company
Pioneer-United Telephone Company
United Telephone Company of Iowa
United Telephone Company of the West
United Telephone Company of Indiana, Inc.
United Telephone Company of Missouri
Capital City Telephone Company
United Telephone Company of Kansas, Inc.
United Telephone Company of Arkansas
Gulf States-United Telephone Company
United Telephone Company of Ohio
The United Telephone Company of Pennsylvania
New Jersey Telephone Company
United Telephone Company of New Jersey
Columbus-United Telephone Company
United Inter-Mountain Telephone Company
United Telephone Company of the Carolinas, Inc.
Carolina Telephone & Telegraph Company
Greenwood-United Telephone Company
United Telephone Company of Florida
United Telephone System

GENERAL TELEPHONE SYSTEM

Operating exchange areas shown in black.



World Telecommunications

Volume 3

The United States, Canada, and Europe

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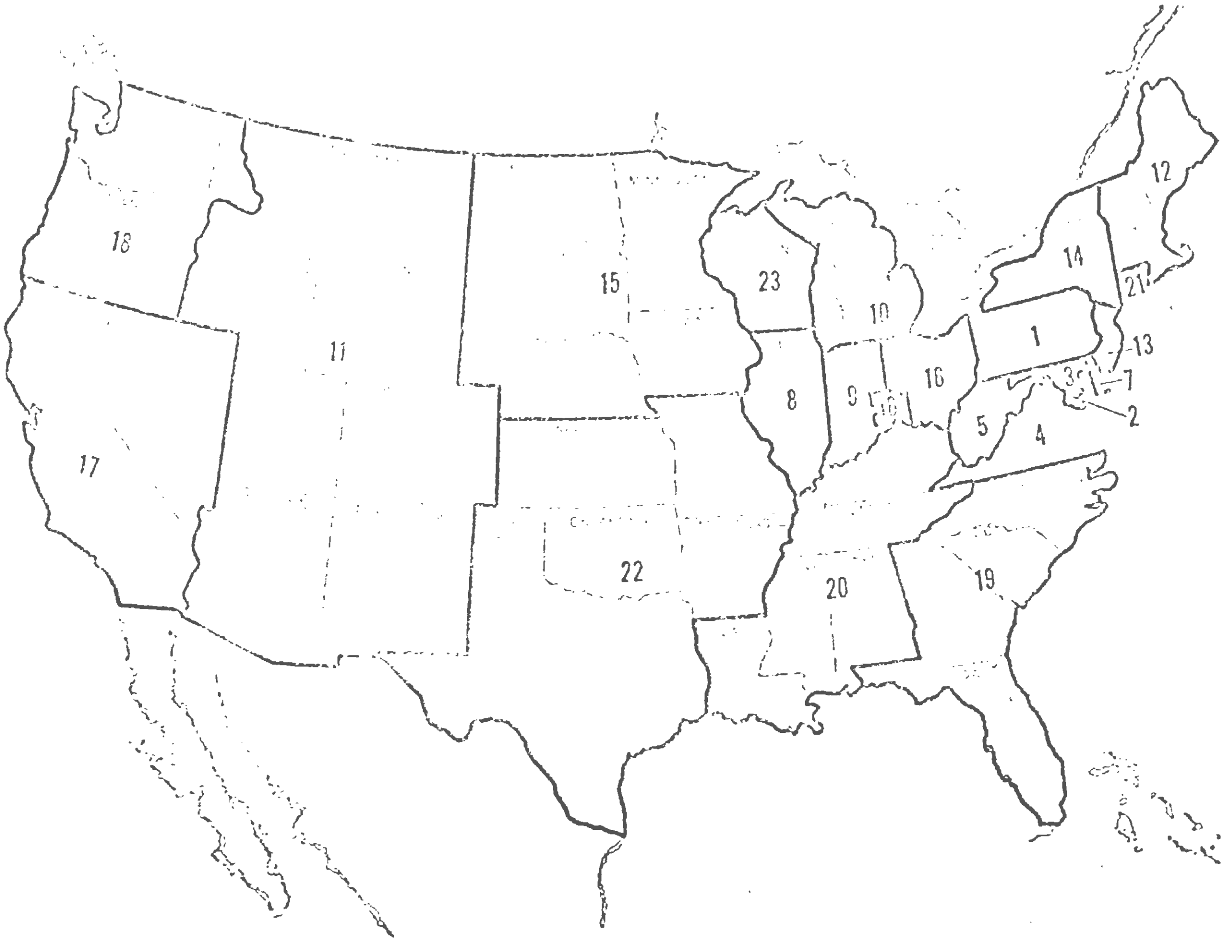


1 Bell Telephone Company of Pennsylvania
2 The Chesapeake and Potomac Telephone Company (D.C.)
3 The Chesapeake and Potomac Telephone Company of Maryland
4 The Chesapeake and Potomac Telephone Company of Virginia
5 The Chesapeake and Potomac Telephone Company of West Virginia
6 Cincinnati Bell Inc.
7 Diamond State Telephone Company
8 Illinois Bell Telephone Company
9 Indiana Bell Telephone Company, Inc.
10 Michigan Bell Telephone Company
11 Mountain States Telephone & Telegraph Company
12 New England Telephone & Telegraph Company
13 New Jersey Bell Telephone Company
14 New York Telephone Company
15 Northwestern Bell Telephone Company
16 Ohio Bell Telephone Company
17 Pacific Telephone & Telegraph Company
18 Pacific Northwest Bell Telephone Company
19 Southern Bell Telephone & Telegraph Company
20 South Central Bell Telephone Company
21 Southern New England Telephone Company
22 Southwestern Bell Telephone Company
23 Wisconsin Telephone Company

Figure US–3 Operating Areas Served by Bell Telephone Companies

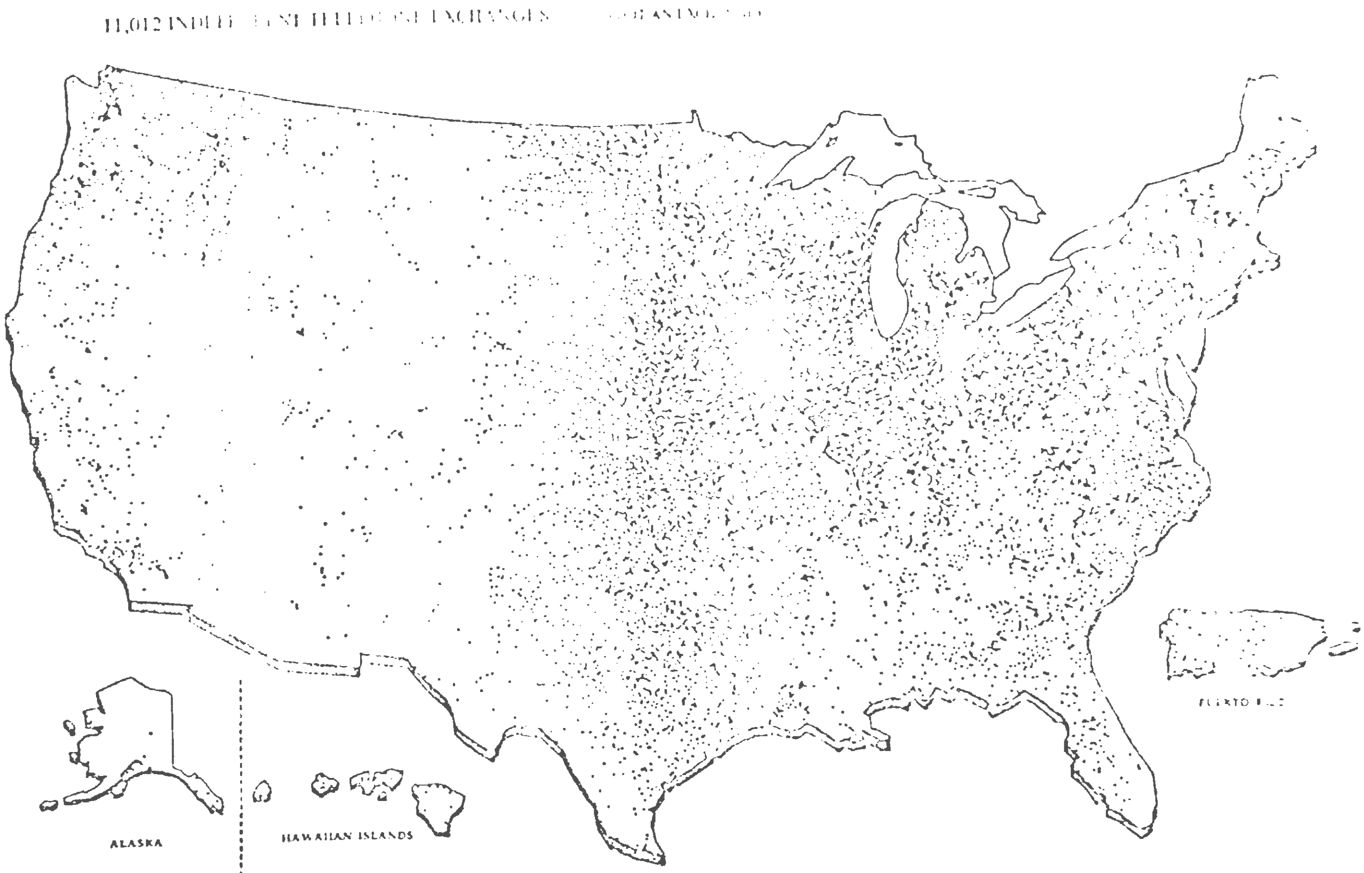


Figure US–5 Locations of Independent Exchange Areas in the United States

TABLE US-4

PRINCIPAL INDEPENDENT TELEPHONE HOLDING COMPANIES

Rank	Holding Company	Headquarters	Percent of Independent Telephones	Cumulative Percent of Independent Telephones
1	General Telephone & Electronics	New York City	46.13	46.13
2	United Utilities	Kansas City	11.42	57.55
3	Continental Telephone	St. Louis	6.68	64.23
4	Central Telephone & Utilities	Lincoln, Nebraska	4.58	68.81
5	Mid-Continent Telephone Corp.	Hudson, Ohio	2.54	71.35
6	Rochester Telephone Corp.	Rochester, N.Y.	2.53	73.8[illegible]
7	Puerto Rico Telephone Co.	San Juan	1.41	75.29
8	Lincoln Telephone & Telegraph Co.	Lincoln, Nebraska	1.06	76.35
9	Commonwealth Telephone Co.	Dallas, Pa.	0.63	76.9[illegible]
10	Florida Telephone Corp.	Ocala, Florida	0.51	77.4[illegible]
	Next Ten		2.95	[illegible]

Source: USITA

TABLE US-11

BELL AND INDEPENDENT TELEPHONES IN THE UNITED STATES BY TYPE OF SERVICE

		Bell System[1]					Independent Telephone Companies[2]				
		1970	1969	1968	1967	1966	1970	1969	1968	1967	1966
		(thousands and percent)					(thousands and percent)				
Total [illegible]		96,5[illegible]	92,[illegible]	[illegible]	[illegible]	79,903	19,004	17,961	16,749	15,462	14,616
Residential	Main	45,5[illegible]	[illegible]	[illegible]	41,312	39,91[illegible]	10,820	10,315	9,782	9,217	--
	Extension	23,61[illegible]	[illegible]	[illegible]	18,770	17,380	3,505	3,146	2,806	2,[illegible]	2,124
	PBX	54	61	64	65	71					
Business	Main	8,114	7,870	7,517	7,225	7,004	1,522	1,444	1,356	1,262	
	Extension	5,74[illegible]	5,400	5,151	4,855	4,603	1,332	1,282	1,182	1,070	1,036
	PBX	10,18[illegible]	10,675	9,72[illegible]	9,334	9,115	1,681	1,600	1,460	1,398	1,257
	Centrex	3,2[illegible]7	2,526	2,316	2,151	1,767					
Percent Distribution											
Residential	Main	47.2	47.7	48.5	49.3	50.0	53.0	57.5	58.3	59.5	
	Individual	39.5	39.1	38.8	33.4	37.8	28.7	27.1	25.4	23.7	
	2 Party	5.5	6.2	7.0	8.0	9.0	6.7	7.0	7.2	7.5	
	4 Party	1.0	1.0	1.1	1.2	1.3	12.2	13.0	14.1	15.3	
	Multiparty	1.1	1.3	1.5	1.7	1.9	9.1	10.4	11.8	12.8	
	Extension	24.5	23.8	23.1	22.4	21.7	18.3	17.6	16.8	15.2	
	PBX	0.1	0.1	0.1	0.1	0.1					
Business:	Main	8.4	8.5	8.5	8.6	8.8	7.5	8.0	8.1	8.1	
	Extension	5.9	5.9	5.9	5.8	5.8	6.9	7.2	7.1	6.9	7.1
	PBX	10.9	10.9	11.0	11.2	11.4	8.4	8.9	8.7	9.0	8.6
	Centrex	3.4	3.1	2.9	2.6	2.2					
Percent Increase (Decrease) Over Prior Year											
Residential	Main	3.1	3.5	3.4	3.4	3.8	4.9	5.3	6.1		
	Extension	7.2	8.5	8.2	7.9	9.0	11.4	12.1	18.6	11.3	
	PBX	(11.3)	(4.7)	(1.5)	(8.5)	1.4					
Business	Main	3.1	4.7	4.0	3.2	3.1	5.6	6.2	7.1		
	Extension	4.4	6.2	6.1	5.4	6.1	7.8	8.5	10.3	3.2	
	PBX	1.1	3.6	3.6	3.0	4.3	5.0	9.6	4.3	12.0	
	Centrex	11.6	16.3	17.0	21.7	20.0	-	-	-	-	
Total		4.2	5.3	5.1	4.8	5.3	5.8	6.6	7.1	6.3	
Coin Telephones			1,468	1,447	1,415	1,395	174	165	155	145	139
Touch-Tone[3] Telephones[4] (included above)		11,000	7,500	4,500	2,500	1,000	160	90	40		
Public Mobile Telephones			30	27	25	23	10	9	8	7	6
Percent Capable of Direct Distance Dialing		95	94	93	91	90	80	77	73	67	64

1. Excluding Southern New England Bell and Cincinnati Bell in which ATT has only minority interest.
2. Includes data for independent telephone companies reporting to USITA; these account for 93% of all independent telephones
3. Registered trademark of ATT
4. Estimated

Sources: ATT, USITA.

ATTACHMENT 2

PRELIMINARY LMR COST, COVERAGE, AND TARIFF DATA

Wes Harding

March 24, 1972

In order to make recommendations in the area of Land Mobile Radio, it is necessary to be aware of the performance and costs of current 150 and 450 MHz systems. The history of LMR and the basic characteristics of current systems are discussed in a paper by Dr. Hoke Willis. Portions of the paper are contained in the summary document which is being prepared under another task. The cost and performance features of current systems are important because these systems will compete with new 900 MHz systems in areas where spectrum congestion is not yet critical. This will impact on the rate at which new systems are introduced and thereby delay the completion of a truly national system.

The cost data collected in this task were obtained from manufacturers' catalogs and conversations with suppliers. The data have been reduced and plotted on several graphs. Figure 1 shows the cost of 150 and 450 MHz mobile transceivers as a function of transmitter power output. Note that the costs for a seven-channel transceiver for 150 MHz RCC use is on the order of $1,500 while an eleven-channel, 150 MHz IMTS transceiver would run about $1,700. The revenue requirement for these transceivers alone is $500 or more per year. Corresponding base station transceiver costs are shown in Figure 3. Portions of this data were used to develop the plot in Figure 4 which shows the cost per mobile as a function of the number of mobiles in the fleet for a typical 150 MHz single-channel system.

Figure 5 indicates the nature of the cost trade-offs between privately owned LMR systems and service offered by common carriers. Curves showing base station and mobile capital investment costs amortized over 3-, 5-, and 7-year periods on a per mobile per month are given. Also plotted is the line corresponding to leasing the mobile transceivers and obtaining service through a common carrier. With allowance for operating expenses the break-even point appears to be in the range from 1 to 3 mobiles.

Since costs depend upon the coverage area required, Figure 6 was prepared to show the range versus antenna height at two power levels for 150 and 450 MHz. A curve corresponding to 900 MHz coverage was also added. It is based on curves contained in the Motorola filing. Note that a 150 MHz system would cover over twice the distance as a 900 MHz system with the same basic characteristics.

Tariff information for mobile telephone service was obtained from the Colorado Public Utilities Commission. This information is summarized in Table 1. It is planned to obtain similar information from other areas.

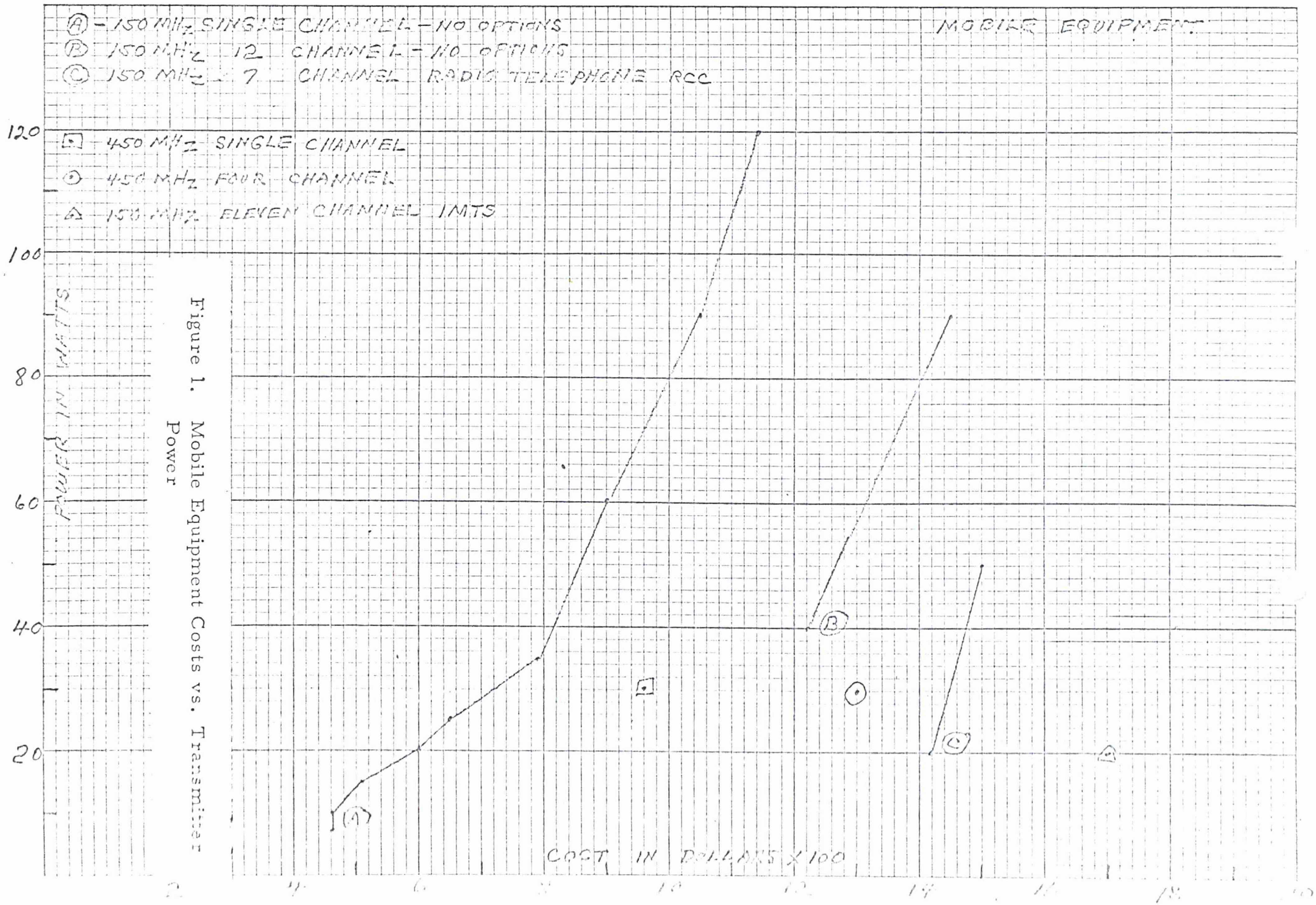


Figure 1. Mobile Equipment Costs vs. Transmitter Power

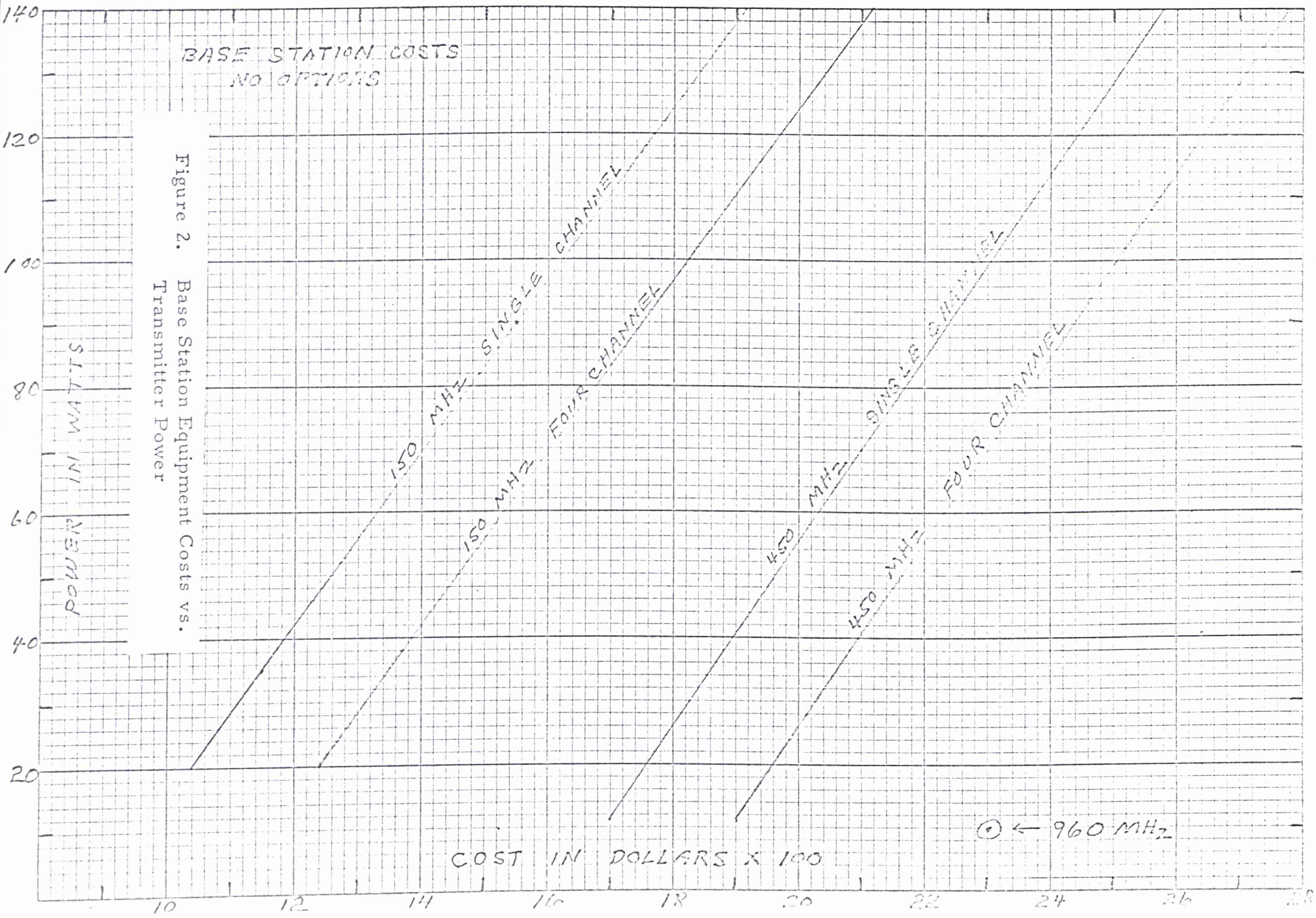


Figure 2. Base Station Equipment Costs vs. Transmitter Power

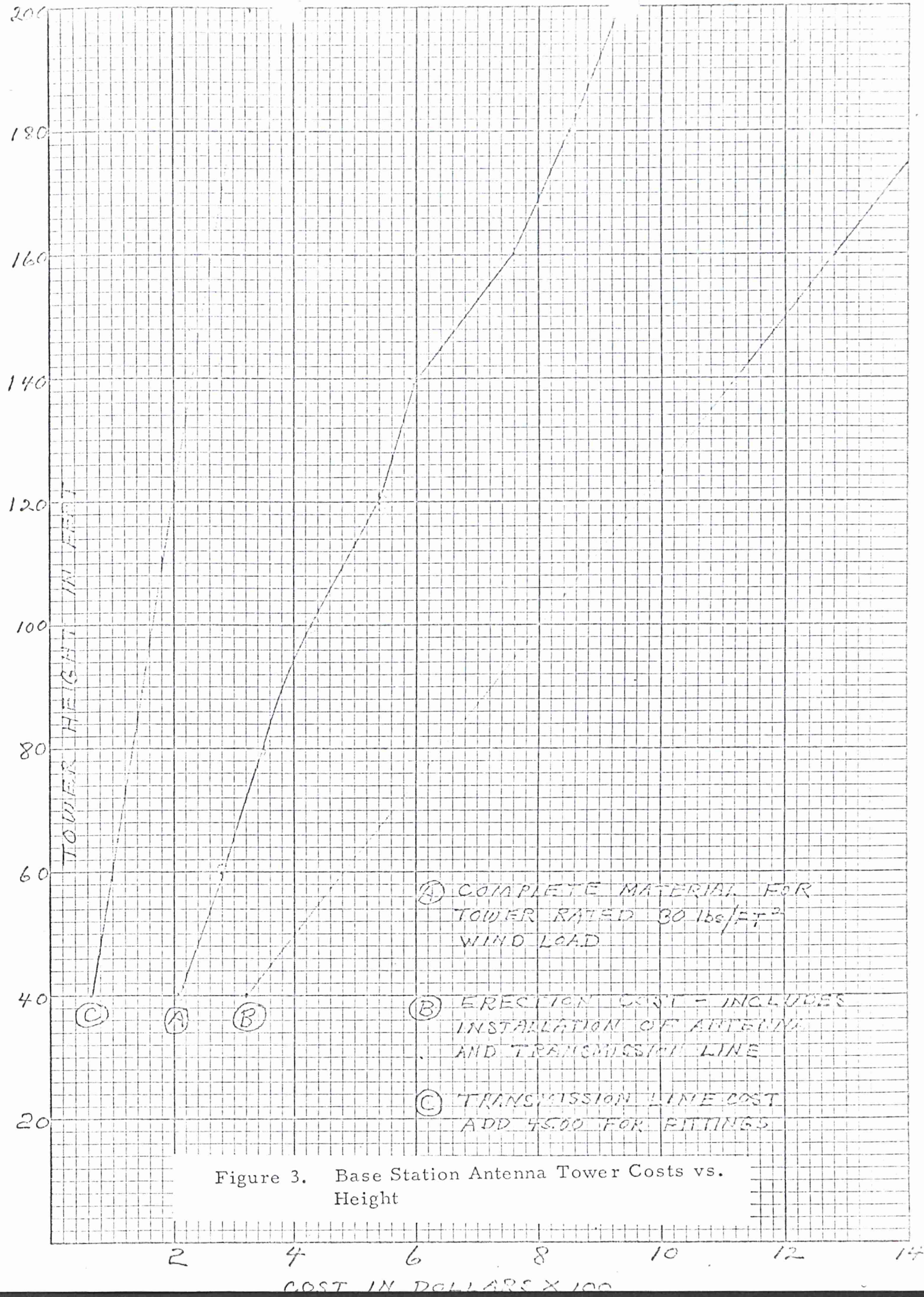


Figure 3. Base Station Antenna Tower Costs vs. Height

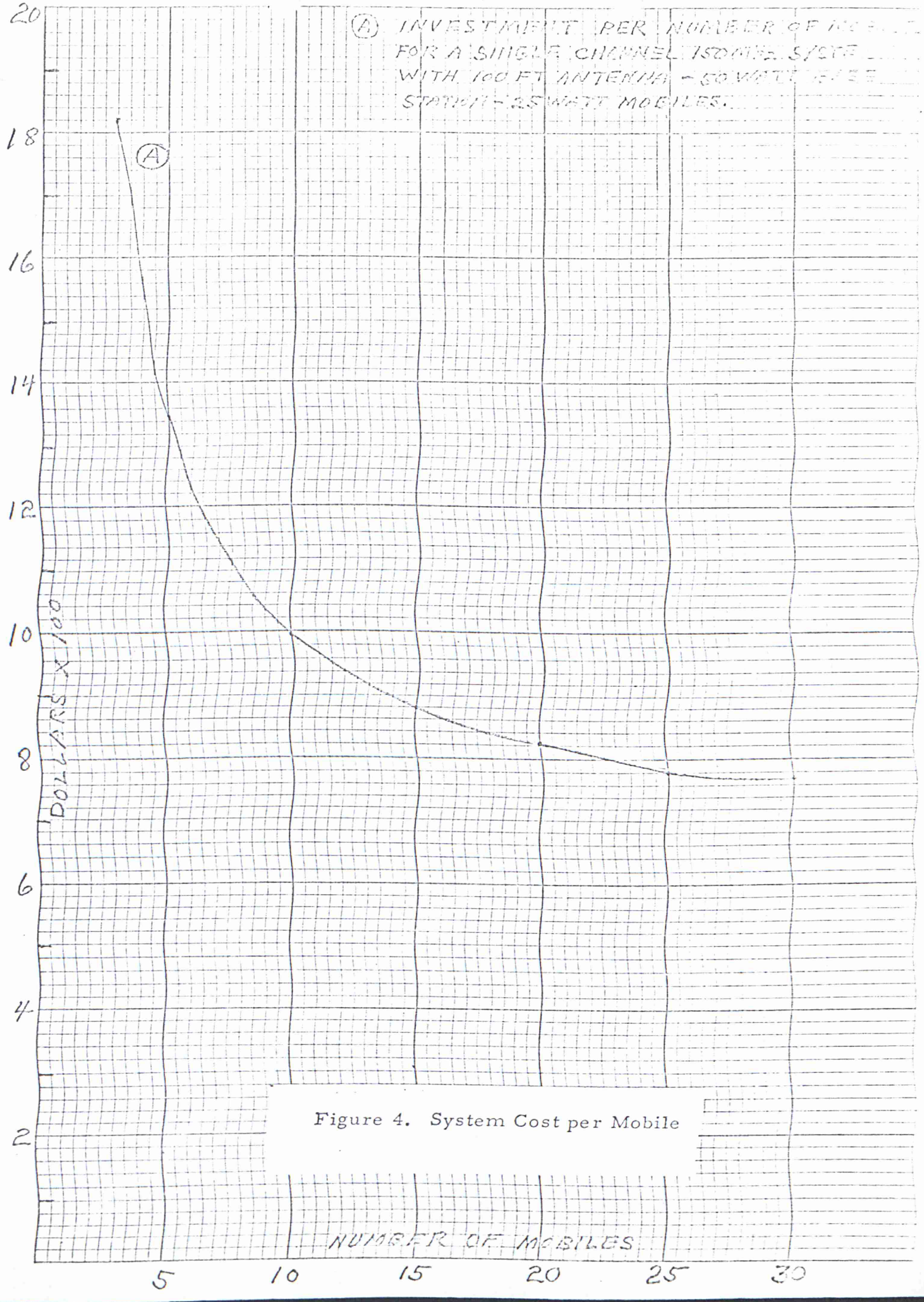


Figure 4. System Cost per Mobile

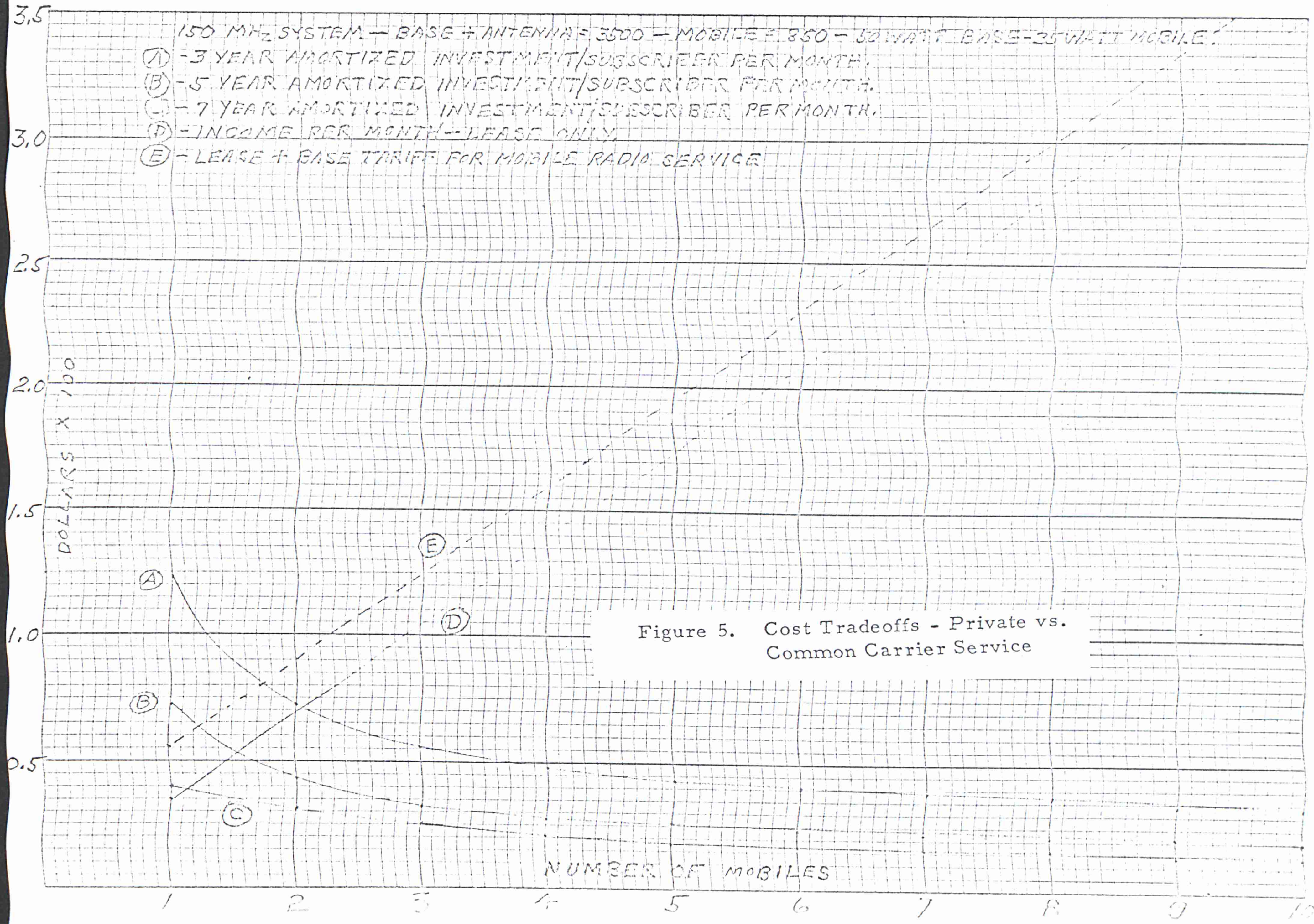
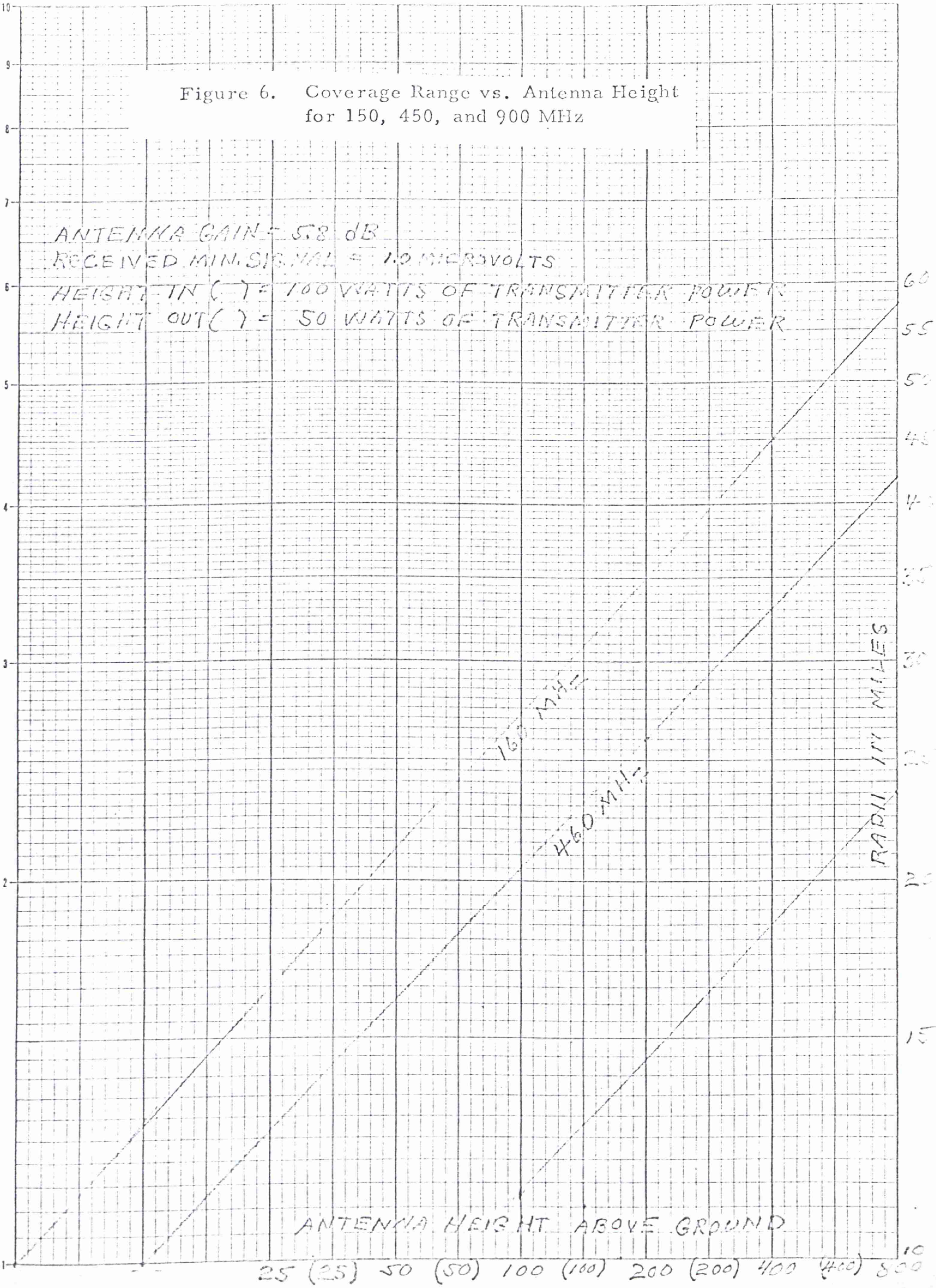


Figure 5. Cost Tradeoffs - Private vs. Common Carrier Service

Figure 6. Coverage Range vs. Antenna Height for 150, 450, and 900 MHz



NAME	MOUNTAIN-BELL	ANSWER-PHONE	MOBILE RADIO TEL		MOUNTAIN BELL	ANSWER-PHONE	MOBILE RADIO TEL
COMPANY OWNED EQUIPT. COST/MONTH	65.00	35.00	35.00	SUBSCRIBER OWNED EQUIPMENT	0	0	0
INSTALLATION CHARGE	80.00	25.00	30.00	INSTALLED BY SUBSCRIBER	10.00	0	0
LAND RADIO SERVICE COST/MONTH	15.00	17.50/100MIN. .15/CALL OVER	19.50/100MIN. 12.50/HR OVER		15.00	17.50/100MIN. .15/CALL OVER	19.50/100MIN. 12.50/HR OVER
MAINTENANCE IN AREA COST/MONTH	0	8.00	8.00	OPTIONAL	5.00	8.00	8.00
MAINT. 15MI BEYOND COST/MONTH	0	-	-	OPTIONAL	10.00	-	-
MAINT. EA. ADD. 15MI COST/MONTH	0	-	-	OPTIONAL	5.00	-	-
TELEPHONE COSTS IN TOLL-FREE AREA	BUSINESS RATE	0	BUSINESS RATE		BUSINESS RATE	0	BUSINESS RATE

Table 1. Tariff Information for LMR Services (Colorado)

ATTACHMENT 3

Land Mobile Radio Spectrum Requirements and Implications - Tulsa, Oklahoma Area

Dale N. Hatfield
March 23, 1972

Summary

* Projections of demand for LMR services in 1980, 1990, and 2000 for the Tulsa, Oklahoma SMSA were made by extrapolating from data contained in the AT&T and Motorola filings. These projections show a range of estimates between 13,000 and 40,000 users by 2000.
* The spectral efficiency required to handle this demand could be easily met with a system similar to the current IMTS configuration which gains spectral economy through trunking. The estimated spectrum requirements for 2000 range from 12 MHz to 60 MHz.
* Since the spectrum efficiency is gained through trunking and since most of this is gained with as few as 16 channels, several competitors could be accommodated without a significant increase in the total spectrum requirements.
* It is clear that the fixed (shared) costs of such systems will be less than for a cellular system covering the same area. Hence fewer subscribers are required to reach the point where all significant economies of scale are realized. It can be surmised that the several competitors permitted on the basis of spectrum efficiency might also be allowed without a significant economic penalty when compared with a single monopoly supplier. Quantitative confirmation of this will be undertaken in a subsequent analysis.

1. Introduction

As part of the OT/PSD effort to provide analytical support to the OTP in the matter of FCC Docket 18262, a preliminary analysis of mobile communications for the Tulsa, Oklahoma, area was undertaken. Tulsa was chosen because (1) there is some question as to whether the complexity of the High Capacity Mobile Telecommunication System is required on the grounds of spectral efficiency in moderately and smaller sized cities, (2) the lack of a serious spectrum constraint may allow a greater degree of competition, and (3) it was considered in the AT&T analysis.

2. Tulsa Demography

According to the 1971 Statistical Abstract, the Tulsa Standard Metropolitan Statistical Area (SMSA) had a population of 477,000 in 1970. The Tulsa SMSA is composed of Creek, Osage, and Tulsa counties and covers a total of 3,781 square miles. It ranks 68th in terms of SMSA population. The city of Tulsa itself had a population of 332,000 and covers 171.9 square miles. For reference purposes this data has been combined in Table 1 with similar data for Philadelphia and Chicago. Note the significant differences in population densities.

3. Mobile Radio Demand

The required spectral efficiencies and the costs per mobile unit are a function of the demand for mobile service. For the purposes of this analysis the demand in Tulsa was estimated on the basis of the population using data from the filings.

The population of the Tulsa SMSA was estimated as follows:

Table 1

SMSA and City Areas and Population
(From 1971 U.S. Statistical Abstract)

	SMSA		CITY	
	Area (Sq. Mi.)	Population (1000s)	Area (Sq. Mi.)	Population (1000s)
Chicago	3,720	6,979	222.6	3,367
Philadelphia	3,553	4,818	128.5	1,949
Tulsa	3,781	477	171.9	332

Population (1000s)

	Year		
	1980	1990	2000
High Est.	556	648	750
Low Est.	528	577	620

These estimates are based on projecting the 1970 Tulsa population (477,000) at the same growth rate as the U.S. as a whole. From 1960-1970 the population of Tulsa increased at about the same rate as the U.S. population even though the growth rate in Oklahoma was slightly less. The U.S. population growth was based on the Series B (high estimate) and series E (low estimate) projections in the 1971 Statistical Abstract.

3.1 AT&T Estimates

AT&T market estimates were based on an analysis of 27 major areas with a population of 71 million persons. By the year 2,000 they project a combined market of between 2.5 million and 7 million for these 27 major areas. The Philadelphia SMSA represented about 6.5% of the population of these 27 major areas in 1970. This projects to a total market of between about 162 thousand and 455 thousand. AT&T actually presents their projections for Philadelphia and they range from about 130 thousand to 410 thousand. (These projections are reproduced in Figure 1.) The difference can be accounted for by the more elaborate techniques they used or, perhaps, simply by the fact that Philadelphia may not grow as fast as some of the other major areas. The projected population growth for Philadelphia SMSA is as follows:

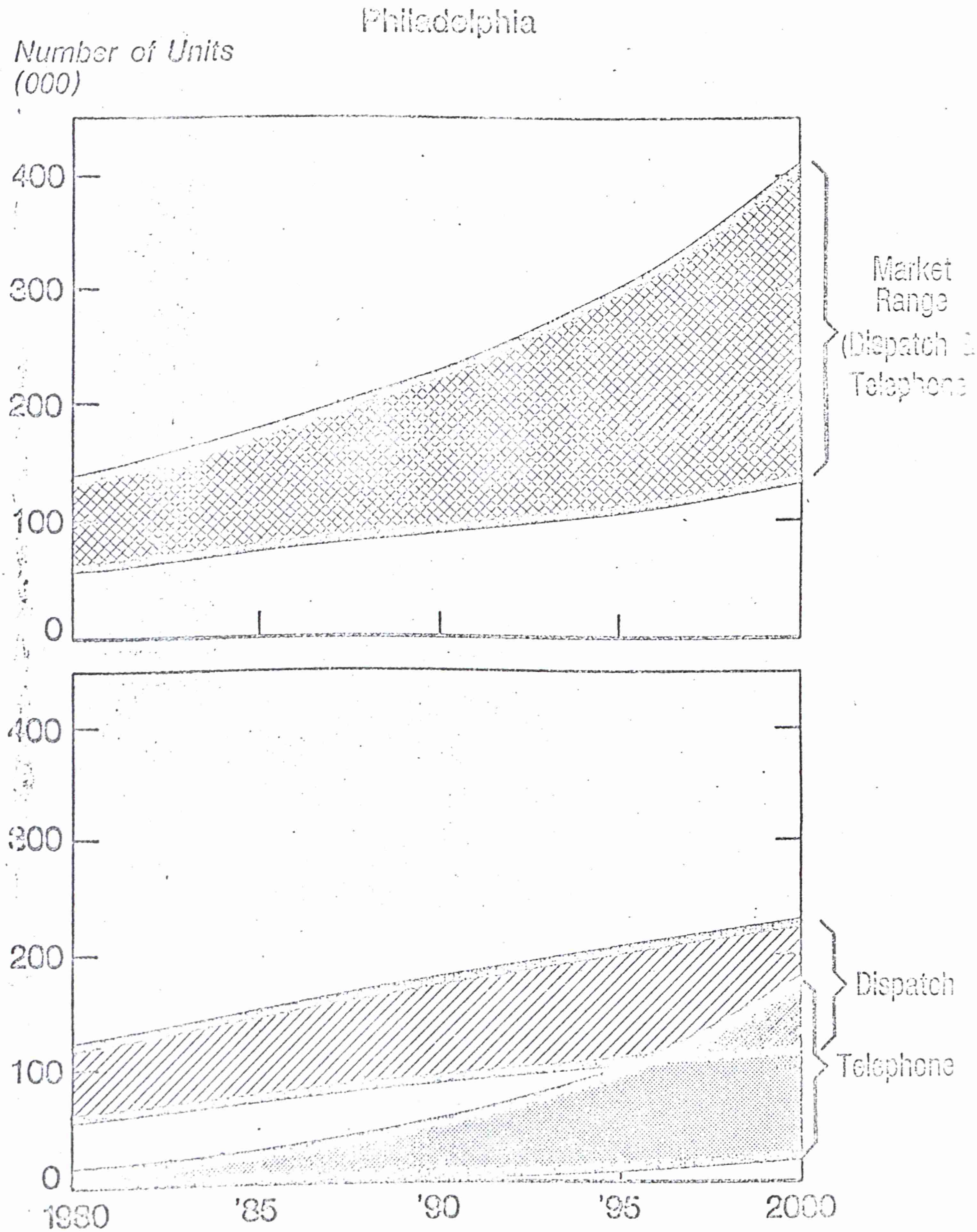
Population (1000s)

	1980	1990	2000
High Est.	5,600	6,770	7,580
Low Est.	5,330	5,840	6,280

Fig 1. (From the December 20, 71 filing of AT&T under FCC Docket 18262

Figure 1

Mobile Communications Estimated Market Range



Using the low and high population estimates with AT&T's low and high market estimates from Figure 1, respectively, gives estimates of the number of people per mobile as follows:

	Number per Mobile		
	1980	1990	2000
High Pop. & High Mkt. Est.	40	29	19
Low Pop. & Low Mkt. Est	89	65	48

Using these same ratios with the projected Tulsa SMSA population produces the following estimates of demand:

	Mobile Users (Tulsa) (1000s)		
	1980	1990	2000
High Est.	14	22	40
Low Est.	6	9	13

3.2 Motorola Estimates

Motorola provides very detailed market estimates for the Chicago SMSA through 1980. For private LMR services they estimate a total of 233,000 transmitters by 1980 but 42,000 of these are for Public Safety services. Excluding these and using their estimate of a 1980 Chicago population of 7,950 thousand gives a ratio of one mobile per 42 people (1:42). This estimate is for private systems.

In their analysis, AT&T does not indicate what percentage of the total private, dispatch type business they hope to capture. In 1980 the optimistic ratio derived in the previous section is 1:40. Since the amount of MTS service is almost negligible it would appear that the two projections are roughly the same. This could occur in two ways. AT&T anticipates getting nearly all of the dispatch type business (excluding Public Safety) or that AT&T projections are more optimistic such that they count on getting amount of new business not included in the Motorola projections. If the former is the case, it would allow other uses to be made of part of the 40 MHz allocated for private systems (e.g., it could be used by RCCs).

Returning to the question of demand in Tulsa, it would appear that the projections made in the previous section are not inconsistent with the projections inferred from the Motorola estimates for dispatch service.

Motorola also makes projections of demand for mobile telephone service in Chicago. They estimate 25,000 subscribers by 1980 and 43,000 by 1990. These produce ratios of 320:1 and 220:1, respectively. The corresponding ratios for AT&T in MTS are 280:1 and 125:1. These latter figures were obtained by noting that MTS represented 14% and 24% of the totals in 1980 and 1990 for the "optimistic" projections (Figure 1). These percentages were then applied to the results in the previous section. It is difficult to get the corresponding percentages for the "pessimistic" projections because of poor resolution on the graph. However, the MTS percentage is even lower for the pessimistic case. This would tend to narrow the difference. Because Motorola assumes a saturation effect beyond about 1988, the difference will be greater by the year 2000.

Again it would appear that the Motorola near-term projections are not inconsistent with the estimates made for Tulsa in the previous section.

4. Mobile Radio Supply

There are two aspects of LMR supply to be considered. One is the different system configurations and the second is the institutional arrangements. These will be considered in sections 4.1 and 4.2, respectively.

4.1 System Configurations

In this section, spectrum requirements for alternative system configurations for both dispatch and telephone type service will be considered first. Then combined systems for the two will be evaluated. Distinguishing between dispatch and telephone service requires separate demand schedules for each. These were obtained by applying the ratios of telephone users to dispatch users in Figure 1 from the AT&T filing to the forecasts of mobile users for Tulsa in section 3.1. The results are as follows:

Mobile Users - Tulsa SMSA (1000s)

		1980	1990	2000
High Est.	Telephone	2	5	18
	Dispatch	12	17	22
Low Est.	Telephone	0	.5	2
	Dispatch	6	8.5	11

4.1.1 Dispatch Services

Three system configurations for dispatch service will be considered: (1) conventional private systems sharing individual channels, (2) a common user system with a central base station and pooled channels, and (3) a dispersed array or cellular system. For this analysis it will be assumed that the offered busy hour traffic per mobile is .004 Erlangs (.576 calls per hour - CPH - and an average duration of 25 seconds) in accordance with the AT&T assumption. The corresponding busy hour traffic for the projected number of mobiles using dispatch service is as follows:

Tulsa SMSA

Busy Hour Dispatch Traffic (Erlangs)

	1980	1990	2000
High Est,	48	68	88
Low Est.	24	34	44

4.1.1.1 Conventional Private Systems

In conventional private systems each user shares a channel with other users if he has only a few mobiles or, if he has a large fleet, he may have exclusive use of one or more channels. For single channel systems the blocking probability (P_b) is approximately equal to the traffic carried in Erlangs. For a 5% blocking probability the average waiting time to get onto the channel is negligible and at 50% it is one message duration or 25 seconds in this case. The number of channels required to handle the busy hour traffic estimated in 4.1.1 is:

Tulsa SMSA

Busy Hour Channel Requirements

		1980	1990	2000
High Est.	$P_b = .05$	960	1360	1760
	$P_b = .50$	96	136	176
Low Est.	$P_b = .05$	480	680	880
	$P_b = .50$	48	68	88

For two frequency simplex operation, each with a 40 kHz bandwidth, the bandwidth required per channel is 80 kHz. Converting the above table to bandwidth required gives:

Tulsa SMSA

Busy Hour Bandwidth Requirements (MHz)

		1980	1990	2000
High Est.	$P_b = .05$	76.8	108.8	140.8
	$P_b = .50$	7.68	10.88	14.08
Low Est.	$P_b = .05$	38.4	54.4	70.4
	$P_b = .50$	3.84	5.44	7.04

Note that all of projected busy hour, dispatch traffic in the year 2000 could be handled with just 14.1 MHz of bandwidth and a blocking probability of 50%. This same traffic could be handled in the allocated 40 MHz with a blocking probability of less than 20%.

Because of the characteristics of signal propagation at 900 MHz, it is not always practical to cover large areas with single base stations. This does not appear to be the case in Tulsa, however. In figure 4-2 of their Technical Report, AT&T indicates that they will provide coverage of about 500 square miles (mi^2) in Tulsa. This is considerably less than the area in the SMSA (3,781 mi^2) but about three times the area of the city itself (172 mi^2). Private system coverage for a 500 mi^2 area would require a coverage radius of about 13 miles. Using figure 2.2 of the Motorola report, this could be accomplished with a base station antenna height of about 300 ft and a transmitter power of 50 W. (This also assumes a mobile antenna gain of 3 dB, a base station antenna gain of 9 dB, a receiver sensitivity of .5µV and 90% coverage). The required mobile transmitter power could be reduced by a higher base station antenna or through the use of remote receivers. A map of the Tulsa area with 13 mile and 20 mile coverage radii are shown in Figure 2.

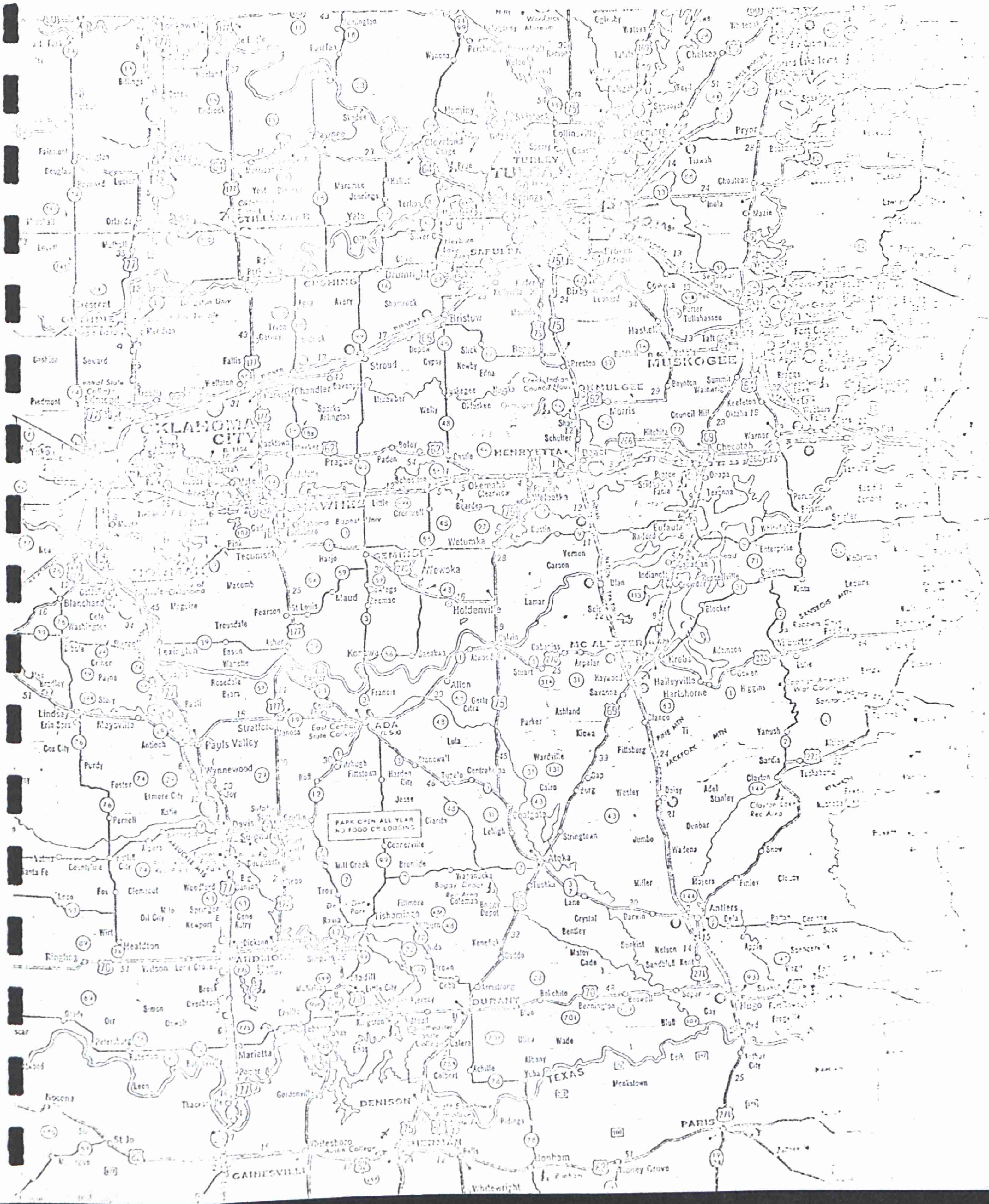
4.1.1.2 Common User System with Central Base Station and Pooled Channels

In this system, each mobile is equipped to operate on 2 or more shared channels so that he has to wait only if all channels are busy. This is similar to the current AT&T IMTS system. Access to a number of channels (trunking) permits a dramatic increase in traffic carried for the same level of service. At the 5% blocking level, 16 independent channels would have a capacity of .08 Erlangs but with trunking the capacity would be approximately 10 Erlangs. Thus if mobiles and base stations were equipped with a 16 channel capability and users were consolidated such that each group would offer about 10 Erlangs of busy hour traffic then the 88 Erlangs of busy hour traffic (5% blocking probability) projected as the high estimate for the Tulsa area in 2000 could be handled with 9 such groups or only 144 channels. Again allowing 80 kHz per channel, this would translate into a requirement for 11.52 MHz of spectrum.

4.1.1.3 Cellular System

Since the amount of dispatch traffic for the year 2000 can easily be handled with the available frequency allocation, the spectrum constraint is not binding and there is no need to go to a cellular system to get spectrum efficiency. However a modified cellular system may be required to extend coverage to the entire SMSA.

Figure 2. Map showing coverage of Tulsa with radii of 13 and 20 miles.



The largest hexagonal cell proposed by AT&T has a radius (r) of 4.2 miles and the corresponding coverage area (A) is computed as follows:

$$A = \frac{3}{2} r^2 \sqrt{3} \approx 45.8 \text{ mi}^2$$

The 500 mi^2 area could be covered with 11 cells. Four of these could reuse channels in other cells since the basic pattern proposed by AT&T uses seven channel sets. Without details on vehicle density in Tulsa, it is not possible to lay out the cells. With an average of over 100 channels per cell and with mobiles having an 800 channel capability, each cell would be capable of handling an average of over 84 Erlangs of traffic (5% blocking probability) which is approximately the total amount of traffic under the high estimate for the year 2000.

4.1.2 Mobile Telephone Service (MTS)

Two system configurations for telephone service will be considered: (a) a system with a central base station and pooled (trunked) channels which is comparable to the current IMTS system and (b) a cellular system. Again the AT&T assumption of offered busy hour traffic will be used. For MTS this is .03 Erlangs per mobile. Using the projections of the number of mobile telephone users from section 4.1 and this figure of .03 Erlangs per mobile gives the following estimates:

Tulsa SMSA

Busy Hour Telephone Traffic (Erlangs)

	1980	1990	2000
High Est.	60	150	540
Low Est.	0	15	60

4.1.2.1 Pooled Channel System

This system would operate in the same fashion as that described in section 4.1.1.2. The increased spectral efficiency is obtained through the higher utilization possible with pooled channels and multi-frequency mobile transceivers. At a 2% blocking probability (the AT&T design goal), less than 80 channels (or 6.4 MHz) would be required to provide for the 60 Erlang low estimate for the year 2000. The high estimate of 540 Erlangs for the same year would require on the order of 600 channels or 48 MHz.

4.1.2.2 Cellular System

Using the same approach as in section 4.1.1.3, each of the 11 cells could carry an average of over 80 Erlangs of traffic at a blocking probability of 5%. This indicates more than adequate capacity for the 540 Erlang maximum estimate.

4.1.3 Combined Spectrum Requirements

Since private systems are not applicable to MTS service and since the cellular system capacity so far exceeds the demand, only the combined spectrum requirements for a pooled channel system will be considered in this section. Separately the systems would require the following amounts of spectrum:

		Estimated Spectrum Requirements (MHz)		
		1980	1990	2000
High Est.	Telephone (P_b = 2%)	6	15	48
	Dispatch* (P_b = 5%)	6	9	12
	Total	12	24	60
Low Est.	Telephone (P_b = 2%)	0	2	6
	Dispatch* (P_b = 5%)	4	5	6
	Total	4	7	12

*Based on 16 channel trunking.

It is clear that there is adequate spectrum available in Tulsa through the year 2000 without going to the complexity of a full cellular system. This is still true when a generous allowance is made for channels which cannot be assigned due to their use in the surrounding area.

4.2 Industry Structure Implications

Even though the analysis in section 4.1 is not complete, certain preliminary observations can be made regarding the implications for industry structure:

- There is adequate spectrum available to permit competition.
- The fixed (shared) costs of an automated, trunked system should be significantly less than for a full cellular system and hence fewer subscribers will be required to get the full benefits of economies of scale.
- The foregoing would imply that several competitors could exist without total costs significantly exceeding the costs of a single monopolist or exceeding the available spectrum.

5. Future Work

The analysis discussed in this paper will be refined and extended in the following ways:

1. The demand estimates of section 3 will be revised based on discussions with SAI.
2. The spectrum requirements of section 4 will be confirmed using the computer simulation model.
3. The costs of the automated, trunked system will be analyzed so that the cost-supply curve can be compared with those of the cellular system.

4. Using some simplified rules of thumb for demand (i.e., the number of telephone and dispatch users per 1,000 of population) the spectrum requirements for each city in the U.S. will be estimated and the cities requiring a cellular system because of the spectrum constraint will be identified. This will be done for both "optimistic" and "pessimistic" demand growth.

```
"CCC" GRID SIMULATION  DYNAMIC MODEL
XDS 940 VERSION MARCH 1, 1972
     3-24-72  8:3

++GRID DIMENSIONS
   NX = 1
   NY = 1
   DS = 1

++SPACE DIVERSITY FACTOR
   RHO = 10000.

++NO. OF CHANNELS PER STATION
   NC = 1

++NO. OF RECEIVERS PER STATION
   NRS = 1

++NO. OF CHANNELS FOR SYSTEM
   MAXCH = 100

++AVG. CALL LENGTH (SEC)
   HOLD = 19

++CALLS PER HOUR
   CPH = 20

++QUANTIZING FACTOR
   KOF = 20

++READOUT TIME (MIN)
   ROT = 30

++RANDOM SEED
   IK =474926

QUEUE OPERATION? YES
GAUSSIAN DIST.?  NO
BLOCK AREA CRITERA? NO

NO SORT MODE.

TIME =   59.98 MIN.      KTIC =       3788
CALLS PER HOUR:        17.01
AV. TIME ON SYS.:      20.45  SEC.
COMPLETED CALLS:          17
TRANS. ON SYS.:            0
TRANS. IN QUEUE:           0
CALLS DIR.PLA.:           83
CALLS REQ.Q WAIT:         13
AVG.TRN. ON SYS.:        .11
CALLS GOING TO Q:      13.27  %
CALLS TO Q/REC LI:       .00  %
AV.TRN. IN Q:            .01
AV. TIME IN QUEUE:     18.42  SEC
Q HIST.:        5      1      2      1      2      2

SINCE LAST REPORT:         1
MAX. TRAN. ON SYS:         1
MAX. TRAN. IN Q:        4.75  SEC.
MAX TIME IN Q:           .00
AV. TIME IN QUEUE:      4.75  SEC.
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ATTACHMENT 5

DRAFT

TECHNOLOGICAL ALTERNATIVES
AND IMPLICATIONS

Gene G. Ax

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Boulder, Colorado 80302
March 22, 1972

TABLE OF CONTENTS

TECHNOLOGICAL ALTERNATIVES
AND IMPLICATIONS

Gene G. Ax

1. INTRODUCTION

This short paper will summarize some of the major technological alternatives and implications considered by the primary companies and associations that submitted proposals and/or filings to the FCC in conjunction with Docket 18262 concerning land mobile radio communications in the 900 MHz portion of the spectrum. In this interim paper, an attempt will be made to summarize why the various technological alternatives, as expressed by the indicated companies and organizations, are or are not being considered further. In the final report, I hope to offer some of my own thoughts on these and other technological alternatives which have not been specifically addressed. For example, multiple-access techniques, such as RADA and MADA, will be considered along with others that may be discovered in the technical literature and from discussions with government and industry personnel. If it appears desirable, and can be accomplished rather easily, limited measurements may be made. For example, it may be possible to assess the effect of flat fading on single sideband amplitude modulation systems in the 900 MHz mobile environment by sending a voice message through the channel simulator that ITS has.

2. AT&T

Technological alternative system ideas by this company are taken from Appendix B entitled "Alternative System Concepts" from their technical report [1].

2.1 Time-Division Multiplex (With PAM)

Pulse amplitude modulation (PAM) is considered to, perhaps, be competitive with the FM system being proposed and they plan, as resources permit, to study it further for the following reasons:

1. Broadband pulses that can be resolved between multipath components offer the possibility of inherent time diversity to minimize the frequency-selective fading of the mobile environment.

2. Pulse transmission techniques would add a degree of privacy because it would be hard to synchronize to a particular channel.

3. Hardware complexities of frequency-division multiplexed systems with closely spaced channels could be avoided by multiplexing in the time domain (as would be necessary with PAM).

4. System-operating algorithms and channel arrangements could, through software changes, adapt the timing of the system to better match particular propagation conditions.

2.2 Deterministic Coverage Plan

This plan represents a refinement of their regular contiguous hexagonal cellular system that is based on a statistical description of the radio propagation effects. The cell structure could be based on deterministic measurements of radio propagation conditions in each area with some channel reuse distances being less than those given by the statistical models and others being greater. With this plan it should be possible to lessen the average radio-channel-reuse distance with a resultant greater value for mobiles/MHz/Unit area. Multiple directive antennas at each base station could play a part in tailoring the cell structure to each particular area.

In a deterministic coverage plan one could make use of the known distribution of average signal strengths throughout the cells by comparison with the average signal strengths received from a vehicle at the base station(s) to assign channels in a relatively interference free fashion without the need for special vehicle-locating hardware. This procedure, however, requires a special channel set for call attempts with a much larger reuse interval (distance).

It is claimed that several topics need further study on this base station assignment approach before the procedures can be outlined in detail. These include base station layout procedures; extent and detail of measured field strength required; accuracy and performance of the base station assignment algorithms; size, speed, and complexity of the system controlling computer; the landline interface; and the economics of implementation.

2.3 Frequency-Division Multiplex

A comparison of required transmitter powers and spectrums for FM/FM, FM/SSB, SSB/SSB, and SSB/FM multiplex signals is made with regard to average signal level, flat and frequency-selective fading, and co-channel interference. Their study maintains that conventional FM channels (SSB/FM) require less transmitter power than any of the other three and much less spectrum than for FM/FM and FM/SSB for the UHF mobile telephone application. Flat and frequency-selective fading affects SSB/FM less seriously than it does the others. Flat fading seriously affects SSB/SSB and frequency-selective fading rules out FM/FM and FM/SSB for the high capacity mobile telephone system. Intermodulation can be a more serious problem with SSB/SSB, FM/FM, and FM/SSB since higher peak transmitter powers are required. It is emphasized that these techniques are analyzed in the absence of diversity reception techniques.

It is claimed that the four types of systems considered here are the common types that would normally be considered for mobile radio applications.

2.3.1 Spectrum and Power Requirements

They point out that if one used FM/FM, FM/SSB, or SSB/SSB instead of conventional SSB/FM from base to mobile that the two-way bandwidth required could be reduced between 25 and 50 percent. FM/FM or FM/SSB are not feasbile for mobile to base transmissions and SSB/SSB suffers severely from flat fading. The 25 to 50 percent bandwidth reduction, however, comes at the expense of a peak transmitter power requirement that is from 15 to 20 dB greater than that required for the SSB/FM choice being considered.

The peak power advantage of SSB/FM over SSB/SSB primarily results from the signal-to-noise ratio improvement one obtains with FM over AM for the large modulation index (≈ 4) planned for the SSB/FM technique in their high-capacity mobile radio system. Its advantage over FM/FM and FM/SSB is because of the small modulation index (≈ 0.06) for the subchannels. FM/FM and FM/SSB would have to occupy approximately twice as much bandwidth as SSB/FM in order that the same peak powers would be required. This gain obtained by the increased bandwidth would be accompanied by far higher FM thresholds than for SSB/FM channels.

2.3.2 The Effect of Flat Fading

The effect of flat fading on SSB/SSB is such that it renders it unusable for mobile radio at UHF and higher frequencies. The fading signal has the effect of mixing the time variable transmission coefficient of the medium with the desired modulation. At these frequencies Doppler frequencies (and their harmonics) are on the order of audio frequencies. Thus, the distortion due to fading is not easily removed by AGC techniques. It is claimed that even several branches of diversity reception does not make SSB/SSB usable for telephone quality communication.

The effect of flat fading on FM/FM, FM/SSB, and SSB/FM is approximately the same since their FM thresholds are about the same.

2.3.3 Frequency-Selective Fading

For appropriate modulation design parameters for a high-capacity mobile radio system and for a time delay spread of 4 microseconds FM/SSB and FM/FM multiplex systems would be wide enough in bandwidth such that the intersubchannel interference would render them unsatisfactory for UHF mobile telephony.

2.3.4 Co-channel Interference

For efficient utilization of the spectrum each channel should be reused as often as possible geographically. This is limited, of course, by acceptable co-channel interference. The important point here is to note that SSB/SSB has been ruled out because of its poor performance under the flat Rayleigh fading nature of the UHF mobile radio channel. Under this assumption and the assumption of path loss being proportional to the fourth power of distance the FM/FM and FM/SSB systems require, for the same output signal-to-interference ratios, a total spectrum space several times that required for the SSB/FM system being proposed. If, indeed, SSB/SSB was usable in this flat Rayleigh fading environment, its required total spectrum would only be about one half that needed for the proposed SSB/FM system.

2.3.5 Receiver Intermodulation

It is claimed that SSB/SSB has an intermodulation interference that is from 45 to 60 dB higher before demodulation than for SSB/FM and that the capture effect of SSB/FM gives it an even greater advantage. Likewise, FM/FM and FM/SSB should be unaffected by intermodulation interference unless other multiplex transmissions of approximately equal strength originate from the same base station where the intermodulation interference could again be 45 to 60 dB higher than for SSB/FM.

2.4 Comments

A disconcerting aspect of the whole appendix on "alternative system concepts" is that only one direct reference is given. In fact, outside of the above reference, I don't believe that the whole technical report makes reference to work done outside the Bell System.

3. MOTOROLA, INC.

Alternative system concepts by this company are taken from Appendix 3 of their submission to the FCC on December 20, 1971 [2].

3.1 Techniques Applicable to Multi-channel Systems

They feel that the costly power trade offs at 900 MHz will necessitate high transmitter sites with a consequent premium on available space such that the luxury of one antenna per transmitter cannot be afforded. Thus, they maintain that any multi-channel system must use a minimum number of antennas per system. The following candidate systems are considered:

3.1.1 Combining on Single Antenna
3.1.2 Common Power Amplifier
3.1.3 FDM/FM Multiplex
3.1.4 Single Sideband/Master Carrier System
3.1.5 Time Division Multiplex

3.1.1 Combining on Single Antenna

A common technique for combining multiple transmitters on a single antenna is that used by the Bell System with their IMTS mobile telephone system. This consists of several levels of approximately 3 dB isolation pads; the number of pads halving at each stage from the transmitters to the antenna. For possible systems at 900 MHz the transmitters were limited to four 500 watt units on a single antenna giving 100 watts of power from each transmitter into the common antenna.

3.1.2 Common Power Amplifier

A twenty-channel system is analyzed here to show that the peaking phenomena of common power amplifiers along with reasonable intermodulation specifications for these amplifiers requires amplifiers rated at unreasonably high powers in order to maintain acceptable adjacent channel interference levels. This is true, according to the analysis, even when a guard band as wide as the occupied spectrum is used between the groups of channels. They maintain that there is little practical hope for a common amplifier approach.

3.1.3 FDM/FM Multiplex

This technique of combining several SSB channels together to FM modulate a single carrier solves the common antenna problem very nicely; however, it is not considered to be a good candidate for the mobile telephone environment for the following reasons:

1. Frequency-selective fading produces occasional severe distortion in the higher subchannels regardless of transmitter power (this is characteristic of multiplicative channel distortions).

2. Danger of interference to channels in other blocks if the deviations are not properly controlled.

3. Poor signal-to-noise ratios in the higher subchannels.

3.1.3.1 Field Tests

A field test comparing a 20 channel FDM/FM system with a composite modulation index of 0.35 with a conventional single channel narrowband FM (5 KHz deviation) system was made. Receiver noise figures were the same for both systems. These field tests substantiated numbers 1 and 3 of the reasons given above for the FDM/FM system not being a good candidate system.

3.1.4 Single Sideband/Master Carrier System

In the interest of possible spectrum economy and erasure of the common antenna problem an SSB multiplex system with a master reference carrier was considered. This system was considered to not be usable for the following reasons:

1. Flutter interference due to fading.
2. Poor signal-to-noise ratio performance.

3.1.4.1 Field Tests

Listening tests comparing this multiplex system to the reference narrow-band FM system were made and found to be disappointing. The tests substantiated items 1 and 2 above. The master carrier AGC system tends to reduce the effects of flutter fading on the lower subchannels but only up to about 20 KHz. In any case, the noise rise in the fades was considered to be very objectionable. Because of the poor performance, work was discontinued on this system.

3.1.5 Time-Division Multiplex

Time-division multiplexing (TDM) voice channels utilizing either digital or analog samples was considered. However, digital modulation with TDM requires much greater bandwidth than analog systems for good quality speech transmission. At least 50 kHz of bandwidth per voice channel is required for any reasonable quality. For a well-behaved channel analog samples of voice signals would require much less bandwidth than for digital voice. However, when one matches this modulation to the 900 MHz mobile environment and practical filters considerable bandwidth must be utilized in order to reduce cross-talk to acceptable levels.

Motorola indicates that, even though the multiplexing techniques previously mentioned above do not have merit, they have been investigating a new multiplex technique that may be promising for the 900 MHz mobile environment. No indication of what this technique may be is given. However, they indicate that this technique is under investigation and is being field tested. When the tests are complete it will be reported on.

4.1 EIA

This section will summarize appropriate points of the submission to the FCC [3] concerning Docket 18262 by the Land Mobile Communications Section of the Industrial Electronics Division of the Electronic Industries Association (EIA).

4.1 Frequency Modulation

They concluded that frequency modulation provides the optimum spectrum utilization in the land mobile service.

4.2 Multiplexing

Multiplexing and other forms of modulation have been considered as a means of improving spectrum utilization. The Section concludes that although other forms of modulation can theoretically increase the number of channels in a given segment of spectrum, FM provides for optimum spectrum utilization when sharing in time, frequency, and geographically. In other words, it should maximize mobiles/MHz/Unit Area, a true measure of optimum spectrum usage.

4.3 SSB at UHF

Their conclusion is that SSB, whether single channel or multiplex, would give unacceptable performance for the Land Mobile Radio Services. Two prime reasons for this are given. First is the required frequency stability of 1.5 parts in 10^8. This, although achievable, would be expensive. The second reason is more compelling (cannot be eliminated by sophisticated designs). This has to do with the flutter fading of the signal. For example, this fading rate is given to be 172 Hz for a vehicle traveling at 60 mph. This fading rate and its first few harmonics will be detected and will fall into the audio band. At these high flutter rates AGC techniques cannot work without causing severe speech envelope distortion.

1. Bell Laboratories (1971), "High-Capacity Mobile Telephone System Technical Report," December.

2. Motorola, Inc. (1971), "Technical and Marketing Data on System Design and User Needs at 900 MHz," Docket 18262, December [illegible].

3. Electronic Industries Association (1969), "Comments of the Land Mobile Communications Section of the Industrial Electronics Division of the Electronic Industries Association." Submitted to the FCC Concerning Docket 18262, February 3.

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