report

COLLINS

Iowa Police Radio System Propagation Study

Collins Radio Company

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This final report embodies the results of a propagation study conducted by Collins Radio Company of the Iowa Police Radio System (IPRS). The study was a 3-month program initiated by Planning Research Corporation under subcontract W-9011.

The study objective was to analyze the present IPRS, develop near-term improvement recommendations, and finally develop a cost-effective long-term communication plan responsive to future requirements and the TRACIS message environment.

This document presents the results of the analysis and the detailed communications plan; volume II provides the reference data base and analysis details. The analysis considered propagation factors and operational requirements, message traffic loading, costs, equipment capabilities, and future expansion. The study applied these factors in the analysis of the three frequency bands available for Police Radio Services to enable a selection of an optimum communication plan.

1.1 SYSTEM ALTERNATIVES

The results of the analysis of this propagation study produced three alternatives, each offering responsive degrees of performance for the improvement of the Iowa Police Radio System (IPRS). The three alternatives are as follows:

1.1.1 Low-Band (VHF) Upgrade

This alternative requires the moderate reconfiguration and minor extension of the present system facilities. The operation of the system remains in the currently used frequency band and requires the lowest total cost for implementation. While this alternative is viable for the improved servicing of current day voice requirements, it lacks flexibility of channelization to accommodate the voice and/or data traffic densities projected for the near-term future TRACIS environment.

1.1.2 High-Band (VHF) Conversion

This alternative takes maximum advantage of the reconfigured and extended configuration of the low-band upgrade alternative described above. In addition a moderate extension is required. In comparison to the other alternatives, this one is intermediate in cost. It will provide viable and responsive services for the peak level traffic densities expected in the near-term TRACIS environment. However, this alternative, while more flexible than the low-band upgrade, does also have channelization limits. Should additional services, not now identified as firm planning requirements, such as 2-way (full-duplex) voice links, paging, emergency highway radio call boxes, special surveillance links, etc, be required, then this alternative would also lack the flexibility of adequate channelization to accommodate those services.

1.1.3 UHF Conversion

This alternative requires a significantly extended system configuration to provide fully responsive services not only for the near-term TRACIS environment, but potential beyond that as well. Adequate flexibility of channelization for future service requirements is an intrinsic capability of this alternative. The alternative, however, is the most costly of the three put forth.

After careful appraisal of each alternative's estimated system costs and performances in response to projected user requirements, a final recommendation for the high-band (vhf) system was made. It is firmly believed that this system option will be the most cost-effective solution for meeting the near and midterm user requirements in the fully operational TRACIS environment. The high-band implementation will be phased with a limited low-band upgrade. A further recommendation is made to the Iowa Director of Communications to periodically reexamine the state requirements for new and extended services that may require and justify implementation of a uhf system after the economic life of the high-band vhf system has been reached. This report therefore constitutes a first step in that review of uhf viability.

1.2 SYSTEM COSTS

Detailed cost estimates were prepared on each of the three system alternatives that emerged from the analysis effort. Table 1-1 displays the summary costs of each system alternative by cost components. Shown in table 1-1 are the costs associated with base, repeater, and control site construction and radio frequency (rf) equipment; each is further delineated into major cost elements as shown. The detailed cost breakouts are presented later in this report. Note that the mobile equipment constitutes 45 to 75 percent of the total system costs, and hence is a major factor as well as constraint in approaching a choice of implementation for the recommended system.

1.3 IMPLEMENTATION AND FINANCIAL PLAN

In order to properly introduce the new high-band vhf system into the existing IPRS environment several overall guidelines must be observed as follows:

a. Implementation must be orderly, nonimpactive on current operations and improving overall operations with each step.
b. Operational status must be achieved at or near the time when the full services of the new system are needed.
c. Financial support for accomplishing all implementation steps must be both tolerable and justifiable.

The specific approach to implementing the conversion to the recommended high-band (vhf) system and the financial support necessary for each step are displayed in table 1-2. The overall approach blends together some of the low-band (vhf) upgrade with the ultimate and total conversion of the upgrade system to high-band (vhf). Table 1-2 displays five major implementation steps and their associated financial requirements broken down by cost components monies as anticipated from state revenue and federal grant sources. In addition table 1-2 displays for each implementation step the fiscal year commitment for state and federal monies. As shown in table 1-2, the first two steps in implementation include an upgrade of the current low-band IPR system. The purpose for this is as follows:

a. The reconfiguration and extension of the current system is fundamental to implementing the high-band system. All fixed facilities resulting from these steps will be needed in the high-band implementation.

Table 1-1. System Alternate Costs.

SYSTEM REQUIREMENTS COST COMPONENTS		SYSTEM ALTERNATIVES		
		A	B	C
		LOW-BAND-VHF ($)	HIGH-BAND-VHF ($)	UHF ($)
Base repeater and control site construction	Site acquisition and preparation	6,600	11,200	37,800
	Building/tower acquisition and erection	199,117	176,850	631,610
	Subtotal	205,717	188,050	669,410
Radio frequency (rf) equipment	Base, repeater, and control site equipment	29,800	438,600	819,720
	Mobile equipment	753,000	757,500	1,200,000
	Subtotal	782,800	1,196,100	2,019,720
Totals		988,517	1,384,150	2,689,130

b. These steps will permit a more orderly transition from low to high band operation.
c. More near-term improvements are realizable since these steps will improve current area coverage service probability and lessen interference in adjacent areas of the IPR system.
d. These steps permit lower level funding requirements in the approaching fiscal year, and gain the time necessary to enter the total funding requirements into future budgeting periods.

The last three steps of the implementation approach the conversion of the low-band system to full operation in high band. Figure 1-1 displays on time scale the state, federal and total funding levels necessary to achieve implementation. Included in figure 1-1 are comparative milestones for the IPRS implementation and the TRACIS implementation. Note that by the time TRACIS achieves full traffic densities, the IPRS is 70 percent converted. Shortly after that time, the IPRS high band achieves 100 percent conversion.

1.4 SUMMARY

In summary we believe the selection of the recommended system will fully meet the near and midterm needs of the IPRS users operating in the TRACIS environment. We further believe that the implementation approach will permit a sound, orderly transition from current low-band to future high-band operation. Finally, we believe the implementation selected is compatible with the expected levels of funding support allocatable to police operations in the State of Iowa.

Table 1-2. Implementation and Financial Plan.

IMPLEMENTATION STEPS	FY	FINANCIAL REQUIREMENTS									
		STATE FUNDS		FEDERAL FUNDS		STATE FUNDS TOTAL	FEDERAL FUND TOTAL	TOTAL STATE AND FEDERAL FUNDS BY FY			
		RF EQUIP (25%)	CONSTRUCT (50%)	RF EQUIP (75%)	CONSTR (50%)			72	73	74	71-74
1. Low-band upgrade of all base and repeater sites except Storm Lake base and associated repeater equipment.	72	5,300	52,175	15,900	52,175	57,475	68,075	125,550	-	-	125,550
2. Low-band upgrade of mobile equipment for 4-frequency operation to minimize interference. Upgrade includes Denison, Belmond, and Cedar Rapids Area and IHP Districts 4, 7, 8, 11.	72	26,250	-	78,750	-	26,250	78,750	105,000	-	-	105,000
3. High-band conversion of Storm Lake base, repeater and control sites, new consoles and patch facilities, plus mobile, in IHP District 5, 6 units.	72	36,150	22,865	108,450	22,865	59,015	131,315	190,330	-	-	190,330
4. High-band conversion of Des Moines, Cedar Falls, Maquoketa, and Lewis base, repeater and control sites, new consoles, patch facilities and mobile units in IHP Districts 1,2,3,8,9, 10, 12.	73	145,210	40,840	435,630	40,840	186,050	476,470	-	662,520	-	662,520
5. High-band conversion of Denison, Cedar Rapids, Belmond, and Fairfield base, repeater and control sites, consoles, patch facilities and mobile units in the IHP Districts 4, 7, 8, 11, 13, 14.	74	110,490	54,050	331,470	54,050	164,540	385,520	-	-	550,060	550,060
Totals		323,400	169,930	970,200	169,930	493,330	1,140,130	420,880	662,520	550,060	1,633,460
Summary											
Low-band upgrade		31,550	52,175	94,650	52,175	83,725	146,825	230,550	-	-	230,550
High-band conversion		291,850	117,755	875,550	117,755	409,605	993,305	190,330	662,520	550,060	1,402,910

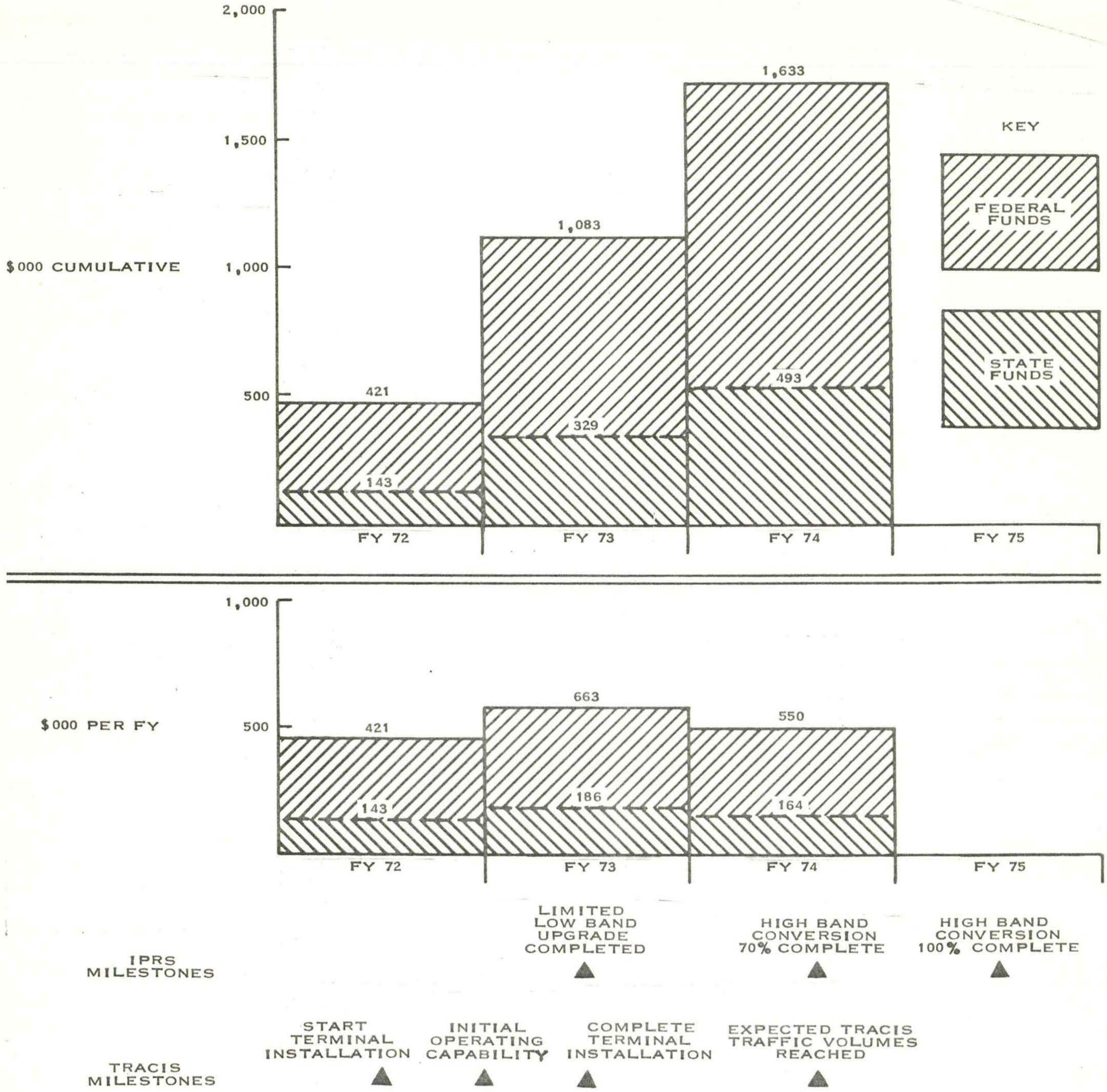

Figure 1-1. IPRS/TRACIS Financial Schedule Milestones.

The Iowa Police Radio (IPR) Service is a statewide network that provides the 2-way radio service for the Iowa Highway Patrol (IHP). The present system operates from 9 base and 12 repeater stations (four 1-way) on a single frequency pair in low band to cover the entire state. This study was authorized when the State was faced with several problems that included the following:

a. An increase in message traffic at the implementation of TRACIS
b. The expense of replacing some very old low-band equipment
c. Known poor coverage in various areas of the state
d. A bothersome interference problem between the several communications regions of the State on the primary communication channel.

Collins Radio Company was asked to perform a propagation study and a system analysis for the purpose of recommending a communications plan for implementing an IPR system responsive not only to present needs but those of the future.

In the following paragraphs the results of the present system analysis are presented. These paragraphs deal with both the propagation and nonpropagation aspects of the present system. The remaining portions of this section briefly describe the application of computer prediction and analysis techniques as applied to communication studies such as the Iowa police radio network.

Computer analysis techniques have made possible a vast change in the ways of performing communications studies and systems analyses. The results obtained from this study were largely made possible through the use of a rapid computational procedure that has capability to consider all the necessary characteristics of the electromagnetic medium, including the terrain between transmitter and receiver, the transmitting and receiving equipment parameters, the external interference, and the statistics of time varying parameters such as noise. The present system analysis is related fundamentally to older methods in terms of transmission loss, signal strength, grade of service, and percent coverage. These are measures of a system performance calculated or measured formerly for a particular transmission path between two locations. While the method used for this study relates to these simplified methods, its capability to account for complex parameters and their statistical variations allows for a higher order of system performance rating to be used. The performance rating used in our analysis is termed service probability.* Service probability is presented as equal value contour lines of 30, 50, 70, and 90 percent levels superimposed on Iowa maps and centered on base stations or repeaters. Service probability is a statistical term that includes the following criteria for the IPR study:

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*Definition of service probability:
Given Rr (gr) = wanted to unwanted signal ratio for a grade of service gr and R (qt) = available wanted to unwanted signal ratio for a fraction of a specified period of time. With Rr (gr) and qt fixed, satisfactory service exists if R (qt) > Rr and service probability is defined as the probability that R (qt) > Rr.

a. The desired signal level at a receiver to provide a sentence intelligibility well over 95 percent at the minimum probable signal level,
b. A noise interference level that is to be expected due to man-made, atmospheric, and galactic noise.
c. A location variability margin due to terrain (highway cuts/fills and crests) where 70 percent of the possible antenna locations are better than that for which the computation is made.
d. A time availability of 95 percent that means the signal level due to time related factors is greater than the value assumed 95 percent of the time.

The predictions of system performance based on the preceding techniques have been verified as part of the study: through the historic record of areas where known poor operation exists, a state survey of actual mobile to repeater/base operations, and a program of field strength measurements that are compared directly with the computer predictions. Results of these predictions and comparisons are shown pictorially and in writing in the various report sections.

The field measurements program that was performed at Ashton, Iowa, provided a sufficient data quantity for making a qualified judgment of the service probability relationship to field strength and communications intelligibility for the base to mobile situation at both low band, high band, and uhf. Plots are included as figures 2-1 through 2-3 showing the contour of operationally observed communication and the predicted service probability. These figures show the operational communications relationship between the service probability derived from computations and from field results. Furthermore, the choice of a 50-percent service probability minimum for system design was verified.

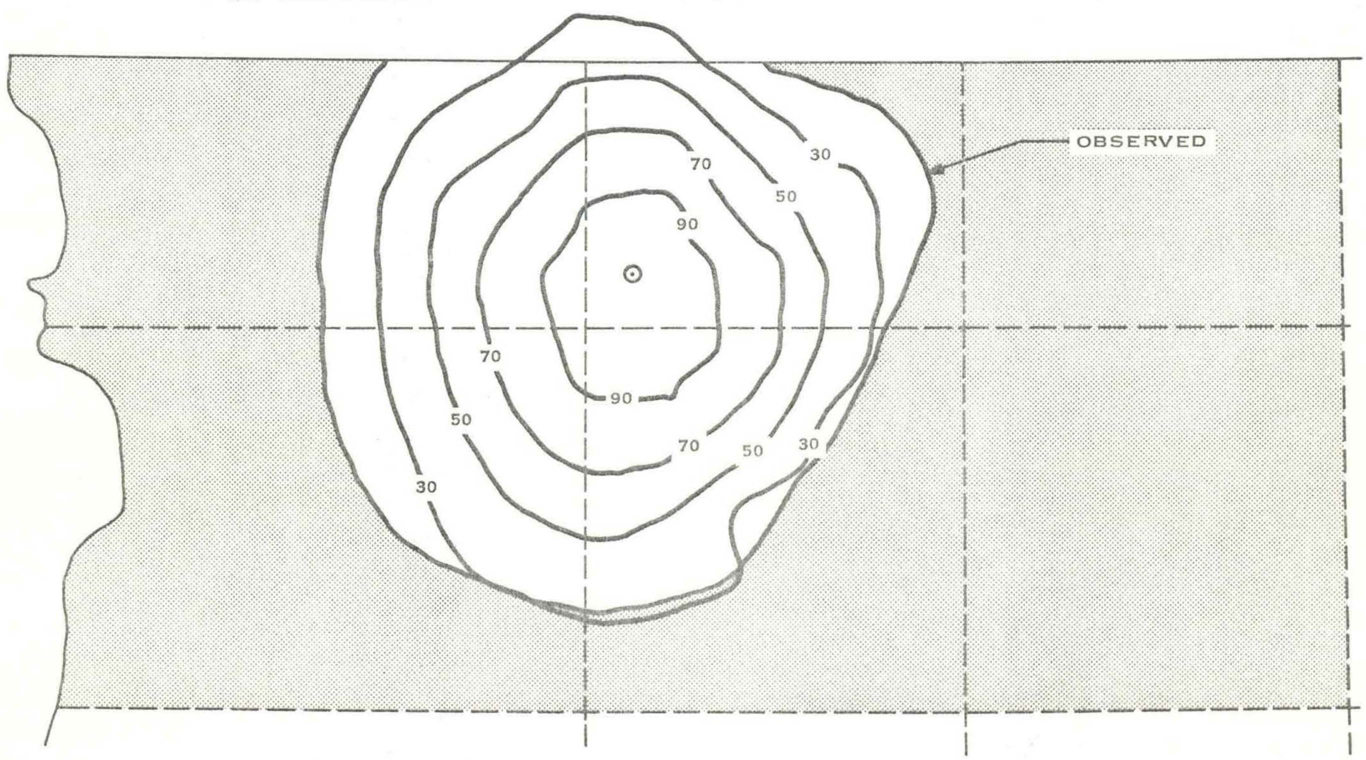

Figure 2-1. Predicted Service Probability Versus Observed Coverage, 42.68 MHz, Base to Mobile at Ashton, Iowa.

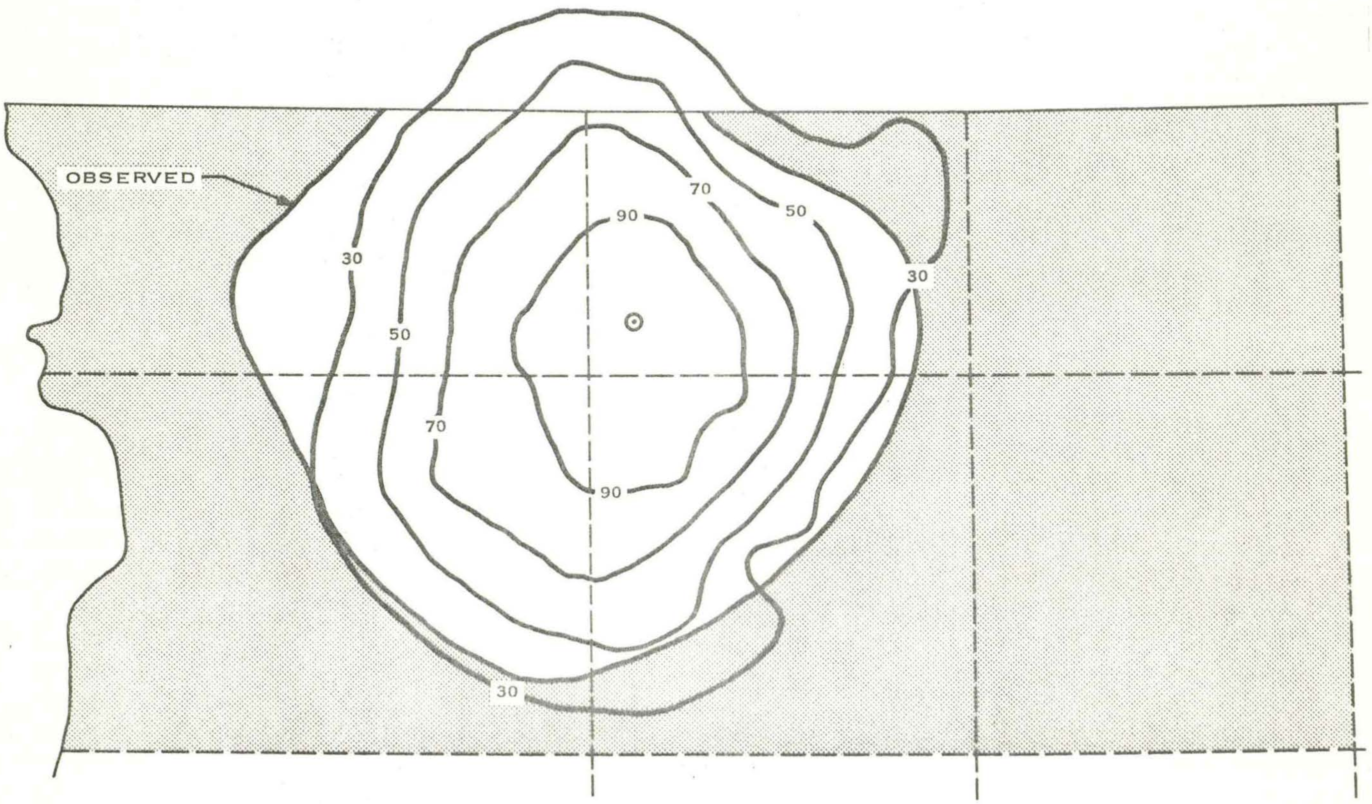

Figure 2-2. Predicted Service Probability Versus Observed Coverage, 155.37 MHz, Base to Mobile at Ashton, Iowa.

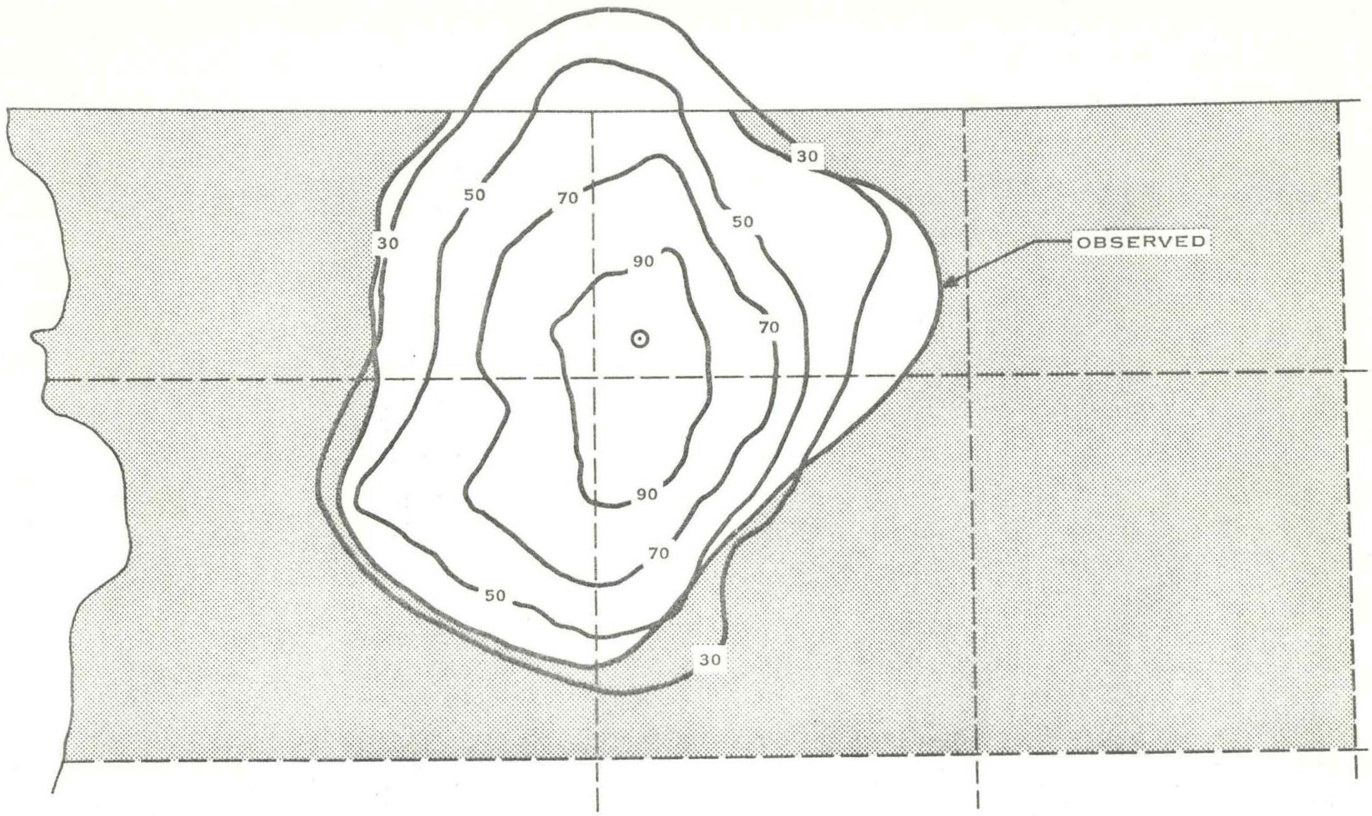

Figure 2-3. Predicted Service Probability Versus Observed Coverage, 461.725 MHz, Base to Mobile at Ashton, Iowa.

2.1 RADIO PROPAGATION FACTORS

The characterization of system performance relating to propagation coverage is one of the more difficult concepts to explain and present. It has been customary in land mobile services to use the term "percent coverage" as an indicator of performance for a given area. However, it is seen that this term is not a statistically well-defined performance index; that is, it gives no indication of the effects of time variations nor is it capable of indicating spatial variations. It may be concluded that what is really needed is the confidence level or expectation that a particular grade of service will be met for a specified fraction of time (time availability) and a specified fraction of locations (location variability).

With these two percentage figures used to compute the confidence level, the service probability is a statistically meaningful performance index and a suitable factor in cost effectiveness optimization processes.

Service probability has as its fundamental basis, an available signal to noise ratio that exceeds a minimum desired signal to noise for a specified grade of service at a distance from a transmitter. This ratio is dependent upon the frequency used, the modulation type, the transmitted bandwidth, the transmission line loss to the antenna, the antenna effective height and gain, the propagation loss, the receive antenna, the receive characteristics, and finally, the required sentence intelligibility. All these parameters are amenable to direct computation for given conditions and known system components.

In analyzing a 2-way land mobile radio system, it is important to include statistical parameters that will account for the terrain over which the mobile units must traverse. The available signal power variations due to path geometry changes are accounted for by the location variability factor, Q_L. The rationale for the selection of location availability Q_L was based on the fact that the mobile unit's location is invariably on a road. Tests have shown that if the reasonable assumption is made that all roads are always better than the worst 30 percent of all locations, the marginal service probability contours (50 percent) fall very nicely on those known to exist. Hence the location availability selected for this study is 0.7, which provides a protection factor for operation from below average terrain.

The choice of a time availability of 95 percent provides a protection factor that assures the assumed signal-to-noise ratio is obtained for 95 percent of the time. It should be noted that time relationships for precipitation static and sporadic E (skip) propagation at 42 MHz are not included in this quantity; however, they are analyzed separately as shown later in this section.

The selection of a median required signal-to-noise ratio is of prime importance in the determination of the performance of any communications system. An articulation index of 0.3 corresponding to about 90 percent sentence intelligibility for a narrow-band FM system and typically requires a 47-dB carrier-to-noise ratio (cnr) in a 1-Hz bandwidth. An articulation index* of 0.6 was chosen for the system proposed corresponding to an intelligibility of greater than 95 percent and a cnr of 50 dB, which is adequately beyond the knee of the FM detector threshold curve and approximately equal to 20 dB of quieting.

2.1.1 Initial Survey

During the first two weeks of the Iowa police radio system study, a state-wide field survey was conducted. Visits were made to the base stations, many repeater sites, and to district offices of the Iowa Highway Patrol. A mobile radio unit, car 910, was made available by the IPR for the survey. The radio in it was calibrated to make measurements of signal levels as the unit moved through the state. Although the data was not a primary source for field measurement data to verify the computer predictions, it provided an excellent correspondence of results between measured and predicted values of field strength. This data is included in volume II.

Interviews with Iowa police radio supervisors provided the location of propagation trouble spots in the state. Figure 2-4 shows a map which was prepared from this survey data.

Contour maps of service probability were developed for the present low-band radio system utilizing the known system values for equipment and terrain listed in volume II. These service probability predictions of the present system performance matched very well the known areas of unreliability.

*The articulation index is a statistically derived value which depends only on the signal and noise spectrum at the typical listener's auditory input. It can be related to phoneme, syllable, word and sentence intelligibility. An articulation index of 0.6 provides typically the following percentages of intelligibility: syllable, 80; phoneme, 92; word, 96; and sentence, 99.

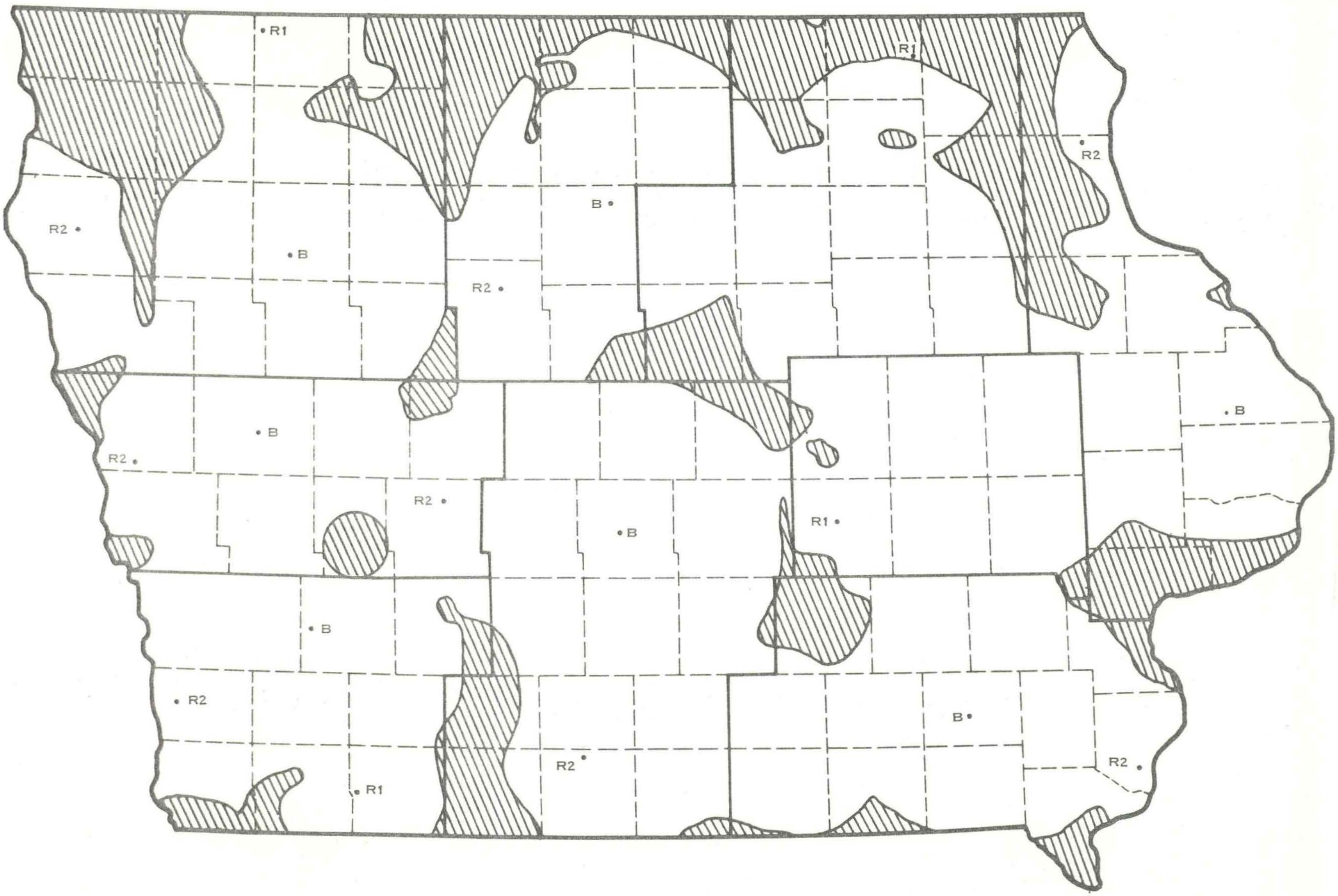

Figure 2-4. Map of Iowa With Poor Coverage Zones Marked.

Flexibility was provided in calculation of the service probability to allow for different operating requirements. Types of characterizations were formed to describe the various operation and interference regions. The useful types are defined as follows:

Type 0 -- Base-to-Mobile

Provides state-wide contour plots of service probability for a composite of bounded regions with interference due to overlapping regional coverage included.

Type 1 -- Base-to-Mobile or Mobile-to-Base

Provides state-wide contour plots of service probability as in type 0 with interference excluded.

Type 4 -- Mobile-to-Base

Provides state-wide contour plots of maximum* service probability with no regional boundaries and no interference from adjacent areas.

Type 5 -- Mobile-to-Base/Repeater

Provides state-wide contours of maximum service probability including interference from any other mobile source but no consideration of regional boundaries.

Other types are defined in volume II.

2.1.2 Base-to-Mobile Propagation Coverage

The type 0 contour plot for base-to-mobile coverage is shown in figure 2-5. It has an unreliable coverage area of 5,812 square miles. Significant regions exist with marginal coverage.

The type 1 contour plot for base-to-mobile coverage is shown in figure 2-6. The unreliable coverage area for this plot is 3,540 square miles. The same basic unreliable areas exist as in type 0. It can be seen that there were several additional relatively small zones where signal interference from adjacent regions caused reduced reliability.

Interference from within a region or from adjacent regions can cause a severe operational problem in the field when a mobile unit receiver is captured by an undesired signal. This can happen in several areas when operations are in the fringe of an operating region and at this time it may become necessary to direct service requests through another jurisdiction for relay, adding to the burden of that jurisdiction.

Volume II shows a method of accounting for interference of the kind described herein.

2.1.3 Mobile-to-Base/Repeater Propagation Coverage

A plot of service probability contours for type 4 mobile-to-base is shown in figure 2-7. The area of unreliable service is 9,480 square miles. In the mobile-to-base area lies a prime

*Implies mobile-to-base contact is made via the base station at which service probability is greatest.

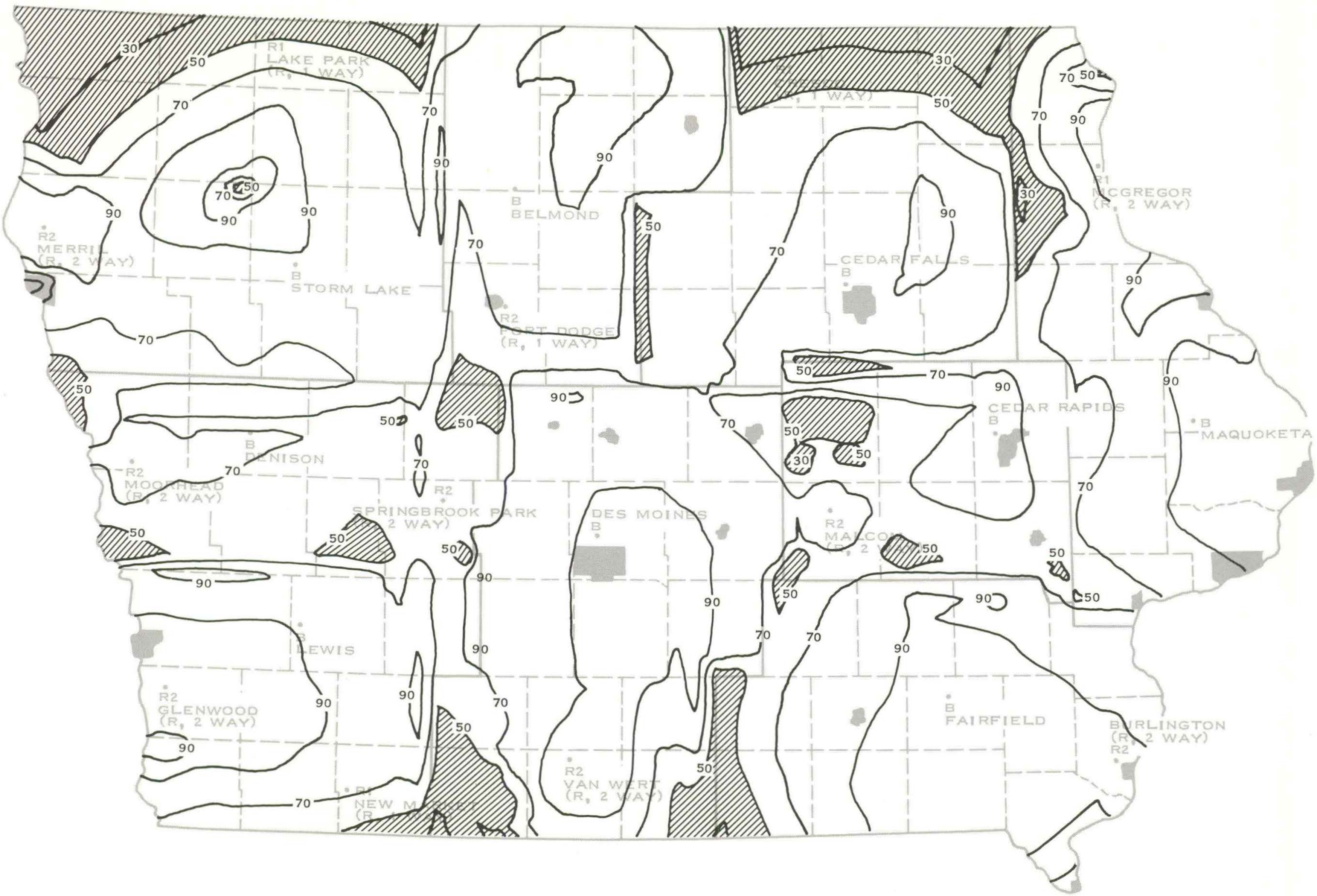

Figure 2-5. Type 0 Service Probability, Base to Mobile, Present System.

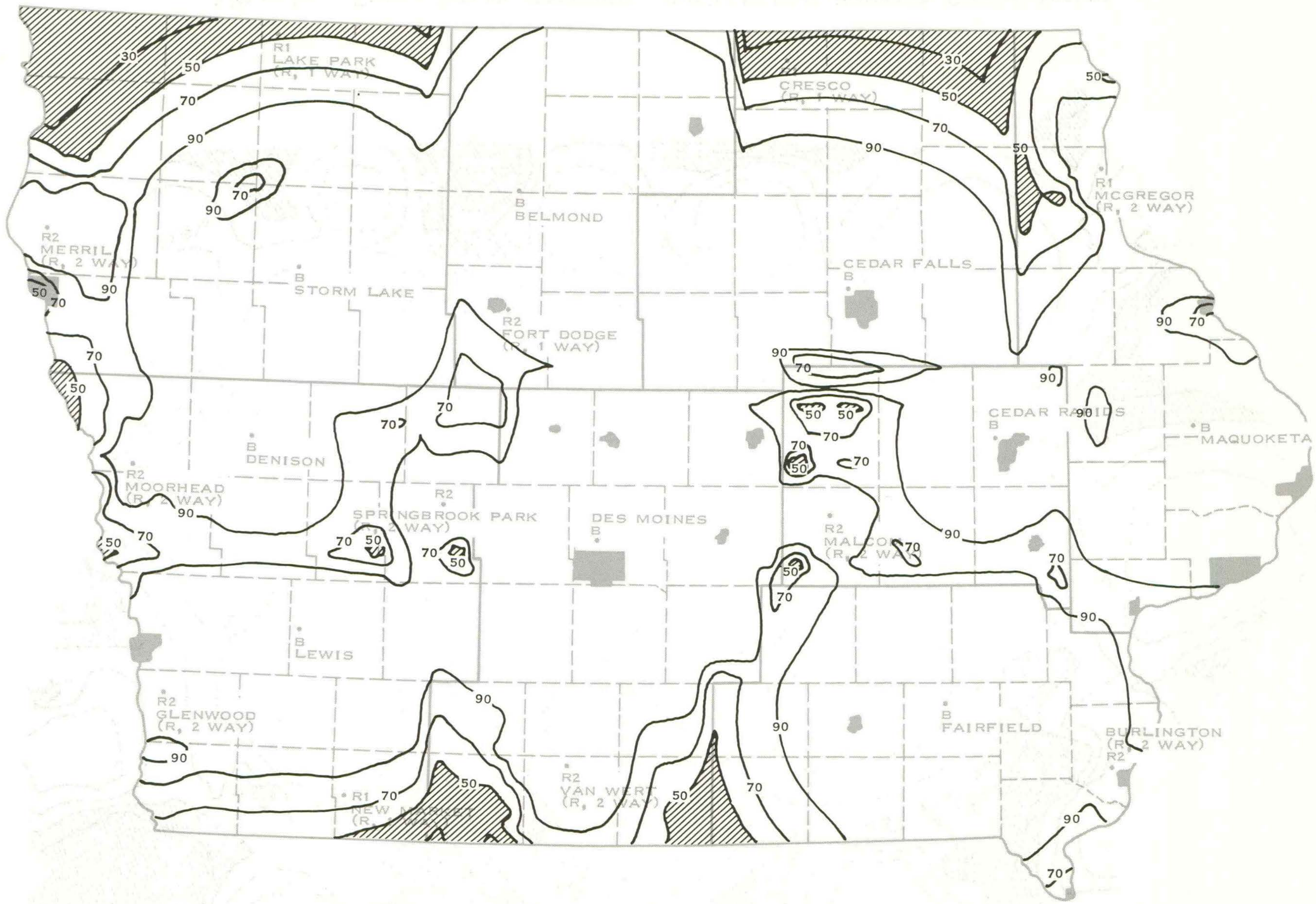

Figure 2-6. Type 1 Service Probability, Base to Mobile, Present System.

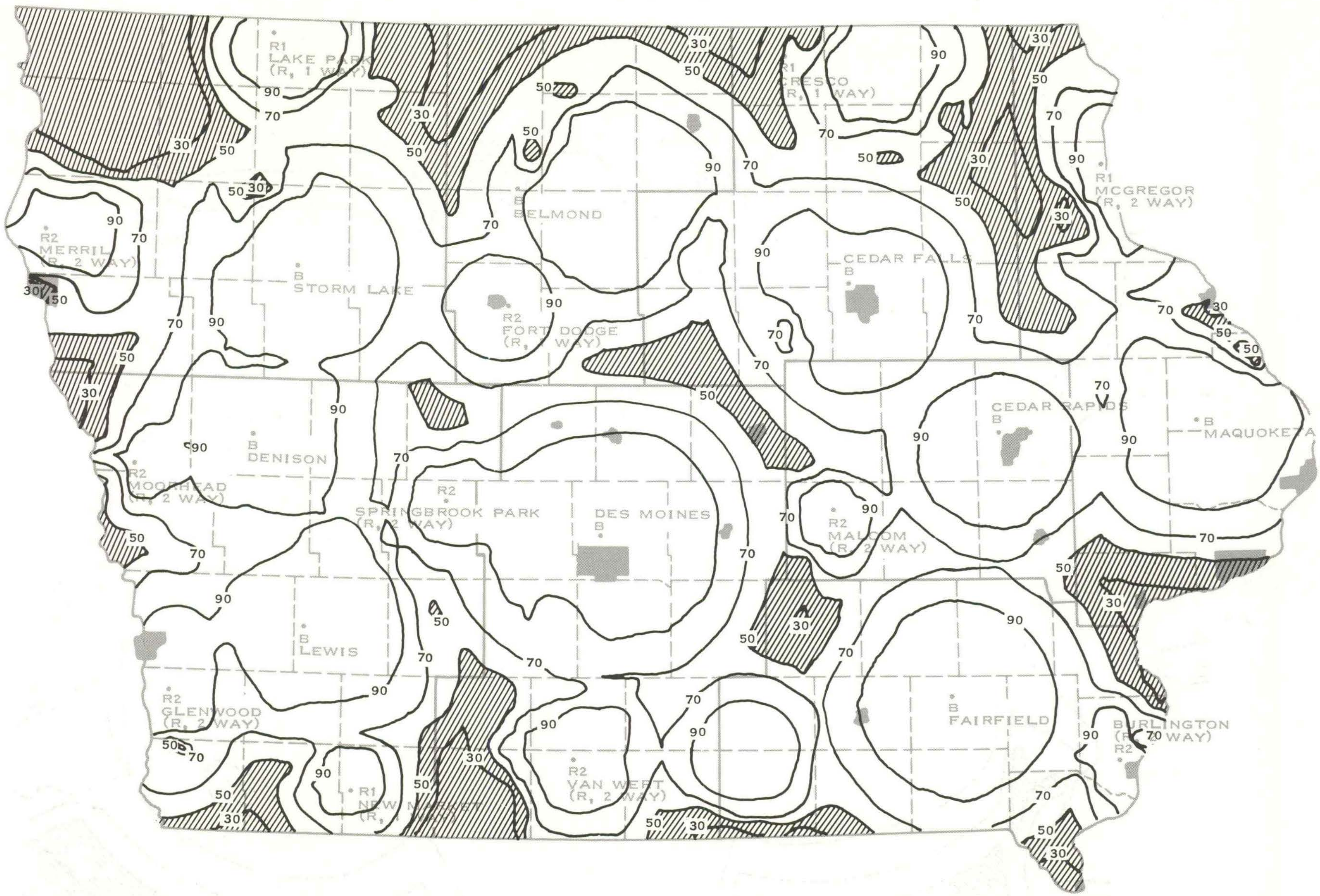

Figure 2-7. Type 4 Service Probability, Mobile to Base Repeater, Present System.

problem in present system communication reliability. In many regions, it is necessary for the mobile unit to drive to a hilltop or move a fair distance in order that a call can be made.

A plot of service probability contours for type 5 mobile-to-base is shown in figure 2-8. The area of unreliable operation is 11,300 square miles. Interference has increased the unreliable area by 1,820 square miles.

Precipitation static in low band at the base station and at the repeater receiver may cause a great reduction in service probability, due to increased noise level at the receiver. While its probability of occurrence is low, the onset usually comes when need for emergency communication is great (tornados, severe rainstorms, blizzards, etc) so the effects are definitely beyond a nuisance level.

2.1.4 Interference

2.1.4.1 Sporadic E (Skip)

A computer study was made of ionospheric propagation of sporadic E interference into Iowa (E_S). This study utilized the ESSA-78 ionospheric prediction method to produce contour maps of the probability of E_S occurrence from a region encompassing basically the continental US plus Mexico and Southern Canada. The computer program gives an accurate statistical description of the sporadic E parameters, so that at a given frequency (that is, 42.6 MHz) the probability of E_S occurrence could be calculated and contour plotted.

The probability of E_S occurrence is a function of location, month, sunspot number, and time. E_S can occur any time, of course, but it is mainly prevalent during summer months, local noon. The contour maps show some rather interesting facts. If an emitter (source of interference) is located in the West Coast region or Mexico, then on the average, the probability of interference propagated into Iowa for the period estimated can be as high as 11 percent. The only other states that use the IPR frequencies of 42.58 and 42.74 MHz are Texas and Michigan. The maximum probability of interference from Texas is 7.5 percent and from Michigan 2 percent. Figure 2-9 shows a worst case contour map of the probability of E_S, low band, in Iowa.

While these probabilities have a low yearly average, when interference occurs it causes a receiver capture and blocks the desired signals when operating as near as 10 miles from a base station.

The conclusions derived from the interference study indicate that E_S is primarily only a nuisance in the present system, but shows also the potentially degrading effect the West Coast region and Mexico could have on low-band frequencies; that is, 42.34 MHz and 42.44 MHz used in California would be unacceptable for the IPR.

With regard to all states that operate on IPR licensed frequencies, the E_S interference severity is summarized in table 2-1.

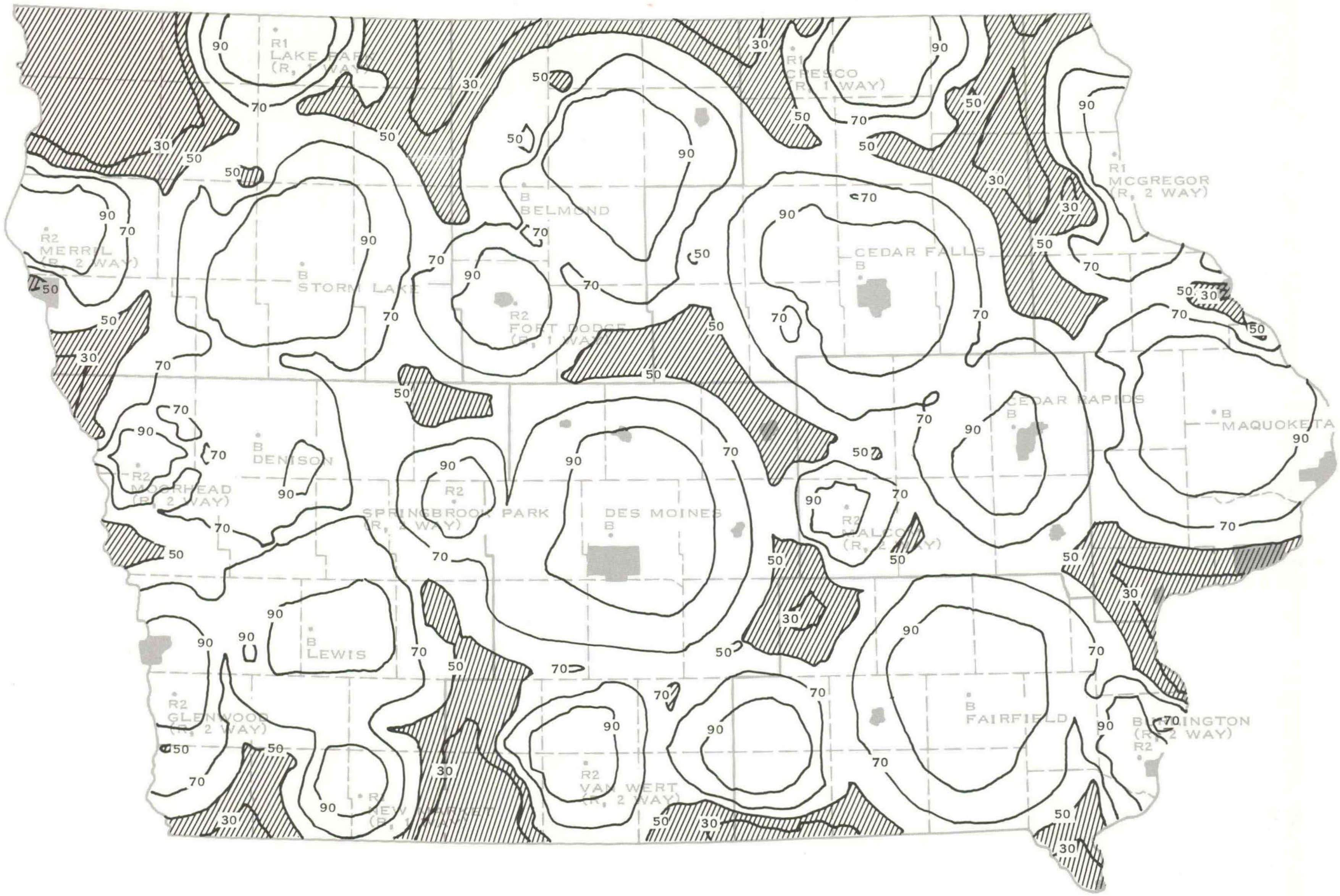

Figure 2-8. Type 5 Service Probability Contours, Mobile to Base, Present System.

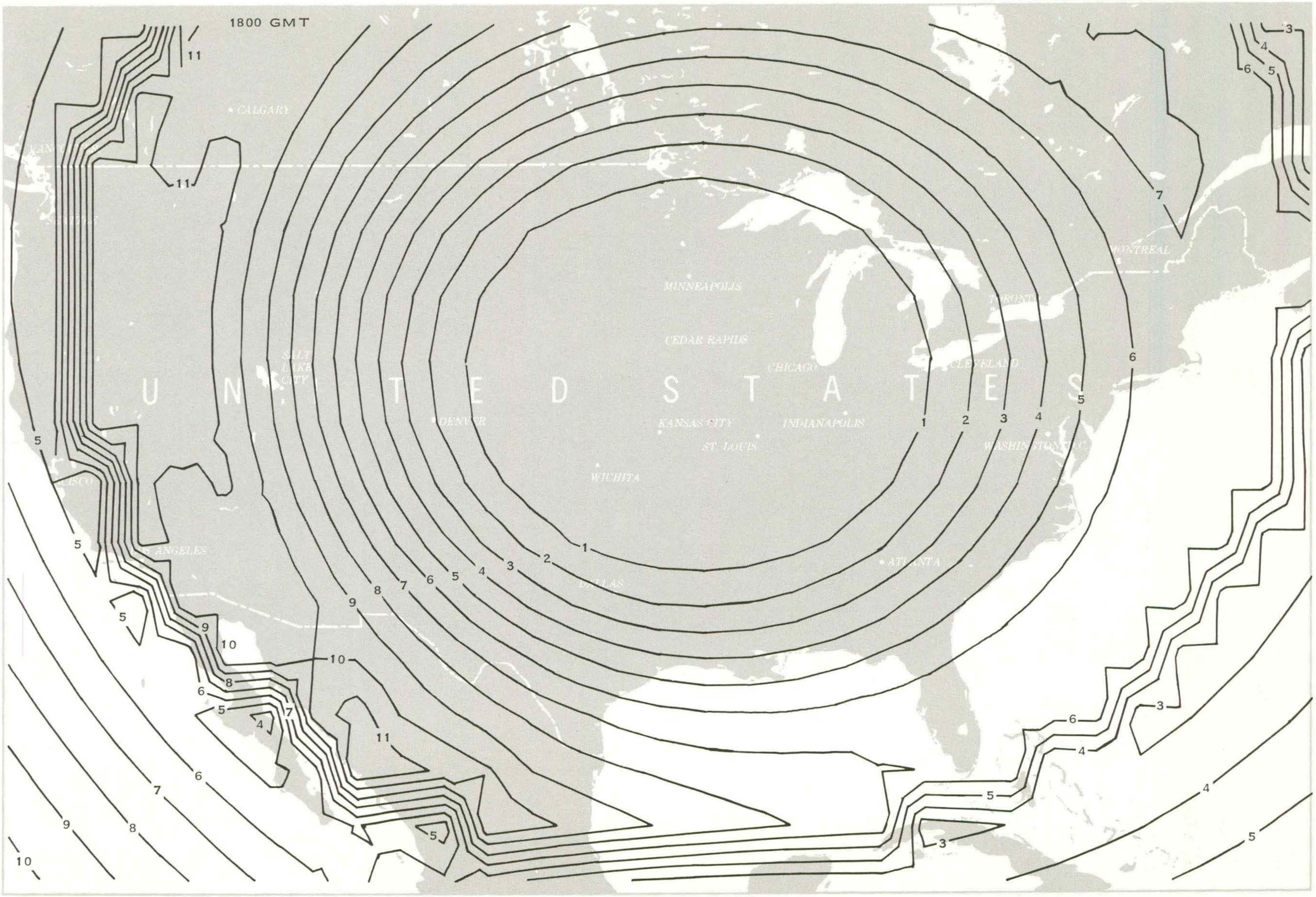

Figure 2-9. Probability of Occurrence of Sporadic E in Iowa at 42.6 MHz.

Table 2-1. Summary of E_S Interference Severity.

FREQUENCY	STATE	MAXIMUM PROBABILITY OF E_S (%)
42.24	California	10
	Idaho	8
42.40	California	10
	Washington State	11
42.58	Michigan	2
42.68	Michigan	2
	Virginia	3
42.74	Michigan	2
	Texas	7.5
42.80	Kentucky	2
	North Carolina	3

2.1.4.2 Adjacent Regions

The common transmit frequency used throughout the state for base and repeater stations combined with a fairly large overlap of usable signal strength in many areas leads to interference through capture of a receiver by an undesired transmitter. This can require that a mobile unit issue requests for repeat messages from his dispatcher, adding to the message traffic burden. Messages may be lost and control commands missed. Interference effects reduce the service probability to operating units. While overlap of usable signal energy is always present, the system could operate on a staggered frequency arrangement between adjacent regions to reduce interference.

2.1.4.3 Precipitation Static

Precipitation static effects have been previously mentioned as a source of interference in base and repeater stations. The causes and magnitudes of the effect are not well documented in the radio literature since the causes are natural and highly variable in time and intensity and are affected by antenna type and condition, tower height, grounding, and physical construction practices. Precipitation static is caused by electric changes draining into or from a thunderstorm cell and by rain, which frequently has electrical charges differing from earth potentials. Both of these sources cause a variable current to flow in or be induced into the antenna. A similar effect may be found when it is snowing or when dust particles impinge upon the antenna structure.

Certain antenna types such as the top mounted dipole are known to be severely affected. Side-mounted dipoles, having large radius ends and corners, and a dielectric coating may reduce the precipitation pickup by 15 to 20 dB. The precipitation static effect is much reduced in the higher frequency bands. Figure 2-10 shows the effect of precipitation static at low band for each base and repeater station assuming an increase in the base station noise level by 40 dB and in the repeater noise level by 20 dB.

Figure 2-10. Type 1 Mobile to Base Service Probability Reduced by Severe Precipitation Static at Low Band.

2.2 NONPROPAGATION FACTORS

Generally, the present system is serving current needs in most of the major population and highway traffic zones of the state. There are, however, several significant areas of unreliability due to low-signal levels and to interference of adjacent regions. Operational command and control activities are sometimes inefficient due to the communication separation of radio dispatch/operation/control and the district offices. The following sections detail various aspects of present system operation, and discuss causes for unreliability or inefficiency in operation. These must be improved for operation in the rapid message handling TRACIS environment.

2.2.1 Separation of IPR Base Stations and IHP District Offices

A positive control is not now readily possible in situations requiring IHP supervisory decisions due to the separation of most base stations from the district offices, and due to the associated limitations in communication between the district office and the patrol officer in the mobile unit.

There are several possible solutions to overcome these problems which include: location of the radio control center at the district office by facilitating remote control of the base station over a multichannel control link; assigning an IHP supervisor to the base station facility; and providing a positive dedicated communication with audio patching capability at the base station to allow direct contact with the patrol officer.

It would appear the most efficient solution is to provide the dedicated communication channel, since remote control of a complex communication facility is quite expensive, and the assignment of a full-time IHP supervisor to the radio room is not cost effective, since the need for positive command and control is thought to be a relatively infrequent event.

The requirement is to keep the district office informed of the important events and to facilitate direct command and control by the district office during the occasions that require it. The dedicated communication channel would seem to satisfy this requirement.

2.2.2 Message Traffic Analysis

A limited amount of data relating to the present message traffic handled by the IPR stations was obtained to form a part of the study data base. This data included records of traffic handled by message type on a monthly basis for the last two years. In addition, data from one base station indicating the typical daily message loading was obtained. TRACIS message loads were also provided by Planning Research Corp. (PRC). This data provided the information discussed in the following paragraphs.

An analysis of the present system message load indicates that a single half-duplex (2-frequency simplex) channel can handle adequately the traffic with a minimum delay time. Later system usage, namely the start of TRACIS, may require an additional communication channel and a separate channel for one-way-receive-only data in the mobile unit.

The present message load maximums and minimums indicated from a recent survey of car contacts at an IPR base station was a peak count of 48 contacts per hour and a low count of 4 contacts per hour. (See volume II.) (A car contact is defined as a single or multiple exchange of information between the base station and mobile unit for a continuous period of time). Typically, the shorter message exchanges are in the order of 6 to 10 seconds in length, although some are quite lengthy. The broadcast of an item* averages 30 to 40 seconds and the summaries** are even longer. As a result, there is an average car message length of about 15 to 20 seconds. During peak hours, the channel utilization is (48 x 20 = 960 s), approximately 27 percent of the available channel time. Referring to figure 2-11, the probability of finding a clear channel during the busiest or peak hours is 0.74 and the average waiting time (delay), figure 2-12, is approximately 0.3 of a message length or 6 seconds.

After the TRACIS system is installed and operating, the additional message load expected during peak periods is 48 messages per hour above the present traffic count. Additionally, these messages are assumed to require 25 seconds of channel time per message. The time estimate includes initial contact, acknowledgment, TRACIS request, call back, acknowledgment, and TRACIS answer. During the peak hours, then, this adds 1,200 seconds to the present channel utilization making a total of 3,160 seconds, which is 60 percent of the available channel time. The probability of finding a clear channel under these conditions is 0.4 and the average delay or waiting time is 1.5 message lengths or about 34 seconds. Thus, for slightly more than twice the channel time utilized, the wait time has increased by six times.

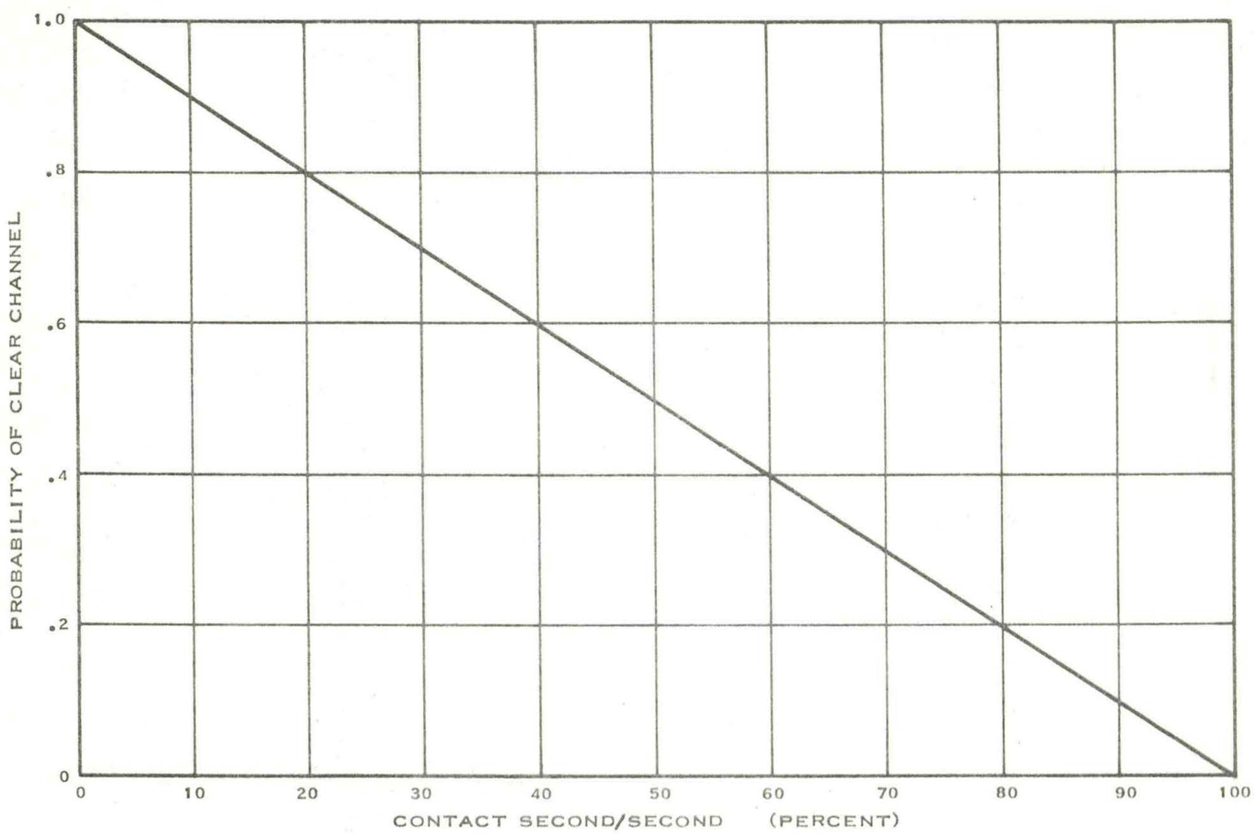

Figure 2-11. Probability of Clear Channel Peak Hour Traffic.

*Items are messages giving detailed descriptions of a crime, runaway, stolen car, and similar incidents broadcast as all-point bulletins.

**Summaries are messages broadcast in the morning and afternoon, which recap all the items broadcast during the previous shift.

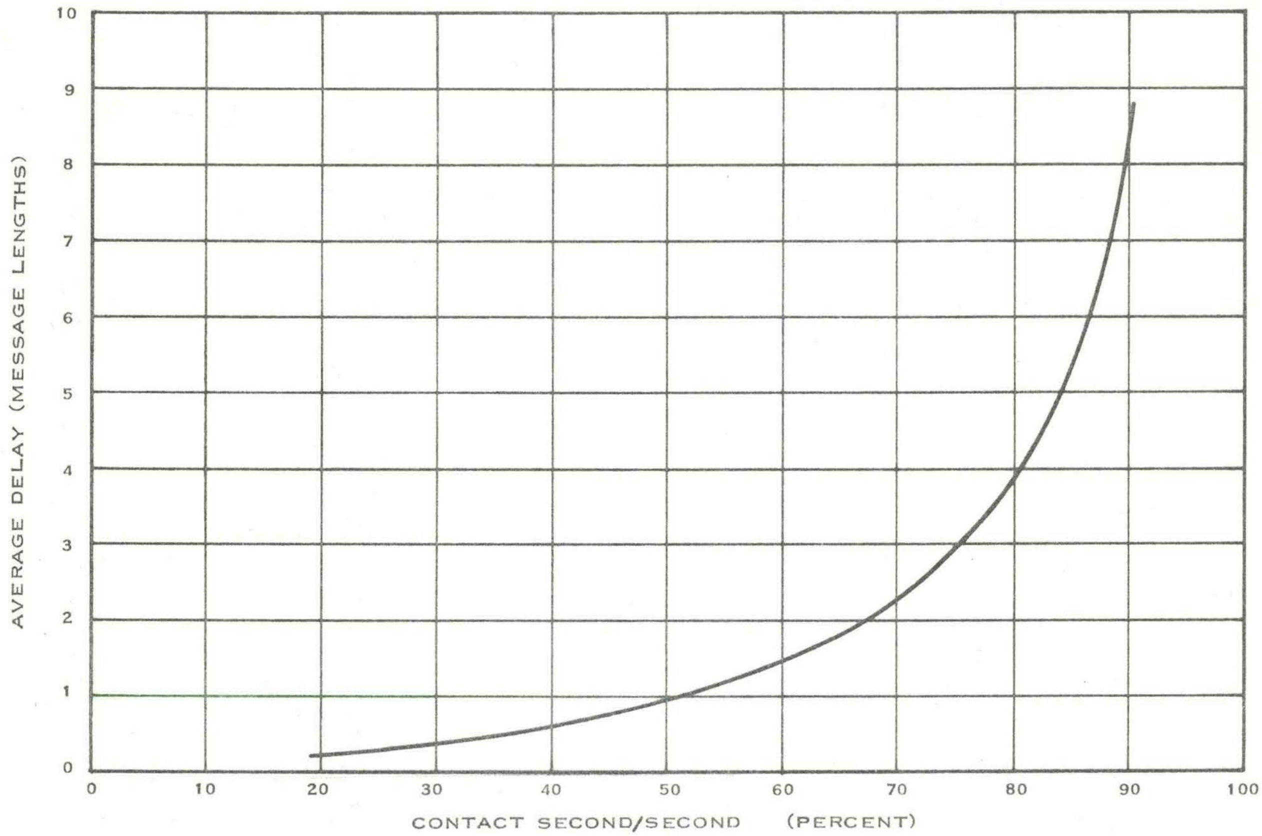

Figure 2-12. Message Wait Time Versus Contacts.

It can be seen by this summary of the traffic analysis and by referring to the figures that a gradual increase in message traffic, beyond TRACIS, of 5 to 10 percent a year, or an increase in the number of officers in the patrol will cause delay times that will become intolerable in the TRACIS/police environment. Clearly, an additional simultaneous channel will be required in only a year or two hence especially during peak message load operating periods. This fact is one of the primary factors that forces the choice to a frequency band other than low band.

2.2.3 Operating Region Boundaries

Base and repeater stations are used for communication to and from mobile units operating within an assigned geographic area. It is important that the mobile transmissions are received at the base station either directly or through a repeater. Likewise base-to-mobile transmissions must be received at the mobile units. A well-designed system will have cost effectively positioned base stations and repeaters to provide adequate service probability.

In the Iowa Police Radio where base stations are presently fixed and their move quite expensive, it is judged more cost effective to move a regional boundary than to construct extended repeaters or to move a base station. Such is the case for the region boundary between Belmond and Cedar Falls regions.

2.2.4 Monitoring of 37.10 MHz in Mobile Units

It would appear the original utility of monitoring 37.10 MHz in the mobile units has been lost since that frequency is now shared with local governments. This is not to say that the ability to monitor this frequency has no value. But the fact remains that many of the large counties and cities no longer use this frequency, which makes statewide usefulness limited. A significant cost savings can be made if the requirement for monitoring 37.10 MHz is omitted, since the radios require dual front ends to receive it. Additionally, the receiver sensitivity is reduced when the dual front end is used.

The base stations may need to monitor this frequency and pass the important and pertinent information on to the patrol units as required.

System Recommendations

System design of a land mobile radio facility involves a complex set of problems. It must deal with electromagnetic propagation effects through a wide frequency range making allowance for effects of terrain and distance on transmission loss, antenna characteristics, electronic equipment parameters, noise generation (both natural and manmade) and interfering signals.

It is equally necessary to consider the uses to which the system must be responsive. Among these are the expanding message traffic, the operating discipline, the growth and expansion brought on by public safety demands, and an expanding technology that allows for a great increase in information transfer.

A first effort in system design is to develop a list of requirements that the system shall meet and toward which it can be expanded in the future as conditions change.

From these requirements and techniques, candidate systems can be analyzed for performance and cost. The best choice is a system that meets present and future requirements at a lower cost.

3.1 SYSTEM REQUIREMENTS

This section outlines the requirements for an improved IPR system that will meet present and projected communication needs, including TRACIS. Table 3-1 lists the message structure resulting from various IPH operations that require communications support. The following paragraphs discuss the implications and requirements imposed by that message structure on the future IPR system.

3.1.1 Coverage, Interference, and Noise

A fundamental requirement for an upgraded and improved IPR system is the extension of signal coverage (increase of service probability) into the fringe areas of the present system. This extension of performance includes mobile-to-base (talk-back) as well as base-to-mobile channels. Possible solutions to the coverage problem include the use of higher towers at existing base and repeater sites, the use of gain antennas at base, repeater, and mobile (high band and above) stations, and the establishment of additional repeaters. The relative merits and costs of these techniques are discussed in paragraph 3.3.

An equally important requirement is for the elimination of interregion interference such as exists in the present system. The solution of this problem requires the implementation of an effective frequency staggering plan on a regional basis as shown in figure 3-1. Because of projected message traffic loads, a staggered frequency scheme is required regardless of what frequency band or system type is chosen.

A secondary requirement exists for the reduction of interference to system operation caused by sporadic E (skip), precipitation static, and manmade noise. All three of these degrading factors are most severe in the low band. Within low band, reduction of interference effects are limited to changing of antenna types in the case of precipitation static and changing of operating frequency in the case of sporadic E. Considerable improvements in noise, skip, and precipitation static are obtained by a change to the high or uhf bands.

Table 3-1. Present and Projected IHP Radio Communication Requirements.

IHP OPERATION	MESSAGE TYPE	PRIMARY MESSAGE FLOW
1. Responsive services		
a. Requested IHP services, accidents, etc.	Local dispatch	B → M M → B → M
b. IHP requests for field asst, ambulance, motorist service, etc.	Field request	M → B
2. Preventive patrol		
a. Broadcast alerts, stolen vehicles, missing persons, emergencies, severe weather.	All-call broadcast	B → M
b. Records access, TRACIS, NCIC, etc.	Inquiry and reply	B ⇄ M
3. Administrative and routine		
a. Logistics and coordination, equipment trouble, court appearance, report to district office, etc.	Routine exchange	B ⇄ M
b. Status In/out of service, location.	Routine exchange	M ⇄ B
4. Tactical area		
a. Criminal apprehension, speed trap, raids, high-speed chase, etc.	Coordination	M ⇄ M
b. Crowd control, civil disturbance, natural disaster.	Various	Various, including mobile communication van.
M = Mobile B = Base		

3.1.2 Elimination and Mitigation of Factors Causing Unreliability

The computation of service probability and choice of factors leading to achieving the selected value of 0.50 (50 percent) takes into account several statistical parameters that have variations. This provides a safe margin in usable signal-to-noise ratio before intelligibility is affected.

NOTE

The Ashton area field survey team found good intelligibility to and sometimes beyond the 30 percent predicted service probability on all bands.

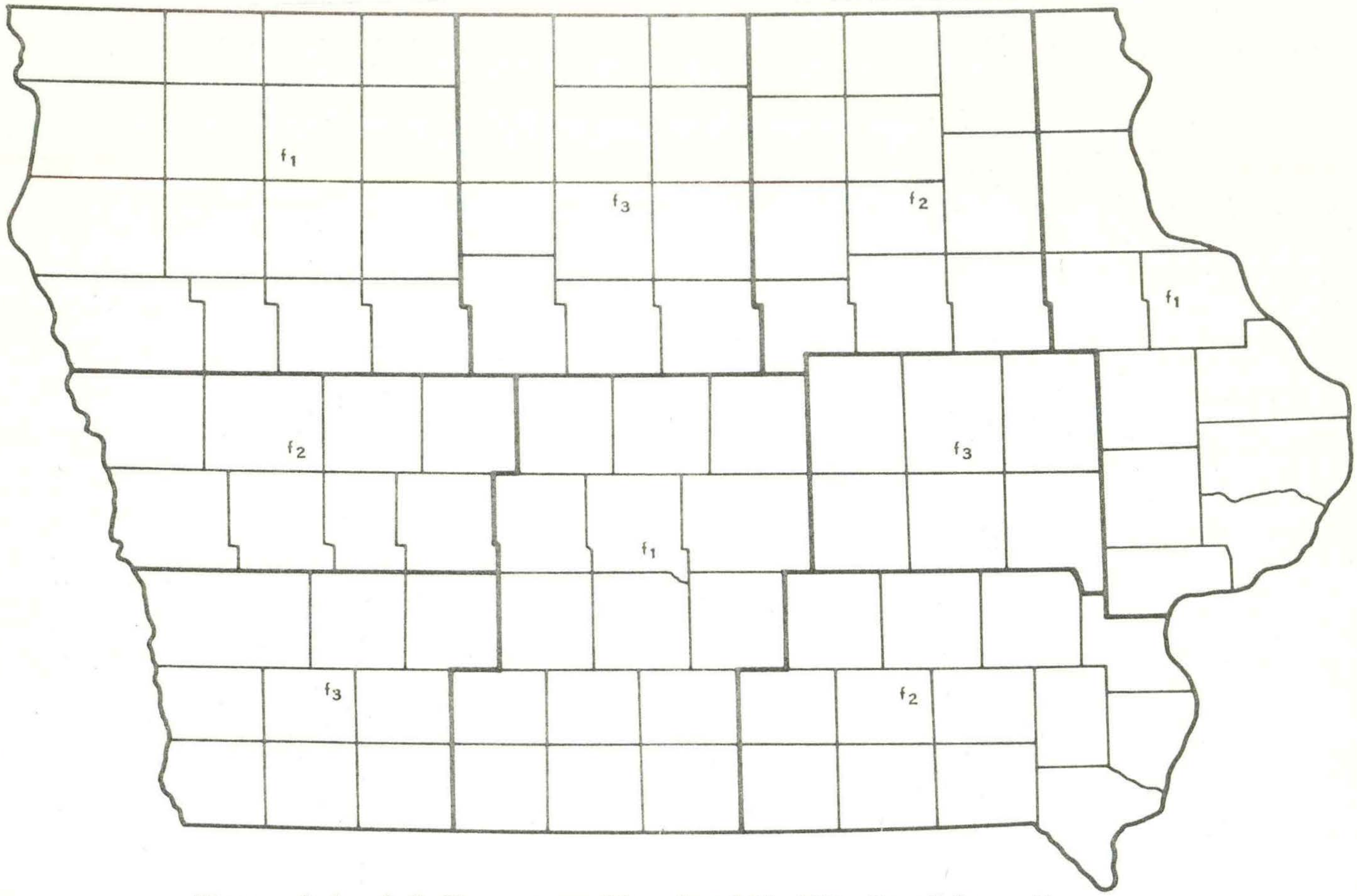

Figure 3-1. A 3-Frequency Plan for 155-MHz Band Operation.

There are factors at low band that can vary much in excess of the margin provided. To design a low-band system having a signal-to-noise margin under all conditions would be very costly and quite foolish, in fact, considering other limitations of that frequency range. The factors of sporadic E propagation and precipitation static are the primary causes of unreliability, and their levels can vary from undetectable to 40 or 50 dB above 1 microvolt per meter.

Another factor leading to unreliability is interference. This can be mitigated by frequency staggering. To some extent, this also aids message channel crowding and the associated increase in message wait times.

3.1.3 Boundary Lines of Jurisdiction and Propagation Regions

Command and control areas should match reasonably well to cost effective service probability boundaries. The only serious problem area in the proposed system upgrade and for the optimized system plan is in the Belmond/Cedar Falls common boundaries.

Moving Hardin and Franklin Counties into the Belmond operating area will satisfy the requirement.

3.1.4 Command and Control Collocation With Radio Operation

One of the requirements for a desirable system operation design is to allow commanders an ability to dispatch mobile operations in times of stress and to monitor the radio operations.

There are two primary methods for this. One is to have the radio operations in the District Headquarters. The second is to have 2-way communications from the District Headquarters to the base station operation.

A brief analysis shows the latter method would be required generally even if the radio operations were in the same building (it would be difficult to locate in the same room). The difference is in the length of the communication links.

There is another fairly important factor in this decision in the required location of base station radio antennas in a low noise area and at a reasonable height. Urban areas where district offices are usually located do not offer the lowest noise or ideal antenna sites.

The recommendation is to retain base stations essentially remote from District Command with the use of either 2-way radio or telephone linkages between them that allow for immediate switchover of control when needed at the District Command. This can be accomplished by placing an "audio patching" unit in each base station radio control console with attendant radio, landline dialup or leased wire connections at the district office. It is assumed that the capability will exist for making an audio patch into two district offices where they occur in a single operating region.

3.1.5 Multiple-Channel Communications

Growth in message quantity and the necessity for maintaining minimum message wait times, as determined from the message traffic analysis (paragraph 2.2.2), requires that the system be expandable to a second channel at each base and repeater station. Expansion to a data transmit channel from base/repeaters to mobiles is also desired as a later add-on without system redesign.

The mobile units should have the following capability for operation and expansion of operation:

a. Receive

1. A primary channel frequency that handles the bulk of traffic.
2. A statewide channel frequency for direct mobile-mobile and air-mobile.
3. Expansion to a secondary channel frequency for overflow traffic and for data reception.
4. An adjacent area frequency.
5. A scanning head is recommended for the receivers. It should have a priority scan capability.

b. Transmit

1. A primary channel in the operating region.
2. A statewide frequency for direct mobile-mobile and air-mobile.
3. A secondary channel when expansion requires.
4. An adjacent area frequency.

NOTE

It should not be required that each mobile unit have a duplex capability (simultaneous transmit/receive) unless special command units in each region are so equipped.

Base stations will require capabilities to provide the following:

a. A primary region channel capable of full-duplex operation and simultaneous operation with other channels. This channel should be capable of mobile-to-mobile relay on request
b. A base and mobile statewide channel that is single frequency simplex
c. A point-to-point channel (155.37 MHz)
d. Capability for expansion to a secondary region channel with full-duplex operation and for data transmission when needed.

Repeater stations will require the same primary region channel capability as their base stations.

A mobile relay capability between any two points in the region is recommended and can be obtained if the above requirements are satisfied.

3.1.6 Control Links

The control link between base and repeater stations is required to have signal transmission and equipment characteristics that do not degrade the intelligibility of the messages transmitted. The reliability of the link must be sufficient to avoid degradation of the IPR system. The control channel should be full duplex allowing for 2-way transmission and reception and should have expansion capability for addition of a secondary region channel.

3.1.7 Iowa Highway Commission Radio Facilities

Iowa Highway Commission high-band radio facilities offer a potential for shared use subject to FCC provisions in volume 5, section 89. Possibilities exist for emergency use, mobile relay, and for signal coverage in areas where needed.

In satisfying the requirements for the IPRS, all available channels on the standard high-band mobile radios are assigned to other frequencies. Utilization of the IHC radio facility, therefore, would require added radio channels or a second radio in the mobile units.

Accordingly, the recommendation of this study is not to include plans for using the IHC radio system.

3.2 FREQUENCY BAND SELECTION

The three bands that are practical for public safety usage are low band (near 42 MHz), high band (155 MHz), and the uhf region (near 460 MHz). Each of these frequency regions have their distinguishing propagation characteristics. Present IPR system operation is at low band with control link frequencies in the high band. Characteristics and selection criteria in terms of system requirements are delineated with a final choice dependent on meeting the basic requirements in a cost effective manner.

3.2.1 Low Band

Police radio services operate in the frequency range of 37.02 to 46.02 MHz. Not all are assigned to these services. One of the advantages of the low band for a fixed set of station parameters is that the signal coverage is better than the other two bands; however the low-band region is one in which frequencies are still low enough to propagate occasionally via the sporadic E (skip) as discussed in paragraph 2.1.4.1 . Direct mobile-to-mobile range is much greater than in the higher frequency bands. Atmospheric noise normally is rather low at 42 MHz, the primary noise sources are manmade. In a well-designed receiver, set noise is less than external (manmade) noise. The manmade noise levels in Iowa are basically what is termed "the rural category" with levels only 13 to 20 dB above thermal noise. Precipitation static is a degrading factor for communication in low band, particularly at the base stations. The phenomena that produces it is complex and not well understood. Means for reducing its effects, however, are known; that is, rounded ends and corners, large radius wires, and dielectric coating of antenna elements. By proper antenna design, it may be possible to reduce precipitation static pickup. During an electrical storm, there still may be significant excess noise over the normal level of manmade noise.

The transmission loss beyond line-of-sight in the 42-MHz band is less than in the other available frequency bands; hence, interference into adjoining regions or adjacent states is a greater problem.

Frequencies at low band have a relatively long wavelength that makes the design of cavities and duplexers impractical for 2-frequency simultaneous operation at either base stations or mobile units. The requirement for multiple channels having independent operation is the primary factor that rules out the use of low band for an expanding system.

The physical size of the antenna for low band makes it difficult to obtain structures with gain directionality often needed to obtain a specific area of coverage.

There are fewer features for expandability in the low-band equipment and new developments leading to improved features are very limited today.

The IPR low-band system utilizes a high-band control link between the base and satellite repeaters. These are operated as single-channel units in a 2-frequency simplex configuration. Wire lines can be used if their reliability is adequate.

3.2.2 High Band

Police radio services operate in the frequency range of 154.650 to 159.210 MHz. Not all of these frequencies are assigned to this service.

At high-band frequencies, sporadic E effects are essentially negligible and precipitation static, while still present during severe onsets, is quite low in intensity with respect to low band, and is nearly negligible. Manmade noise is the only external noise source of consequence, averaging only 7 dB above thermal noise.

The propagation losses are higher in this band than in low band, but these are essentially offset by reduced external noise fields and the availability of higher gain antennas. Interference into adjacent regions is considerably less than at low band, but there exists the "rusty bolt effect" (cross modulation and partial rectification of signal energy due to partially conducting surfaces), and a higher probability of tropospheric duct propagation. These effects are relatively minor when compared to the sporadic E propagation and the precipitation static problems of low band.

Mobile-to-mobile operating ranges are reduced to a 5 to 10 mile radius in the high band. This frequency band is heavily used by local governments and surrounding states. The availability is mentioned in a later section. The prime aspect of this band is that with a minimum frequency separation of 0.500 MHz, full-duplex operation is technically feasible, which satisfies a future system requirement.

Gain antennas are readily available with various directional gain characteristics required for optimizing the receive/transmit signal coverage. Antenna elements are approximately one-third the size of low-band units, require less tower mounting area, and have a lower cost than a corresponding low-band antenna.

The high-band mobile units have essentially the same performance characteristics as the low-band units.

Base station and repeater units are not significantly different for low-band and high-band operations.

Provision for a mobile relay operation at the base and/or repeater stations can increase the utility of mobile operations and allow for command or dispatch operations.

The external noise levels are lower in this band by approximately 13 dB, and the currently available receiver noise figures are approximately 4 dB and do not degrade system performance.

Portable equipment is readily available and can be set up for the operating frequencies of mobile or base primary channels for flexibility.

The control link for high-band systems is typically either in the 460 or 960 MHz frequency range. FCC frequency allocation policies limit usage of the 460-MHz control link usage to 1 year authorization. It is therefore unwise to utilize the 460-MHz control link.

The spacing of 960-MHz control links is limited to line of sight and seldom can exceed 40 miles. When the distance to be spanned is greater than 40 miles, a 2-hop control link is required.

Typically, the 960-MHz control link equipment provides up to six full-duplex voice bandwidth channels. This, plus the inherent reliability of line-of-sight links, satisfies the requirements desired for control link channels.

3.2.3 UHF (453 to 457 MHz)

Radio propagation distances in the uhf band are intermediate between the short line-of-sight ranges obtained at microwave frequencies and the extended coverage beyond line-of-sight obtained at low band. As discussed previously, the additional loss at high band relative to low band (beyond line of sight) is fully compensated by higher gain antennas and lower system noise levels. However, the transition from high band to uhf yields only modest increases in antenna gains and modest reduction in system noise; consequently, the propagation losses beyond line of sight at uhf are not fully recovered and the coverage range is reduced.

Since the useful range at uhf exceeds the line-of-sight range only by a modest amount (approximately 5 mi), it becomes more advantageous to space uhf stations on the basis of the line-of-sight control link distance rather than the full distance afforded by the uhf station. This relatively close spacing results in a grid or network of stations that form a cellular coverage system. Figures 3-2 and 3-3 show a possible uhf system plan for Iowa that uses the cellular approach to statewide coverage. The cellular system

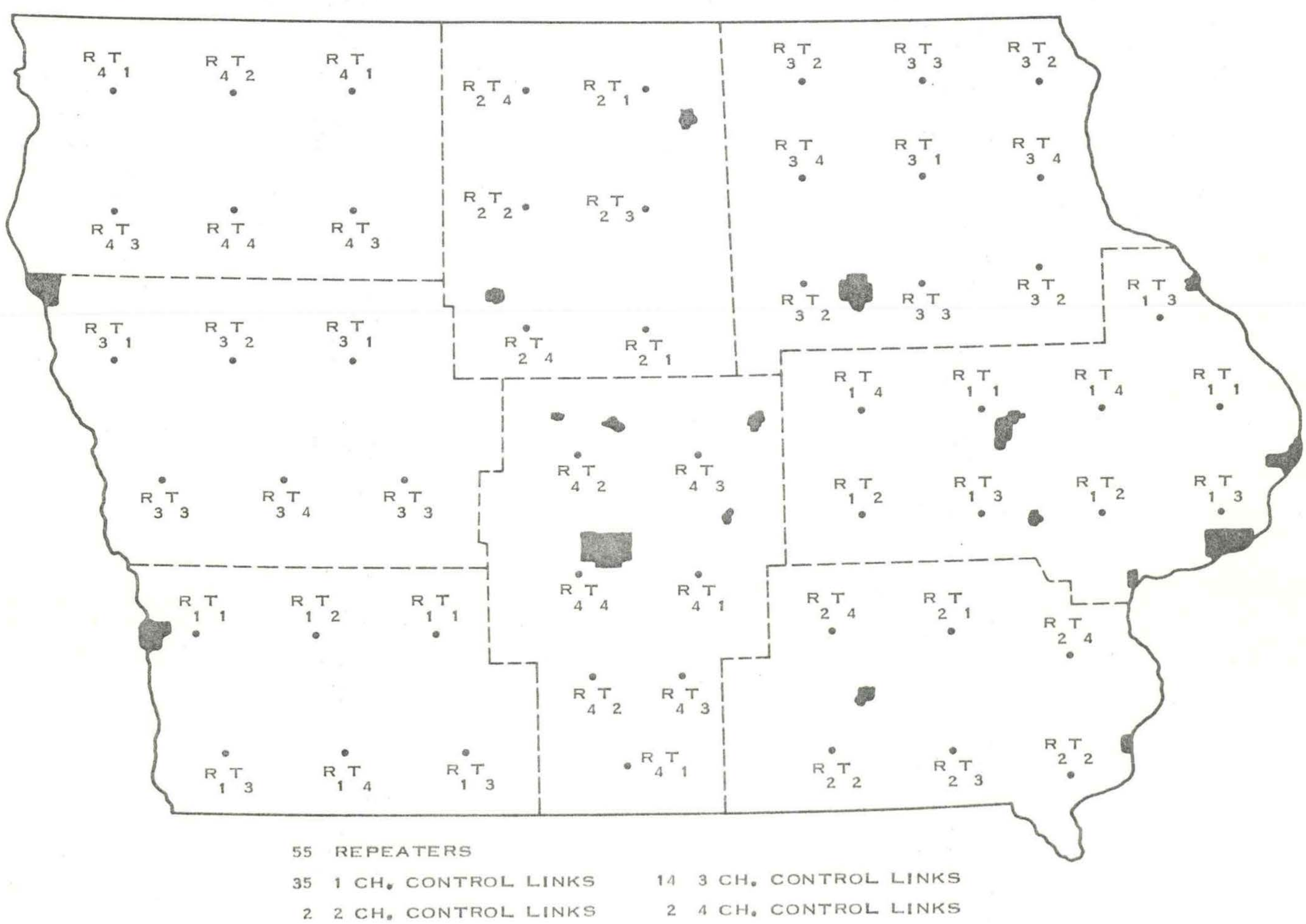

Figure 3-2. Frequency Plan for 460-MHz Band Operation, Typical.

(figure 3-2) differs from a centralized system(such as the present IPR system) in that each region is a miniature "state" composed of six cells, wherein frequency staggering is used to avoid intercell interference. Each of the six cells in a region contains a repeater that is controlled from a regional center via microwave control links. Because there is considerable overlap in the uhf coverage area of adjacent cells, service probability tends to be high over the entire region. The distributed nature of the cellular system means that each station carries only a fraction of the region's message traffic, and in the event of a repeater failure, only a small coverage area is lost. The major disadvantage of a cellular system is the large number of stations required and the resulting increased cost.

As mentioned above, uhf propagation loss is greater than either low or high bands beyond line-of-sight distances. Within line of sight, uhf coverage can be better than the lower frequencies in towns and cities where there are many reflection surfaces and angles to scatter radio energy and thus "fill in" the signal nulls that exist at the lower frequencies. However, uhf shadowing is more severe behind a single large obstacle, such as a hill. These shadow losses are overcome in the cellular uhf system by providing overlapping saturation coverage of the regions.

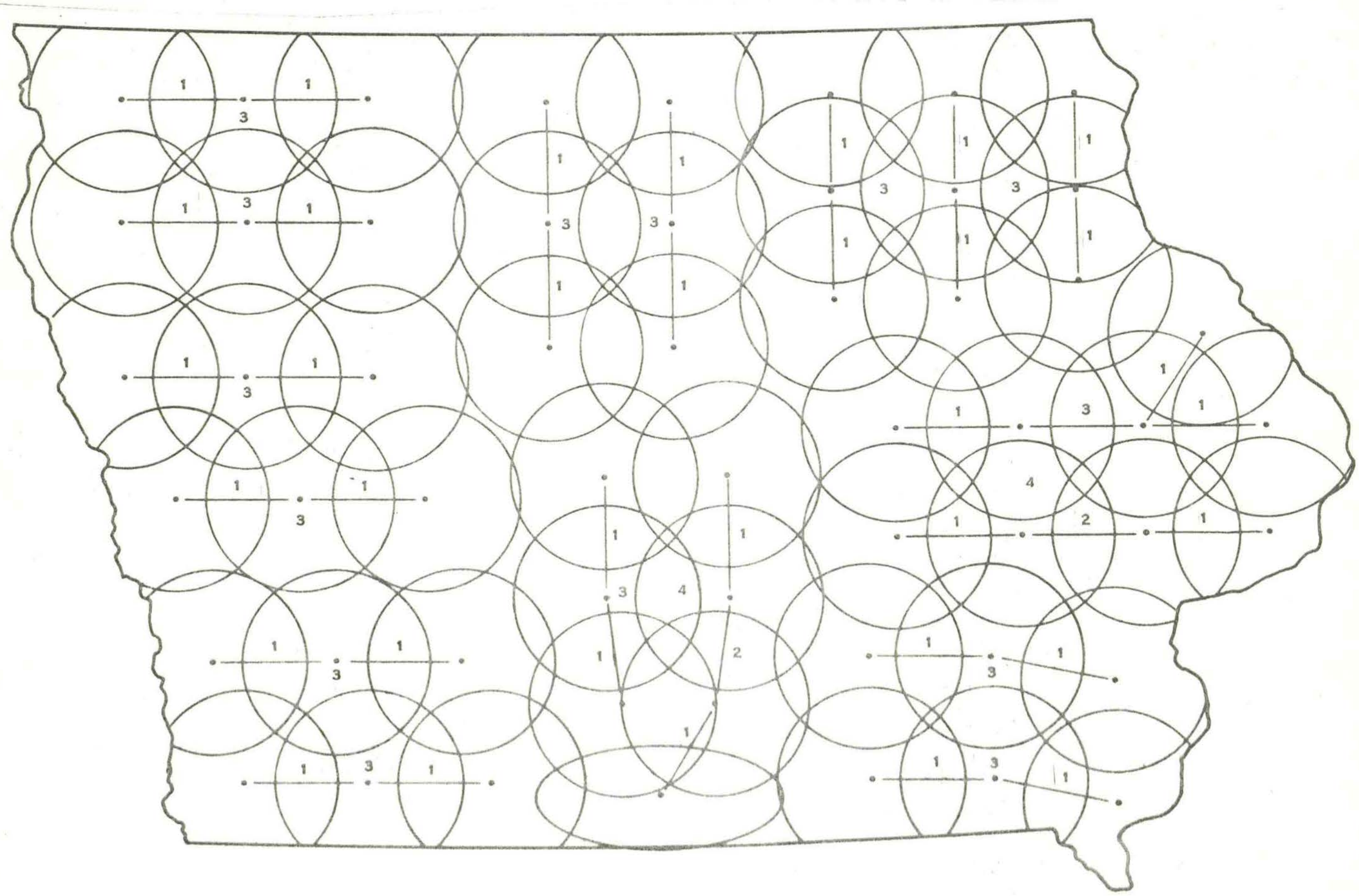

Figure 3-3. Typical Site Possibilities and Channel Control Links for a UHF System Operation.

At uhf, sporadic E (skip), precipitation static, and manmade noise are negligible factors. Internal receiver noise becomes the limiting factor in signal reception. Recent development of uhf mobile equipment makes full-duplex system operation practical. Because of the multiple repeater transmit frequencies in a region, a frequency-scanning mobile receiver is required. These are commercially available and allow a priority ordering of channels.

3.2.4 Review and Selection of Frequency Band

The primary factors involved in selection of a frequency band for the Iowa Police Radio System are reliable coverage, adequate message capacity, expandability to meet future requirements, and cost effectiveness.

Although low-band offers good coverage area, it is fundamentally limited by the availability of frequencies to accommodate a frequency-staggered, multiple channel system. Full-duplex operation is impractical at low band, further limiting multiple channel systems. Such a system is required to eliminate interregion interference and accommodate projected message traffic loads. In addition, sporadic E (skip) and precipitation static are disruptive sources of interference for which there is no effective cure at low band.

Refinement of the existing IPR low-band system for improved area coverage represents the least expensive alternative, but the resulting system would provide only temporary relief of existing problems. Selective upgrading of the present system is recommended only where expedient within the framework of transition to another frequency band.

The uhf band, with an attendant cellular coverage system offers considerable reliability and flexibility to meet IPR communication requirements. At the present time there is virtually no difficulty in obtaining uhf frequency assignments in the Middle West. Noise and interference problems are minimal. Uhf equipment offers the widest variety of operating features and carries a greater potential for future development than low and high band equipment.

In cellular uhf systems, the density of repeater stations is much greater than in either the low or high bands. This makes it necessary to consider a completely revised siting plan with many more sites required to provide statewide coverage. The control link equipment is collocated with each control center and repeater station making possible a statewide communication network. If the requirements for statewide point-to-point communication channels were consolidated, it might be found cost effective to move to the uhf frequency band with an appropriate microwave control/communication system. It is clearly beyond this study to determine that choice. In fact, a uhf system for IPR is ruled out on economic grounds when the large additional cost for new sites and microwave equipment is not shared by a number of state agency users.

The high band offers an extremely cost effective match between IPR requirements and operating flexibility. A sufficient number of frequencies are presently available to accommodate a staggered frequency plan and to provide for moderate channel expandability.

The problems of sporadic E (skip), precipitation static, and manmade noise are all reduced to the extent that their possible effect on system reliability is very small. A full complement of equipment options and operating modes is available, including capability for full-duplex channels, which allows mobile relay.

Because increased antenna gains and decreased noise levels fully compensate for additional propagation losses, statewide coverage can be obtained at high band using approximately the same number of sites as would be required for total low-band coverage.

Implementation of a high-band system for Iowa involves the replacement of present base, repeater, and mobile equipment at a total cost between that of a low-band upgraded system and a uhf cellular system. Considering added system capability per dollar, however, high band offers the greatest cost effectiveness of the three frequency bands. High band is recommended on the basis of cost effectiveness and ability to meet future communications requirements of the IPR.

3.3 SYSTEM SELECTION

3.3.1 System Possibilities

Analysis of the present system shown in section 2 indicates an upgrade possibility that would make possible a completely adequate signal service probability.

A realization that the low-band system had other inadequacies leading to unreliability led to a parallel analysis of the high-band propagation. This analysis showed the feasibility of achieving a required service probability on high band with essentially the same physical improvements in the low-band system configuration.

When the basic communication system requirements were thoroughly analyzed and after cost effectiveness analysis was started, it became evident that system requirements could be met with a high-band system built essentially on the sites and towers of an upgraded low-band system.

Iteration of low-band antenna gain and directivity, tower heights and location changes for repeaters through the prediction program produce an increasingly reliabile service area with a relatively small cost increase. An occasional high-band check during this upgrade process proved that the design was converging to a usable system in that band. While uhf prediction analyses were made simultaneous, it was apparent that the layout of the present system sites could not be used for a move to a uhf system. It is a natural consequence that the final system proposal would evolve through merging the low-band upgrade system with a time phased high-band installation as will be discussed in section 4.

3.3.2 Cost Effectiveness and Performance Index

After each system update analysis, computer contour maps of service probability were produced. From these the "dead zone" area in square miles (areas with less than 50-percent service probability) was measured through use of a planimeter. A cost figure was estimated for each update. These cost and dead zone areas were applied to a formula to obtain a performance index. The performance index Q, is a function which, when minimized, represents an optimum solution in terms of all the system variables.

Let Q = f (C,A) where C = cost of update and A = dead zone area, square miles. The function used for minimization found to be most meaningful is:

$$Q = \frac{C}{\left(\frac{A_o - A_1}{A_o}\right)^2}$$

where:

A_o = present system dead zone area

A_1 = updated system dead zone area

and $\frac{A_o - A_1}{A_o} = P_i$ (percent improvement).

Figure 3-4 shows the graphic results of the update sequence for the low-band system upgrade computed for mobile to base and base to mobile with a combined value for the system. The final dead zone area was as follows:

TYPE	D_Z AREA SQUARE MILES
I B-M	0
I M-B	690

During the final system configuration phase, the qualitative nature of design decisions was found to be more important than the specific performance index. Since a significant minimum Q was produced at the eighth low-band system update, it was believed that this represented the optimum system configuration on which to build the proposed high-band system. The criterion used in final system design was to assure meeting the communication channel requirements with a minimum of equipment and making allowance for later expansion.

During the phase-over process to high band from low band, it is recommended that a slightly less than optimum low-band system reliability be allowed. Common sense rules that rather than change over all the base station antennas, which would provide improved coverage at considerable effort and expense, there be allowed certain limited areas of marginal service probability (under 50 percent but above 30 percent).

3.3.3 System Upgrade -- Low Band

The upgraded low-band system uses all of the existing base stations of the present system. It was determined during the optimization process that it was not cost effective to eliminate or move any base stations. The rationale was the following: the cost of moving an unmanned repeater is much less than moving a base station. The optimization process proceeded from this point in a small change, step-by-step manner from the existing system configuration. The resulting service probability is shown in figures 3-5 and 3-6 for the upgraded low-band system. The Storm Lake region is shown as it will perform on high band.

This process produced a low-band system that resembles the present in terms of number of communication regions. The main features of the low-band upgrade, if implemented completely, are the following:

a. Base station power is reduced at those presently utilizing 3-kHz transmitter allowing for lower cost replacement transmitters when required.
b. Install gain antennas at all base stations to increase the effective radiated power (ERP), reduce susceptibility to precipitation static, and provide some directivity to increase station coverage in both base to mobile and mobile to base. See tables 3-2 and 3-3 for listing of recommended changes.

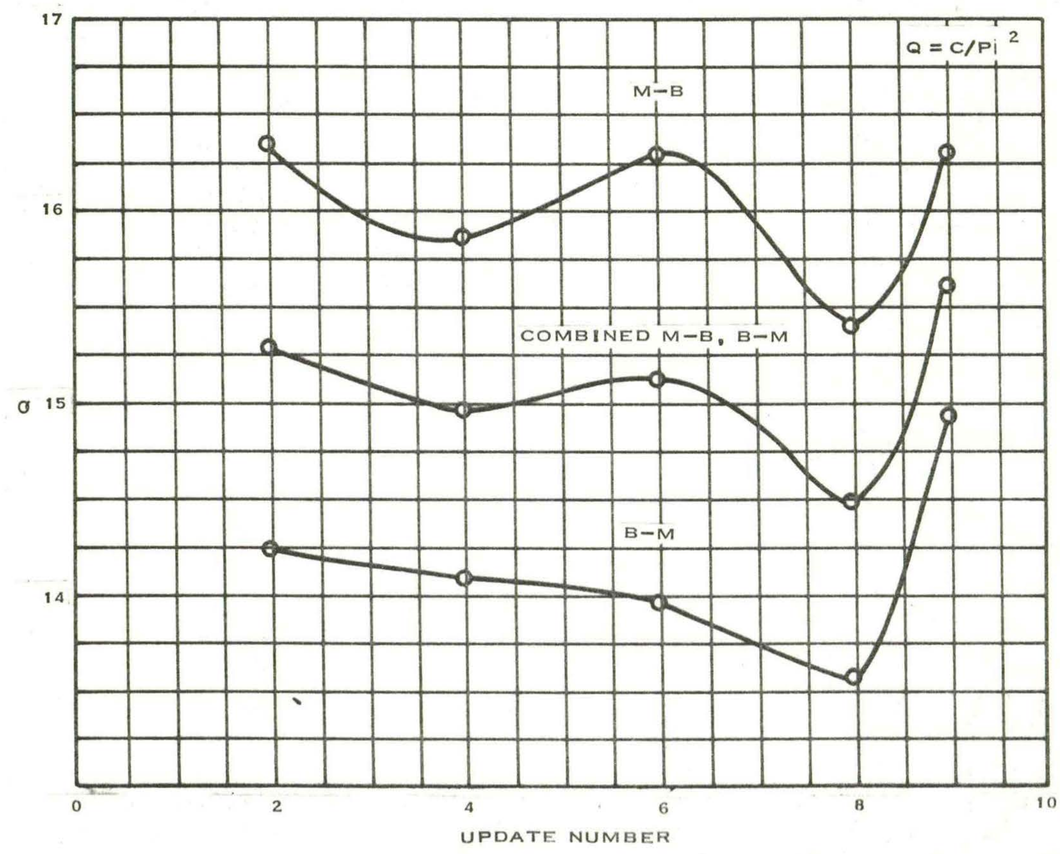

Figure 3-4. Cost Effectiveness Versus System Upgrade M-B, B-M, Combined.

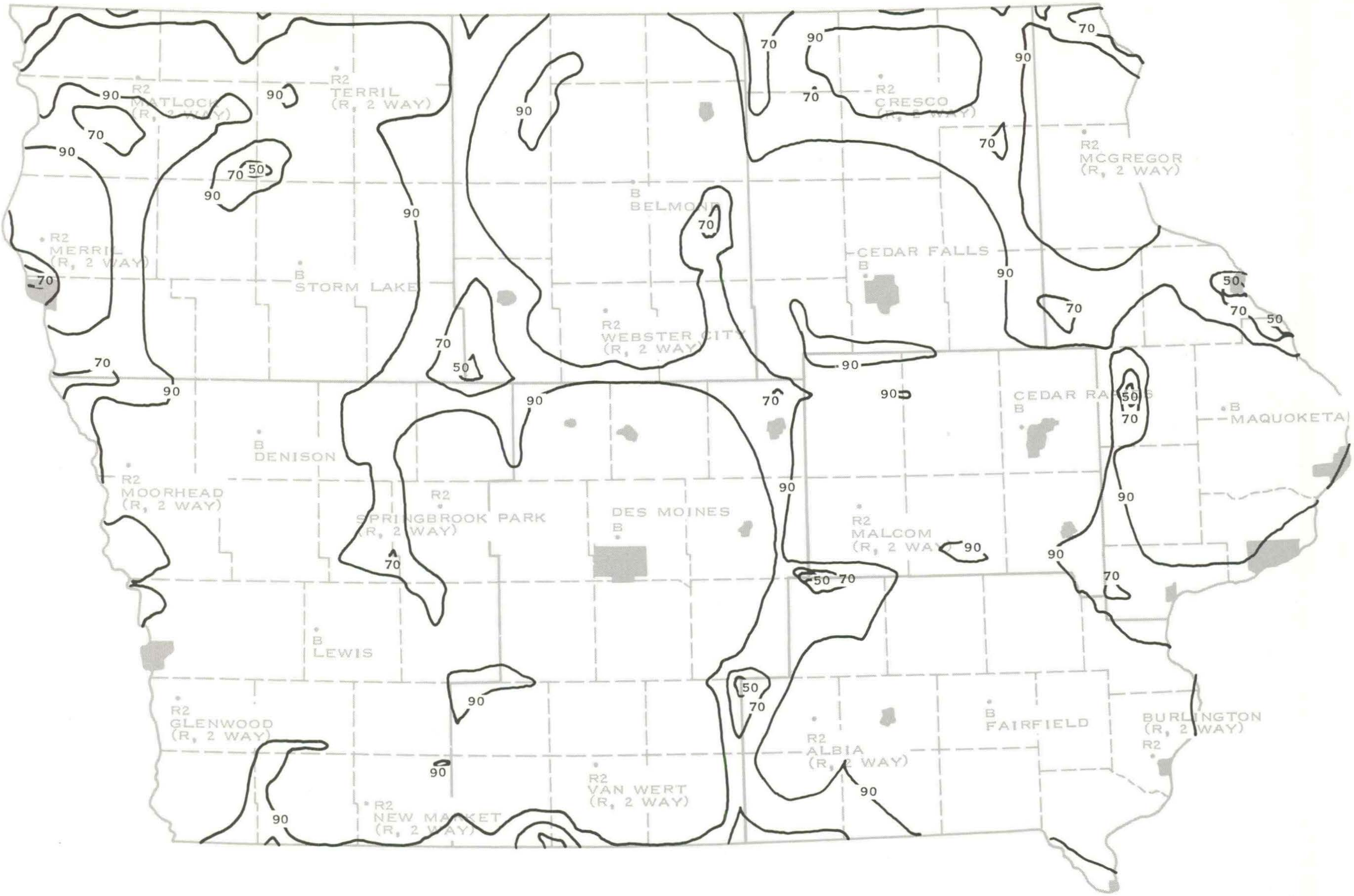

Figure 3-5. Type 1 Base-to-Mobile Service Probability Contours -- Upgraded Low-Band System.

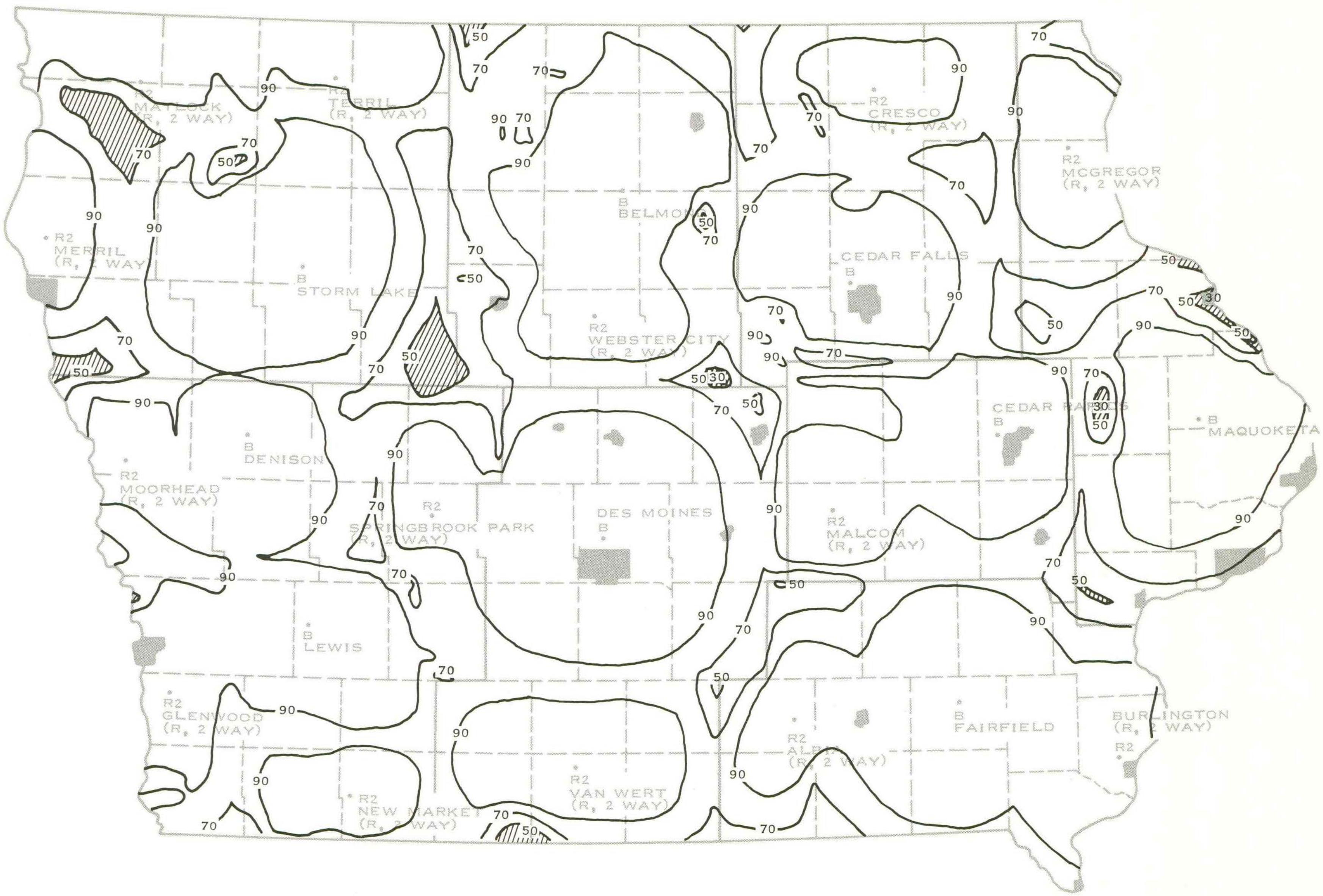

Figure 3-6. Type 1 Mobile-to-Base Service Probability Contours -- Upgraded Low-Band System.

Table 3-2. Summary - Base Stations Low-Band Upgrade.

LOCATION	PRESENT ANTENNA	NEW ANTENNA	ADDITIONAL CHANGES RECOMMENDED
Belmond	Andrew 900-SP	DB-212-3	Reduce power to 500 watts, install control consoles.
Cedar Falls	Andrew 900-SP	DB-212-3	Reduce power to 500 watts, install control consoles.
Cedar Rapids	Andrew 900-SP	DB-212-3	
Denison	Andrew 900-SP	DB-225-2	Install control consoles.
Des Moines	Andrew 900-SP	DB-212-3	Reduce power to 500 watts.
Fairfield	Andrew 900-SP	DB-212-3	Reduce power to 500 watts, install control consoles.
Lewis	Andrew 900-SP	DB-215	Reduce power to 500 watts.
Maquoketa	Andrew 900-SP	DB-215	Reduce power to 500 watts.
Storm Lake	Andrew 900-SP	DB-225	Reduce power to 500 watts, install new control consoles.
			Note: All receive phone patch equipment.

c. Generally increase the effectiveness of all repeaters by raising the antenna heights, using directional gain antennas and moving four of them to obtain better coverage. The Lake Park repeater is eliminated, placing two repeaters, one in the region near Terril and the other near Matlock. (See table 3-3.).

d. Implement a staggered 3-frequency plan, eliminating most of the interregion interference. Figure 3-1 is an identical plan for low-band and high-band.

e. Recommend new operator control consoles at those base stations that do not have new consoles. A feature recommended at all base stations is an audio patching capability for District Office command and control.

f. Use 4-frequency mobile radios permitting statewide use and eliminate the dual front-end option by dropping the requirements for monitoring 37.10 MHz.

g. Change the communication region boundary between Belmond and Cedar Falls to provide a communication region that utilizes the capabilities of both base stations more effectively.

Table 3-3. Summary, Repeater Changes, Low-Band Upgrade.

LOCATION	PRESENT ANTENNA	NEW ANTENNA	PRESENT TOWER HEIGHT AND TYPE	NEW TOWER HEIGHT AND TYPE	ADDITIONAL CHANGES
New Market	Coaxial	DB-214-2	50-ft pole	280-ft guyed	Two-way, 100 W
Glenwood	DB-214-2		120-ft ss	280-ft guyed	
McGregor	DB-214-2		120-ft ss	280-ft guyed	Moved 7 to 8 miles
Merrill	Omniunipole	DB-214-2	120-ft ss		
Lake Park	Pair of yagis		80-ft water tower		Eliminate -- use equip elsewhere
Terril		DB-214-2		120-ft ss	Installation and new equipment, 100 W
Matlock		DB-214-2		120-ft ss	Installation and new equipment, 100 W
Moorhead	Coaxial	DB-214-2	50-ft pole	120-ft ss	
Guthrie Center Springbrook	Coaxial	DB-214-2	80-ft ss	120-ft ss (Van Werts)	
Burlington	2 yagis		80-ft water tower	280-ft guyed	
Rathbun	Coaxial	DB-214-2	100-ft ss		Make 2-way, 100 W, move to near Albia
Malcom	Coaxial	DB 212	60 ft	120-ft ss	
Cresco	Coaxial	DB-214-2			Move, make 2-way, 100 W
Ft. Dodge	Coaxial	DB-214-2	100-ft (leave)	120-ft ss	Move to Webster City, make 2-way, 100 W
Van Wert	Coaxial	DB-214-2	120-ft ss	280-ft guyed	

Table 3-4 provides a summary of the low-band upgrade implementation costs.

Table 3-4. Cost Summary Low-Band Upgrade.

Site acquisitions	$ 6,600
Building and construction costs	199,117
Site equipment	29,800
Mobile radios for 4-frequency operation	753,000
Total	$988,517

3.3.4 System Upgrade--High Band

The same principles for low-band optimization apply to high band. While the propagation losses are higher at 155 MHz than at low band, this is mainly offset in the line-of-sight range by a lower external noise field and the availability of higher gain antennas. Thus, the site locations of the low-band optimum system is also that of the high-band optimum system. High-band system trial computer runs were made in the course of optimizing the low-band parameters. Several updates of the high-band system were made after the optimized low-band system completion. While the 90 and 70 percent service probability contours fall at about the same place for both high and low bands, the lower percentage contours have shrunk somewhat because a greater protection factor is used in high band near and beyond the line-of-sight distance. As a result of this, it was considered necessary to place an additional repeater just east of Muscatine.

Detailed propagation coverage is given in figures 3-7 and 3-8 for the high-band system.

Listing of site equipment specifications are included in section 5.

The state/region frequency staggering plan is shown in figure 3-1. This frequency plan requires three frequency pairs selected to provide full-duplex operation and a single frequency used statewide. It is important to obtain frequencies that do not produce intermodulation and interference products that preclude their use at the same base station. Some analysis is required to determine the compatibility of a given set of frequencies.

A note of caution is appropriate when considering the ultimate expandability of high band since the practical limit of simultaneously operated full-duplex circuits is two when used together with the point-to-point (155.37 MHz) and statewide frequencies.

The ability to find three available frequency pairs that will meet the spacing and the intermodulation criteria become inordinately difficult and require additional filtering, duplexers, and antennas. The cost summary for high-band implementation is shown in table 3-5.

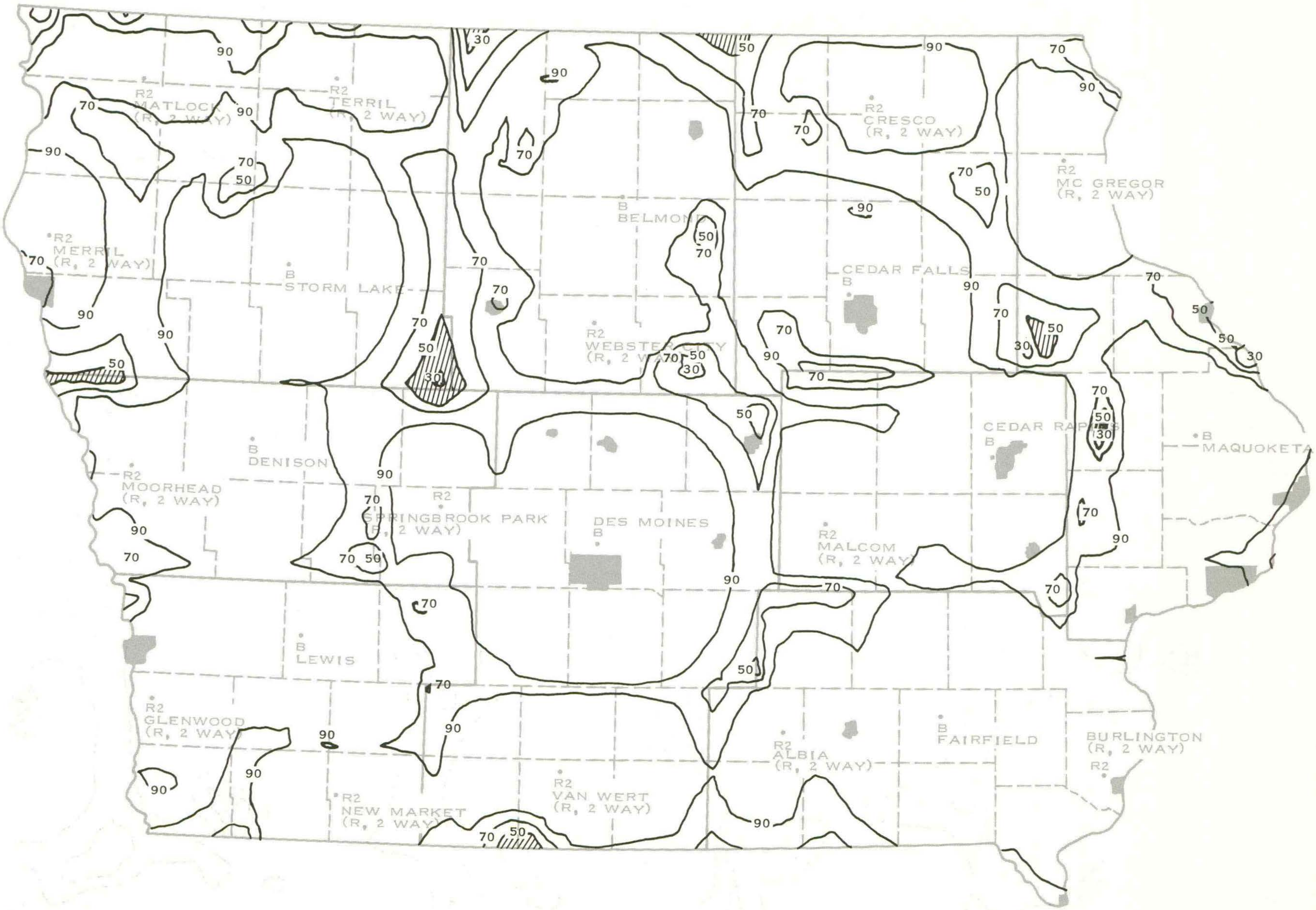

Figure 3-7. Proposed System Service Probability Mobile to Base, 155 MHz.

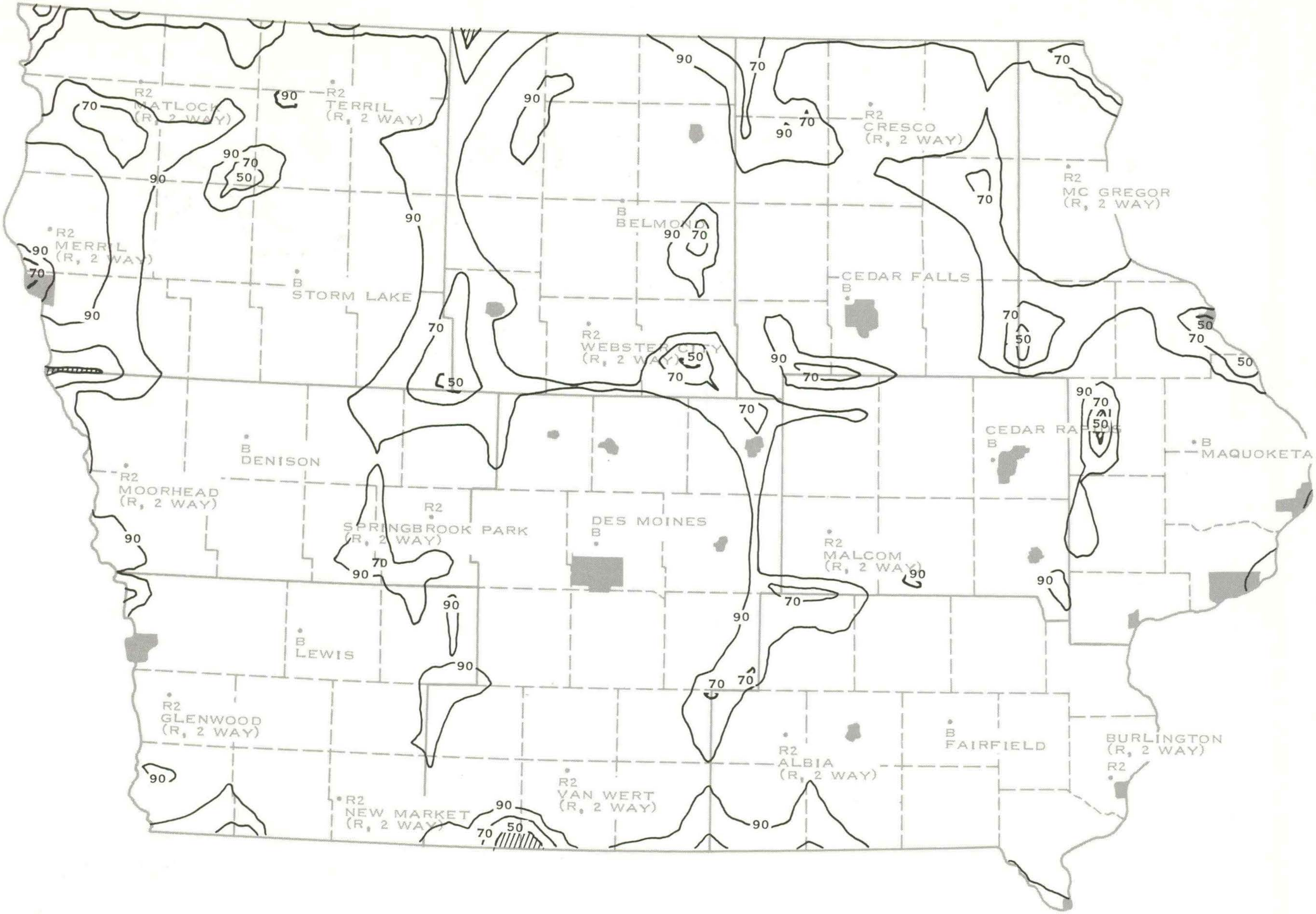

Figure 3-8. Proposed System Service Probability Base to Mobile, 155 MHz.

Table 3-5. High-Band Cost Summary (Assuming Low-Band Upgrade).

Site acquisition (Muscatine)	$ 11,200
Building and construction costs	$ 176,850
Site equipment (base/control/repeaters)	438,600
Mobile radios	757,500
Total	$1,384,150

3.3.5 System Recommendations -- UHF

The frequency selection process described in paragraph 3.2.3 provides a description of the uhf frequency band usage and design possibilities. There are several possibilities for future statewide usage of a uhf system. Primarily, there should be a periodic review of the state's future requirements for extra channels. When it appears that a third duplex channel will be required or if a statewide microwave communication network is probable, there should be a serious study made of the move to uhf. The cost figures indicate that unless these additional requirements exist, a move to uhf is not cost effective.

Figure 3-2 shows how a cellular frequency plan would be assigned to each of the present operating regions and figure 3-3 shows a typical grid layout of approximate propagation coverage. There is a direct dependence upon the microwave control link propagation path length for point-to-point coverage, which dictates repeater placement. The typical base station has essentially disappeared leaving possible a Regional Control Center from which the region operation is carried out.

An estimated cost summary is shown in table 3-6 for implementation of a uhf system.

Table 3-6. UHF Cost Summary.

Site acquisitions (54)	$ 37,800
Building and construction costs	$ 631,610
Site equipment	819,720
Mobile radios	1,200,000
Total	$2,689,130

The following paragraphs present a detailed description of the communication plan for the Iowa Police Radio system including performance expectation, implementation schedules, costs, future capabilities for expansion, and limitations. Briefly, the plan consists of concurrent limited low-band system upgrade and a high-band system conversion.

The communication plan begins by proposing modifications to the present low-band system that are intended to be carried over into the final high-band system. Since there will be a period of several years from the start of the system changeover to full high-band use, the low-band system is upgraded to a point where it can reliably support the TRACIS message response time and quantity. The plan provides for the immediate conversion of one communication region to high band during the first year of implementation. This approach allows the immediate operation on frequencies obtained for high-band use and specifies that the most expensive area in terms of low-band upgrade is to be converted directly to high band. A detailed description of the proposed system is contained in the paragraphs that follow.

4.1 DESCRIPTION OF PLAN

One of the guidelines used in influencing the low-band system upgrade was that major changes in base station and repeater sitings and tower heights should be made with the idea that they could be carried over to the final recommended system. The recommended high-band system uses each existing upgraded low-band facility without tower or siting change. The only addition to the station complement is a second repeater in one region.

The plan begins as early as fiscal year 1972 and is phased for timely completion and cost effective implementation.

One of the proposed first steps is to obtain seven interference free frequencies for high-band conversion, which permits the first year implementation of high band at Storm Lake. In parallel with the Storm Lake region conversion effort, the low-band upgrade of present facilities should proceed. Table 4-1 summarizes the proposed fiscal year 1972 system changes.

Table 4-1. System Changes FY-72 Proposed Per Operating Region -- Summary.

OPERATING REGION	CHANGE DESCRIPTION
Storm Lake -- Base	Replace low band with high band equipment and install 2 control consoles with audio patch capability.
Lake Park -- repeater	Remove entirely and deploy equipment elsewhere.
Merrill -- repeater	Replace low-band with high-band equipment. Use existing low repeater equipment at an upgraded repeater or at Maquoketa.
(Cont)	

Table 4-1. System Changes FY-72 Proposed Per Operating Region -- Summary (Cont).

OPERATING REGION	CHANGE DESCRIPTION
Storm Lake -- Base (Cont)	
Terril -- repeater	Provide site, buildings, tower (120 ft) and high band 2-way repeater and antenna.
Matlock -- repeater	Provide site, buildings, tower (120 ft) and high band 2-way repeater and antenna.
Control Links -- 960 MHz	Provide sites, buildings, towers, antennas and single-duplex channel 960-MHz control links between base and repeater stations.
Mobile radios	Provide high-band mobile units -- 45 estimated.
Belmond -- Base	Replace present antenna with directional antenna, reduce power, change operating frequency, and provide audio patch capability.
Fort Dodge -- repeater	Move to near Webster City, make 2-way; provide site, buildings, 120-foot tower, and new directional antenna.
Mobile radios	Purchase and install four frequency mobile radios -- estimate 52 required.
Cedar Falls -- Base	Purchase and install audio patch capability.
Cresco -- repeater	Move to site south of present, make 2-way procure site, construct building and tower base, install equipment and new directional gain antenna.
Mobile radios	No change.
Cedar Rapids -- Base	Change operating frequencies and provide audio patch capability.
Malcom -- repeater	Change to 120-ft tower, add new directional gain antenna, change frequency.
Mobile radios	Purchase and install four frequency radios sufficient for 50 mobile units.

Table 4-1. System Changes FY-72 Proposed Per Operating Region -- Summary (Cont).

OPERATING REGION	CHANGE DESCRIPTION
Denison -- Base	Replace antenna with directional gain, change operating frequency, and provide audio patch capability.
Moorhead -- repeater	Change to 120-ft tower, add new directional gain antenna and change frequencies.
Springbrook Park -- repeater	Change to 120-ft tower, add new directional gain antenna and change frequencies.
Mobile radios	Purchase and install four frequency radios sufficient for 36 mobile units.
Fairfield -- Base	Purchase and install audio patch capability.
Rathbun -- repeater	Relocate to near Albia, procure site, construct building, mount tower, make 2-way and change to directional gain antenna.
Burlington -- repeater	Construct 280-ft tower on expanded site, and remount yagi antennas.
Mobile radios	No change.
Maquoketa -- Base	Reduce transmitter power, change to directional gain antenna, and provide audio patch capability.
McGregor -- repeater	Relocate near Watson, procure site, construct building, mount 280-ft tower and mount new directional gain antenna.
Mobile radios	No change.
Lewis -- Base	Purchase and install audio patch capability.
Glenwood -- repeater	Procure additional site area for erecting new 280-ft tower.
New Market -- repeater	Procure additional site area, erect 280-ft tower, make 2-way, and provide new directional gain antenna.
Mobile radios	No change.

Table 4-1. System Changes FY-72 Proposed Per Operating Region -- Summary (Cont).

OPERATING REGION	CHANGE DESCRIPTION
Des Moines -- Base	Purchase and install audio patch capability.
Van Wert -- repeater	Procure additional site area, erect 280 ft tower and provide new directional gain antenna.
Mobile radios	No change.

4.1.1 Frequency Plan

A staggered frequency plan is recommended for use in the high-band system. The plan requires three frequency pairs staggered throughout the State as shown in figure 3-1, where F1, F2, and F3 indicate a frequency pair. In addition, a single statewide frequency is required. The plan satisfies the system recommendations of paragraph 3.1.1

Since the communication plan calls for immediate implementation of high band, a modified frequency plan for the low-band upgrade is proposed in the interest of economy. Both plans are discussed below.

4.1.1.1 Low-Band Frequency Assignments

In order to provide relief to those regions in which the adjacent region interference is most severe, the following operational frequencies are recommended:

a. Assign a new operating frequency pair (from those already licensed in the State of Iowa) to the Cedar Rapids, Belmond, and Denison communication regions (for example, 42.40 and 42.24 MHz).
b. The remaining communication regions are to remain on the existing frequency pair (42.58 and 42.74 MHz).
c. Mobile units in the Cedar Rapids, Belmond, and Denison regions are to be equipped with four frequency radios having the following frequency arrangements:

MOBILE UNIT	TX	RX
F1	42.24	42.40
F2	42.40	42.40
F3	42.74	42.58
F4	42.58	42.58

The capability to monitor 37.10 MHz should not be provided in these mobile units. This will permit an assessment of the impact of not monitoring this frequency in any mobile unit once the high-band system is fully deployed, and will permit alternate operating procedures to be tried in order to fill the gap left by abandoning it.

4.1.1.2 High-Band Frequency Assignments

The proposed high-band system will operate with three primary frequency pairs staggered throughout the state to provide interregion isolation. The primary pair assigned to each region will operate in much the same manner as the present low-band frequency pair. Additional capabilities will be available that are not present in low band however. The frequencies will be chosen to permit full-duplex operation at the base and repeater stations. Full-duplex operation increases a single-channel message carrying capability due to the fact that the base station can receive a call from a mobile unit while talking to another.

With this capability the base station and the repeater station will be able to function as mobile relay stations under the control of the base station operators.

A fourth frequency will be assigned to all base stations and mobile units and used in a single-frequency simplex manner on a state-wide basis. The purpose and capabilities of this single frequency assignment are the following:

a. To provide a short range mobile-to-mobile communication channel
b. To provide an aircraft to mobile unit frequency that will not interfere with any of the primary communication channels of the several regions
c. To provide a limited but useful overload channel to the base stations that can be used during peak message load hours when required.

Each mobile unit will be capable of operating in any communication region with these four frequencies provided in his mobile unit.

The base stations will continue to use 155.370 MHz as a point-to-point frequency. 155.370 MHz is presently used in a single frequency simplex mode and its use in the high-band system will be the same. It is expected that the use of the 155.37-MHz point-to-point frequency will be reduced by the addition of TRACIS terminals in many of Iowa's cities and counties.

The control link frequencies will be pair selected in the 952- to 960-MHz range. This will free up the present control link frequencies used in the low-band system. These control link frequencies are not suitable for use in the high-band system as primary region frequencies because they are too closely spaced and are adjacent to the 155.37-MHz point-to-point frequency. Frequency selection is discussed in the following paragraph.

4.1.1.3 High-Band Frequency Selection

To implement the proposed high-band system, seven frequencies in the 154.650- to 159.210-MHz range are required, besides the present 155.37-MHz simplex frequency. One frequency pair with full duplex capability separated sufficiently from 155.37 MHz is required and one additional single frequency simplex channel is required. The frequency band from 154.650 to 159.210 is too narrow to permit simultaneous transmission and reception on all the required frequencies so some compromise is in order. The problems of frequency selection are primarily due to the requirement to operate two simplex frequencies (155.37 MHz and statewide frequency) together with the regional primary frequency pair and the selection of suitable primary channel frequencies for use in Iowa. Some frequencies may be available for use by IPR from other public safety services such as Local Government Service. The following guidelines for frequency selection are proposed:

a. Select the statewide frequency (F4), from one of the present control link frequencies (for example, 155.460 MHz) near 155.370 MHz. It is important that the statewide frequency be selected near 155.37 MHz. However, during the transition from low band to high band the use of one of the present control link frequencies may not be practical due to the interference caused.

b. Select the primary channel base station transmit frequency in each region (total of 3 required for the state) from the frequencies in the range from 154.650 to 154.860 MHz. The highest frequency in this range is 500 kHz below 155.370 and 155.460 MHz and will permit reception on these frequencies while the primary channel is transmitting. Candidate frequencies in this range include 154.665, 155.770, 154.800, 154.815, and 154.845 MHz. These frequencies appear to be noninterfering and available for use in Iowa from a check of frequencies used within the state and neighboring states.

c. Select the primary channel base station receive frequency in each region (total of 3 required for state) from the frequencies in the range from 156.000 to 159.210 MHz. The lowest frequency in this range is 500 kHz above 155.460 MHz and will permit reception on the primary receive channels while transmitting on the 155.370-MHz point to point, or on the statewide simplex frequency. Candidate frequencies from this range include 156.030, 156.090, 156.150, 158.970, 159.090, and 159.210 MHz.

d. Additional frequency selections for future expansion are to be made so that the primary and secondary base station transmit frequencies are grouped together in the lower part of the band and the receive frequencies are grouped together in the upper part of the band permitting full duplex operation on both frequencies (figure 4-1). When a final list of candidate frequencies has been chosen, and tentative assignments have been made, an analysis of the intermodulation products ("rusty bolt" effect), and mixer action products needs to be performed so that undesired combinations of frequencies can be avoided.

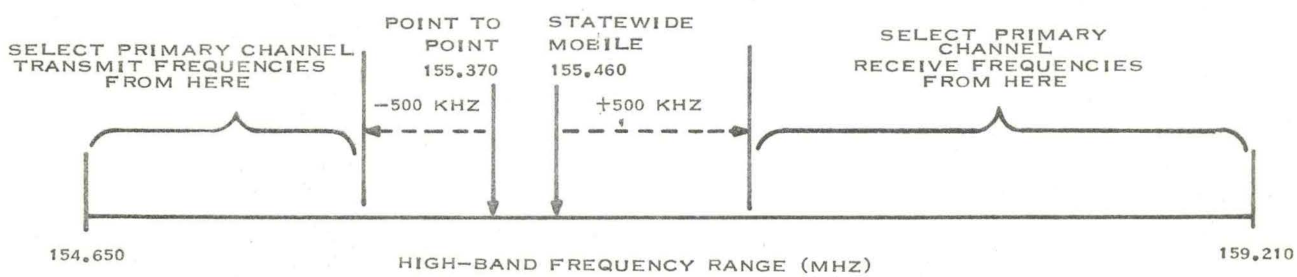

Figure 4-1. High-Band Frequency Selection.

It should be noted that if the proposed frequency selection plan is not followed, the expandability of the system is compromised.

Table 4-2 compares the base station transmit and receive capability of the present system to the proposed system.

Figure 4-1 depicts the areas of the frequency band in which the frequencies should be selected.

4.1.2 Proposed Low-Band Upgrade

The proposed low-band system upgrade, summarized in table 4-1, is to be completed during the first fiscal year of the implementation schedule. The proposed upgrade is a compromise of the optimum low-band system upgrade primarily due to economic factors and the proposed

Table 4-2. Comparison of Present and Proposed Systems.

PRESENT				PROPOSED				
IF TRANS-MITTING ON	CAN RECEIVE ON			IF TRANS-MITTING ON	CAN RECEIVE ON			
	MAIN LOW BAND	155.37	REPEATER CONTROL LINK		PRIM-ARY	STATE-WIDE	155.37	ALL REPEATERS
Main low band	No	Yes	Yes	Primary	Yes	Yes	Yes	Yes
				Statewide (155.460)	Yes	No	No	Yes
				155.37	Yes	No	No	Yes
155.37	Yes	No	No	Any repeater control	Yes	Yes	Yes	Yes
Any repeater control link	Yes	No	No					
Main and 155.XXX	No	No	No					

high-band implementation. Some changes to optimize the low-band system are therefore waived as unnecessary and uneconomical in view of the short time they will be used. The recommendations that have been proposed are in keeping with the decision to provide a responsive radio system at low band until the high-band system is fully in use.

4.1.2.1 Base Station Changes

The optimum low-band system, described in paragraph 3.3.3, called for reduced power at all base stations presently using 3-kW transmitters and the installation of gain antennas at all base stations.

The reasons for this were to permit the purchase of lower cost replacement base station transmitters and to obtain antenna directivity into the areas of poor coverage and to reduce radiation in other directions. Additionally, the change in antennas would reduce to some degree the susceptibility to precipitation static.

The proposed base station changes as specified in the detailed specifications of section 5, consist of changing only the antennas at Denison, Belmond, and Maquoketa, reducing the transmit power to 500 watts only at Belmond and Maquoketa, and installing an audio (phone) patching capability at all base stations. The antenna changes at the above stations should be done without relocating the existing 155.370-MHz point-to-point antennas. It may require collocating the two antennas on part of the tower.

4.1.2.2 Repeater Station Changes

The proposed changes at the repeaters correspond to the optimum low-band system upgrade specifications discussed in paragraph 3.3.3 and detailed in section 5. All existing 1-way repeaters are made 2-way repeaters. All but two (Rathbun, Cresco) repeater tower heights are increased, 4 repeaters are moved (McGregor, Ft. Dodge, Cresco, and Rathbun) and all but three (Glenwood, McGregor, and Burlington) require new antennas.

Tower sites must be selected so that the antenna effective height is not reduced. New site locations correspond to areas where a prominent location can be found. Any deviation of more than 3 or 4 miles in the placement of a repeater site, or changes in equipment and antenna parameters, will cause the coverage reliability to change.

The feedlines selected for the low-band upgrade have been chosen based on future use in the high-band system.

4.1.2.3 Region Boundaries

The region boundaries in the proposed system have remained essentially the same as the present system. Two additional counties have been assigned to the Belmond communication region (Franklin and Hardin) taking them from the Cedar Falls region.

It is recommended that consideration be given to realigning district boundaries to coincide with the communication region boundaries around the State. Elimination and consolidation of some district commands may be in order when aligning with communication regions, particularly in the northern part of the state. Effective communications will be enhanced if a more centralized IHP command is provided with which the radio stations cooperate.

4.1.3 High-Band System

The high-band system proposed is designed to meet the requirements set forth in paragraph 3.1, and is a cost effective approach. The system can be installed on the same sites that are utilized for the upgraded low-band system with a minimum of added facilities. The time-phased installation into the operating region is scheduled to match a reasonable budgetary cycle and the system should be implemented to a point of complete operation by the time TRACIS has reached operational message loads.

The high-band system is designed so that expansion to add additional channels can be accomplished at any time found desirable and on a regional basis. Equipment is specified that can be updated and expanded without discarding major terminal or mobile components.

The system is predicated on the assumption that a sufficient set of noninterfering frequencies can be allocated for the State. While this cannot be assured in the present study, examination of adjoining state usage and in-state usage provides a reasonable probability that this is the case.

4.1.3.1 High-Band Capabilities.

The capabilities of the high-band system as it is initially implemented are depicted in figure 4-2. These capabilities are summarized below:

a. Primary base-to-mobile and mobile-to-base communication on two frequency semifull duplex channel (F1). (Base station can operate full duplex but mobile units cannot.) Example: Car D to base station.
b. Same as a above through a repeater (remote base station) control link to base station, car A to repeater to base.
c. Close range car-to-car communications on statewide single-frequency simplex operated channel (F4).
d. Aircraft-to-car or base station on F4.
e. Mobile relay enabled by base station operator for long distance car to car communications on F1 through either repeater or base station, car A to car B.
f. Base-to-mobile and mobile-to-base on single frequency channel F4.
g. Audio patching capability in base station permitting car A to communicate with car E with operator controlled switch. Other combinations such as landline, and point-to-point radio to mobile can also be patched when desired.
h. Provision for continued use of 155.37-MHz equipment for point-to-point communication.

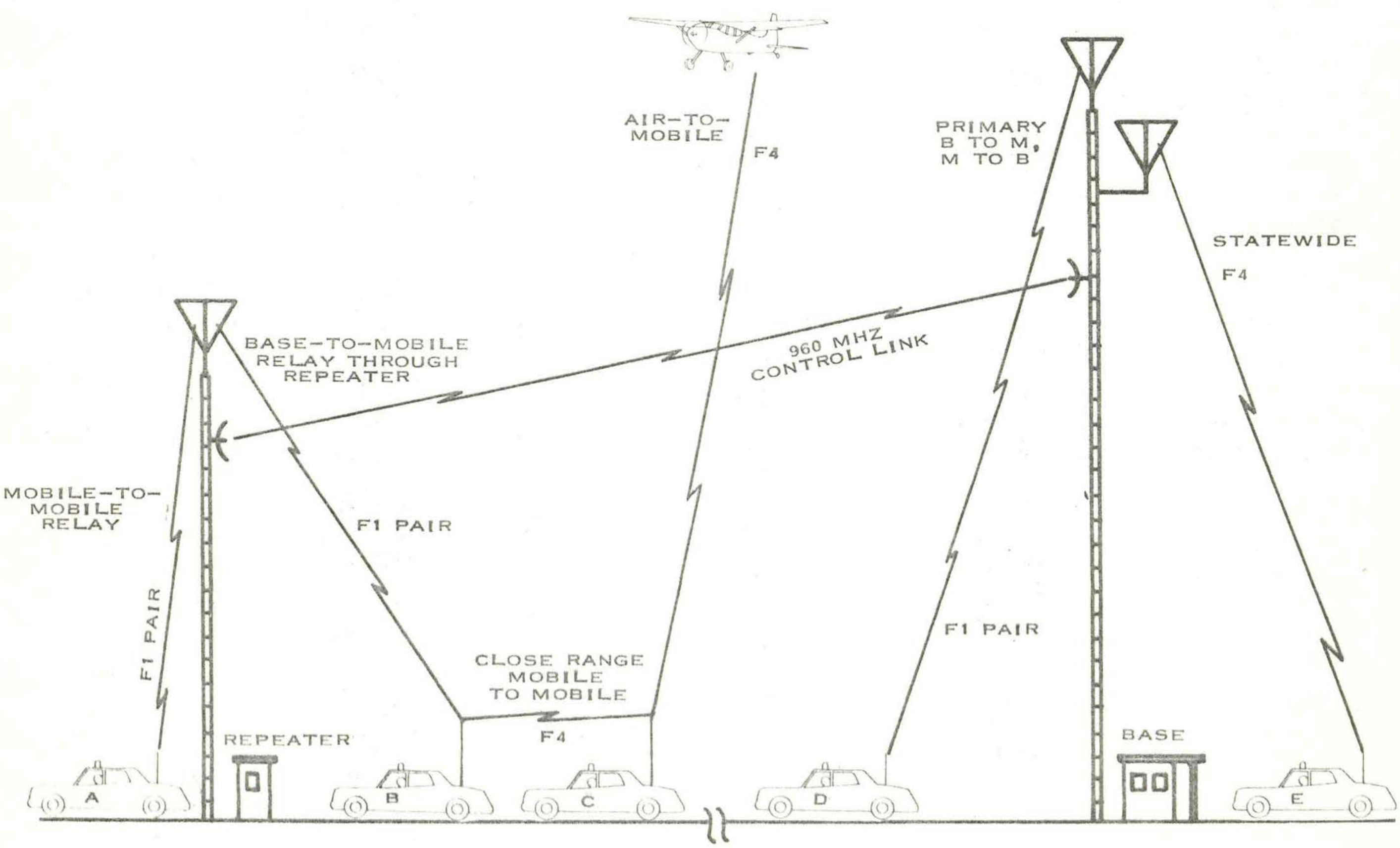

Figure 4-2. Regional Communication Capability.

4.1.3.2 Equipment Complement

The high-band equipment specifications are presented in section 5 in which the details of each station (base, repeaters, and control links) are included. The paragraphs below will present the general equipment configuration at each type of station.

It is recommended that all radio equipment be equipped with the tone squelch options that are available.

4.1.3.2.1 Base Stations

The base station equipment complements for high-band implementation are shown in figure 4-3. The primary channel transmitter/receiver is a base station and repeater unit with minimum output power of 300 watts. It is connected through a duplexer to a top mounted antenna. A second base station, with a 300-watt output capability, is used on the statewide frequency (F4) and on the 155.37-MHz point-to-point frequency. This second station is a two frequency transmit and receive radio with separate audio lines from the receiver. The existing 155.37-MHz radio is used for backup for the new point-to-point radio. If the primary transmitter is disabled, the statewide frequency channel can be used on an emergency basis until the primary transmitter is repaired. Reasonable spares should be retained at central locations to limit downtime on the primary channel.

A new antenna is required for the primary channel frequency. The gain and directivity is specified in section 5. The existing feedline from the low-band system is used for this antenna. The existing point-to-point antenna and feedline are used for the statewide frequency and 155.37 MHz.

The control link radios operate in the 960-MHz band providing full duplex control links to the remote base/repeater stations. Four-foot diameter antennas are required for the control links. One 960-MHz base station full-duplex channel is required for each repeater to be controlled from the region base station.

4.1.3.2.2 Repeater Station

The repeater includes a single 100-watt full duplex base station radio operating on the regional primary frequency pair. A 960-MHz radio is required to transmit and receive over the control links. The primary high-band antenna and the 960-MHz dish are the only antennas installed initially at the remote stations. New feedlines installed during the low-band upgrade are generally used for the high-band system.

The capabilities of the repeater are similar to the base station on the primary channel, providing full-duplex transmission and reception and providing a mobile relay capability. The mobile relay capability is enabled by the base station operator. It is recommended that this feature be enabled only upon request.

When a repeater serves a highly populated area, provisions should be made to provide the statewide frequency capability at the repeater station at a later date. This will require a control link capable of multiple channels.

4.1.3.2.3 Control Links

The control links between the base stations and the remote base/repeater stations will operate in the 960-MHz frequency band. The initial installation requires a single-channel full-duplex control link. Some of the control links will require repeaters because of their length.

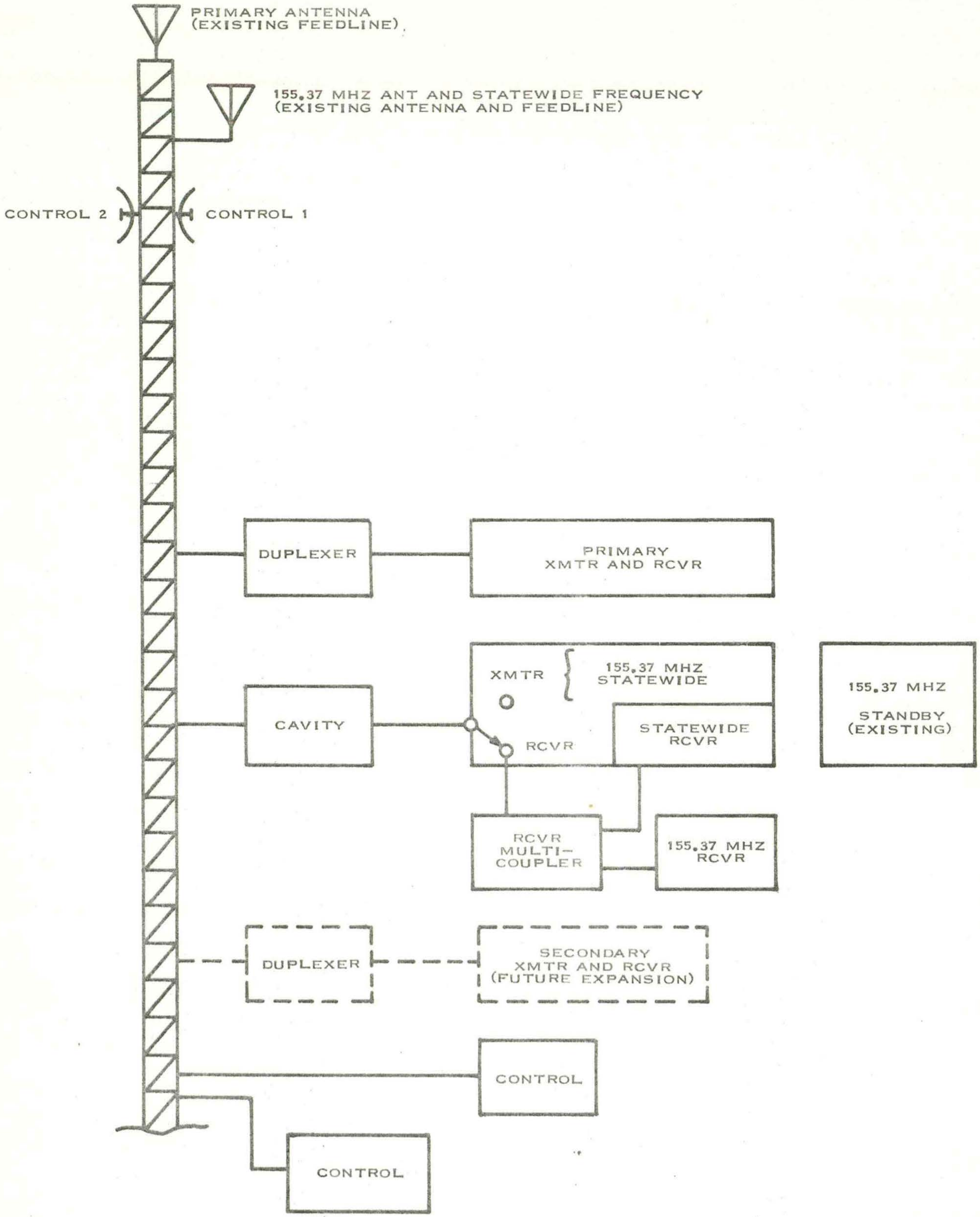

Figure 4-3. Typical High-Band Base Station Complement.

In areas where the primary message load originates or is destined to the vicinity of a repeater, the original control link radios should be capable of expansion to carry more than one channel although only one channel will be installed initially for economic reasons. This will permit the statewide frequency to be added at a later date. A second region frequency at a repeater can also be added whenever the message load demands.

4.1.3.2.4 Mobiles

The mobile unit radio recommended should provide the following capabilities:

a. Power output -- 100 watts
b. Four frequency transmit and receive
c. Wide spaced transmit option
d. Tone coded squelch option
e. Provide for conversion to frequency scanning capability with priority selection

Mobile antennas recommended are those which provide 2.5 dB gain.

4.2 PERFORMANCE OF HIGH-BAND SYSTEM

During the low-band upgrade propagation analysis, which went through several iterations of system siting changes and tower height changes, etc, high-band propagation analysis runs were periodically prepared using typical high-band equipment parameters on the low-band base and repeater station sites. The similarity was great between low-band and high-band in statewide coverage. Basically, the higher gain antennas at both the base station and on the mobile units (as well as a reduction in the noise level), compensated for the increased propagation loss at the higher frequency. Since the propagation coverage from a service probability standpoint was almost identical, the most cost effective move to high band was to use the existing low-band investment as much as possible. When the final decision was made to go to a high-band system, more propagation runs were made in an attempt to provide a minimum of "dead zone" square miles. One of the results of this optimization process was to locate a repeater near Muscatine to provide reliable coverage to the southern end of the Maquoketa region which includes the Quad-cities area. Other changes included directional antennas, lower loss feedlines, and power adjustments. No other site changes were made for the final high-band system. Figures 3-7 and 3-8 show the resultant high-band mobile-to-base and base-to-mobile system coverage in terms of service probability.

The proposed system includes 960-MHz full-duplex links to control repeater stations. These control links should be capable of carrying several multiplexed voice channels to allow for future system growth. The control link parameters recommended in section 5 include 5-watt radios and 4-foot diameter parabolic dishes. The control link antennas are generally mounted between 40 and 80 feet below the tops of repeater and base station towers, to permit clearance with existing or future side-mounted antennas. The control link parameters have been selected to provide toll quality for up to 6 voice channels. In several cases, control link repeaters are added to ensure that control links are never a limiting factor in overall system performance.

4.3 IMPLEMENTATION SCHEDULE

The implementation schedule of the proposed communication plan is predicated on a funding level estimated to be available from the State of Iowa and matching Federal grants. The proposed schedule was prepared to minimize the problems of transition to the high-band system.

As previously mentioned, the first year of the schedule plans for both a low-band upgrade and the initial change to high band at the Storm Lake region. It is estimated that this work can be completed during fiscal year 1972. Table 4-3 shows the fiscal year implementation schedule and the attendant costs in terms of State and Federal funds for the entire plan.

Tables 4-4 through 4-12 show the detailed cost for the low-band system upgrade. Tables 4-13 through 4-21 show the detailed costs for conversion of each communication region to high band once the low-band upgrade is accomplished. Table 4-22 shows a summary of the cost allocations for the combined low-band upgrade and high-band system conversion.

4.4 EXPANDABILITY OF SYSTEM

The expansion of the high-band system capabilities can provide Iowa with a police radio network that will be adequate for many years. The initial system provides one full duplex channel in each region, allowing the base station operators to receive a call from one unit while talking to another. It is wholly feasible to add a second full duplex channel in each region. The second primary frequency will be required to handle future increases in voice and data message traffic.

Mobile units can be equipped to operate full duplex for special applications; however, statewide use of mobile full duplex operation is not recommended because of the size and added expense of the duplexers required.

4.5 LIMITATIONS OF SYSTEM

A high-band system is not without certain limitations that should be mentioned here. The frequency range assigned to high band is heavily used and future expansion depends on the number of frequencies that can be obtained that are interference free. Even with unlimited frequencies available, there are limitations in the number of full duplex channels that can be operated from a given base station because of the "rusty bolt" effects (intermodulation products) that are produced. The practical limit may be two or three such channels.

Table 4-3. Total Implementation Plan and Cost.

SCHEDULE	STATE	FEDERAL
FY-72		
Low-band upgrade All stations (except Storm Lake low-band equipment)	$ 83,725	$ 146,825
Storm Lake (high-band equipment)	59,015	131,315
	$142,740	$ 278,140
FY-73		
Des Moines	56,340	155,220
Cedar Falls	42,715	95,845
Maquoketa	49,815	126,925
Lewis	37,180	98,480
	$186,050	$ 476,470
FY-74		
Belmond	37,305	87,545
Fairfield	52,770	119,380
Cedar Rapids	32,340	86,220
Denison	42,125	92,375
	$164,540	385,520
Totals	$493,330	$1,140,130
Grand Total	$1,633,460	

Table 4-4. Low-Band Costs.

BELMOND REGION	COST	
	RF (Electronics)	Construction
Belmond Base		
Audio patching capability	$ 500	$
Antenna		290
Installation		150
Repeater (Blairsburg)		
New radio equipment (repeater and base)	4,300	
Tower (new)		3,600
Antenna		435
Cable		200
Land and site preparation		700
Building		1,700
Labor (move and install)		850
Mobile Units		
40 radios	56,000	
Totals	$60,800	$7,925

Table 4-5. Low-Band Costs.

CEDAR FALLS REGION	COSTS	
	RF (Electronics)	Construction
Cedar Falls Base		
Audio patching capability	$ 500	$
Repeater (Lourdes)		
Radio equipment (repeater and base)	4,300	
Tower		3,600
Antenna		435
Cable		200
Land		700
Building		1,700
Labor		850
Totals	$4,800	$7,485

Table 4-6. Low-Band Costs

CEDAR RAPIDS REGION	COSTS	
	RF (Electronics)	Construction
Cedar Rapids Base		
Audio patching capability	$ 500	$
Repeater (Malcom)		
Tower (moved for other location)		2,150
Antenna		192
Cable		200
Labor		500
Mobile Units		
11 radios (assumed balance required can come from Des Moines)	15,400	
Totals	$15,900	$3,042

Table 4-7. Low-Band Costs.

DENISON REGION	COSTS	
	RF (Electronics)	Construction
Denison Base		
Audio patching capability	$ 500	$
Antenna		155
Installation		150
Repeaters (Moorhead, Guthrie Center)		
2 towers (moved from other locations)		4,300
2 antennas		870
Cable		400
Labor		1,050
Mobile Units		
24 radios	33,600	
Totals	$34,100	$6,925

Table 4-8. Low-Band Costs.

DES MOINES REGION	COSTS	
	RF (Electronics)	Construction
Des Moines Base		
Audio patching capability	$500	$
Repeater (Van Wert)		
Tower		8,400
Antenna		435
Cable		830
Land		600
Labor		1,000
Totals	$500	$11,265

Table 4-9. Low-Band Costs.

FAIRFIELD REGION	COSTS	
	RF (Electronics)	Construction
Fairfield Base		
Audio patching capability	$ 500	$
Repeaters (Burlington, Albia)		
New radio equipment (Albia repeater and base)	4,300	
2 towers		12,000
1 antenna		435
Cable		1,000
Land		700
1 building		1,700
Miscellaneous labor		1,525
Totals	$4,800	$17,360

Table 4-10. Low-Band Costs.

LEWIS REGION	COSTS	
	RF (Electronics)	Construction
Lewis Base		
Audio patch capability	$ 500	$
Repeaters (New Market, Glenwood)		
*2 towers		16,800
1 antenna (New Market)		435
Cable		1,660
Rf equipment (New Market)	4,300	
Land		1,200
Labor (installation of equipment antenna)		2,100
Totals	$4,800	$22,195

*All tower costs include construction and installation.

Table 4-11. Low-Band Costs.

MAQUOKETA REGION	COSTS	
	RF (Electronics)	Construction
Maquoketa Base		
Audio patching capability	$500	$
Antenna		570
Installation		150
Repeater (Watson)		
Tower		8,400
Land		1,000
Cable		830
Building		1,700
Labor		2,500
Totals	$500	$15,150

Table 4-12. Low-Band Costs.

STORM LAKE REGION (FOR RADIO EQUIPMENT SEE HIGH BAND COSTS)	COSTS	
	RF (Electronics)	Construction
Storm Lake Base		$
No change		
Repeaters (Merrill, Terril, Matlock, Lake Park		
No change (Merrill)		
Disassemble (Lake Park)		500
*2 towers		7,300
Cable		400
2 land acquisition and site preparation		1,400
2 buildings		3,400
Totals		$13,000

*All tower costs include construction and installation.

Table 4-13. High-Band Costs.

BELMOND REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Belmond Base		
2 high-band radios	$ 6,800	$
Receivers (spare)	2,000	
Antenna and cable		300
Duplexers and cavity		1,235
Consoles (2)		20,000
Installation		1,140
Repeater (Blairsburg)		
1 radio	3,400	
Antenna		265
Installation		400
Totals	$ 12,200	$23,340
Control Link		
*2 channel units	10,280	
Installation		1,030
Totals	$ 10,280	$ 1,030
Mobiles		
52	78,000	
Totals	$100,480	$24,370

*Includes antenna and feedline.

Table 4-14. High-Band Costs.

CEDAR FALLS REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Cedar Falls Base		
2 high-band radios	$ 6,800	$
Receivers	2,000	
Antenna and cable		300
Console (2)		20,000
Duplexer and cavity		1,235
Installation		1,140
Lourdes Repeater		
1 radio	3,400	
Antenna		265
Installation		400
Totals	$ 12,200	$23,340
Control Link		
4 channel units	20,560	
1 tower		4,500
1 building		1,700
1 land acquisition		700
1 installation		2,060
Totals	$ 20,560	$ 8,960
Mobiles		
49	73,500	
Totals	$106,260	$32,300

Table 4-15. High-Band Costs.

CEDAR RAPIDS REGION		EQUIPMENT COSTS	
		RF (Electronics)	Construction
Cedar Rapids Base			
2 high-band radios		$ 6,800	$
Receivers		2,000	
Antenna and cable			300
Duplexer and cavity			1,235
Installation			1,140
Malcom Repeater			
1 radio		3,400	
Antenna			265
Installation			400
	Totals	$ 12,200	$ 3,340
Control Link			
4 channel units		20,560	
1 tower			3,000
1 building			1,700
Land acquisition			700
Installation			2,060
	Totals	20,560	$ 7,460
Mobiles			
50		75,000	
	Totals	$107,760	$10,800

Table 4-16. High-Band Costs.

DENISON REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Denison Base		
2 high-band radios	$ 6,800	$
Receivers	2,000	
Antennas		300
Consoles		20,000
Duplexer and cavity		1,235
Installation		1,140
Moorehead Repeater		
1 radio	3,400	
Antenna		265
Installation		400
Springbrook (Guthrie Center) Repeater		
1 radio	3,400	
Antenna		265
Installation		400
Totals	$ 15,600	$24,005
Control		
6 channel units	$ 30,900	
1 tower		4,500
Installation		3,090
Buildings		1,700
Land acquisition		700
Totals	$ 30,900	$ 9,990
Mobiles		
36	54,000	
Totals	$100,500	$33,995

Table 4-17. High-Band Costs.

DES MOINES REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Des Moines Base		
2 high-band radios	$ 6,800	$
Receivers	2,000	
Antennas and cable		300
Duplexer and cavity		1,235
Installation		1,140
Van Wert Repeater		
Radio	3,400	
Antenna		265
Installation		400
Totals	$ 12,200	$ 3,340
Control		
4 channel units	20,560	
1 tower		6,000
Installation		2,060
Land acquisition		700
Building		1,700
Totals	$ 20,560	$10,460
Mobiles		
110	165,000	
Totals	$197,760	$13,800

Table 4-18. High-Band Costs.

FAIRFIELD REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Fairfield Base		
2 high-band radios	$ 6,800	$
Receivers	2,000	
Antenna and cables		300
Consoles (2)		20,000
Duplexer and cavity		1,235
Installation		1,140
Albia Repeater		
1 radio	3,400	
Antenna		265
Installation		400
Burlington Repeater		
1 radio	3,400	
Antenna		265
Installation		400
Totals	$ 15,600	$24,005
Control (2 Repeaters)		
8 channel units	41,120	
2 towers		6,000
2 buildings		3,400
2 land acquisition		1,400
2 installation		4,120
Totals	$ 41,120	$14,920
Mobiles		
51	76,500	
Totals	$133,220	$38,925

Table 4-19. High-Band Costs.

LEWIS REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Lewis (Atlantic) Base		
2 high-band radios	$ 6,800	$
Receivers	2,000	
Antenna and cables		300
Duplexer and cavity		1,235
Installation		1,140
Glenwood/New Market (R)		
2 radios	6,800	
2 antennas		530
2 installation		800
Totals	$ 15,600	$ 4,005
Control		
6 channel units	$ 36,500	
Tower		3,000
Installation		3,650
Building		1,700
Land acquisition		700
Totals	$ 36,500	$ 9,050
Mobiles		
47	70,500	
Totals	$122,600	$13,055

Table 4-20. High-Band Costs.

MAQUOKETA REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Maquoketa Base		
2 high-band radios	$ 6,800	$
Receivers	2,000	
Antenna and cable		300
Duplexers and cavity		1,235
Installation		1,140
Muscatine/McGregor Repeater		
2 radios	6,800	
2 antennas		530
2 installations		800
Totals	$ 15,600	$ 4,005
Control (To Muscatine/McGregor)		
8 channel units	41,120	
2 towers		9,600
2 buildings		3,400
2 land acquisitions		1,400
2 installations		4,120
Totals	$ 41,120	$18,520
Mobiles		
65	97,500	
Totals	$154,220	$22,525

Table 4-21. High-Band Costs.

STORM LAKE REGION	EQUIPMENT COSTS	
	RF (Electronics)	Construction
Storm Lake Base		
2 transmitters	$ 6,800	$
Receivers	2,000	
2 consoles		20,000
Antenna and cable		300
Duplexer and cavity		1,235
Audio patching capability	500	
Installation		1,140
Repeaters (Merrill/Matlock/Terril)		
3 radios	10,200	
3 antennas		795
3 installations		1,200
Totals	$ 19,500	$24,670
Control		
10 channel units	57,600	
2 towers		10,500
2 buildings		3,400
2 land acquisitions		1,400
2 installations		5,760
Totals	$ 57,600	$21,060
Mobiles		
45	67,500	
Totals	$144,600	$45,730

Table 4-22. Combined Low-Band System Upgrade and High-Band System Installation Costs.

BASE STATION	REQUIRED FUNDS				FUNDS TOTAL		IMPLEMENTATION FISCAL YEAR
	STATE		FEDERAL		STATE	FEDERAL	
	RF	CONSTRUCTION	RF	CONSTRUCTION			
Belmond	25,120	12,185	75,360	12,185	37,305	87,545	FY-74
Cedar Falls	26,565	16,150	79,695	16,150	42,715	95,845	FY-73
Cedar Rapids	26,940	5,400	80,820	5,400	32,340	86,220	FY-74
Des Moines	49,440	6,900	148,320	6,900	56,340	155,220	FY-73
Denison	25,125	17,000	75,375	17,000	42,125	92,375	FY-74
Fairfield	33,305	19,465	99,915	19,465	52,770	119,380	FY-74
Maquoketa	38,555	11,260	115,665	11,260	49,815	126,925	FY-73
Lewis	30,650	6,530	91,950	6,530	37,180	98,480	FY-73
Storm Lake	36,150	22,865	108,450	22,865	59,015	131,315	FY-72
Statewide low-band upgrade (Except Storm Lake)	31,550	52,175	94,650	52,175	83,725	146,825	FY-72
Totals	323,400	169,930	970,200	169,930	493,330	1,140,130	

Detailed Site Specifications

This section contains detailed specifications, site-by-site, for both the recommended low-band and high-band IPR system upgrades. Radio equipment specifications are written in general terms, to include equipment available from several manufacturers. Antennas are specified by the appropriate type number of DB Products, Inc., as an expedient method of defining the intended radiation pattern; antennas of other manufacturers having equivalent gain and pattern characteristics are equally suitable.

Frequency designators F1 through F4 correspond to the staggered regional frequency plans recommended in section 4. Designators C1 through C5 refer to a general five frequency-pair control link plan for the proposed high-band system.

Table 5-1. Belmond Base Site Specification, Low Band.

BASE OPERATING REGION Belmond

SITE: Type Base — Coordinates 42° 54' 30''N 93° 37' 00''W — Area * Acres

Nearby Town Belmond — Building Size * — Tower Height 320* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO BLAIRSBURG	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-212-3 collinear mounting	*	*	
Max gain	9 dBd	*	*	
Orientation (at max gain)	North	*	187.5° T	
Height on tower	Top (collocate with point-to-point antenna)	*	*	
Feedline	*	*	*	
RADIO SYSTEM:				
Type	*	*	*Rcvr Xmtr	
Power output	Reduce to 500 W	*	80 W	
Frequency	F2	*155.370	*Rcv 155.505 Xmt 155.460	

*Same as present facility

Table 5-2. Blairsburg Repeater Site Specification, Low Band.

BASE OPERATING REGION Belmond

SITE: Type 2-Way Repeater   Coordinates 42° 30' 49" N 93° 40' 45" W   Area 1 Acres

Nearby Town Blairsburg   Building Size 8' x 12'   Tower Height 120 Feet Self-supporting

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO BELMOND	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-214-2		*	
Max gain	6 dBd		*	
Orientation (at max gain)	East-west		7.5° T	
Height on tower	Top		80 ft	
Feedline	1/2" foam		7/8" foam	
RADIO SYSTEM:				
Type	*Rcvr Xmtr		Rcvr *Xmtr	
Power output	100 W		*	
Frequency	F2		Rcv 155.460 *Xmt 155.505	

*Same as present facility at Ft. Dodge

Table 5-3. Cedar Falls Base Site Specification, Low Band.

BASE OPERATING REGION Cedar Falls

SITE: Type Base   Coordinates 42°32'15" N 92°28'00" W   Area * Acres

Nearby Town Cedar Falls   Building Size *   Tower Height 320* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO LOURDES	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*	*	*	
Max gain	*	*	*	
Orientation (at max gain)	*	*	10° T	
Height on tower	*	*	*	
Feedline	*	*	*	
RADIO SYSTEM:				
Type	*	*	*Rcvr Xmtr	
Power output	*	*	80 W	
Frequency	F1	*155.370	*Rcv 155.505 Xmt 155.460	

*Same as present facility

Table 5-4. Lourdes Repeater Site Specification, Low Band.

BASE OPERATING REGION Cedar Falls

SITE: Type 2-Way Repeater Coordinates 43° 17' 30" N 92° 17' 36" W Area 1 Acres

Nearby Town Lourdes Building Size 8' x 12' Tower Height 120 Feet Self-supporting

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO CEDAR FALLS	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-214-2		*	
Max gain	6 dBd		*	
Orientation (at max gain)	East-west		190° T	
Height on tower	Top		110 ft	
Feedline	1/2" foam		RG-8	
RADIO SYSTEM:				
Type	*Rcvr Xmtr		Rcvr *Xmtr	
Power output	100 W		*	
Frequency	F1		Rcv 155.460 *Xmt 155.505	

*Same as present facility at Cresco

Table 5-5. Cedar Rapids Base Site Specification, Low Band.

BASE OPERATING REGION Cedar Rapids

SITE: Type Base — Coordinates 41° 58' 00'' N 91° 43' 00'' W — Area * Acres

Nearby Town Cedar Rapids — Building Size * — Tower Height 220* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MALCOM	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*	*	*	
Max gain	*	*	*	
Orientation (at max gain)	*	*	*	
Height on tower	*	*	*	
Feedline	*	*	*	
RADIO SYSTEM:				
Type	*	*	*	
Power output	*	*	*	
Frequency	F2	*155.370	*	

*Same as present facility

Table 5-6. Malcom Repeater Site Specification, Low-Band.

BASE OPERATING REGION Cedar Rapids

SITE: Type 2-Way Repeater   Coordinates 41° 43' 51'' N 92° 33' 41'' W   Area * Acres

Nearby Town Malcom   Building Size *   Tower Height 120 Feet (Moved from McGregor)

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO CEDAR RAPIDS	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB 212		*	
Max gain	7 dBd		*	
Orientation (at max gain)	North		*	
Height on tower	Top		80 ft	
Feedline	1/2'' foam		7/8'' foam	
RADIO SYSTEM:				
Type	*		*	
Power output	*		*	
Frequency	F2		*	

*Same as present facility

Table 5-7. Denison Base Site Specification, Low Band.

BASE OPERATING REGION Denison

SITE: Type Base — Coordinates 42° 02' 00" N 95° 24' 00" W — Area * Acres

Nearby Town Denison — Building Size * — Tower Height 320* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MOORHEAD	CONTROL LINK TO GUTHRIE CENTER
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-225	*	*	*
Max gain	5 dBd	*	*	*
Orientation (at max gain)	South	*	*	*
Height on tower	Top (collocate with point-to-point antenna)	*	*	*
Feedline	*	*	*	*
RADIO SYSTEM:				
Type	*	*	*	*
Power output	*	*	*	*
Frequency	F2	*155.370	*	*

*Same as present facility

Table 5-8. Moorhead Repeater Site Specification, Low Band.

BASE OPERATING REGION Denison

SITE: Type 2-Way Repeater   Coordinates 41° 54' 30" N 95° 56' 00" W   Area * Acres

Nearby Town Moorhead   Building Size *   Tower Height 120 Feet (Moved from Glenwood)

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO DENISON	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-214-2		*	
Max gain	6 dBd		*	
Orientation (at max gain)	North-south		*	
Height on tower	Top		80 ft	
Feedline	1/2" foam		7/8" foam	
RADIO SYSTEM:				
Type	*		*	
Power output	*		*	
Frequency	F2		*	

*Same as present facility

Table 5-9. Guthrie Center Repeater Site Specification, Low Band.

BASE OPERATING REGION Denison

SITE: Type 2-Way Repeater   Coordinates 41° 46' 00" N 94° 27' 00" W   Area * Acres

Nearby Town Guthrie Center   Building Size *   Tower Height 120 Feet (Moved from Van Wert)

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO DENISON	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-214-2		*	
Max gain	6 dBd		*	
Orientation (at max gain)	North-south		*	
Height on tower	Top		80 ft	
Feedline	1/2" foam		7/8" foam	
RADIO SYSTEM:				
Type	*		*	
Power output	*		*	
Frequency	F2		*	

*Same as present facility

Table 5-10. Des Moines Base Site Specification, Low Band.

BASE OPERATING REGION Des Moines

SITE: Type Base — Coordinates 41° 40' 05" N 93° 37' 05" W — Area * Acres

Nearby Town Des Moines — Building Size * — Tower Height 492* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO VAN WERT	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*	*	*	
Max gain	*	*	*	
Orientation (at max gain)	*	*	*	
Height on tower	*	*	*	
Feedline	*	*	*	
RADIO SYSTEM:				
Type	*	*	*	
Power output	*	*	*	
Frequency	F1	*155.370	*	

*Same as present facility

Table 5-11. Van Wert Repeater Site Specification, Low Band.

BASE OPERATING REGION Des Moines

SITE: Type 2-Way Repeater | Coordinates 40° 52' 12" N 93° 45' 36" W | Area 3 Additional Acres

Nearby Town Van Wert | Building Size * | Tower Height 280 Feet Guyed

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO DES MOINES	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-214-2		*	
Max gain	6 dBd		*	
Orientation (at max gain)	East-west		*	
Height on tower	Top		200 ft	
Feedline	7/8" foam		7/8" foam	
RADIO SYSTEM:				
Type	*		*	
Power output	*		*	
Frequency	F1		*	

*Same as present facility

Table 5-12. Fairfield Base Site Specification, Low Band.

BASE OPERATING REGION Fairfield

SITE: Type Base | Coordinates 41° 05' 21" N 91° 58' 05" W | Area * Acres

Nearby Town Fairfield | Building Size * | Tower Height 320* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO BURLINGTON	CONTROL LINK TO ALBIA
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*	*	*	Andrew 3605-A
Max gain	*	*	*	6 dBd
Orientation (at max gain)	*	*	*	264° T
Height on tower	*	*	*	200 ft
Feedline	*	*	*	7/8" foam
RADIO SYSTEM:				
Type	*	*	*	Rcvr Xmtr
Power output	*	*	*	80 W
Frequency	F1	*	*	Rcv 155.475 Xmt 155.460

*Same as present facility

Table 5-13. Burlington Repeater Site Specification, Low Band.

BASE OPERATING REGION Fairfield

SITE: Type 2-Way Repeater — Coordinates 40° 50' 00" N 91° 12' 00" W — Area * Acres

Nearby Town Burlington — Building Size * — Tower Height 280 Feet Guyed

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO FAIRFIELD	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*		*	
Max gain	*		*	
Orientation (at max gain)	0° T Yagi #1 215° T Yagi #2		*	
Height on tower	Top		200 ft	
Feedline	7/8" foam		7/8" foam	
RADIO SYSTEM:				
Type	*		*	
Power output	*		*	
Frequency	F1		*	

*Same as present facility

Table 5-14. Albia Repeater Site Specification, Low Band.

BASE OPERATING REGION Fairfield

SITE: Type 2-Way Repeater　Coordinates 41° 01' 00'' N 92° 43' 00'' W　Area 1 Acres

Nearby Town Albia　Building Size 8' x 12'　Tower Height 120 Feet Self-supporting

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO FAIRFIELD	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-214-2		*	
Max gain	6 dBd		*	
Orientation (at max gain)	24°/204° T		84° T	
Height on tower	Top		80 ft	
Feedline	1/2'' foam		7/8'' foam	
RADIO SYSTEM:				
Type	*Rcvr Xmtr		Rcvr *Xmtr	
Power output	100 W		*	
Frequency	F1		Rcv 155.460 *Xmt 155.475	

*Same as present facility at Rathbun

Table 5-15. Lewis Base Site Specification, Low Band.

BASE OPERATING REGION Lewis

SITE: Type Base | Coordinates 41° 19' 00'' N 95° 06' 00'' W | Area * Acres

Nearby Town Lewis | Building Size * | Tower Height 320* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO GLENWOOD	CONTROL LINK TO NEW MARKET
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*	*	*	*
Max gain	*	*	*	*
Orientation (at max gain)	*	*	*	*
Height on tower	*	*	*	*
Feedline	*	*	*	*
RADIO SYSTEM:				
Type	*	*	*	*Rcvr Xmtr
Power output	*	*	*	80 W
Frequency	F1	*155.370	*	*Rcv 155.505 Xmt 155.460

*Same as present facility

Table 5-16. Glenwood Repeater Site Specification, Low Band.

BASE OPERATING REGION Lewis

SITE: Type 2-Way Repeater — Coordinates 41° 05' 26" N 95° 45' 00" W — Area 3 Additional Acres

Nearby Town Glenwood — Building Size * — Tower Height 280 Guyed Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO LEWIS	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*		*	
Max gain	*		*	
Orientation (at max gain)	North-south		*	
Height on tower	Top		200 ft	
Feedline	7/8" foam		7/8" foam	
RADIO SYSTEM:				
Type	*		*	
Power output	*		*	
Frequency	F1		*	

*Same as present facility

Table 5-17. New Market Repeater Site Specification, Low Band.

BASE OPERATING REGION Lewis

SITE: Type 2-Way Repeater Coordinates 40° 43' 50'' N 94° 53' 48'' W Area 3 Additional Acres

Nearby Town New Market Building Size * Tower Height 280 Guyed Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO LEWIS	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB-214-2		*	
Max gain	6 dBd		*	
Orientation (at max gain)	East-west		*	
Height on tower	Top		200 ft	
Feedline	7/8'' foam		7/8'' foam	
RADIO SYSTEM:				
Type	*Rcvr Xmtr		Rcvr *Xmtr	
Power output	100 W		*	
Frequency	F1		Rcv 155.460 *Xmt 155.505	

*Same as present facility

Table 5-18. Maquoketa Site Specification, Low Band.

BASE OPERATING REGION Maquoketa

SITE: Type Base — Coordinates 42° 05' 30'' N 90° 44' 00'' W — Area * Acres

Nearby Town Maquoketa — Building Size * — Tower Height 320* Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO WATSON	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	DB 215	*	*	
Max gain	10 dBd	*	*	
Orientation (at max gain)	202° T	*	335° T	
Height on tower	Top (collocate with point-to-point antenna)	*	*	
Feedline	*	*	*	
RADIO SYSTEM:				
Type	*	*	*	
Power output	Reduce to 500 W	*	*	
Frequency	F1	*155.370	*	

*Same as present facility

Table 5-19. Watson Repeater Site Specification, Low Band.

BASE OPERATING REGION Maquoketa

SITE: Type 2-Way Repeater Coordinates 43° 04' 30'' N 91° 19' 45'' W Area 4 Acres

Nearby Town Watson Building Size 8' x 12' Tower Height 280 Guyed Feet

	LOW BAND	HIGH BAND		
	BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MAQUOKETA	CONTROL LINK TO
ANTENNA SYSTEM:				
Mfg type (or equivalent)	*		*	
Max gain	*		*	
Orientation (at max gain)	North-south		155° T	
Height on tower	Top		200 ft	
Feedline	7/8'' foam		7/8'' foam	
RADIO SYSTEM:				
Type	*		*	
Power output	*		*	
Frequency	F1		*	

*Same as present facility at Mc Gregor

Table 5-20. Belmond Base Site Specification, High Band.

BASE OPERATING REGION: Belmond

SITE: Type Base and Mobile Relay   Coordinates 42° 54' 30'' N 93° 37' 00'' W   Area * Acres

Nearby Town Belmond   Building Size *   Tower Height 320* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO BLAIRSBURG	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-264-E		*DB-306	4' parabolic dish	
Max gain	9 dBd	Uses point-to-point antenna system	6 dBd	19 dBi	
Orientation (at max gain)	North		Omni	187.5° T	
Height on tower	Top		*Spiral down from top	250 ft	
Feedline (coaxial)	*1 5/8'' rigid		*1/2'' foam	7/8'' foam	
RADIO SYSTEM:					
Type	Local base/ Repeater		Dual frequency base	Single-channel duplex	
Power output	300 W	Uses point-to-point radio system	300 W	5 W	
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F3	F4	*155.370	C5	

*Same as present facility

Table 5-21. Blairsburg Repeater Site Specification, High Band.

BASE OPERATING REGION: Belmond

SITE: Type Repeater and Mobile Relay — Coordinates 42° 30' 49'' N 93° 40' 45'' W — Area 1 Acres

Nearby Town Blairsburg — Building Size 8' x 12' — Tower Height 120 Feet Self-Supporting

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO BELMOND	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	East-west			7.5° T	
Height on tower	Top			80 ft	
Feedline (coaxial)	1/2'' foam			7/8'' foam	
RADIO SYSTEM:					
Type	Remote repeater			Single channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F3			C5	

*Same as present facility

Table 5-22. Cedar Falls Site Specification, High Band.

BASE OPERATING REGION: Cedar Falls

SITE: Type Base and Mobile Relay — Coordinates 42° 32' 15'' N 92° 28' 00'' W — Area * Acres

Nearby Town Cedar Falls — Building Size * — Tower Height 320* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO LOURDES VIA WILLIAMSTOWN	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-264		*DB-306	4 ft parabolic dish	
Max gain	6 dBd	Uses point-to-point antenna system	6 dBd	19 dBi	
Orientation (at max gain)	Omni		Omni		
Height on tower	Top		*Spiral down from top	250'	
Feedline (coaxial)	*1 5/8'' Rigid		*1/2'' foam	7/8'' foam	
RADIO SYSTEM:					
Type	Local base/ repeater		Dual frequency base	Single-channel duplex	
Power output	300 W	Uses point-to-point radio system	300 W	5 W	
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F2	F4	*155.370	C2	

*Same as present facility

Table 5-23. Lourdes Repeater Site Specification, High Band.

BASE OPERATING REGION: Cedar Falls

SITE: Type Repeater and Mobile Relay — Coordinates 43° 17' 30'' N 92° 17' 36'' W — Area 1 Acres

Nearby Town Lourdes — Building Size 8' x 12' — Tower Height 120 Feet Self-Supporting

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO CEDAR FALLS VIA WILLIAMSTOWN	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	East/west				
Height on tower	Top			80'	
Feedline (coaxial)	1/2'' foam			7/8'' foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F2			C4	

*Same as present facility

Table 5-24. Cedar Rapids Base Site Specification, High Band.

BASE OPERATING REGION: Cedar Rapids

SITE: Type Base and Mobile Relay   Coordinates 41° 58' 00" N 91° 43' 00" W   Area * Acres

Nearby Town Cedar Rapids   Building Size *   Tower Height 220* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MALCOM VIA KOSZIA	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-264		DB-306	4' parabolic dish	
Max gain	6 dBd	Uses point-to-point antenna system	6 dBd	19 dBi	
Orientation (at max gain)	Omni		Omni		
Height on tower	Top		Spiral down from top	160'	
Feedline (coaxial)	7/8" rigid		*1/2" foam	*7/8" rigid	
RADIO SYSTEM:					
Type	Local base/ repeater		Dual frequency base	Single-channel duplex	
Power output	300 W	Uses point-to-point radio system	300 W	5 W	
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F3	F4	*155.37	C5	

*Same as present facility

Table 5-25. Malcom Repeater Site Specification, High Band.

BASE OPERATING REGION: Cedar Rapids

SITE: Type Repeater and Mobile Relay   Coordinates 41° 43' 51'' N 92° 33' 41'' W   Area * Acres

Nearby Town Malcom   Building Size *   Tower Height 120 Feet (Moved from McGregor)

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO CEDAR RAPIDS VIA KOSZIA	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-222 E			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	North				
Height on tower	Top			80'	
Feedline (coaxial)	1/2'' foam			7/8'' foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F3			C1	

*Same as present facility

Table 5-26. Denison Base Site Specification, High Band.

BASE OPERATING REGION: Denison

SITE: Type Base and Mobile Relay Coordinates 42° 02' 00'' N 95° 24' 00'' W Area * Acres

Nearby Town Denison Building Size * Tower Height 320* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MOORHEAD	CONTROL LINK TO GUTHRIE CENTER VIA DEDHAM
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-264 E		*DB-306	4' parabolic dish	4' parabolic dish
Max gain	9 dBd	Uses point-to-point antenna system	6 dBd	19 dBi	19 dBi
Orientation (at max gain)	South		Omni	256° T	
Height on tower	Top		*Spiral down from top	250'	250'
Feedline (coaxial)	*1-5/8'' rigid		*7/8'' foam	7/8'' foam	7/8'' foam
RADIO SYSTEM:					
Type	Local base/ repeater		Dual frequency base	Single-channel duplex	Single-channel duplex
Power output	300 W	Used point-to-point radio system	300 W	5 W	5 W
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F2	F4	*155.370	C1	C5

*Same as present facility

Table 5-27. Moorhead Repeater Site Specification, High Band.

BASE OPERATING REGION: Denison

SITE: Type Repeater and Mobile Relay — Coordinates 41° 54' 30" N 95° 56' 00" W — Area * Acres

Nearby Town Moorhead — Building Size * — Tower Height 120 Feet (Moved from Glenwood)

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO DENISON	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	North/south			76° T	
Height on tower	Top			80'	
Feedline (coaxial)	1/2" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F2			C1	

*Same as present facility

Table 5-28. Guthrie Center Repeater Site Specification, High Band.

BASE OPERATING REGION: Denison

SITE: Type Repeater and Mobile Relay   Coordinates 41° 46' 00" N 94° 27' 00" W   Area * Acres

Nearby Town Guthrie Center   Building Size *   Tower Height 120 Feet (Moved from Van Wert)

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO DENISON VIA DEDHAM	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	North/south				
Height on tower	Top			80'	
Feedline (coaxial)	1/2" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F2			C4	

*Same as present facility

Table 5-29. Des Moines Base Site Specification, High Band.

BASE OPERATING REGION: Des Moines

SITE: Type Base and Mobile Relay — Coordinates 41° 40' 05" N 93° 37' 05" W — Area * Acres

Nearby Town Des Moines — Building Size * — Tower Height 492* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO VAN WERT VIA ST. CHARLES	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	*DB 264	Uses point-to-point antenna system	*DB-306	4' parabolic dish	
Max gain	6 dBd		6 dBd	19 dBi	
Orientation (at max gain)	Omni		Omni		
Height on tower	Top		*Spiral down from top	250'	
Feedline (coaxial)	*1-5/8" Heliax		7/8" foam	7/8" foam	
RADIO SYSTEM:					
Type	Local base/ repeater	Uses point-to-point radio system	Dual frequency base	Single-channel duplex	
Power output	300 W		300 W	5 W	
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F1	F4	*155.370	C3	

*Same as present facility

Table 5-30. Van Wert Repeater Site Specification, High Band.

BASE OPERATING REGION: Des Moines

SITE: Type Repeater and Mobile Relay | Coordinates 40° 52' 12" N 93° 45' 36" W | Area 3 Additional Acres

Nearby Town Van Wert | Building Size * | Tower Height 280 Feet Guyed

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO DES MOINES VIA ST. CHARLES	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	East/west				
Height on tower	Top			200'	
Feedline (coaxial)	7/8" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F1			C1	

*Same as present facility

Table 5-31. Fairfield Base Site Specification, High Band.

BASE OPERATING REGION: Fairfield

SITE: Type Base | Coordinates 41° 05' 21" N 91° 58' 05" W | Area * Acres

Nearby Town Fairfield | Building Size * | Tower Height 320* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO BURLINGTON VIA MT. PLEASANT	CONTROL LINK TO ALBIA VIA OTTUMWA
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-264	Uses point-to-point antenna system	*DB-306	4' parabolic dish	4' parabolic dish
Max gain	6 dBd		6 dBd	19 dBi	19 dBi
Orientation (at max gain)	Omni		Omni		
Height on tower	Top		*Spiral down from top	250'	250'
Feedline (coaxial)	*1-5/8" rigid		*1/2" foam	*7/8" foam	7/8" foam
RADIO SYSTEM:					
Type	Local base/ repeater	Uses point-to-point radio system	Dual frequency base	Single-channel duplex	Single-channel duplex
Power output	300 W		300 W	5 W	5 W
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F2	F4	*155.370	C1	C2

*Same as present facility

Table 5-32. Burlington Repeater Site Specification, High Band.

BASE OPERATING REGION: Fairfield

SITE: Type Repeater and Mobile Relay   Coordinates 40° 50' 00" N 91°12' 00" W   Area * Acres

Nearby Town Burlington   Building Size *   Tower Height 280 Feet Guyed

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO FAIRFIELD VIA MT. PLEASANT	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	20°/200° T				
Height on tower	Top			150'	
Feedline (coaxial)	7/8" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	300 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F2			C3	

*Same as present facility

Table 5-33. Albia Repeater Site Specification, High Band.

BASE OPERATING REGION: Fairfield

SITE: Type Repeater and Mobile Relay   Coordinates 41° 01' 00" N 92° 43' 00" W   Area 1 Acres

Nearby Town Albia   Building Size 8' x 12'   Tower Height 120 Feet Self-Supporting

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO FAIRFIELD VIA OTTUMWA	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dB1	
Orientation (at max gain)	24°/204° T				
Height on tower	Top			80'	
Feedline (coaxial)	1/2" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F1			C4	

*Same as present facility

Table 5-34. Lewis Base Site Specification, High Band.

BASE OPERATING REGION: Lewis

SITE: Type Base and Mobile Relay   Coordinates 41° 19' 00" N 95°06' 00" W   Area * Acres

Nearby Town Lewis   Building Size *   Tower Height 320* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO GLENWOOD AND NEW MARKET VIA RED OAK	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB 215		*DB-306	4' parabolic dish	
Max gain	10 dBd	Uses point-to-point antenna system	6 dBd	19 dBi	
Orientation (at max gain)	East		Omni		
Height on tower	Top		*Spiral down from top	250'	
Feedline (coaxial)	*1-5/8" rigid		*1/2" foam	7/8" foam	
RADIO SYSTEM:					
Type	Local base/ repeater		Dual frequency base	Two-channel duplex	
Power output	300 W	Uses point-to-point radio system	300 W	5 W	
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F3	F4	*155.370	C2	

*Same as present facility

Table 5-35. Glenwood Repeater Site Specification, High Band.

BASE OPERATING REGION: Lewis

SITE: Type Repeater and Mobile Relay — Coordinates 41° 05' 26" N 95° 45' 00" W — Area 3 additional Acres

Nearby Town Glenwood — Building Size * — Tower Height 280 Feet, Guyed

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO LEWIS VIA RED OAK	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	North/south				
Height on tower	Top			200'	
Feedline (coaxial)	7/8" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F3			C3	

*Same as present facility

Table 5-36. New Market Repeater Site Specification, High Band.

BASE OPERATING REGION: Lewis

SITE: Type Repeater and Mobile Relay Coordinates 40° 43' 50" N 94° 53' 48" W Area 3 Additional Acres

Nearby Town New Market Building Size * Tower Height 280 Feet Guyed

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO LEWIS VIA RED OAK	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	East/west				
Height on tower	Top			200'	
Feedline (coaxial)	7/8" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F3			C5	

*Same as present facility

Table 5-37. Maquoketa Base Site Specification, High Band.

BASE OPERATING REGION: Maquoketa

SITE: Type Base and Mobile Relay   Coordinates 42° 05' 30" N 90° 44' 00" W   Area * Acres

Nearby Town Maquoketa   Building Size *   Tower Height 320* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO WATSON VIA LUXEMBURG	CONTROL LINK TO MUSCATINE VIA NEW LIBERTY
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB 215		*2 ea COMM prod 390-509	4' parabolic dish	4' parabolic dish
Max gain	10 dBd	Uses point-to-point antenna system	8 dBd	19 dBi	19 dBi
Orientation (at max gain)	202° T		Ant #1 335° T Ant #2 202° T		
Height on tower	Top		*Near top	260'	250'
Feedline (coaxial)	*7/8" foam		*1/2" foam	7/8" foam	7/8" foam
RADIO SYSTEM:					
Type	Local base/ repeater		Dual frequency base	Single-channel duplex	Single-channel duplex
Power output	300 W	Uses point-to-point radio system	300 W	5 W	5 W
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F1	F4	*155.370	C1	C2

*Same as present facility

Table 5-38. Watson Repeater Site Specification, High Band.

BASE OPERATING REGION: Maquoketa

SITE: Type Repeater and Mobile Relay — Coordinates 43° 04' 30" N 91° 19' 45" W — Area 4 Acres

Nearby Town Watson — Building Size 8' x 12' — Tower Height 280 Feet Guyed

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MAQUOKETA VIA LUXEMBURG	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	North/south				
Height on tower	Top			220'	
Feedline (coaxial)	7/8" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F1			C3	

*Same as present facility

Table 5-39. Muscatine Repeater Site Specification, High Band.

BASE OPERATING REGION: Maquoketa

SITE: Type Repeater and Mobile Relay   Coordinates 41° 28' 00" N 90° 54' 06" W   Area 1 Acres

Nearby Town Muscatine   Building Size 8' x 12'   Tower Height 120 Feet Self-Supporting

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MAQUOKETA VIA NEW LIBERTY	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	East/west				
Height on tower	Top			80'	
Feedline (coaxial)	1/2" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F1			C4	

*Same as present facility

Table 5-40. Storm Lake Base Site Specification, High Band.

BASE OPERATING REGION: Storm Lake

SITE: Type Base and Mobile Relay   Coordinates 42° 36' 00" N 95°11' 24" W   Area * Acres

Nearby Town Storm Lake   Building Size *   Tower Height 320* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO MERRILL AND MATLOCK VIA MARCUS	CONTROL LINK TO TERRIL VIA CORNELL
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-264E		*DB-306	4' parabolic dish	4' parabolic dish
Max gain	9 dBd	Uses point-to-point antenna system	6 dBd	19 dBi	19 dBi
Orientation (at max gain)	West		Omni		
Height on tower	Top		*Spiral down from top	250'	250'
Feedline (coaxial)	*1-5/8" rigid		*1/2" foam	7/8" foam	7/8" foam
RADIO SYSTEM:					
Type	Local base/ repeater		Dual frequency base	Two-channel duplex	Single-channel duplex
Power output	300 W	Uses point-to-point radio system	300 W	5 W	5 W
Duplexer/cavity type	DB-4048		DB-4001		
Frequency	F1	F4	*155.370	C3	C1

*Same as present facility

Table 5-41. Merrill Repeater Site Specification, High Band.

BASE OPERATING REGION: Storm Lake

SITE: Type Repeater and Mobile Relay Coordinates 42° 44' 00" N 96°22' 30" W Area * Acres

Nearby Town Merrill Building Size * Tower Height 120* Feet

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO STORM LAKE VIA MARCUS	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	North/south				
Height on tower	Top			80'	
Feedline (coaxial)	*1/2" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F1			C5	

*Same as present facility

Table 5-42. Matlock Repeater Site Specification, High Band.

BASE OPERATING REGION: Storm Lake

SITE: Type Repeater and Mobile Relay — Coordinates 43° 14' 30" N 95° 55' 30" W — Area 1 Acres

Nearby Town Matlock — Building Size 8' x 12' — Tower Height 120 Feet Self-Supporting

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO STORM LAKE VIA MARCUS	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	East/west				
Height on tower	Top			80'	
Feedline (coaxial)	1/2" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F1			C4	

*Same as present facility

Table 5-43. Terril Repeater Site Specification, High Band.

BASE OPERATING REGION: Storm Lake

SITE: Type Repeater and Mobile Relay Coordinates 43° 17' 36" N 95° 01' 12" W Area 1 Acres

Nearby Town Terril Building Size 8' x 12' Tower Height 120 Feet Self-Supporting

	HIGH BAND			960 MHz	
	PRIMARY BASE TO MOBILE	STATEWIDE BASE TO MOBILE	POINT TO POINT	CONTROL LINK TO STORM LAKE VIA CORNELL	CONTROL LINK TO
ANTENNA SYSTEM:					
Mfg type (or equivalent)	DB-214-2			4' parabolic dish	
Max gain	6 dBd			19 dBi	
Orientation (at max gain)	East/west				
Height on tower	Top			80'	
Feedline (coaxial)	1/2" foam			7/8" foam	
RADIO SYSTEM:					
Type	Remote repeater			Single-channel duplex	
Power output	100 W			5 W	
Duplexer/cavity type	DB-4048				
Frequency	F1			C2	

*Same as present facility

Table 5-44. Control Link Repeater Site Specifications.

BASE OPERATING REGION	NEARBY TOWN	APPROXIMATE COORDINATES	TOWER HEIGHT	CONTROL LINK DESTINATION	NUMBER OF CHANNELS	OPERATING FREQUENCY PAIR
Cedar Falls	Williamstown	42° 59' N 92° 20' W	150'	Cedar Falls Lourdes	1 1	C2 C4
Cedar Rapids	Koszia	41° 49° N 92° 13' W	100'	Cedar Rapids Malcom	1 1	C5 C1
Denison	Dedham	41° 55' N 94° 52' W	150'	Denison Guthrie Center	1 1	C5 C4
Des Moines	St. Charles	41° 17' N 93° 41' W	200'	Des Moines Van Wert	1 1	C3 C1
Fairfield	Ottumwa	41° 03' N 92° 24' W	100'	Fairfield Albia	1 1	C2 C4
	Mt. Pleasant	40° 57' N 91° 30' W	100'	Fairfield Burlington	1 1	C1 C3
Lewis	Red Oak	41° 00' N 95° 10' W	100'	Lewis Glenwood New Market	1 1 1	C2 C3 C5
Maquoketa	Luxemburg	42° 34' N 91° 03' W	220'	Maquoketa Watson	1 1	C1 C3
	New Liberty	41° 43' N 90° 52' W	100'	Maquoketa Muscatine	1 1	C2 C4
Storm Lake	Marcus	42° 53' N 95° 46' W	200'	Storm Lake Merrill Matlock	2 1 1	C3 C5 C4
	Cornell	42° 58' N 95° 09' W	150'	Storm Lake Terril	1 1	C1 C2

Each control link requires:
- Antenna: 4' parabolic dish, 19 dBi gain, mounted near top of specified tower.
- Feedline: 7/8" foam.
- Radio: 5-watt, full-duplex, equipped for specified number of channels.

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